Hilsa: Status of fishery and potential for aquaculture

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Hilsa fishery: Status and potential for aquaculture

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The contribution of WorldFish in organizing the workshop and publishing this book is sincerely acknowledged. Twenty-nine contributors made painstaking efforts in preparing and presenting the articles. These experts are highly appreciated, along with 100 other stakeholders who participated in the workshop and were involved in the brainstorming events for coming up with specific conclusions and recommendations. The sincere endeavors and leading roles played by the editorial team members, Dr. Malcolm C. Beveridge and Dr. Michael J. Phillips of WorldFish and Mr. William J. Collis and Dr. Craig A. Meisner, former directors of WorldFish Bangladesh and South Asia Office, in the organization and management of the workshop and editing the book are worth mentioning.

Finally, we are thankful to professor AKM Nowsad Alam and Mr. Ronnie Shuker for meticulously and conscientiously reviewing the book.

Contents

Foreword

I feel privileged to write the foreword of this book, *Hilsa Fishery: Status and Potential for Aquaculture*, edited by an international team of experts and authored by 10 international expert teams working on different disciplines of the popular hilsa shad fish. Hilsa is a widely distributed fish within the Bay of Bengal and Persian Gulf region and plenteously obtained in the waters of Bangladesh, India and Myanmar. It is famous worldwide for its delicious taste and superb texture, which persists for a long time. Hilsa is unique in that it contains high amounts of both proteins and lipids. The fish is also very rich in amino acids, minerals, micronutrients, vitamins and fatty acids. Particularly important is the enormous quantity of omega-3 polyunsaturated fatty acids in the fish's muscles that has made the fish ideal for health-conscious people and for children and women.

As a result of its importance from social, cultural, food, nutritional, conservation, economic and market perspectives, there has been growing interest in exploring hilsa's potential for aquaculture and stock enhancement with hatchery produced seeds. Several attempts have been made on domestication, breeding and raising of juveniles in brackish water ponds in both India and Bangladesh, but success has been very limited, indicating that coordinated extensive research and development initiatives are needed to establish aquaculture of this important species. Under this backdrop, organizing an international workshop on hilsa involving key professionals and stakeholders seems to me very worthwhile, and the compilation of chapters in this book is worth mentioning.

The book presents 10 review chapters that include the biology and ecology of hilsa, the status of the hilsa fishery in India and Bangladesh, hilsa fishery management, seed production and rearing, food, feeding and nutritional requirements, status of aquaculture, population genetics structure, prospects of improvement, market trends, nutritional values, consumption and utilization, as well as hilsa's social, cultural and religious importance.

Dr. Md. Abdul Wahab has played a pivotal role in organizing the workshop, editing the book and bringing it into printable form. A total of 29 international contributors, who are all hilsa experts in different disciplines, wrote the review articles. Dr. Malcolm C. Beveridge and Dr. Michael J. Phillips of WorldFish Headquarters, and Mr. William J. Collis, former director of WorldFish Bangladesh, took many lead roles in organizing and managing the workshop from start to finish. Prof. AKM Nowsad Alam of the Bangladesh Agricultural University (BAU), Mymensingh, has reviewed the book very meticulously.

I believe that the present book on hilsa as a physical output of the workshop will open a golden avenue to critically analyze current knowledge on hilsa, identify research gaps, point out specific research activities required to develop a viable industry for farming the fish in the brackish and coastal waters of the Ganges River basins, prepare a detailed research and development concept for achieving a viable hilsa industry from social, economic/business, nutritional and environmental points of view, and provide food and income to the people of the Ganges Delta region. The topics described here will improve the technical capacity of the stakeholders at all levels—from hilsa fishers to the consumers, researchers, students, teachers and regulatory bodies—increase the protein-food supply, ensure safe seafood, generate employment and income for poor fishers, traders and processors, and enhance the economic growth of the countries involved.

Gareth Johnstone, PhD
Director General
WorldFish

Preface

Background

Hilsa (*Tenualosa ilisha*), commonly known as Indian shad, is an anadromous fish. It migrates into the Padma and Meghna rivers and their tributaries from the Bay of Bengal for breeding and nursing. It was the most dominant fish in the Ganges river system in the pre-Farakka Barrage period until the middle of the 1970s. Since then, the hilsa catch has declined in the Meghna, Padma and other rivers and in coastal areas. Along with human influence, river siltation, closure of migratory routes, overfishing, use of illegal fishing gear and pollution, hydrological and climatic changes are thought to be responsible for the decline of hilsa production. Since the early 1990s, Bangladesh has initiated scientific research on hilsa fisheries. A few biological research studies, along with a census of hilsa fisher households and the stakeholders in processing and marketing, have been carried out. Based on this research, fish sanctuaries with restrictions on catching brood and juvenile hilsa (*jatka*) have been introduced since 2003. Economic incentives in the form of alternative income generating activities (AIGs) and food grains have been provided to hilsa and *jatka* fishers. This incentive-based management appears to have increased hilsa production from 0.19 million t in 2001–2002 to 0.34 million t in 2010–2011 and improved the livelihoods of the beneficiaries. Despite this apparent success, the sustainability of incentive-based conservation by the public sector is in question. Similar management approaches, if implemented by Myanmar and India, may help sustainable conservation of hilsa fisheries to serve the interest of 250 million Bengalis and save this cultural icon of Bengal.

In order to address the increased demand for hilsa in the markets as well as to revive the livelihood of the many hilsa fishers, there is an urgent need to explore the potential for its aquaculture and stock enhancement with hatchery produced seeds. The importance of hilsa has driven the governments of Bangladesh, India and Myanmar to form a consortium in collaboration with WorldFish and invite Nofima to join its technical expertise to undertake both short-term and long-term efforts toward breeding and producing seeds and explore the potential for its land-based and cage/pen aquaculture in suitable sites in the three countries within the Bay of Bengal region.

Purpose of the present initiatives

Considering the importance of hilsa in the areas of food, nutrition, livelihood and economics of the countries in the region, WorldFish undertook a project to bring Norwegian expertise to South Asia and help in developing a consortium to create a new aquaculture industry for hilsa using its experience with similar migratory salmonid fish. The key activities of the project involved critical analysis of literature and existing experiences and organizing a regional workshop to bring key partners together to define research needs and develop a follow-up concept/proposal. The potential impacts of this collaboration as well as the regional workshop are to establish a new species for aquaculture in brackish water areas, enhance private investment opportunities and improve nutritional and other positive social, economic and environmental benefits.

Primary objective of the workshop

The primary objective is to bring the relevant stakeholders from the research, development, academic and fishing communities from Bangladesh, India and Myanmar through this workshop to share and exchange current knowledge for establishing a research and development consortium between Norwegian scientists and partners in Bangladesh, India and Myanmar toward developing hilsa aquaculture.

Secondary objectives

- to critically analyze current knowledge on the ecology, biology and farming of hilsa
- to identify research gaps and issues of particular research activities required to develop a viable industry for farming hilsa in the brackish and coastal waters of the Ganges River Delta
- to prepare a detailed research and development concept for achieving a viable hilsa industry from social, economic/business, nutritional and environmental points of view
- to provide food and income to the people of the Ganges Delta region, and to reach an agreement among consortium partners toward long-term action programs.

Workshop organization

The regional workshop called Hilsa: Potential for Aquaculture was organized in Dhaka on 16–17 September 2012. Before staging the workshop, several intercountry and inter-institutional teams of hilsa experts from different disciplines were formed through WorldFish and given three months to develop review papers in selected topics. Twelve topics covering biology and ecology, fishery management, aquaculture, fish seeds, feed and feeding, breeding and genetics, social impacts, market demand, utilization and nutrition were covered in this review (details in Anon 2012).

In the workshop, there were an inaugural session and four technical sessions followed by a plenary session. The inaugural session was chaired by Syed Arif Azad, director general of the Department of Fisheries (DoF) in Bangladesh. Dr. Craig A. Meisner, the then newly appointed director of the WorldFish Bangladesh and South Asia Office welcomed the guests. Dr. Md. Anisur Rahman, a hilsa expert from the Bangladesh Fisheries Research Institute (BFRI), presented the keynote paper, and Dr. V. Puvanendran, Nofima, Norway, presented an overview of the purpose and objectives of the workshop and the possibility of bringing advanced technology for hilsa culture and management in light of Norwegian successes in the domestication of marine fish, especially salmonids, and their cage and land-based aquaculture.

The special guests were Prof. Dr. Subhash Chandra Chakraborty, director general of the BFRI, Dr. B. Meenakumari, deputy director general of fisheries at the Indian Council of Agricultural Research in India, Her Excellency Madam Ragne Birte Lund, ambassador for Norway in Bangladesh, and Mr. Ujjwal Bikash Dutta, secretary at the Ministry of Fisheries and Livestock. The speakers univocally supported WorldFish's initiative and asked to carry their endeavors forward for the development of hilsa fisheries through sustainable conservation and exploitation as well as the introduction of suitable production systems under controlled conditions through aquaculture.

Mr. Md. Abdul Latif Biswas, MP and honorable minister at the Ministry of Fisheries and Livestock, kindly graced the workshop as the chief guest. The minister emphasized the sociocultural and nutritional importance of hilsa in the life of the 250 million Bengali people living in Bangladesh, Bangla Prodesh and other states in India, as well as Bengali ethnic communities throughout the world. He highlighted the steps already taken by the Government of Bangladesh (GoB) in the conservation and management of the hilsa fishery in Bangladesh waters by providing subsidies in cash and kinds to hilsa fishers. He also expressed his full support toward the exploration of the potential for hilsa aquaculture in Bangladesh. He sincerely sought tri-country collaboration with India and Myanmar.

Dr. Malcolm C. Beveridge of WorldFish HQ chaired Technical Session I: Hilsa Biology, Ecology and Fishery; Dr. V. Puvanendran, Nofima, Norway, chaired Technical Session II: Hilsa Aquaculture and Cultivability; Dr. Shakuntala H. Thilsted of WorldFish and Dr. AP Sharma of the Central Inland Fisheries Research Institute jointly chaired Technical Session III: Market Demand/Utilization and Consumption; while Dr. Michael J. Phillips of WorldFish took the chair for Technical Session IV: Development of R&D for Hilsa Aquaculture. A total of 12 review papers and a second keynote paper on salmon aquaculture in Norway by Dr. Alte Mortensen of Nofima were presented at the workshop.

About 100 participants, including representatives from the major stakeholders (DoF, BFRI, CIFRI, Myanmar, BAU and other academic institutions, NGOs and fishers) attended the workshop. On Day 2, the participants were randomly divided into three groups for discussion and brainstorming on (i) the biology of hilsa, (ii) production systems, and (iii) environmental issues. They discussed and came up with valuable feedback, which was presented in the plenary session.

Mr. William J. Collis (former country director of WorldFish Bangladesh) and Dr. Michael J. Phillips wrapped up the two-day regional workshop, the largest hilsa workshop ever held in the South Asia region or elsewhere.

Key outputs of the reviews

Sociocultural importance

In all respects Bengalis love fish, and they identify themselves with the saying, *Mache Bhate Bangali*, "rice and fish makes Bengalis." Among the rich biodiversity in the Bay of Bengal region, hilsa holds the highest position and therefore is referred to as *Macher Raja*, "the king of fish." The preference for hilsa is further accelerated through development of different varieties of preparation of menus with the fish and their uses in various occasions related to ceremonial festivals such as pre-marriage events, wedding ceremonies and celebrations afterward, during the celebration of the Bengali New Year, *Pahela Boyshakh*, and in the celebration of religious festivals, especially among the Hindu communities. Thus, hilsa is important socially, culturally and religiously to the Bengalis living in Bangladesh, Bangla Prodesh and other states of India, like Orissa, Bihar and Assam. Hilsa is the national fish of Bangladesh, which reflects the sociocultural importance of hilsa to the people of this country.

Fish utilization and nutritional value

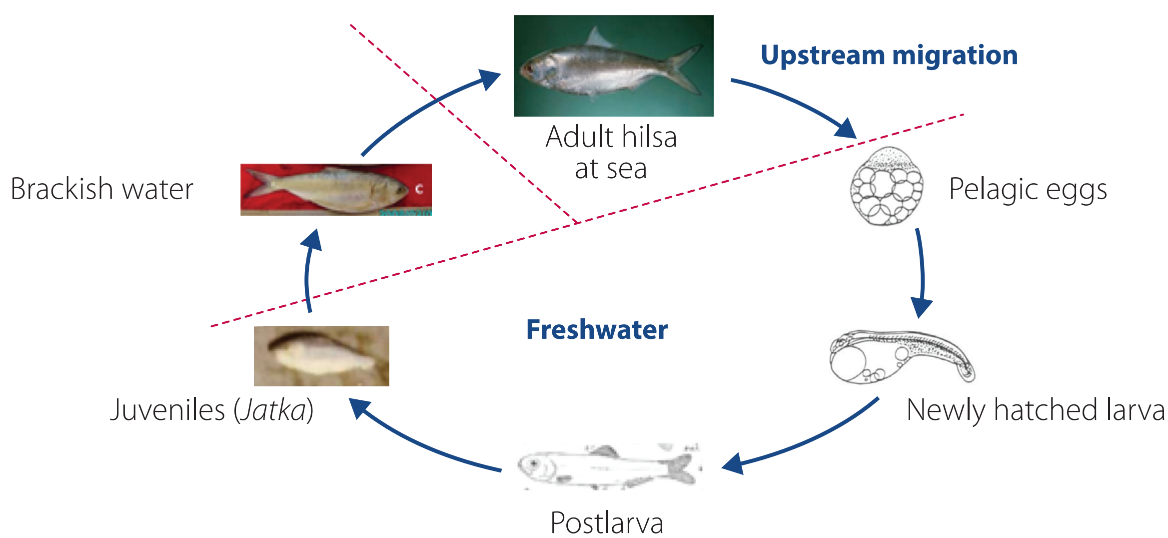
Belonging to a dignified group of a few fish species around the globe, hilsa is a high-protein high-lipid fish. Hilsa is known worldwide for its unique flavor and delicious taste, which lasts for a long time. It possesses an aroma of its own. Hilsa is a favorite fish for its easily digestible proteins (amino acids), fatty acids (such as omega-3), vitamins (such as vitamin A, vitamin D and some members of the vitamin B family and minerals, like selenium, zinc, phosphorus, calcium and iron). The unique taste of hilsa has been attributed to the presence of many monounsaturated and polyunsaturated fatty acids, *viz*. oleic, lenoleic, lenoleneic, arachidonic, eicosapentaenoeic and docosa-hexaenoeic acids. Hilsa can be consumed fresh, frozen, salted (*lona ilish*) or salt-fermented. In all forms, it is very popular among all classes of people because of its superb taste and the high quality nutrition it provides, compared to another highly nutritive famous fish, such as salmon. For all these nutritive qualities and its palatability, hilsa is a strong candidate for aquaculture.

Marketing and market demand

Fishers catch fish and bring them to the landing centers, usually near city markets. The individual or group fishers sell their fish to the fixed person(s), who is responsible for marketing. Both riverine and marine hilsa fishing are organized by *arotder* or *mohajon* (commission agents and organizers/suppliers of capital), who supply boats, nets and operating costs for fishing trips to the rivers and sea. Many fishers work on a daily payment basis and do not have any ownership of the fish they catch. The decision to sell fish is taken by *arotder/mohajon*. As a result of their powerful position in the value chain, 46% of the price paid by the consumers goes to *arotder/mohajon*, while fishers receive only 31% of the retail value.

The demand for hilsa in both local and urban markets has been increasing day by day. There has been an increased demand for the Padma hilsa in West Bengal and other states of India. The ethnic Bengali communities living in Europe, the Middle East and the United States are also dependent on the supply of hilsa from Bangladesh. The price of hilsa varies seasonally. It is usually sold at a reasonable price from September to November, but in other months the price becomes very high. As observed in 2012, the price per kg for hilsa was BDT 2500–3000 during the Bengali New Year. The price of hilsa will go beyond the reach of the majority of low-income people if production is not increased in the coming years.

Biology and ecology of hilsa



Source: Velmurugu Puvanendran

Figure 1. Anadromous lifecycle of hilsa.

Recent developments in the study of the biology and ecology of hilsa shad reveal that the lifecycle of the fish resembles American shad (*Alosa sapidissima*), but the juveniles resemble adult Indian river shad (*Gudusia chapra*), locally called *chapila*. Like American shad, the hilsa shad is generally termed anadromous, but it migrates frequently between freshwater and the sea. Generally, after spawning in freshwater they return to the sea where they remain until the next breeding season. The juveniles grow up to 5–15 cm Standard Length (SL) in freshwater and then move to coastal and estuarine region the and finally to the sea. However, this lifecycle pattern is not followed by all stocks/races of the species; some do not migrate from the sea to the river or vice versa. Hilsa become sexually mature after 1–2 years of life. The size at first maturity is around 22–25 cm SL for males and 28–30 cm SL for females. Size-wise distribution of the sexes in Bangladeshi waters revealed a higher percentage of females in the size group above 40 cm SL. It is a highly fecund fish and does not show any parental care. The peak spawning season is September–October; however, hilsa may spawn throughout the year and their recruitment pattern is continuous with two major peaks, one in July and the other in October. A mature female hilsa may release 2.5 lac to 25 lac eggs depending on the size of the fish.

There is still controversy regarding stocks/races of hilsa in different water bodies. Some workers found a homogenous stock of hilsa in Bangladeshi waters, while others have found heterogeneity among hilsa in different water bodies. The comparative growth curves between the sexes revealed that in the first and second year males and females grew similarly, but after the second year females grew at a considerably faster rate.

Certain environmental factors stimulate and trigger biological activities and the lifecycle of the fish. Monsoons have a great influence on its breeding and migratory behavior. Salinity and monsoon runoff of huge amounts of turbid water are very important for breeding migration, and the productivity of the ecosystem and availability of food are important factors for the abundance of hilsa. Lunar periodicity and time of day also greatly influence its growth and other physiological activities, including spawning and migration pattern.

Hilsa fishery and management

As a result of the declining trend of the hilsa catch, loss of livelihoods for fishers and increasing demand in the domestic and export markets, the GoB has introduced incentive-based management and conservation of the hilsa fishery. The salient features of the management include imposition of bans on catching juvenile hilsa for 6 months in its growing season, a complete ban on fishing brood hilsa for 11 days in October during the full moon to allow breeding, and closure of five sections of the migratory and breeding and nursery grounds by setting up sanctuaries. About 50% of the 0.46 million hilsa fishers have been brought under subsidies by giving cash and providing AIGs to the fishers in response to their participation in the fishery management programs. The positive impacts on the availability of broodstocks and juveniles have been observed since the introduction of the management measures in Bangladesh. In the spawning grounds of the Meghna River (Monpura and Hatia), about 95% of fish have been found to be above 35 cm size, and almost all are breeders. About eight times the amount of eggs and *jatka* were produced in 2011 than in 2007–2008 because of the imposition of an 11-day fishing ban in the spawning grounds. Total hilsa production in Bangladesh increased 54.13% in 2011 in comparison to 2002 as a result of new management interventions.

The latest estimation of the exploitation levels (E) for the hilsa fishery in the river and marine habitats were 0.58 and 0.57, respectively, which indicated overexploitation of the hilsa fishery in Bangladeshi waters. However, there is further potential to increase yield by increasing the exploitation level up to E=0.61 (E_{max}=0.61) for rivers and E=0.65 (E_{max}=0.65) for the marine environment.

Aquaculture and "cultivability" of hilsa

In view of the critical importance of the hilsa fishery from social, cultural, food, nutritional and conservation perspectives, there is a growing interest in farming the species. Scientists in both Bangladesh and India have started trials on the breeding and culture of the species. Some progress has been made, but research efforts have been scattered, with no systematic approach, making it clear that much more focused and coordinated research and development initiatives are required if progress is to be made.

The reviews have highlighted that some successes in gamete collection from wild fish and also from captive broodstock have been made at the BFRI, Chandpur, Bangladesh; however, it is far from meeting the requirements of a sustainable aquaculture program. Hilsa fry averaging 16±7 g in weight and 11±3 cm in Total Length (TL) collected from the Meghna River were stocked at a density of 10 individuals decimal-1 in three experimental ponds with an area of 33 decimals (dec=40 m^2) each. Stocked hilsa fry thrived in the ponds well but exhibited poor growth and survival rates, reaching a final weight of 252±60 g and length of 32±6 cm TL in 15 months. Attempts also have been made in India to hatch larvae from both wild collected gametes and captive broodstock with similarly limited success. The study revealed that hatchery success would require developing technologies of broodstock management, hatchery management, live feed production, larval rearing and ongrowing techniques. On the other hand, success stories of aquaculture of similar shads in other regions, such as Chinese shad (*T. reevesii*) and Malaysian Terubok (*T. toli.*), may provide guiding protocols for hilsa seed production and aquaculture development.

Sources of fry and fingerlings

A continued supply of quality fish seeds, fry and fingerlings is a necessary prerequisite for aquaculture. So far, many attempts have been made at the CIFRI and other hatcheries in India for breeding adult hilsa caught from the river. While there had been success in breeding and fertilization in controlled hatchery conditions, survival was negligible. Breeding efforts on freshly caught hilsa were tried at the BFRI Chandpur station as well, but the efforts were inconsistent and unsuccessful.

Wild collection of natural eggs, fry and fingerlings of hilsa depends mainly on the spawning season, spawning area, nursery area and season of fry and fingerlings availability and opportunity for live catch and transportation. Several attempts were made in Bangladesh to collect 2- to 3-day-old postlarvae/fry of hilsa from the spawning grounds in the Meghna River near Chandpur using *Savar jal*. The BFRI was successful in catching hilsa fry from the spawning grounds in the adjacent Meghna River and transporting them to the land-based nursery/rearing ponds. The yolk sacs of the larvae were absorbed within 5 to 6 days, and then they were fed with cultured rotifers for the next 7 days. From the 14th day, *Artemia* nauplii along with rotifers were given as feed. The survival rate of the fingerlings was recorded to be 50%–70%. Results showed that nursery rearing of hilsa fry and fingerlings could be done in pond conditions.

Hilsa fry and fingerlings up to 23 cm TL, popularly known as *jatka*, are found in the rivers of Bangladesh from November to May. *Jatka* 8.8–11 cm TL and 7–12 g are suitable for transportation for nursery rearing. *Jatka* caught with *jagat ber jal* could be kept alive in water by making a pocket at the cod end. This could be a suitable technique for transportation of live *jatka* for nursery rearing and subsequent aquaculture. However, the BFRI experience revealed that the transportation system of hilsa fingerlings in plastic or fiberglass tanks could be improved by lowering the water temperature of the tank by adding ice and mild anesthetics.

Grow-out systems

In the near future, the open water production of hilsa could come to a standstill, and there may be no scope for further increase. Therefore, there is an urgent need to explore alternative sources of hilsa production in Bangladesh. Culture of hilsa in captive/semi-captive conditions may be an option. Sources of fry and fingerlings is the limiting factor for culturing hilsa in captive conditions. So far, attempts taken in Bangladesh and India have not been satisfactory. A shortage of technical skills and funds did not allow the research efforts to move forward consistently. The BFRI has shown initial success in domestication in earthen ponds, but scientific trials on stocking, feeding and grow-out have yet to be done. Wild caught *jatka*/juveniles may be used for pilot-scale land-based aquaculture in the BFRI or Faculty of Fisheries farm ponds and for cage aquaculture in sheltered rivers in southern Bangladesh, such as in Bhola, Barisal and Patuakhali.

Feeds and feeding

The development of a gizzard along with loss of teeth, development of the pharyngeal organ, well-developed gill rakers and a moderately long intestine indicate a microphagous feeding habit for hilsa. The major food components observed in all stages of the lifecycle of hilsa were diatoms, green algae, blue-green algae, protozoans, rotifers, copepods, cladocerans, ostracods, nauplii, organic matter, plant parts and mud or sand. In general, most Indian and Bangladeshi authors have found that zooplankton is the dominant feed of hilsa during the early stages, with a gradual increased intake of phytoplankton, especially diatoms in the later stages. The intestine of hilsa is thin-walled and of considerable length, and the adult intestine has 10 bends and 5 loops.

The experience of feed development for American shad, salmon and marine shrimp may be useful for the formulation of hilsa feed for its juveniles to grow-out phases. The weaning stage from endogenous to exogenous feed is crucial for the survival of hilsa juveniles. In the case of American shad, the period of low feeding incidence paralleled periods of slow growth from 6 to 21 days of age and high larval mortality from 9 to 14 days of age. The larvae then more actively sought feed after this period, became more efficient at feeding and the incidence of feeding increased. Daily larval mortality turned to a level of less than 0.4% per day, and larvae again began to increase in length. First-feeding larvae selected *Artemia* slightly smaller than the mean length and width available and rejected large nauplii of 0.55 mm in length. There were diel variations in the incidence of feeding, with the peak feeding periods in the evening (18:00–21:00). The incidence of feeding was higher for larvae reared in continuous light.

Breeding and genetics

For artificial breeding, both "wet" and "dry" methods of stripping were adopted, but the wet method proved to be suitable. The most critical stage to establish commercial farming of hilsa involves reproduction, larval and juvenile development and growth performance. However, success in hilsa culture largely depends on a reliable method of transportation of juveniles for stocking.

The population genetic structure of hilsa has been studied using morphometric characterization, allozyme markers, Random Amplification of Polymorphic DNA (RAPD), Restriction Fragment Length Polymorphism (RFLP) and mitochondrial DNA Cytochrome *b* gene nucleotide sequence, with varied results. The hilsa population of the Brahmaputra, Padma, Ganges, Hooghly and feeder canals in India did not exhibit significant genetic diversity, indicating the presence of a genetically unique stock in this region.

Workshop feedback

In the plenary session, the participants were randomly divided into three groups and provided with a set of questions/issues to be addressed. Phillips, Beveridge, Puvanendran and Wahab helped the groups to have good brainstorming sessions before coming up with specific feedback.

Breeding and seed production

i) In response to a question on where they want to be in next 10 years, their feedback was as follows:

- domesticated broodstock development
- expertise on reproductive physiology
- good protocol for producing seeds from captive broodstock
- understanding nursery protocols
- knowledge of disease and pathogens of hilsa
- better knowledge of the genetic structure of the hilsa population
- lifecycle closed
- selective breeding
- gene banking and cryopreservation of milt

ii) Regarding the present status of knowledge on hilsa aquaculture, the participants expressed their feedback as follows:

- Domesticated broodstock development
    - Knowledge on the collection of gametes onboard, fertilization of eggs, transfer of fertilized eggs to the BFRI Riverine Station in Chandpur has been possible. Larvae hatched, but the feeding of larvae was not possible because of a lack of suitable larval feed and a lack of knowledge on water quality requirements in the hatchery as well as for the larvae.

- Good protocol for producing seeds/larvae from captive broodstock
    - There is either very little or no expertise at all on reproductive physiology. Larval rearing protocol needs to be developed and nursery technology needs standardization, since in present conditions larvae survive for only 5–10 days. Planktonic food development protocol needs to be developed. Knowledge on disease and pathogens of hilsa at different stages is very limited.

- Better knowledge of the genetic structure of the hilsa population
    - Little information is available based on RAPD, RFLP and mitochondrial DNA Cytochrome *b* gene nucleotide sequencing. More detailed study is needed. Lack of skills on closed lifecycle, selective breeding, gene banking and cryopreservation of milt is evident.

iii) In response to a question on what gaps there are in current knowledge, the plenary responses were as follows:

- Domesticated broodstock development
    - Influence of sea water on reproductive development is unknown.
    - Water quality information is limited.
    - Feed quality is unknown.
    - Smoltification process is not known (reason for slow growth in freshwater ponds after 1 year needs closer look).

- Reproductive physiology
    - Reproductive hormone development profiling (at different stages/sizes) is needed for in both the sea and freshwater. Knowledge on induced spawning of hilsa is insufficient.

- Good protocol for producing seeds/larvae from captive broodstock
    - Sample fish at different developmental stages, and study the gonads and brain using gene expression studies in different environments (freshwater, estuary and sea).
    - Optimum environmental conditions: light, temperature, dissolved oxygen (DO), turbidity, etc. need to be known.
    - Feeding methods: time, frequency and ration need to be clearly understood.

iv) The plenary was also asked for future research needs to close the knowledge gaps, and they responded as follows:

- Domesticated broodstock development
    - Study the influence of sea water in growth and gonadal development.
    - Study nutritional requirements (types of natural food) and water quality.
    - Study to understand the type of broodstock holding system.

- Reproductive physiology
    - Sample fish at different developmental stages, and study the gonads and brain using gene expression studies in different environments (freshwater, estuary and sea).
    - Body composition, lipid profiling, etc. need to be known.

v) The plenary suggested the development of partnerships among the following institutions:

- DoF, BFRF, BARC/BFRI, universities, CIFRI, private entrepreneurs in India, WorldFish and Norwegian institutes and industry.

Production system

Regarding the production system, the plenary suggested developing a standardized hilsa farming system and a reliable system of seed collection and transport and also improving nursing facility and techniques to grow fish up to market size.

They felt that there is limited knowledge on grow-out systems. The farming environment can be freshwater, brackish or marine water, and production systems can be ponds or cages. The stocking density and feed requirements need to be standardized for extensive/semi-intensive/intensive production systems. Regarding the feed and feeding system, the plenary group emphasized technical skill development for assessing types of feed and their acceptability, nutrition requirements, and also feed formulation, feed conversion ratio or feed efficiency and water quality.

Some ecto-parasite infections in wild stocks have been observed, so preventive methods for anticipated diseases in production systems were suggested.

The economics of production systems were considered to be important for scaling up aquaculture of hilsa, especially the cost-benefit analysis in seed collection and transportation, nursery operations, and grow-out production systems as well as market price for farmed hilsa.

Environment (including wild and farmed fish interactions)

- Knowledge gaps
  - The environment group identified a number of issues where there is a prevailing lack of knowledge. The areas they identified are changes in migratory routes, spawning season and time, changes in spawning grounds, changes in nursery grounds, anticipated impacts of climate change, habitat loss (roads, dams, barrage, siltation, etc.), changes in water quality (pollution, temperature, salinity and pH), ecological changes because of various interventions and impacts of future aquaculture on the environment and vice versa.

- Impact of aquaculture on management
  - The environment group also predicted the foreseeable impacts of aquaculture on the decline in natural stock, possibility of genetic erosion, vulnerability of fishers' livelihoods, complexity of law enforcement, pollution from effluents/feed wastes, impacts on biodiversity, and disease proliferation in the natural fishery.

- Assumptions for success of the stated programs
  - appropriate interventions in place
  - adequate resources mobilized
  - effective implementation
  - no or fewer impacts on environment.

Key recommendations from the workshop

The plenary session suggested the following recommendations:

i) Biology and ecology

- Broodstock
  - Domestication of wild fish into captive broodstock in hatchery ponds or in cages should be tried.
  - Various steps in husbandry of broodstock, such as feeding, fertilization and water quality maintenance, should be thoroughly understood and standardized.
  - Knowledge on broodstock nutrition should be improved, and brood feed should be developed.
  - Basic information on the reproduction of hilsa should be collected and spawning and fertilization techniques should be developed.

- Larval phase
  - Live feed culture of phytoplankton (diatoms) and zooplankton and their nutrition values should be studied.
  - Protocols should be developed for larval feeding in tanks or in aquariums, and provision for aeration for DO and optimum light intensity and temperature regime should be developed.
  - In the critical period of the larval stage change from endogenous feeding to exogenous feeding, the weaning period should be carefully monitored and taken care of for successful seed production.

- Environmental requirements
  - The hydrological dynamics (current, tide, turbulence, silt-mixing, influx of monsoon rain and floods) and water quality parameters, such as total suspended solids (TSS), conductivity, water temperature, secchi disc, total alkalinity, pH, DO, NO_3, NO_2, NH_3, PO_4 and chlorophyll-a should be routinely monitored year-round in the major fishing grounds of hilsa.

    - Climatological factors, such as humidity, rainfall, wind direction, lunar cycles, etc., should be monitored year-round to understand the ecology of hilsa in rivers and estuaries.

Responsibilities: BFRI, CIFRI, DoF, BAU, WorldFish and other relevant universities should address different stages of the biology of hilsa as well as hydrological cycles and water quality requirements for breeding and larval rearing in rivers and estuaries.

ii) Fishery management

- There is a need to strictly adhere to the *jatka* size (23 cm) regulation to control exploitation of hilsa below 500 g to facilitate them to breed at least once in their lifecycle.
- As most juveniles start their downstream migration during March–May after reaching 80–150 mm, a complete ban on the use of non-selective gear, viz. bag nets or scoop nets, during these three months may facilitate the juveniles to migrate to the sea for maturation.
- Similar to Bangladesh, breeding zones should be declared as sanctuaries during breeding seasons in India and Myanmar, and an adequate compensation package should be made available to hilsa fishers.
- Improvement of migratory routes by dredging the estuary mouths may encourage more hilsa broods to migrate upstream.
- A ban on trawling in the inshore marine zones up to 30 km from the mouth of the estuary may improve the hilsa fishery.

Responsibilities: BFRI, CIFRI, DoF, BAU, WorldFish and other relevant universities should address various conservation and management measures and evaluate the existing fish act in each country for sustainable management and exploitation of hilsa in Bangladesh, India and in the region as a whole.

iii) Aquaculture

- The performance of hilsa in different grow-out systems—tanks, ponds, cages and pens—should be tried following standard protocols.
- Hilsa aquaculture should be tried in freshwater, brackish water and sheltered marine waters.
- Optimum stocking density, stocking size, water quality, feeding regimes, environmental regimes, etc., should be standardized.
- The similarity of hilsa with other anadromous fish, like salmon, should be closely looked into if it has any stage of smoltification and any physiological changes for leaving freshwater for marine waters.
- Nutrition requirements of hilsa in grow-out systems and its response to commercial feed should be evaluated. Efforts should be made to develop a special type of feed that is suitable for enhancing the growth of fish in production systems.

Responsibilities: BFRI, CIFRI, DoF, BAU, WorldFish and other relevant universities should address the different stages of grow-out systems for starting aquaculture of hilsa in Bangladesh, India and in the Bay of Bengal region.

iv) Sources of fry and fingerlings

- Hilsa fry and fingerlings may be collected from natural sources, but transportation techniques need to be improved.
- On-board breeding should be done and fertilized eggs should be collected and transported to the nearest hatcheries for fry and fingerlings production.
- Fry and fingerlings production techniques in captive conditions need to be developed.
- Induced breeding techniques of hilsa need to be standardized through intensive research. Planktonic food organisms should be cultured for feeding the early stages of fry during weaning.

Responsibilities: CIFRI, CIBA, BFRI, BAU and universities should undertake both basic and applied research to understand the breeding obstacles, environmental hindrances and feed requirements during the early stages of juveniles.

v) Breeding and genetics

- Knowledge on breeding biology needs to be improved.

- Family-based selective breeding programs for hilsa should be tried.
- It is imperative that a reliable captive breeding protocol be established for the production of quality seed for aquaculture and restocking. The artificial breeding protocols of the Chinese river shad (*Tenualosa revesii*) Japanese eel (*Anguilla japonica*), red seabream (*Pagrus major*), sea bass (*Lates calcarifer*), etc., may act as guiding principles.
- On-board breeding as well as necessary facilities for hilsa breeding should be developed in the hilsa breeding center.
- A detailed study of the hilsa population's genetic structure through informative molecular markers, such as microsatellite, is needed to resolve the controversy of the existence of a single stock or different stocks of hilsa with a separate gene pool in different waters in the region.
- Research to explore the opportunities for increasing the nutritional values of hilsa should be tried.
- Other traits for genetic selection, such as growth rate (survival) and disease resistance, should be tried through the application of biotechnological methods.

Responsibilities: The breeding and genetics divisions of the CIFRI, CIBA, BFRI, BAU and relevant organizations and universities should undertake breeding and genetics study of hilsa.

vi) Feeds and feeding

- Food composition of different size groups (fry, juvenile and adult) of hilsa should be thoroughly studied in spite of the fragmentary information available.
- Efforts may be made to develop mass culture of both green algae/diatoms and zooplankton of river and coastal origin as part of the hilsa hatchery system.
- A plant-based diet for broodstock following the principles of marine shrimp feed may be an initial option for hatchery and grow-out feed preparation.
- Mixed fertilization and feeding practices, land-based pond aquaculture, especially in the case of coastal ponds, should be tried.

Responsibilities: BFRI, CFRI, BAU, WorldFish and other universities should try to develop culture techniques for microalgae and rotifers as well as develop grow-out feed for hilsa aquaculture.

vii) Marketing

- Hilsa fishers in the rivers and estuaries should be provided with a registration card that can be accepted for taking loans from the public and private banks.
- Hilsa fishers should be supported during the ban period as well as during any natural calamities.
- Hilsa fishers involved in the marine fishing boats should have fair wages to uproot exploitation.
- Value addition through product diversification, keeping the original taste and flavor of hilsa intact and the provision of postharvest storage at the landing centers may help with getting fair prices.

Responsibilities: DoF, BFRI, CIFRI, DoF-West Bengal, BAU, processing industries, Ministry of Fisheries and Livestock, Ministry of Commerce, Ministry of Finance in Bangladesh, Marine Products Export Development Agency (MPEDA) in India, Ministry of Commerce in Myanmar.

vii) Research and development (aquaculture and management)

- concrete information on the biology of hilsa, including reproductive physiology and feeding ecology; knowhow: breeding and grow-out, and development of culture packages; stock assessment of juvenile and adult hilsa, harvestable size and total sustainable exploitation; migration pattern of juveniles and brood hilsa, and triggering environmental, climatological and lunar cycles; ecological study of river and estuarine habitats; socioeconomic conditions and livelihoods of fishers; rationalization of conservation and management regimes; capacity building for skilled manpower in breeding, larval rearing, aquaculture and fish population dynamics and hilsa genetics.
- logistical support, including research vessels, on-board hatchery, land transport, etc.

Responsibilities: research organizations (BFRI, CIFRI), academic institutions (universities), extension organizations (DoF, NGOs), policy and legislation, CBOs, law enforcement agencies, and effective regional cooperation among Bangladesh, India and Myanmar.

Conclusions

The reviews on different aspects of the hilsa fishery, from biology to marketing and utilization, as well as the two-day long presentations and open discussions revealed that hilsa is a very important common fishery in Bangladesh, India and Myanmar. Hilsa is very tasty, rich in omega-3 Polyunsaturated Fatty Acids (PUFAs), micronutrients and other essential fatty acids and plays significant socioeconomic and cultural roles in the lives of 250 million people living in Bangladesh, some states of India and Myanmar. It has religious importance to Hindu Bengalis and has a deep attachment to the Bengali New Year, *Pahela Boishakh*. It is also the national fish of Bangladesh.

There have been over 100 years of research efforts on the biology and ecology as well as domestication and breeding of hilsa in both parts of Bengal, but most efforts were scattered and inconsistent. There have been a few works on hilsa genetics and biotechnology. Until the mid-1970s, there was an abundant natural harvest of hilsa when they migrated in schools from the Bay of Bengal to the Ganges River and its tributaries for breeding. Since the installation of the Farakka Barrage on the Ganges in the Indian part of the river and the subsequent blocking of migratory routes and siltation in the major downward rivers, the hilsa catch has severely declined.

Domestication and breeding of hilsa has been tried on several occasions in the CIFRI and BFRI, but no conclusive result has been obtained so far. The only noteworthy success has been the management measures adopted by the GoB that introduced incentive-based hilsa fishery management since 2003 through conservation of *jatka* and brood hilsa. Tremendous success has been achieved by imposing a ban on catching, and declaring five sanctuaries in the major hilsa fishing grounds in strategic locations in the migratory routes along the major downstream rivers. Hilsa production increased from 0.19 t in 2002 to 0.35 t in 2011. However, despite this apparent increased production, there is uncertainty surrounding sustained natural harvest. On the other hand, other beneficiary countries, like India and Myanmar, have not yet started implementation of conservation and management practices based on scientific evidence.

Therefore, a fruitful research on hilsa to develop seed production and aquaculture technologies is the demand of the day. In that perspective, the present initiative of WorldFish to facilitate hilsa research in an organized fashion with regional and international collaboration has earned reputation. The feedback and recommendations coming out of the workshop exercise and compilation of those in this book will help develop a sustainable aquaculture of the valuable hilsa fish in this region.

The Editors

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List of abbreviations

ACIAR	Australian Centre for International Agricultural Research
AKVAFORSK	The Institute of Aquaculture Research, Norway
AIGA	alternative income generating activities
ARDMCS	Aquatic Resources Development, Management and Conservation Service of World Bank
BAU	Bangladesh Agricultural University
BFDC	Bangladesh Fisheries Development Corporation
BFRI	Bangladesh Fisheries Research Institute
BFRI/RS	Bangladesh Fisheries Research Institute/Riverine Station
BoBLME	Bay of Bengal Large Marine Ecosystem
BoBP	Bay of Bengal Programme
CIBA	Central Institute of Brackish Water Aquaculture
CIFA	Central Institute of Freshwater Aquaculture
CIFRI	Central Inland Fisheries Research Institute, India
CPUE	catch per unit effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHA	docosa hexaenoic acid
DO	dissolved oxygen
DoF	Department of Fisheries, Government of Bangladesh
DOM	domperidone
EAA	essential amino acid
EFA	essential fatty acid
EPA	eicosa pentaenoic acid
FAO	Food and Agriculture Organization
FCD	flood control and drainage
FCDI	flood control, drainage and irrigation
FFA	free fatty acids
FRL	full reservoir level
FRSS	Fisheries Research Survey System
GDP	gross domestic product
GEF	Global Environment Facility
GIFT	genetically improved farmed tilapia
GSI	Gonado-Somatic Index
HDL	high density lipoprotein
HFMAP	Hilsa Fisheries Management Action Plan
ICAR	Indian Council for Agricultural Research
ICLARM	International Center for Living Aquatic Resource Management
IPFC	Indo-Pacific Fisheries Council of FAO

IQF	individual quick freezing
LDL	low density lipoprotein
LHRHa	luteinizing hormone-releasing hormone analogue
MAS	marker-assisted selection
MSY	maximum sustainable yield
MUFA	monounsaturated fatty acid
NEAA	non-essential amino acid
Nofima	The Norwegian Institute of Food, Fisheries and Aquaculture Research
NRC	Norwegian Research Council
OA	oleic acid
PUFA	polyunsaturated fatty acid
RAPD	Random Amplification of Polymorphic DNA
RFLP	Restriction Fragment Length Polymorphism
SDI	Sarawak Development Institute
SFA	saturated fatty acid
SL	standard length
STF	Special Task Force
SWOT	Strength – Weakness – Opportunity – Threat analysis
t	metric ton
TL	total length
UNDP	United Nations Development Programme
USFA	unsaturated fatty acid
VSR	Vallabh Sagar Reservoir

Hilsa in Manpura macch ghat.

1. Biology and ecology of hilsa

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Abstract
This chapter reviews the biology and ecology of hilsa shad (*Tenualosa ilisha*: Clupeidae family, Alosinae subfamily), with an emphasis on Bangladesh and India. The lifecycle of hilsa shad resembles American shad (*Alosa sapidissima*), but the juveniles, called *jatka*, resemble adult Indian river shad (*Gudusia chapra*), locally called *chapila*. Hilsa shad are often called anadromous fish, but they migrate frequently between freshwater and the sea. Generally, after spawning in freshwater they return to the sea where they remain until the next breeding season. The juveniles grow up to 5–15 cm in freshwater and then move to coastal and estuarine regions and finally to the sea. However, not all stocks/races of the species follow this lifecycle pattern. Some do not migrate from the sea to the river or vice versa. Hilsa become sexually mature after 1–2 years of life. Their size at first maturity is about 22–25 cm for males and 28–30 cm for females. The size distribution of sexes in Bangladeshi waters reveals a higher percentage of females in the group above 40 cm Standard Length (SL). Hilsa is a highly fecund fish and does not show any parental care. Its peak spawning season is September–October, though spawning can occur throughout the year. Recruitment is continuous, with two major peaks in June–July and September–October.

There is controversy regarding the stocks/races of hilsa in different water bodies. Some researchers claim there is a homogenous stock of hilsa throughout Bangladeshi waters, while others have found heterogeneity among hilsa in different water bodies. The linear relationships between the otolith lengths and total lengths were established with highly significant ($P<0.01$) correlation coefficients. The age groups found were 1+ to 6+ from the otolith study as well as from the length frequency study of hilsa from Bangladeshi waters. The comparative growth curves between the sexes revealed that males and females grew similarly in the first two years, but females grew at a considerably higher rate after the second year.

The hilsa fishery is mainly artisanal and exploited from rivers, estuaries and the sea. The latest estimation of the exploitation levels (E) in riverine and marine habitats was 0.58 and 0.57, respectively, indicating overexploitation of the hilsa fishery in Bangladesh. However, it may be possible to increase yields by increasing exploitation levels up to $E = 0.61$ ($E_{max} = 0.61$) for rivers and $E = 0.65$ ($E_{max} = 0.65$) for the marine environment.

Environmental factors initiate certain biological activities in the lifecycle of hilsa. Monsoons greatly influence its breeding and migration. Salinity and monsoon runoff of large volumes of turbid water are very important for breeding, migration and the productivity of the ecosystem, while the availability of food is the most important factor in determining the presence of hilsa. Lunar periodicity and daylight also greatly influence physiological activities, including spawning and migration.

1.1. Introduction

Shads (Clupeidae family, Alosinae subfamily) belong to a cosmopolitan group of fish that exploit a wide range of habitats throughout the world (Rahman 2001 and 2006). Hilsa shad, commonly known as hilsa (*Tenualosa ilisha*, Hamilton 1822), is an important migratory species in the countries of the Bay of Bengal and the Persian Gulf regions, especially Bangladesh, India and Myanmar. Other countries where the species contributes to the national catch are Pakistan, Iran, Iraq and Kuwait. Some unrecorded catches have also been observed in Indonesia (Sumatra) (Rahman 2001). Currently, 50%–60% of the global hilsa catch reportedly comes from Bangladesh, 20%–25% from Myanmar, 15%–20% from India and 5%–10% from other countries such as Pakistan, Iran, Iraq and Kuwait (Rahman et al. 2010).

The species is a highly popular food fish among the people of Bangladesh and India because of its high palatability, special flavor, moderate size, pleasing shape and shiny appearance. As a result, the market demand for the species is increasing, and it is being exported to other countries (Haldar et al. 2004; DoF 2005; Rahman 2006). As the most important fishery in Bangladesh, the species has great socioeconomic importance, employing about 2% of the total population, i.e. about 2.5 million people (Rahman 2006). It has also socioreligious significance throughout southern India and Bangladesh (Fischer and Bianchi 1984). It is the national fish of Bangladesh. The esteem in which the hilsa is held is reflected in Sanskrit and Bengali literature, where the fish is described as *Machher Raja* ("king of fishes"), and it is said that *illisah jitapiyusah* ("hilsa surpasses nectar") (Whitehead 1985).

Before 1970, the hilsa fishery in most countries was largely artisanal in nature, using traditional methods, and was mainly confined to rivers and estuarine regions. However, because of mechanization and the development of fishing craft, as well as the introduction of larger and more efficient fishing gear, the fishery has gradually shifted toward estuarine and marine environments (Hall and Kashem 1994; Rahman 2001 and 2006; Mome 2007). Nowadays, fishing vessels often travel 93-185 km into the open water of the Bay of Bengal to catch hilsa (Jafri and Melvin 1988; Rahman 2001). A gradual decline in the abundance of the species in rivers may have also contributed to the shift in location of the main fishing effort (Mazid 1998; Hossain 1998; Rahman 2006; Mome 2007).

During the past 20 years, the fishery has gradually declined in the upper reaches of rivers from increasing fishing pressure on both juveniles and adults, loss of spawning grounds and obstruction to migratory routes by anthropogenic activities such as the construction of barrages, dams and fences, along with the deterioration of habitat by industrial and agricultural pollution (Haldar and Rahman 1998; Rahman 2001 and 2006; Mome 2007). These factors coupled with the increasing demand for the fish as food by the rapidly growing population of the region exert an adverse synergistic affect on the abundance of the species in the upper reaches of the rivers. However, catches from the marine environment seem to be increasing, mostly as a result of greater exploitation from the sea through the use of more efficient crafts and gear (Rahman 2006; Mome 2007).

Because of its migratory lifestyle, wide distribution, great popularity and high socioeconomic and socioreligious importance in the region, many fishery biologists, fishery managers and socioeconomists have paid considerable attention to the hilsa shad. A number of review articles and bibliographical works have already been published. Jones (1952) presented the first comprehensive bibliography of scientific papers, government reports and newspaper articles on hilsa from 1822 to 1951. Pillay (1955) provided a comprehensive summary of the literature on the biology and fisheries of hilsa, which was followed by a synopsis of biological data of the species (Pillay and Rosa 1963). Sarkar and Momen (1982) and Jafri and Melvin (1988) organized bibliographies, including some abstracts on every aspect of the species.

However, before 1985 there had been no organized program of research on this migratory species. In 1985, a one-year intercountry research program was conducted under the Bay of Bengal Programme (BoBP). Initially, the countries involved in the BoBP were Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka and Thailand (BoBP 1987). Studies carried out in the past in the Bay of Bengal region were almost exclusively on the hilsa of inland waters, including estuaries; little attention had been paid to the marine phase of the life history of the fish, except for some work in Myanmar (BoBP 1987). Jafri (1988) and Rahman (2006) both reviewed the biology and fishery of the species, while Bhaumik and Sharma (2011) reviewed the status of the hilsa fishery in the Hooghly-Bhagirathi river system. Recent activities have mainly concentrated on management-oriented research and socioeconomic aspects of the species (Rahman and Moula 1992; Rahman 2006; BoBLME 2011).

It is essential to summarize all published and, wherever possible, unpublished works on this valuable species in a single compendium to help future studies and farming of hilsa. The present chapter is devoted to summarizing all available information on the biology and ecology of the species.

1.2. Taxonomy

The taxonomy of the species described in the following sections and subsections is based mainly on publications by Pillay and Rosa (1963), Fischer and Whitehead (1974), Whitehead (1985), Jafri and Melvin (1988), the Shad Foundation (1998), Rahman (2001), FishBase (2012), Wikispecies (2012) and EOL (2012).

Systematic position[1]

The systematic position of the species is as follows:

Phylum: Vertebrata
Subphylum: Craniata
Superclass: Gnathostomata
Series: Pisces
Class: Teleostomi
Subclass: Actinopterygii
Order: Clupeiformes
Suborder: Clupeoidei
Family: Clupeidae
Subfamily: Alosinae
Genus: *Alosa*

Species: *A. sapidissima, A. aestivalis, A. agone, A. alabamae, A. algeriensis, A. alosa, A. immaculata, A. braschnikowi, A. maeotica, A. saposchnikowii, A. chrysochloris, A. mediocris, A. fallax, A. kessleri, A. killarnensis, A. macedonica, A. pseudoharengus, A. caspia, A. sphaerocephala, A. suworowi, A. tanaica, A. vistonica, A. volgensis, A. pontica and A. curensis*

Genus: *Hilsa*

Species: *H. kelee*

Genus: *Gudusia*

Species: *G. chapra, G. manmina*

Genus: *Tenualosa*

Species: *Tenualosa ilisha* (Hamilton 1822), *T. macrura* (Bleeker 1852), *T. reevesii* (Richardson 1846), *T. thibaudeaui* (Durand 1940), *T. toli* (Valenciennes 1847)

1.3. Nomenclature

The nomenclature of *Tenualosa ilisha* has undergone a number of revisions (Jafri and Melvin 1988). The species was first described by Russell in 1803. However, Hamilton (1822) first named the fish as *Clupanodon ilisha* and provided the first recognized description. Günther (1868) subsequently described the species as *Clupea palasah*. Day (1865) termed it *Alausa palasah*, while Cantor (1849) and Bleeker (1852) called it *Alausa ilisha*. Day (1878), Lloyd (1907), Tirant (1929) and Steindachner (1896) redescribed the species as *Clupea ilisha*. Fowler (1941) provided a summary of hilsa nomenclature and detailed taxonomic characteristics, calling the species *Macrura ilisha*. The most commonly used name *Hilsa ilisha* comes from Regan (1917), Fowler (1934), Shaw and Shebbere (1937) and Misra (1953). Finally, *Tenualosa ilisha*, the latest name, was first used by Munro (1955). Fisher and Bianchi (1984) subsequently supplied classification information for the redescription of the species. The most frequently used and published name of the species remains *Hilsa ilisha*, though the recent trend is to use *Tenualosa ilisha* (Hamilton 1822). Synonyms still in use are *Hilsa ilisha* (Hamilton 1822) and *Hilsa palasah* (Cuvier 1829). The Food and Agricultural Organization (FAO) uses the following names for statistical purposes: Hilsa shad (English), Alose hilsa (French) and Sábalo hilsa (Spanish). Finally, common names and vernacular names of hilsa vary in different areas and languages (Table 1).

[1] Species belonging to three further genera—Brevoortia, Ethmalosa and Ethmidium—are excluded from further consideration here, for the sake of brevity.

Country	Area/ Language	Standard Common name(s)	Vernacular name(s)
Bangladesh	Bengali English	Ilish Hilsa	Adults: Ilish mach/Ilse mach/Ilish/Ilisha/Ilshe Juveniles: Jatka/Jhatka/Jadka Hilsa/Jatka
India	Narbada Bengali Hindi Assam Orissa Bengal Tamil Telugu Sindhi Malayalam Marathi West Bengal Chilka Lake Canarese Oriya	Hilsa/Indian shad Ditto Ditto Ditto Ditto Ditto Ditto Ditto Ditto Ditto Ditto Ditto Ditto Ditto Ditto	Chaksi/Chaski Hilsa/Ilish Hilsa Ilihi Ilish/Ilisha/Ee-liha Ilish/Ilisha/Eee-lish Oolum/Ulum/Ullam/Sevva Palasah Pala/Palo/Pulla Paluva/Valava/Paliyah Palla Hilsa/Koira (juveniles) Hilsa/Jodi (juveniles) Paliya Pussai
Pakistan	Punjabi Sindh	Hilsa Ditto	Ilish/Jatka (juveniles) Palla/Pulla
Myanmar	Burmese	Hilsa	Nga-tha-lauk/Nga-thalank
Sri Lanka	Tamil	Hilsa/River shad	Sevva/Oolum/Ullam
Iraq	Arabic	Sbour	Shour/Sbour
Iran	Farsi	Soboor	Soboor
Indonesia	The Sumatra	Hilsa	Terubok
UK/US/Canada/Australia	English	Hilsa shad/Indian shad	Hilsa
Poland	Polish	Hilza indyjska	Hilsa indyjska
Kuwait	Arabic	Sbour	Sbour

Sources: Pillay and Rosa 1963; Whitehead 1985; Rahman 2001.

Table 1. Standard common names and vernacular names of hilsa shad.

1.4. Identifying characteristics

Hilsa is a moderate or large herring type of fish that is approximately 45–50 cm SL. The maximum size recorded in Bangladesh is 59.8 cm TL and 3.2 kg in weight; in India it is 61.4 cm in length and 4.25 kg in weight (Bhaumik et al. 2012). Its body is moderately deep and elongated but laterally compressed. The belly is fairly sharply keeled with 30–33 scutes (16–17 scutes before and 14–15 behind the insertion of the ventral fin). The top of its head does not have numerous fronto parietal striae. The head varies in length from 28%–32% of the standard length, and the mouth terminal has a distinct median notch on the upper jaw. The eyes are embedded with broad adipose lids. It has no teeth. The gill rakers are straight, fine and numerous, with 100–250 on the lower part of the gill arch. The caudal fin is deeply forked and almost as long as the head, about 25%–31% of standard length. The caudal peduncle is as deep as it is long. The anal fin is short and well behind the dorsal fin base. The scales are moderate, arranged in irregular rows and cover the caudal fin. The fish is shiny silver in color and shaded on the back. In young, there is a dark blotch behind the gill opening followed by a series of small spots along the lateral line, though in adults these may not be visible (Figure 1).

Despite having those identifying characters, hilsa juveniles resemble adults from a number of other species found in the same environment. Among researchers in Bangladesh, the most common similar species to hilsa are sardines and *chapila* (*G. chapra, G. manmina*). Rahman et al. (2011) and the DoF (2012) have developed distinguishing characteristics of hilsa (*jatka*), sardines, *chapila* and *choukka* (Figure 2).

1.5. Geographical distribution

1.5.1. Marine distribution

The marine distribution of the species coincides with India's monsoon region (northern part of the Indian Ocean). It ranges from the Persian Gulf to southern Vietnam, including the Bay of Bengal, Java and the South China Sea, the coasts of the Indian Ocean, the Persian Gulf, the Gulf of Tongking, the Arabian Sea, the Gulf of Oman, the Gulf of Aden, south to Durban and Madagascar and some of the coastal waters of Sri Lanka and Laos (Figure 3). In the Persian Gulf, the distribution is mainly concentrated in the marine waters of Iran and Iraq. In the Arabian Sea, the species is concentrated off the west coast of India from the Gulf of Cutch along the Saurashtra coast, the Bombay coast and the foreshore areas near the mouths of the Narbada and Ulhas rivers. It is occasionally found along the Malabar (Kerala) coast as well. In the Bay of Bengal region, hilsa concentrate mainly in the marine waters of Bangladesh, especially in and around the Meghna estuary region. Other areas of the Bay of Bengal include the Madras coast, the Kakinada coast near the mouth of the Godavari, the Visakhapatanam coast, the Chandipore (Balasore, Orissa) coast, the Midnapore (West Bengal) coast and along the inshore region of Myanmar down to the Mergui Archipelago. In brief, the species is mainly concentrated in the Bay of Bengal, especially in the territorial waters of Bangladesh, India, Pakistan and Myanmar, among which the waters of Bangladesh possess the greatest concentration.

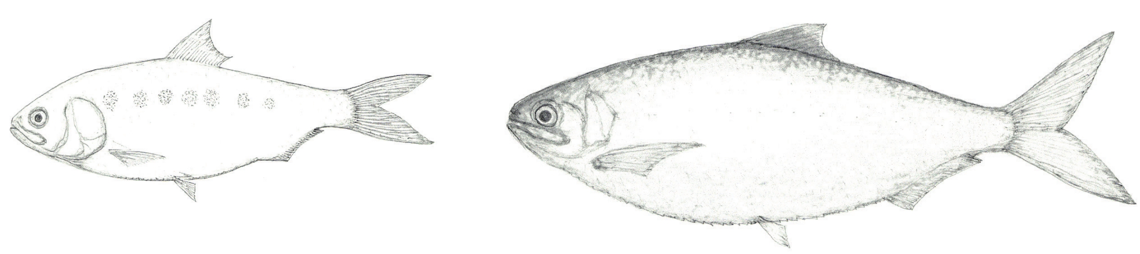


Figure 1. The hilsa shad: (a) juvenile showing a series of black spots along the lateral line; (b) adult without black spots. [Redrawn after (a) Fischer and Whitehead (1974), (b) Shad Foundation (1998) and Rahman (2001).]

Sources: Rahman et al. 2011; DoF 2012.

Figure 2. Picture of three similar species, hilsa (*jatka*), sardines and *chapila*.

1.5.2. Brackish water and freshwater distribution

Adult hilsa migrate from saline waters to brackish waters and freshwaters for spawning or feeding purposes. Eggs, larvae and juveniles have also been found in coastal waters and the upper reaches of rivers. Distribution in rivers and lakes is summarized in Table 2. In Bangladesh, the species is widely distributed in coastal areas, estuaries and rivers. The main rivers are the Padma, Meghna, Jamuna as well as their major tributaries and distributaries. In India, it is mainly distributed in the lower reaches of the Godavari, Hooghly and Narbada rivers and their estuaries and adjacent areas as well as in Chilka Lake. In Iran and Iraq, the main rivers are the Shatt-al-Arab, Tigris and Euphrates. In Myanmar, it is mainly found in the lower region of the Irrawaddy (Irabati), Sittang and Naaf rivers. In Pakistan, the most important rivers are the Sind (Indus), Jhelum and Ravi (Jafri 1988).

Figure 3. Geographical distribution of hilsa shad.

Country	Names of rivers/lakes
Bangladesh	**Principal rivers** Meghna, Padma, Jamuna, Brahmaputra **Major rivers** Sibsa, Baleswari, Pasur, Rupsa, Madhumati, Kocha, Lohalia, Tetulia, Biskhali, Buriswar, Karnaphuli, Feni, Naaf, Kharkhana, Arial Khan, Khairabad, Muhuri, Surma, Halda, Kushiyara, Matamuhuri, Maheskhali Channel **Minor rivers** Sangu, Baral, Atai-Nabaganga, Kobadak, Chitra, Bhairab, Betna, Kumar, Little Feni, Selonia, Mongla, Ilisha, Ghuaisakhali, Bhadra, Khulpetua, Kaliganga
India (Western Region)	Narbada, Tapti, Purna, Ulhas, Savitri, Kali Vembanad
India (Eastern Region)	Godavari, Hooghly, Cauvery, Krishna, Mahanadi, Ganges (and its tributaries), Padma, Brahmaputra, Barak. Also the smaller rivers of Korayar, Pamaniyar, Vellar, Palar, Pennar, Manneru and Uppeteru, and also in Chilka Lake.
Iraq	Shatt-al-Arab, Tigris, Euphrates, Lake Hammar
Iran	Shatt-al-Arab
Pakistan	Sindh (Indus), Jhelum, Ravi
Myanmar	Irrawady (Irabati), Naaf, Sittang

Sources: Pillay and Rosa 1963; FRSS 1990; Rahman 2001; FishBase 2012.

Table 2. Distribution of hilsa shad in rivers and lakes.

1.6. Bionomics and life history

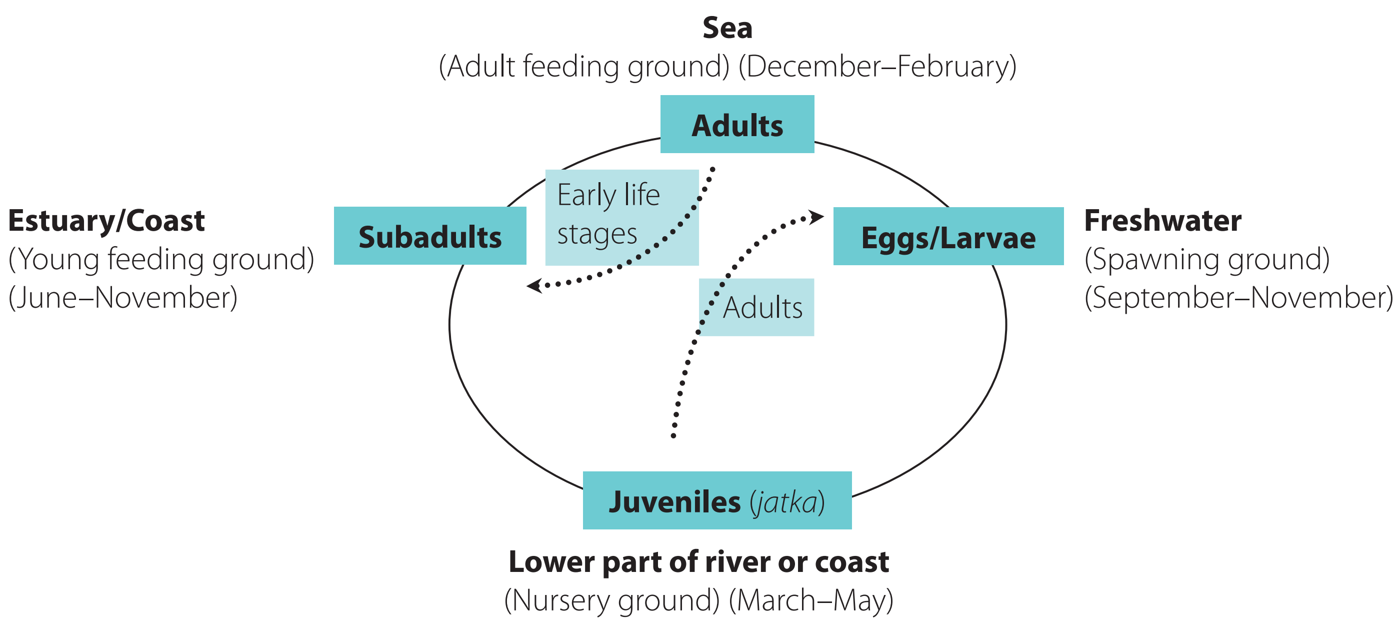
1.6.1. Lifecycle

The lifecycle of hilsa shad resembles American shad, *Alosa sapidissima* (Bhuyan and Talbot 1968). It has also some similarity with European shads, *Alosa alosa* (Allis shad) and *Alosa fallax* (Twaite shad) (Aprahamian 1982; Bristow 1992). After spawning in freshwater, shads return to the sea where they generally remain until the next breeding season (Figure 4). However, this lifecycle pattern is not followed by all stocks/races of the species; some do not migrate from the sea to the river or vice versa (Blaber et al. 2003; Rahman 2006).

Hilsa spawn in freshwater and deposit eggs demersally. The eggs hatch after 23–26 hours at an average temperature of 23°C (Jones and Menon 1951). The size of the hatchlings varies between 2.3 and 3.1 mm (Kulkarni 1950; Motwani et al. 1957; Karamchandani 1961). When the larvae are able to swim, they try to find suitable nursery grounds, normally in the lower part of the rivers or in coastal waters. In Bangladesh, juvenile hilsa in nursery grounds are called *jatka* (Rahman and Haldar 1998). *Jatka* resemble adult Indian river shad (*Gudusia chapra*), locally called *chapila*, and many fishers and consumers generally refer to *jatka* as *chapila* in the market (Mazid 1994; Rahman 1997).

Hora and Nair (1940a) reviewed the historical information on *jatka* and confirmed that it is the young of hilsa. Using molecular genetic technology, Rahman and Naevdal (1998) confirmed that *jatka* are the offspring of hilsa by comparing genotype and genotype distributions with previous analyses of hilsa.

Jatka remain around the nursery grounds for about 5–6 months and attain a maximum size of 15–16 cm (Raja 1985; Mazid and Islam 1991) but with a dominant size of 10–12 cm (BFRI/RS 1994; Rahman and Haldar 1998). However, Hossain (1975) reported that when *jatka* become larger than 7 cm they may migrate to the deeper parts of the river, and finally when they reach about 12 cm they disappear from the river entirely. Gradually, *jatka* acquire the ability to tolerate saline water and move downstream into the estuary, where they spend their early life stages in brackish water. Later, the young move offshore where they feed and grow into adults. After maturation, the adults again migrate upstream to spawn, and the pattern repeats (Figure 4).



Sources: Rahman and Moula 1992; Rahman 1997 and 2006; Rahman et al. 2012.

Figure 4. Typical lifecycle of the anadromous hilsa shad. Note that some stocks may be riverine while some may be marine (indicated by hatched line). The period shown in parentheses indicates when a certain stage is most abundant.

1.6.2. Migration

Like American shad, hilsa shad are generally anadromous, but they have also been described as diadromous, as they migrate frequently between freshwater and the sea. The adults migrate upstream to spawn at the start of the southwest monsoon and associated flooding of the rivers. During the peak breeding season, the adults move in shoals to estuaries and rivers and may migrate upstream as much as 1200 km (usually 50–100 km) to spawn (Pillay and Rosa 1963; Mazid 1994; Rahman 1997 and 2006; Rahman et al. 2010; FishBase 2012). However, not all races/stocks of hilsa follow the same migration pattern. In the northern Indian Ocean, there are some purely riverine anadromous stocks that migrate between the sea and the rivers (the riverward migration is for spawning) and a number of stocks that spend their entire lives in the marine environment (BoBP 1987). As the most important stocks/races of the species are anadromous, greater attention has been focused on that group.

In general, the anadromous type of hilsa migrates upstream for spawning, which is triggered by the heavy inflow of fresh water from rivers during the monsoon season (June–July). During this period, the number of fish increases dramatically in the upstream areas. In the peak spawning season (September–October), the catch rate in the upstream is also highest (BFRI/RS 1994; Rahman and Haldar 1998), indicating the mass migration of the species during this period. Considerable fluctuations in the abundance of brood hilsa in the estuaries and rivers of the upper Bay of Bengal may be a result of variations in the intensity of the monsoon during the breeding season (Rahman 1997). A second peak migration takes place in winter, January–February (Bhuyan and Talbot 1968; Rao 1969; Ghosh and Nangpal 1970), which could be influenced by the rise in water temperature (Jones 1957; Nair 1958), current velocity and an increase of plankton in the upstream areas (Ghosh and Nangpal 1970).

Hilsa may also migrate upstream for feeding (Hora 1941). Young hilsa have been found to migrate along with the brood hilsa and may travel a considerable distance before they are sexually mature (Pandit and Hora 1951). By contrast, juveniles of the species migrate from their nursery grounds (riverine or coastal) to the estuaries during the onset of the monsoon season for feeding and growth (Raja 1985; BFRI/RS 1994).

The extent of migration varies considerably in different rivers. In the Ganges, it is reported to be as far as 1287 km, reaching Agra and Delhi, but in India's Purna River hilsa may migrate fewer than 8 km (Pillay and Rosa 1963). In Myanmar's Irrawady River, the fish may migrate upstream to Mandalay, a distance of 724 km. In the Hooghly and Brahmaputra rivers, hilsa ascend about 300 km, but are restricted to 56–97 km in the Godavari, Krishna and Cauvery rivers, while in the Indus, the migration is up to the Ghulam Muhammad Barrage, which is 161 km from the sea. As a result, the Jhelum River stock has become landlocked (Pillay and Rosa 1963). Hilsa tagged in Bangladeshi waters have been recaptured in Iranian waters (Mazid 1998; Rahman 2001).

During the past two decades, natural migratory patterns of fish have been heavily interrupted by the construction of dams, barrages, dikes, regulators, defenses for flood control and irrigation or fishing purposes, without any provision for the passage of fish (Ghosh 1987; Kowtal 1994). Al-Nasiri and Al-Mukhtar (1988) reported that water pollution in Basrah, Iraq, has affected the hilsa stocks remarkably. In India, the construction of the Farakka Barrage on the Ganges in 1972 has impacted hilsa migration, hence its abundance further upstream (Chandra et al. 1987; Jhingran and Gupta 1989; Mukhopadhyay 1994; Chandra 1994; Haldar and Rahman 1998). The Ukai and Kakrapara dams in Gujarat have similarly affected hilsa migration in the country's Tapti River (Pisolkav 1994; Dubey 1994). Because of the construction of obstructions and dams in the Kumar, Nabaganga and Feni rivers in Bangladesh, the hilsa fishery in these rivers has been lost (Haldar and Rahman 1998). Although the migration of hilsa is restricted by barrages, they still run far up the Ganges (FishBase 2012). Many researchers have identified barriers to hilsa migration as a major factor contributing to the decline of the species (Mazid and Islam 1991).

1.6.3. Reproduction

Hilsa are heterosexual. The females are distinguishable by the flat urinogenital opening and bulging abdomen when gravid and the males by a narrow genital opening and the presence of prominent papillae. However, hermaphroditism has also been found (Chacko and Ganapati 1949; Swarup 1958). The species appears to be polygamous and fertilization is external (Pillay and Rosa 1963). Hilsa release eggs that are demersal in nature and eggs are fertilized externally. The larvae hatch approximately 22–26 hours after fertilization (BFRI/RS 1994) and are then transported by waves and tidal currents to the nursery grounds (Rahman 2006).

1.6.4. Maturity stages

Hilsa become sexually mature after 1–2 years of life. Their size at first maturity is about 22–25 cm for males and 28–30 cm for females (Pillay and Rosa 1963; BFRI/RS

1994). In Bangladeshi waters, their size at first maturity is reported to be 26.5–30.5 cm for males and 30–35 cm for females (Dunn 1982). In the Godavari River, the smallest mature male and female were 25 cm and 37 cm, respectively (Pillay and Rao 1962). In the Hooghly River, however, the size at first maturity was found to be 16–17 cm for males and 19–20 cm for females (Pillay 1958). Pillay and Rao (1962) formulated a useful guide to determine the maturity stages on the basis of external and internal appearance of the gonads in male and female hilsa and to assess the period of spawning and size at first maturity (Table 3). Male hilsa with mature

Maturity Stage	Characteristics	
	Female	Male
Stage I (Immature)	Ovaries thin and extending to about half of body cavity length. No ova visible to the naked eye. When separated apart under the microscope, oocytes can be seen, transparent, with nucleus and no yolk granules. Diameter of ova less than 50 µm.	Testes very thin, ribbon-like, whitish and extending to about three-quarters of body cavity length. Strands of tissue with spermatogonia can be distinguished when teased under the microscope.
Stage II (Maturing)	Ovaries about 5 mm in diameter, length slightly more than half of body cavity length. Ova not visible to the naked eye, but faintly discernible when ovary is teased apart. Ova appear transparent, with a few yolk granules apparent in larger ova. Diameter of maturing groups of ova up to 150 µm.	Testes slightly broader and thicker than in Stage I.
Stage III (Maturing)	Ovaries about 7.5 mm thick, occupying three-quarters of body cavity length, ova yolked and visible to naked eye. When teased apart under the microscope ova are opaque and <300 µm.	Testes larger, but not yet extend to half of body cavity length. Spermatogonia discernible under the microscope.
Stage IV (Maturing)	Ovaries occupy three-quarters of the body cavity. They are much thicker, yellow in color, over 15 mm in thickness. Ova opaque and less than 300 µm.	Testes extend to about half of the abdominal cavity, appreciably larger, white in color and soft in texture. Spermatocytes and a few spermatids are visible under a microscope.
Stage V (Maturing)	Ovaries occupy the whole length of the body cavity, much thicker and granular and yellow in color. Ova about 550 µm.	Testes occupy almost the whole of the body cavity, whitish and soft. Large number of spermatids in clusters are apparent.
Stage VI (Mature)	Ovaries occupy whole length of body cavity and have maximum thickness. Large transparent ova that ooze out at slightest pressure. Diameter of ripe ova up to 850 mm or slightly more.	Testes broader and thicker than previous stage, pinkish-white in color and soft in texture. Large number of clusters of tailed sperms is visible. Spermatids are also visible in good numbers. Vas deferens is full of milt, which may come out with a little pressure.
Stage VII (Partly spent spawning in progress)	Ovaries smaller in size than that of at Stage VI, less firm to the touch, contain a few large ova with diameter of about 850 µm, which may be partly or fully transparent, but majority of ova nearer to 550 µm.	Testes less thick and soft compared to the previous stage and extend only to about half of abdominal cavity. Full of spermatozoa and spermatids, the latter in fewer numbers. Vas deferens with large number of spermatozoa.
Stage VIII (Spent)	Ovaries considerably smaller, reddish, flaccid, fibrous, with a few large ova scattered among connective tissue. Majority of ova below 200 µm.	Testes very thin and ribbon-like. A few spermatozoa may be present in vas deferens. Spermatogonia are present in good numbers.

Reorganized after Pillay and Rao 1962.

Table 3. Maturity stages of male and female hilsa shad.

gonads are available more or less throughout the year (Moula et al. 1991) (Table 4). Samples with undeveloped gonads are observed only in December and January (Moula et al. 1991; Pillay and Rao 1962). The percentage occurrence of males and females in different stages of maturity (Table 3) reveals that spawning of hilsa takes place from August to November with subsidiary spawning in June and July as well as January to March (Islam et al. 1987; Moula et al. 1991).

1.6.5. Sex ratio and fecundity

Many researchers have found the sex ratio in natural populations to differ significantly from that of the theoretically expected ratio 1:1, though this was not always the case (Table 5). Size-wise distribution of sexes in Bangladeshi waters revealed a higher percentage of females in the size group above 40 cm SL (Mazid 1998).

Hilsa is a highly fecund fish and does not show any parental care. Fecundity varies with size, locality and environment (Table 6). Gravid females with a length ranging from 30 to 55 cm produce between 100,000 and 2 million eggs (Pillay 1958; Pillay and Rao 1962; Shamsuddoha and Abdul Hye 1970; De 1980). The relationship between fecundity and weight appears to be linear.

Month	Sex	Number of specimens	Stages of maturity (%)							
			IIa	IIb	III	IV	V	VI	VIIa	VIIb
January	Male	25	16.00		16.00	24.00	44.00			
	Female	25	4.00		32.00	36.00	28.00			
February	Male	26			3.85	23.08	19.23	3.85	38.46	11.54
	Female	24			12.50	12.50	41.67		33.33	
March	Male	33					27.27		41.18	6.06
	Female	17			11.76	11.76	35.29		41.18	
April	Male	14	7.14	35.71	21.43				14.29	21.43
	Female	11			18.18	63.64	18.18			
May	Male	35	14.29	17.14	17.14	31.43	11.43		5.71	2.86
	Female	15			6.67	6.67	80.00		6.67	
June	Male	38	21.05	13.16	34.22	23.68	2.63		2.63	2.63
	Female	12		8.33	8.33	16.67	66.67			
July	Male	37		2.7	18.92	35.14	32.43	15.38	10.81	
	Female	13					69.23		15.38	
August	Male	31	3.23	6.45	25.81	45.16	9.68	3.23	6.45	
	Female	19			5.26	10.53	68.42	10.53	5.26	
September	Male	27			4.35	25.93	40.74	7.41	7.41	3.70
	Female	23			4.35	73.91	73.91	8.70		
October	Male	28		3.57		10.71	78.57	7.14		
	Female	22			4.55	31.82	59.09	4.55		
November	Male	17		5.88	11.76	17.65	64.71		2.94	2.94
	Female	34			2.94	8.82	82.35			
December	Male	37	8.11	10.81	37.84	32.43	10.81			
	Female	13	7.69	7.69	23.08	15.38	46.16			

Sources: Moula et al. (1991); Rahman (2006).

Table 4. Monthly percentage of occurrence of hilsa shad in different stages of maturity in the Meghna River in 1987.

Study area/water body	Ratio (male : female)	Reference
The Godavari	1.00 : 9.00	Chacko and Ganapati (1949)
Indian waters	1.00 : 1.53	Pillay and Rao (1962)
The Hooghly	1.00: 1.00 (approx.)	Jones and Menon (1951)
The Ganges	1.00: 1.00 (approx.)	Pillay (1958)
The Narbada	3.50: 1.00 (in July) 1.00: 1.00 (other season)	Karamchandani (1961)
The Bay of Bengal (Chittagong)	1.00 : 1.08	Islam et al. (1987)
The Bay of Bengal (Cox's Bazar)	1.00 : 1.18	Ditto
The Meghna estuary (Khepupara)	1.00 : 0.42	Ditto
The Meghna (Chandpur)	1.00 : 1.08	Ditto
The Meghna	1.00 : 0.57	BFRI/RS (1994)
The Bay of Bengal	1.00 : 1.14	Ditto
The Padma	1.00 : 0.24	Ditto
The Meghna estuary	1.00 : 0.98	Ditto
Bangladesh waters (average)	1.00 : 0.70	Ditto

Table 5. Sex ratio of hilsa shad in different water bodies.

Study area/water body	Size group	Fecundity (x 000)	Reference
The Hooghly	Average	250–1,600	Pillay (1958)
The Hooghly estuary	Average	373–1,323	De (1980)
The Godavari	910 g	1,282	Chacko and Ganapati (1949)
The Narbada	2,100 g	1,864	Kulkarni (1950)
The Indus	Average	700–2,900	Pillay and Rosa (1963)
The Godavari	300–350 mm TL	100–2,000	Pillay and Rao (1962)
The Indus	Average	755–2,917	Bhuyian and Talbot (1968)
The Padma	273–420 mm FL	348–1,466	Shamsuddoha and Abdul Hye (1970)
The Padma (type A)	342–520 mm TL	660–1,547	Quddus et al. (1984)
The Padma (type B)	260–470 mm TL	399–670	Ditto
The Padma	287–523 mm TL	266–1,931	BFRI/RS (1994)
The Bay of Bengal	325–492 mm TL	375–1,423	Ditto

Table 6. Fecundity of hilsa shad in different water bodies.

1.6.6. Spawning season

The peak spawning season for hilsa is September–October, but they may also spawn in other seasons and occasionally throughout the year (Table 7) (Bhanot 1973; Mazid 1994; BFRI/RS 1994; FishBase 2012). Swarup (1959) examined histological changes in the gonads of hilsa and concluded that hilsa spawn several times during a spawning season. By contrast, Swarup (1959) and Mitra and Ghosh (1979) found two breeding seasons, which suggested bimodal annual spawning cycles of the species. Mathur (1964) stated that the first spawning period was in February–April and the second in October. These observations were confirmed by Pillay and Rao (1962) and Moula et al. (1991), but Nair (1958) found atresia in February–March and concluded this was not a true spawning season. Raja (1985), however, pointed out two distinct spawning stocks or varieties, which were also reported by Quddus (1982). One, the broad morph, spawns in the monsoon season and the other, described as a slender morph, spawns in winter. Chandra (1962) described the results of a larval fish survey of the Hooghly estuary, and the information supports the assertion of a prolonged spawning season. Similarly, Ghosh and Nangpal (1970) supported the hypothesis of post-winter spawning in a study of hilsa in the freshwater section of the Ganges.

1.6.7. Spawning ground

Hilsa spawn in all freshwater reaches of rivers (Hora 1938; Motwani et al. 1957; Chandra 1962; Quereshi 1968; Mazid and Islam 1991; Mazid 1994 and 1998). Older hilsa spawn for the second and the third time in the higher reaches of the river, while younger hilsa making their first spawning migration, which may make them more sensitive to changes in salinity, spawn in the lower portions.

Hora (1938) suggested that immature specimens of less than one year stay in the river for a longer period and only spawn toward the end of the first year of their life or in the second. Karamchandani and Pisolkar (1976) identified the location of hilsa spawning grounds in India's Tapti River, 5–12 km upstream of Bodhan in the vicinity of Piperia (a freshwater region), some 56 km from the sea. Karamchandani (1961)

Study area/water body	Peak season(s)	Lean season(s)	Reference
The Hooghly	May, July–August	All other months	Hora and Nair (1940) and (1941)
The Hooghly	July–November	January–March	Pillay (1958)
The Ganges	September–December	July–August	Motwani et al. (1957)
The Ganges	March–August	January–February, June–July	Nair (1958)
The Ganges	September–November	----	Chandra et al. (1987)
The Narbada	August	June–July, September	Karamchandani (1961)
The Saurashtra coast	April–May	----	Pillay (1962)
The Godavari	August–November	----	Pillay and Rao (1962)
The Hooghly	February–March, July–August October–November	All other months	Bhanot (1973)
Bangladeshi waters	October–November, July–August February–March	Ditto	Mazid (1994)
The Meghna	January–March, July–October	----	Shafi et al. (1978)
The Godavari	August–November	February–April	Pillay and Rao (1962)
The Meghna	October–November	All other months	Moula et al. (1991)
Bangladeshi waters	monsoon and winter	Ditto	Raja (1985)
The Padma (type A)	July–October	Ditto	Quddus et al. (1984)
The Padma (type B)	January–March	Ditto	Ditto
The Hooghly estuary	August–October	Ditto	Chandra (1962)
The Ganges	post-winter	Ditto	Ghosh and Nangpal (1970)
Bangladeshi waters	October–November	June–July, January–March	BoBP (1987)
Kuwaiti waters	June	May, July	Al-Baz and Grove (1995)

Table 7. Spawning seasons of hilsa shad in different water bodies.

reported the location of the freshwater spawning grounds in the Narbeda River. Pillay (1964), on the other hand, suggested that hilsa on the Saurashtra coast may be marine spawners. Mazid and Islam (1991) and BFRI/RS (1994) reported one major spawning ground in Bangladeshi waters in the Hatia-Sandwip-Monpura area (Figure 5).

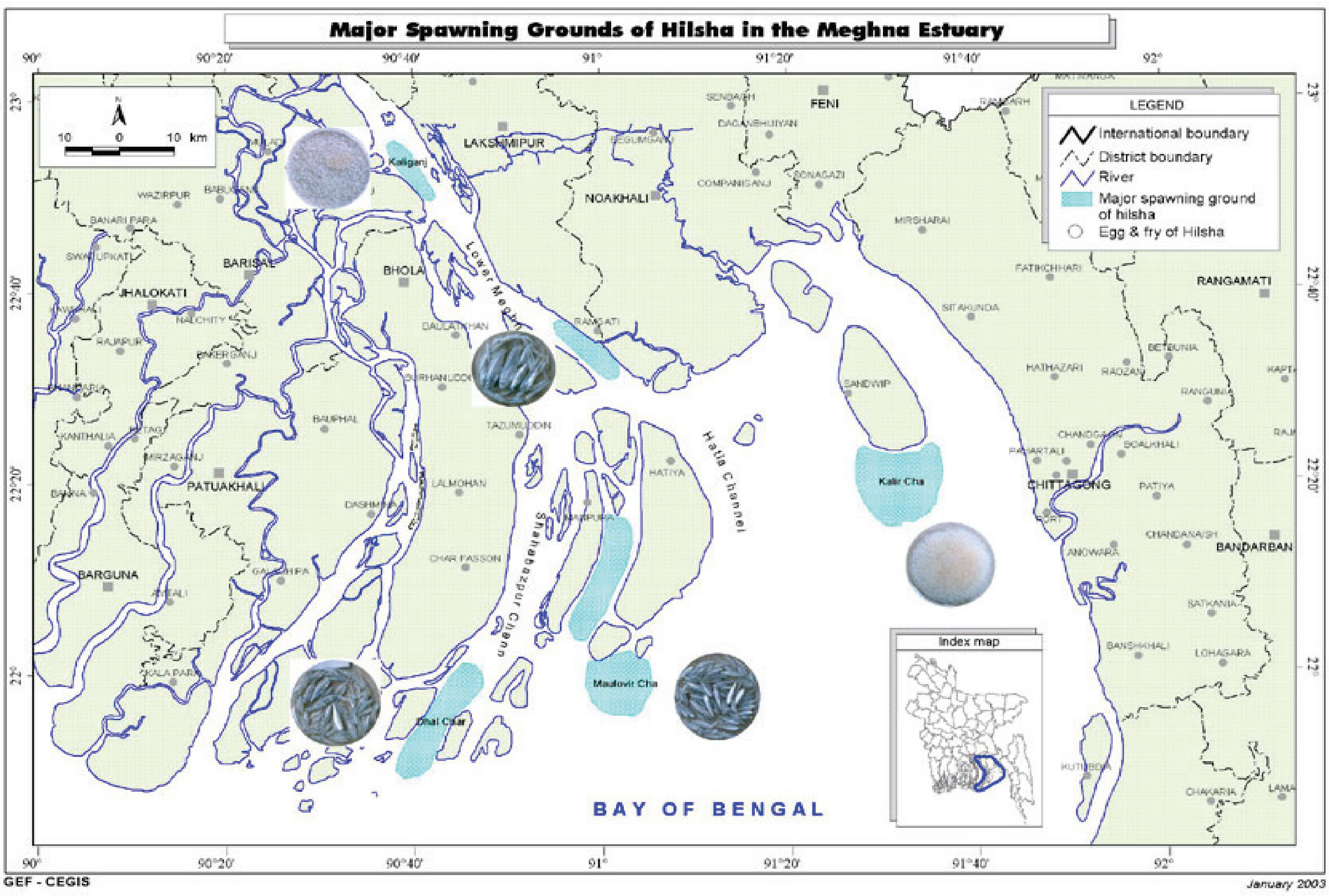
1.6.8. Nursery grounds

There are two main nursery grounds (Figure 5) in Bangladeshi waters (Mazid and Islam 1991; BFRI/RS 1994; Mazid 1998; Rahman and Haldar 1998). The largest riverine nursery ground is situated in the Meghna River, in and around Chandpur, from Mawa (Munshiganj) down to Hazimara. Juveniles (2–12 cm) appear in this nursery ground in November and remain up to June, but the peak period is approximately mid-February to mid-May. Another large nursery ground is situated in the coastal belt from Kuakata (Patuakhali) to Dubla Island (Khulna). Within this area, comparatively larger (11–15 cm) *jatka* are caught in December–January. Nursery grounds in the rivers of other countries seem to be situated in their respective migratory rivers, but no specific information is available.

1.7. Population (stocks) biology

1.7.1. Stock discrimination

There is still controversy regarding stocks/races of hilsa in different water bodies (Rahman 2006). Some researchers (Ahmed 1961; Das et al. 1987) found a homogenous stock of hilsa in Bangladeshi waters, while others (Quddus et al. 1984b; Rahman and Moula 1992; Rahman et al. 1997; Rahman and Naevdal 1998) have found heterogeneity among hilsa in different water bodies. Most Indian researchers have suggested more than one stock in Indian waters (Pillay et al. 1963; Dutta 1966; Ghosh et al. 1968; Ramakrishnaiah 1972;



Source: Halder 2003.

Figure 5. Spawning and nursery grounds of hilsa shad in Bangladeshi waters.

Rajyalakshmi 1973; BoBLME 2011). Possible races/stocks of hilsa, as reported by different researchers, are summarized in Table 8.

The chemical composition of otolith cores (from spawning grounds) of the fish collected from the same habitat as collected for genetic and morphological variation by Salini et al. (2004) are consistent with the results from the genetic and morphological studies (Milton and Chenery 2001 and 2003). All three methods indicate that the hilsa populations in the Bay of Bengal should be treated and managed as a single population (BoBLME 2011).

1.7.2. Age and growth

Aging of hilsa is a problem (Rahman 2001). Chacko et al. (1948), Chacko and Kirshanamurti (1950), Raj (1951) and Chacko and Dixithulu (1951) proposed a direct correlation between the number of scale radii and fish length. Pillay (1958) cautioned that it is difficult to use the number of growth rings (radii) on hilsa scales to determine age and growth. While similar problems have been found in European populations of shad (*Alosa* sp.), careful examination of the scales makes age determination possible (Aprahamian 1982). Other researchers (Pillay and Rao 1962; Rajyalakshmi 1973; De and Datta 1990a) used the length-frequency method to determine the age, though it was found unreliable as the frequency distributions often overlapped because of protracted spawning periods and size selective sampling. Moreover, computer-based software, such as ELEFAN or FiSAT, was not used to discriminate length modes, so the conclusions drawn must be treated with caution. Quddus (1982) proposed using otoliths as a good tool for age determination of hilsa. Quddus et al. (1984a) subsequently discussed the age and growth of the two types of hilsa (which they called "broader" and

Water body	Parameter/Method used	Possible races/stocks	Reference
Indian waters	Morphometric and meristic characters	Several stocks	Pillay et al. (1963)
Ditto	Ditto	3 types (fluvial anadromous, fluvial and marine ecotypes)	Dutta (1966)
The Ganges	Length and height	3 types (broad, broader and slender)	Ghosh et al. (1968)
Chilka Lake and Hooghly River	Biological characters	2 stocks (Chilka Lake and Hooghly stocks)	Ramakrishnaiah (1972)
Godavari River	Behavior	2 stocks (migratory and nonmigratory stocks)	Rajyalakshmi (1973)
Bangladeshi waters	Vertebrae counts	Single stock	Ahmed (1961)
Ditto	Morphometric and meristic characters	2 types (slender and broader types)	Quddus et al. (1984b)
Ditto	Ditto	Single stock	Das et al. (1987)
Ditto	Ditto	4 morphological groups (marine, estuarine, Padma and Meghna)	Rahman and Moula (1992)
Ditto	Ditto plus electrophoresis	Ditto	Rahman et al. (1997a)
Ditto	Genetic study	2 stocks (marine and riverine stocks)	Rahman and Naevdal (1998)
Ditto	Genetic study	Homogenous stock	Hussain et al. (1998)
Entire distribution range	Allozymes and morphometric analysis	No significant differences within Bangladesh or within the Bay of Bengal (SE India and Myanmar) samples, but significant differences between the samples from Kuwait, Bangladesh and Indonesia	Salini et al. (2004)

Table 8. Possible races/stocks of hilsa shad in different water bodies.

"slender") from the Padma and Meghna rivers using otoliths. In the case of the broader type, hyaline zones appeared in June and July while those in the slender type appeared in January and February, during their respective spawning seasons. Consequently, it appears that the stress of spawning may induce a growth mark.

1.7.3. Growth from length-frequency analysis

Similar to other fish, hilsa grow faster in their early stages of life, up to about 600 mm (BoBP 1987). Sujansinghani (1957) reported the results of a three-year study conducted on the growth of hilsa in the Hooghly estuary. Growth increments were estimated to be 15–20 mm/month in the first 2–3 months after hatching, thereafter decreasing to approximately 10 mm/month.

Length-frequency of hilsa in commercial catch in Bangladeshi and Indian waters showed a general size range of about 15–52 cm (Azad et al. 1987; Gupta 1989; Rahman 2006). Hilsa were classified into four size groups, small (<30 cm), medium (30–39 cm), large (40–49) cm and extra large (>50 cm). More than 90% of catches fall within 30–50 cm (Azad et al. 1887). Total lifespan was reported to be at least 5 years (Bhuyan and Talbot 1968), but Pillay and Rao (1962) found that hilsa in Indian rivers live at least 6 years. However, in Bangladeshi waters, the length-frequency analysis using Bhattacharya's method indicated that there were four or five modal groups, at 22, 37, 41, 47, and 50 cm within the exploited size range (BoBP 1987). Rahman (2001) separated six age groups, and they ranged from 1+ to 6+ (Table 9).

1.7.4. Growth from otoliths examination

Linear relationships between otolith length and lengths of hilsa were established for different environments and sexes (Rahman 2001). The correlation coefficients of the relationships were highly significant ($P<0.01$) for all equations, which are thus suitable for estimating the length of fish from otolith-length.

Daily growth rings on otoliths have also been used to age hilsa in Bangladeshi waters. Growth increments were visible for the first few hundred days, but thereafter the microstructural pattern became unreadable (BFRI/RS 1994, Mazid 1998). It was concluded that this method is appropriate for small fish (<40 cm), but for large fish an alternative method is required (Hossain 1985; BFRI/RS 1994; Mazid 1998). Rahman (2001) used hilsa otoliths to validate length-based methods of aging. Rahman and Cowx (2006) also found lunar periodicity in the growth of hilsa, based on analysis of otoliths.

Age groups 1+ to 6+ were found from the otolith study as well as from the length-frequency study of hilsa from Bangladeshi waters (Table 9). Discrete length groups predicted on the basis of biological information were validated by comparing them with annual growth rates determined from otolith readings. The overall length ranges for a particular age group obtained from length frequency analysis was compared with the minimum and maximum lengths obtained from the otolith reading (Table 9). In the majority of cases, the range of lengths obtained from length frequency analysis was within the minimum and maximum lengths obtained for that age group from the otolith reading. However, in some cases the maximum values from length frequency analysis were slightly higher than those determined from the otolith readings (Rahman 2001).

Age group	Otolith reading			Length-frequency analysis		
	Average	Minimum	Maximum	Average	Minimum	Maximum
1+	265	248	277	263	236	290
2+	314	277	377	334	294	357
3+	380	339	429	382	351	427
4+	429	381	481	424	406	455
5+	478	447	514	479	454	506
6+	519	468	553	525	512	539

Source: Rahman 2001.

Table 9. The minimum, maximum and average TL (mm) for each age group of hilsa (both sexes combined, Bangladeshi waters) as obtained from otolith reading and length-frequency analysis.

1.7.5. Length-weight relationship

The parameters *a* and *b* of the length-weight relationship, $w = al^b$ where *w* = weight of fish, *l* = length of fish, *a* = constant, and *b* = exponent have been estimated for hilsa from a range of water bodies (Table 10). The value of the exponent (b) varies between 2.52 (Quddus et al. 1984a) and 3.10 (Al-Baz and Grove 1995), indicating a fairly symmetric growth rate of the fish (Rahman 2006).

1.7.6. Growth differences between the sexes

Growth curves of male and female fish reveal that in the first two years both males and females grew similarly in the Padma and the Meghna rivers, but after the second year the females grew at a considerably higher rate than males in both rivers (Rahman 2001). The mean TL for the largest age group (7 years old) known from the otolith study was approximately 47.5 cm for males and 55 cm for females. The asymptotic TL (L_∞) was also higher for females (59 cm) than males (55.5 cm) (Rahman 2001).

1.7.7. Population (stock) dynamics

Growth and mortality parameters of hilsa in different water bodies using length-based stock assessment methods with some validation with otoliths readings are available from different authors.

Growth parameters: Growth parameters (asymptotic total length, curvature parameter *K* and phi-prime ø` values) of hilsa from different water bodies determined from length-based stock assessment methods are presented in Table 11. The estimated von Bertalanffy growth parameters by different researchers from different water bodies were found to differ slightly, or in some cases appreciably, from each other.

Mortality parameters: Mortality parameters of hilsa in different water bodies, estimated from length-based stock assessment methods, are presented in Table 12, including natural mortality (*M*), fishing mortality (*F*), total mortality (*Z*) and exploitation level (*E*) of hilsa in different water bodies. Although the estimated mortality parameters and exploitation rates of hilsa from different water bodies show little sign of overexploitation, all authors propose an increase in the length at first capture (L_c) as a precautionary management.

1.7.8. Recruitment pattern

There are two major recruitment events each year for hilsa: August and October, though there are some indications of further recruitment in April (BoBP 1987). However, as hilsa may spawn throughout the year, the recruitment pattern is probably continuous with one or two major peaks (BFRI/RS 1994; Mazid 1998). It should be noted that the continuous or biseasonal spawning can lead to difficulties in discriminating growth parameters of hilsa from length-frequency data (Rahman 2006).

Rahman and Cowx (2008) also found the recruitment patterns for both river and marine populations were more or less continuous, with two major pulses, of which one was distinctively larger than the other. For the rivers, the larger pulse was between March and May, the second between November and January. In the marine environment, recruitment pulses were

Water body/area	Sex	Values of the parameters		Reference
		Constant (a)	Exponent (b)	
Meghna estuary	Male	0.0177	2.760	Islam et al. (1987)
Ditto	Female	0.0269	2.890	Ditto
Meghna River	Male	0.0280	2.740	Ditto
Ditto	Female	0.0210	2.870	Ditto
Bay of Bengal	Both	0.0305	2.730	Ditto
Bangladeshi waters (broader type)	Both	0.00003	2.527	Quddus et al. (1984a)
Bangladeshi waters (slender type)	Both	0.00014	2.561	Ditto
Brahmaputra River	Both	-5.163	3.063	Chaudhury et al. (1987)
Hooghly estuary	Both	0.0315	2.800	Gupta (1989)
Kuwaiti waters	Male	0.011	2.983	Al-Baz and Grove (1995)
Ditto	Female	0.007	3.104	Ditto

Note: w, weight of fish in g; *l*, length of fish in cm; *a*, constant; and *b*, the exponent.

Table 10. The parameters of the length-weight relationship ($w = al^b$) of hilsa shad in different water bodies.

Study area/Water body	L_∞ (mm)	K (year-¹)	Phi prime (ø`)	Reference
Padma River (type A)	642	0.19	2.89	Quddus et al. (1984a)
Padma River (type B)	680	0.16	2.87	Ditto
Brahmaputra River	700	0.25	3.09	Chaudhury et al. (1987)
The Bay of Bengal	580	0.83	3.45	Van der Knaap et al. (1987)
Ditto	570	0.78	3.40	Ditto
Ditto	550	0.90	3.43	Ditto
Hooghly River	600	0.85	3.49	Gupta (1989)
Ditto	592	0.80	3.45	Ditto
Bangladeshi waters	611	0.71	3.44	BFRI/RS (1994)
Ditto	583	0.74	3.40	Rahman et al. (1998)
Meghna River	570	0.66	3.33	Miah et al. (1998)
Kuwaiti waters	527	0.28	2.89	Al-Baz and Grove (1995)
Rivers of Bangladesh	588	0.82	3.45	Rahman (2001)
Marine waters of Bangladesh	610	0.80	3.47	Rahman (2001)
Coastal waters of Bangladesh	609	0.66	3.38	Rahman et al. (1999)
Bangladesh waters	615	0.83	3.48	Rahman et al. (2000)
Rivers of Bangladesh (1999)	600	0.82	3.47	Haldar et al. (2004)
Rivers of Bangladesh (2000)	625	0.72	3.45	Haldar et al. (2004)
Rivers of Bangladesh (2008)	588	0.82	3.45	Rahman and Cowx (2008)
Marine waters of Bangladesh (2008)	610	0.80	3.47	Rahman and Cowx (2008)
Rivers of Bangladesh (2009)	530	0.83	3.37	Rahman et al. (2012)

Table 11. Growth parameters of hilsa shad in different water bodies (phi-prime, $ø` = \log_{10} K + 2 \log_{10} L_\infty$).

Water body	Fishing mortality (F, yr^{-1})	Natural mortality (M, yr^{-1})	Total mortality (Z, yr^{-1})	Exploitation level (E)	Reference
Bay of Bengal	0.62	1.27	1.89	0.33	Van der Knaap et al. (1987)
Ditto	0.45	1.23	1.68	0.27	Ditto
Hooghly River	0.67	1.32	1.99	0.50	Gupta (1989)
Bangladeshi waters	1.25	1.16	2.41	0.52	BFRI/RS (1994)
Ditto	1.43	1.18	2.61	0.55	Rahman et al. (1998)
Meghna River	1.14	0.89	2.03	0.56	Miah et al. (1998)
Kuwaiti waters	0.80	0.50	1.30	0.62	Al-Baz and Grove (1995)
Rivers of Bangladesh	1.38	1.00	2.38	0.58	Rahman (2001)
Marine waters of Bangladesh	1.32	0.98	2.30	0.57	Rahman (2001)
Coastal waters of Bangladesh	2.16	1.12	3.28	0.67	Rahman et al. (1999)
Bangladeshi waters	2.01	1.28	3.29	0.61	Rahman et al. (2000)
Rivers of Bangladesh (1999)	2.49	1.28	3.77	0.66	Haldar et al. (2004)
Rivers of Bangladesh (2000)	1.62	1.17	2.79	0.58	Haldar et al. (2004)
Rivers of Bangladesh (2008)	1.38	1.00	2.38	0.58	Rahman and Cowx (2008)
Marine waters of Bangladesh (2008)	1.32	0.98	2.30	0.57	Rahman and Cowx (2008)
Bangladeshi waters (2009)	1.87	1.36	2.23	0.58	Rahman et al. (2012)

Table 12. Mortality parameters and exploitation levels of hilsa shad fishery from different water bodies.

relatively shorter, with the larger pulse during March and April and the shorter pulse during January and February (Rahman and Cowx 2008).

1.7.9. Exploitation level (E) and relative yield per recruit (Y`/R)

Rahman and Cowx (2008) estimated that exploitation levels for hilsa fisheries in riverine and marine habitats were 0.58 and 0.57, respectively (Table 12). Others have also found evidence of overexploitation in hilsa fisheries in Bangladesh, e.g. $E = 0.56$ (Miah et al. 1997), $E = 0.66$ (Rahman et al. 1999) and $E = 0.60$ (Rahman et al. 2000). The trend toward overexploitation possibly reflects a recent dramatic fall in hilsa catches in some regions in the country, as reported in the media (Talukder 2000; Khan 2000). While there are opportunities to increase yields by increasing exploitation levels to $E = 0.61$ ($E_{max} = 0.61$) for riverine and $E = 0.65$ ($E_{max} = 0.65$) marine environments, fisheries should maintain biologically optimum exploitation levels by following the $E_{0.1}$ principle, which is approximately $E = 0.55$ for rivers and $E = 0.62$ for marine populations (Rahman and Cowx 2008).

1.8. Environmental conditions regulating hilsa biology and migration

Like other migratory species, hilsa's biological activities are mainly stimulated by the complex interaction of biotic and abiotic factors. Certain environmental factors clearly trigger certain biological activities and the lifecycle of the fish. As a euryhaline species, hilsa has a very strong osmoregulatory mechanism and can tolerate a wide range of salinity. However, its preference of salinity ranges varies depending on the stage of its lifecycle (Rahman 2001 and 2006; Milton and Chenery 2001 and 2003). For breeding and nursing of the juveniles, they prefer freshwater, while the young (pre-adults) need estuarine and coastal waters, though for maturation hilsa need high saline marine water. The monsoon season greatly influences breeding and migration, as do temperature, rainfall, water currents, freshwater flow, turbidity, sandy bottom, circular current, etc. Lunar periodicity and daylight also influence growth and other physiological activities, including spawning and migration (Rahman and Cowx 2006).

The monsoon runoff of large amounts of turbid water above 100 NTU, preferably 100–140 NTU turbidity, is a prerequisite for attracting shoals of brood hilsa to the Hooghly-Bhagirathi system (Bhaumic et al. 2011). Depth plays a limited role in the movement of migrating hilsa, and water columns of 18–20 m are ideal for stress-free movement of broodstocks. Of course, hilsa pass through comparatively lower depths (average 10 m) in winter months. The size of migratory hilsa in winter is smaller than during the monsoon season. The temperature of river-estuarine water has dropped by 1.5°C from an average of 31.3°C (29.5°C–32.6°C) to 29.8°C (29.3°C–30.2°C) during monsoon migration of brood fish. On the other hand, in late winter (February) the ambient temperature rises by 1.8°C from an average of 27.6°C (26.8°C–28.4°C) to 28.6°C (27°C–31.8 °C), which might influence upstream migration and breeding of hilsa (Bhaumic et al. 2011).

Among chemical factors, salinity plays a determining role in breeding migration into the system. Since the salinity of the river-estuarine system remains below 0.1 ppt for the greater part of the yearly migration, the breeding activities are never hindered. In the system, hilsa have an alkaline environment (pH 7.7–8.3) during their stay and lifespan, and the dissolved oxygen content, by and large, fluctuates in the range of 5–7 ppm. However, during the monsoon season the average oxygen level increases by 1.22 ppm from 4.63 ppm to 5.85 ppm (Bhaumic et al. 2011).

Bangladesh has a network of 230 rivers in three major systems, namely the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna, and these three river basins drain a catchment area of 1,720,000 km^2 of which only 7% lies in Bangladesh (UN 1995; BoBLME 2011). About 2.4 billion metric tons of sediments are carried by these river systems annually in Bangladesh (Holemen 1986). The confluence of the Padma-Meghna rivers is the most important nursery ground for hilsa.

In India, hilsa is a year-round fishery with two distinct peaks: the monsoon season and winter in the Bhagirathi-Hooghly linkage of the Ganges river system. These peaks feature broodstocks in varying stages of maturity. The monsoon peak contains 90%–95% mature hilsa while the winter stocks are a mixed population of immature and mature fish. Prolonged and extensive monitoring of migratory and breeding behavior and rearing grounds of hilsa emerged with some physicochemical and biological factors, which are cumulatively responsible for stimulating and triggering the migration of adult hilsa into the system.

Productivity of the ecosystem and availability of food are important factors for determining the presence of hilsa. Detailed ecosystem-wide analysis would be required to identify the key ecosystem components or services that may be affecting hilsa productivity (Milton 2010; BoBLME 2011). Chlorophyll levels of the river-estuarine system fluctuated between 0.114 µg/L. and 0.180 µg/L.

during the monsoon season. It has been observed that the values are comparatively higher in some stretches where the nursery grounds have been located. Ahmed et al. (2005) prepared a paper on the primary production and fish yields in the Meghna River system and calculated a yield of 7 kg/m^3 of river per annum.

The Central Inland Fisheries Research Institute (CIFRI) has been conducting investigations on the ecology and fishery of hilsa in the Ganges river. The CIFRI possesses data on biotic and abiotic factors of the water and sediments in the river. Decadal data on catch, migration, spawning behavior and reproductive biology is available (Bhaumic et al. 2011). Depending on the available experimental data, it estimated the threshold values of physicochemical parameters for hilsa migration, breeding and rearing (Table 13).

As well as the threshold values of hydrography and the physicochemical parameters for breeding and nursery activities of hilsa, the following conditions were recorded and could be considered ideal for the Hooghly-Bhagirathi river system:

	Breeding activities	**Nursery activities**
Depth	>20 m for migration and prebreeding congregation	Comparatively shallower depth near river-estuarine margins above the congregation grounds
Turbidity (NTU)	100–140	Comparatively low turbid areas (70–80 NTU)
Temperature (°C)	29.3–30.2	29.8–30.8
Salinity (ppt)	<0.1	<0.1
DO (ppm)	5.0–6.8	4.8–6.8
p^H	7.70–8.30	7.9–8.40
Chlorophyll (µg/l)	0.114–0.180	0.140–0.180

Source: Bhaumic et al. 2011.

Table 13. Threshold values of physicochemical parameters for hilsa migration, breeding and rearing.

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Andharmanik River sanctuary in Kalapara.

2. Hilsa fishery management in Bangladesh

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Abstract
Hilsa (*Tenualosa ilisha*) is the most important species fishery in Bangladesh and the country's national fish. It accounts for more than half of Bangladesh's total marine catches, over 11% of total fish production and about 1% of GDP. The fishery plays an important role in employment, foreign exchange earnings and poverty reduction in the country. Since the 1960s, the inland hilsa landing has decreased by 41%. As a result of the degradation of natural habitat during the past three decades, the feeding, spawning, nursery and migratory grounds in upstream rivers have been reduced. The hilsa fishery has also suffered from overfishing during breeding, spawning and recruitment. If appropriate protective and conservation measures are not taken for the fishery in inland waters, the area of the hilsa catch could move farther downstream and eventually be restricted to the sea. The ongoing hilsa management initiatives of the DoF have been designed to enhance the conservation of hilsa during the seasonal ban period as well as to improve the livelihood of *jatka* fishers by creating alternative income generation. Another dimension of the conservation program is to raise awareness among stakeholders on the importance of conserving gravid brood fish and *jatka* (juvenile hilsa).

Recruitment of hilsa occurs more or less continuously throughout the year, peaking in June and July. The size at first capture has increased significantly (from 19.9 to 26 cm). This is probably from enforced protection of *jatka* in recent years. In 2011, studies conducted in what is now known as the main spawning grounds of Monpura and Hatia showed that more than 95% of fish were >35 cm TL and almost all were brood hilsa. The percentage of spent fish was 36.3%, which was 72.5% higher than in 2002. This was before the new management regime was introduced, indicating that hilsa were successfully breeding in the spawning grounds. The volume of eggs and *jatka* produced in 2011 was eight times higher than in 2007–2008 thanks to the introduction of an 11-day fishing ban in the spawning grounds during the peak October full moon spawning period. The evidence indicated positive impacts from the implementation of the fishing ban. Because of the introduction of measures to enhance social capital and conservation of stocks in the major hilsa breeding areas, hilsa production had increased. The abundance of *jatka* in the nursery grounds had been 189% higher than in previous years. Total hilsa production in Bangladesh increased by 54.1% in 2011 compared to 2002–2003.

2.1. Introduction

As the national fish of Bangladesh, hilsa is the country's most important species fishery. The fish has gained international recognition for its nutritional value, taste and delicacy. It accounts for more than half of the country's total marine catch and more than 11% of total fish production and about 1% of GDP (FRSS 2012). The average annual production of hilsa is 250,000 t, worth BDT 100 billion (BDT 400/kg). It also contributes about BDT 3500 million/year to foreign exchange earnings. The fishing season extends from June to March, with a major peak in September–October and a minor one in February–March. The fishery is artisanal and the gear used is mainly drift nets and set gill nets operated from traditional nonmechanized and mechanized wooden boats. About 460,000 fishers from 148 *upazilas* (similar to counties) are directly employed in hilsa fishing, with an indirect employment of an estimated 2.5 million throughout the hilsa value chain (transportation, processing, trading, etc.). Thus, the fishery plays an important role in employment, foreign exchange earnings and poverty reduction in the country. Currently, 50%–60% of production comes from Bangladesh, 20%–25% from Myanmar, 15%–20% from India and the remaining 5%–10% from countries such as Iraq, Kuwait, Malaysia, Thailand and Pakistan.

The fisheries sector of Bangladesh is highly diverse in resource type and species. Production during 2010–2011 from different components of inland and marine fisheries was 3.06 million metric tons. A total of 795 species of fish and shrimp were found in fresh, brackish and marine waters of Bangladesh. Inland aquaculture, together with coastal shrimp culture, accounted for 47.7% of total production during 2010–2011, whereas the inland open water fisheries contributed 34.5%. Inland aquaculture and inland open water fisheries thus dominate fisheries production, accounting for 82.2% of the total catch. The balance (17.84%) is the contribution of the marine sector (FRSS 2012).

From 2001 to 2010, industrial marine catches increased by about 117%, whereas artisanal catches increased by only 59%. However, development of the marine sector is vital in the context of fish supplies and the well-being of the people of the country. In addition to hilsa, which contributes 11% to total catch, shrimp/prawn contributes 7.8%, Bombay duck (*Harpondon nehereus*) 2%), jew fish (*Poa*, *Lambu*, *Kaladatina*) 1.2%, pomfret (*Rup Chanda*) 1.3%, sea catfish (*Tachysurus* spp.) 0.6%, and sharks, skates and rays 0.1%. It is also suspected that several marine fish species remain underexploited and that a comprehensive stock assessment exercise would be worthwhile.

2.2. Species diversity and distribution of hilsa

Three species of hilsa shad are found in Bangladeshi waters under the genus *Tenualosa* and *Hilsa*, one of which is exclusively marine while the other two occur in marine, estuarine and freshwaters. Two of the species belong to the genus *Tenualosa*, *T. ilisha* (ilish) and *T. toli* (*chandana ilish*), while the other, five-spot herring, comes under the *Hilsa* genus *Hilsa kelee/kanagurta*. *T. toli* is confined to seawater, whereas *H. kelee* occurs both in inland and marine waters. Geographical distribution and present status of the genus *Tenualosa* and *Hilsa* in Bangladesh are shown in Table 1. Four other species, which are almost identical to hilsa, occur occasionally in the coastal waters of Bangladesh: *Ilisha elongata* (*ramgacha/ramchowkka*), *I. Melastoma* (*peti chowkka*), *I. Megaloptera* (*Chowkka/Chowkka faisha*) and *I. filigera* (*coromondel ilish*).

Scientific and local names	Global distribution	Present status and distribution in Bangladesh
Tenualosa ilisha (*Hilsa*, *Ilish*, *Ilisha* in Bangladesh)	Myanmar to Arabian (Persian) Gulf; Indonesia; mainly in the Bay of Bengal	Mainly captured in the lower Meghna, Tetulia, Arial kha and other major rivers of the southern region, their estuarine parts and in the wider Bay of Bengal
T. toli, (Chandana ilish in Bangladesh and Terubok in Malaysia)	Bay of Bengal; Sarawak, Malaysia; Indonesia	Now very rare in seawater.
Hilsa kelee/kangurta, (Gurta ilish in Bangladesh and India)	Indo-West Pacific: all coasts of Indian ocean; Bay of Bengal; Gulf of Thailand; Java Sea and east of Papua New Guinea; Lower Mekong	Catch status not available

Table 1. Geographical distribution and present status of the genus *Tenualosa* and *Hilsa* in Bangladesh.

Currently, the main species of the Bangladesh hilsa fishery is *T. ilisha*, which contributes more than 99% of the total hilsa catch. Previously, a considerable quantity of *T. toli* was caught in Bangladeshi waters, especially in the Cox's Bazar region. Hossain et al. (1987) reported 0.1% and 6% contributions of *T. toli* in the gillnet fishery at Chittagong and Cox's Bazar landings, respectively, while *T. ilisha* were approximately 85%. Recently, *T. toli* has been almost absent in commercial and subsistence catches at these two centers. As a result, it is thought that the species may be endangered in Bangladesh.

2.3. Abundance and distribution of hilsa in Bangladesh

Hilsa occur in inland, marine and coastal waters of Bangladesh almost throughout the year. Until the introduction of mechanized boats and nylon nets in the early 1980s, catches of hilsa were mainly restricted to inland waters and estuarine areas, with very little from the coastal zone. Now, the main catches are concentrated in the estuaries, coastal zones and in the seas. The distributions of hilsa in Bangladesh are discussed below.

2.3.1. Distribution of hilsa in the Bay of Bengal

Details of the marine distribution of hilsa in Bangladesh are not available. Although in earlier days, the marine hilsa catch was restricted to the coastline, catches now come from the main part of the Bay of Bengal, extending up to 200–250 km from the coastline. As fishing technology develops, boats are fishing over greater areas in the Bay of Bengal, and so it is likely that as a result the reported distribution of the species in the bay is increasing.

2.3.2. Distribution of hilsa in the inland waters

T. ilisha was once available throughout the year in all the major rivers—the Padma, Meghna, Jamuna, Rupsa, Shibsa, Bishkhali, Pyra, Ilisha, etc.—mainly in the lower reaches toward the coastal areas of the Bay of Bengal. Hilsa were also abundant in the Karnafuly, Feni and Muhuri rivers and in most branches and tributaries of the Padma (Ganges) and the Brahmaputra (Ahsanullah 1964; Quereshi 1968; Haldar et al. 1992). Among the latter, the Garai, Kumar, Madhumati, Arial Khan, Nabaganga, Dhaleswary, Kaliganga and Buriganga were important. According to Raja (1985), the range of migration of hilsa in the Brahmaputra extended as far as Tezpur, a distance of 306 km from the border of Bangladesh, northward into India. Pillay and Rosa (1963) reported that hilsa ascend the full span of the Ganges Delta system. Ahmed (1954) reported that except for the districts of Rangpur, Dinajpur, Bogra and the Chittagong Hill Tracts, which were not fed by large rivers, all other districts in Bangladesh enjoyed good quantities of hilsa in some parts of the year.

In inland waters, hilsa and *jatka* (juvenile hilsa) occurred in about 100 rivers, but at present their main concentration is in the lower Meghna, Tetulia, Arial kha and other major rivers of the southern region and estuaries. The distribution of hilsa mainly depends on water flow and flooding of the rivers. In years of heavy flooding, they are caught in the small channels and floodplains. Considerable quantities of hilsa are also caught in the lower Arial kha, Madhumati and Padma rivers, with lower quantities in the Jamuna and Brahmaputra rivers. Over the past 10–30 years, hilsa fisheries have been completely lost from about 35 rivers, and hilsa are now caught only occasionally from 8 to 10 rivers. The estimated production loss from these rivers was about 20,000–25,000 t and about 45,000–50,000 people lost their livelihoods as hilsa fishers.

2.4. Historical trends in hilsa catches

Between 1983–1984 and 2010–2011, national hilsa landings in Bangladesh have ranged between 144,438 and 339,845 t, with an average of 224,751 (Figure 1). The average landings from inland and marine sectors

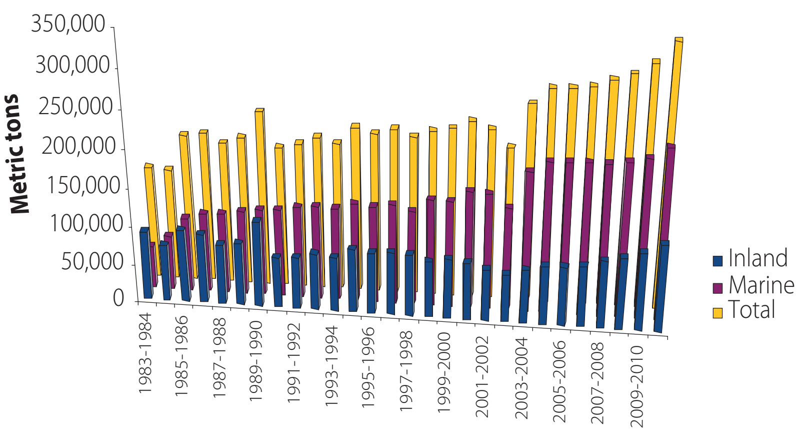

Figure 1. Trends in hilsa production during 1983–2010.

were 82,293 t and 142,3479 t, respectively. There has been an upward trend in total hilsa landings from Bangladeshi waters over this period, with substantial increases in the recent past as a result of the implementation of a number of management interventions since 2003. During the past two decades, hilsa production from inland waters declined about 12%. The number of marine fishing boats and the amount of gear have increased about four-fold since 1984–1985, greatly increasing fishing pressure in the marine sector. In addition, the intensity of marine catches increased after the introduction of nylon nets and mechanized boats. During the 1960s, inland hilsa landings ranged between 125,000 and 147,000 t, with an average of 136,000. In comparison with the 1960s, inland hilsa landings have decreased by about 41%. Marine catches in Myanmar have increased significantly in recent years. It is a matter of some concern that if appropriate protection and conservation measures are not undertaken immediately with regard to the hilsa fishery in inland waters, the area of hilsa availability may continue to shift downstream and eventually be restricted to marine areas only.

2.5. Biological attributes of hilsa

2.5.1. Population parameters and exploitation rate of hilsa

The exploitation rate of hilsa during 1992–2009 was higher (0.52–0.66) than the theoretically optimum level (0.50). During the same period, size at first capture (Lc) decreased over time from 35 to 13.1 cm. This reduction in size and the increasing exploitation rate resulted in a greater catch of small/undersized hilsa, signaling unsustainable production. Through the Global Environmental Fund (GEF) study, Haldar (2004b) found that overexploitation of hilsa continued until 2003 with little increase in E_{max} values (0.61–0.63). Size at first capture has since increased significantly (19.9–21.2) (Table 2) thanks to the enforced protection measures on *jatka* catches in recent years.

2.6. Natural and anthropogenic impacts of hilsa fisheries in Bangladesh

2.6.1. Natural impacts

Among the 230 rivers in Bangladesh, 54, including the big rivers—namely the Padma, Brahmaputra (Jamuna), Meghna, Surma, Kuhsiara and Karnaphuli—originate in and flow through Nepal, India and China. These rivers carry huge amounts of silt, and siltation has become a serious threat to the inland fishery of Bangladesh. The Meghna river system in particular carries considerable quantities of silt, which are deposited at the mouth of the Bay of Bengal. Extensive erosion at the mouth of the Meghna, such as in Hatia, Sandwip, Bhola and Noakhali, as well as river-borne sands and silts, has resulted in continuous change in river hydrology and bottom topography and has created many emergent and submerged islands. In Bangladesh, some 2179 million metric tons of sediment is carried by the Ganges-Brahmaputra river system, creating emergent and submerged islands and changing ecology, thus blocking the migratory routes of a number of aquatic animals, including hilsa (Curray and Moore 1971).

2.6.2. Anthropogenic impacts

As a result of the construction of the Farakka Barrage on the Ganges River in 1975 and the implementation of numerous flood control and drainage (FCD) measures and flood control, drainage and irrigation (FCDI) structures, as well as other infrastructure, river flows in Bangladesh have been reduced considerably, and the hilsa fishery has been affected severely.

Parameters	1992	1995	1996	1997	1998	1999	2000	2002	2003	2009
Asymptotic length (L_∞) cm	61.1	58.3	59.97	61.50	66.00	60.00	62.50	53.70	53.60	53.00
Growth constant (K)/yr	0.74	0.74	0.99	0.83	0.67	0.82	0.72	0.86	0.60	0.83
Total mortality (Z/yr)	2.41	2.61	3.19	3.29	3.43	3.77	2.79	3.51	3.03	3.23
Natural mortality (M/yr)	1.16	1.18	1.41	1.28	1.25	1.28	1.17	1.36	1.09	1.36
Fishing mortality (F/yr)	1.25	1.43	1.78	2.01	2.18	2.49	1.62	2.15	1.94	1.87
Exploitation rate (E)	0.52	0.55	0.56	0.61	0.63	0.66	0.58	0.61	0.64	0.58
Maximum yield/recruit (E_{max})	-	-	0.71	0.69	0.60	0.59	0.46	0.58	0.63	0.57
Size at first capture (L_c) cm	35.0	30.0	30.34	30.25	27.06	22.80	13.12	19.87	21.21	26.00
Growth performance (ø)	-	3.40	3.55	3.50	3.46	3.47	3.45	3.51	3.03	3.37

Table 2. Estimated values of population parameters of hilsa in Bangladesh waters during 1992–2009.

About 1500 km of hilsa stream and riverine habitat in the upper region of the country have been lost (Haldar et al. 2001). The upper Padma and almost all its branches and tributaries have become shallow, and some stretches have dried up completely. Haldar and Rahman (1998) reported that hilsa landings at Chandpur declined by 25.8% between 1978–1988 and 1989–1994 because of the loss of freshwater discharge from the upstream international river. The moderate hilsa fishery that existed in the Kumar River is no longer available because of the closure of the river under the Ganges-Kobadak project. Construction of the dam across the mouth of the Feni River, under the Muhuri Irrigation and Flood Control Project, has destroyed a commercial hilsa fishery of about 500 t/year (Haldar et al. 1992). As a result of the low discharge of water from the Ganges River and the consequent heavy siltation in most rivers, upstream feeding, spawning, nursery and migratory areas of hilsa have been reduced.

In Bangladesh, the disposal of all kinds of untreated waste/effluents into rivers is widespread. Moreover, industrialization, urbanization, increased use of fertilizers, agrochemicals and pesticides and the discharge of municipal wastes increasingly pollute the river system. Rivers such as the Buriganga and Shitalakhya, which were once suitable habitats for hilsa, have been totally destroyed by severe pollution. Water quality in the Shatnol-Gazaria areas has become unsuitable for hilsa and other aquatic organisms because of the high level of ammonia and other toxic substances as well as the lack of natural food organisms. Pollution in Bangladesh is likely to become endemic and widespread in the near future, further affecting hilsa fisheries unless proper management measures are developed and implemented.

The hilsa fishery has also been suffering from indiscriminate overfishing of *jatka* and gravid brood fish. Fish mortality has increased in step with the decrease in size at first capture. A large amount of fishing gear operates in inland waters as well as in the marine environment. Some illegal gear is used to indiscriminately harvest small *jatka*. Once the *jagot ber jal* (large beach seine net) was the main type of gear use, capturing about 80% of the total catch of *jatka*, but it is not commonly used these days. Instead, the most harmful types of gear—small mesh *current jal (*monofilament nets*)*, *mosahri jal* (mosquito nets), seine nets, *behundi jal* (set bag nets) and *char ghera jal* (nets used for fencing small submerged islands—are used illegally in nursery grounds to indiscriminately capture *jatka* of all sizes. The total catch of *jatka* has been estimated at about 190,200 t from all areas of the country (BFRI 2002). If 10%–15% of caught *jatka* are protected, assuming an average growth of 500 g/year and a 10%–15% survival rate, an additional 150,000–200,000 t of adult hilsa could be produced from the natural waters of Bangladesh.

2.7. Socioeconomic aspects of hilsa fishers

2.7.1. General features and demographic profile of hilsa fishers' households

Most hilsa fishers' houses are located along riversides (Leterme et al. 2004). Most villages are accessible by rickshaws, but only 1.5% of them can be reached by bus. There was no electricity or other modern amenities needed to maintain a decent life, and telephone landlines were absent, though the situation has since changed and most villages are now able to access mobile phone networks. Everywhere there is mobile connection.

Most fishers are professional fishermen and depend primarily on fishing or on selling their labor to work for other fishers. The mean family size of fishers' households is seven (3.6 males, 3.4 females), which is above the national average. About 83% of fishers are illiterate (the national average is 58.9%) and 42% of households have only one family member earning an income. The vast majority of fishers (82%) use drinking water from underground tube wells. Only 52% of households have a sanitary latrine. About 88% of fishers can be described as landless (<0.5 acre land holding), others having marginal (8.5%) or small-scale (2.51%–4.50%) landholdings.

2.7.2. Number of hilsa fishers and their geographical distribution

A detailed list of the hilsa fishers and family numbers up to the village level in different districts is given in Table 3. From the table, it appears that about 460,000 hilsa fishers belonging to 183,000 families exist in Bangladesh. They belong to 3700 villages in 1400 unions, 143 *upazilas* and 40 coastal districts of Bangladesh. Their main concentration (63.4%) is in six districts of the Barisal division followed by eight districts of the Chittagong division (28.6%). Overall, about 92% of the hilsa fishers belong to two divisions.

2.8. Crafts and gear of inland waters and catch per unit effort

Fishers mainly use *chandi, kosa dingi* and mechanized boats for hilsa fishing. About 100,000 crafts are currently engaged in hilsa fishing. The types of gear used to capture hilsa are mainly set gill nets (*Chandi jal*) and drift gill nets (*Gulti*, *Kona*, *Current jal*). Fishers are also using some seine nets (*Jagat ber jal*, purse seine nets) but recently the use of *Jagat ber jal* has become rare. Fishing gear, namely small mesh *current jal*, *behundi jal* (set bag nets), *moshari ber jal* and *Char ghera jal*, which are widely used to catch juvenile hilsa indiscriminately in certain regions, has been identified as harmful (Figure 2). Trends in catch per unit effort (CPUE) of gill nets during 1998–2011 are shown in Table 4.

2.9. Mechanized and nonmechanized boats/gear of the marine sector and their catch

From a census carried out in 1999–2000, the number of mechanized boats and amount of gear were found to be 18,992 and 75,968, respectively, which were 6.6 and 26.8 times higher than a decade earlier. However, catch per boat over the same period did not increase significantly. Because the numbers of boats and nets in Table 3 are used for marine hilsa catch estimation,

	District						
	Dhaka	**Chitta gong**	**Barisal**	**Raj shahi**	**Khulna**	**Sylhet**	**Total**
Total districts	12	8	6	7	5	2	40
Total upazilas	34	27	38	24	18	2	143
Total unions	374	277	337	227	172	17	1,404
Total fishers	75,687	257, 715	308, 270	27,636	78,268	9,500	757, 076
Total hilsa villages	579	773	1,743	307	260	41	3,703
Total hilsa fisher families	8,902	66,608	100,270	2,897	4,570	383	183,630
Total hilsa fishers	17,454	142,649	285,001	6,372	11,783	825	464,084
Full time (%)	26	56	65	24	10	10	32
Part time (%)	74	44	35	76	90	90	68

Table 3. Numbers of hilsa fishers, by district, in Bangladesh.

Gear	**CPUE (kg/net/day)**	**Area covered**	**Source**
Gill net	45.7 (mean)	Meghna River (Chandpur-Hatia)	Rahman et al. (1998)
Gill net	33.0 (mean)	Meghna River (Chandpur-Hatia)	Rahman et al. (1998)
Set gill net (*Chandi*)	8.0–22.0	Meghna River (Chandpur-Alexander), Tetulia, Karkhana, Pyra)	BFRI (2005)
Drift gill net (*Gultijal*)	20.0–50.0	ditto	BFRI (2005)
Current net	10.8–22.6	ditto	BFRI (2005)
Set gill net (*Chandi jal*)	4.5–30.0	Meghna River (Chandpur-Sakuchia, Monpura)	BFRI (2007)
Drift gill net (*Gulti jal*)	5.8–50.0	ditto	BFRI (2007)
Current net	4.0–9.0	ditto	BFRI (2007)
Drift gill net (*Gulti jal*)	7.5–35.0	ditto	BFRI (2010)
Current net	4.5–11.0	ditto	BFRI (2010)

Table 4. Catch per unit effort by gill nets during 1998–2011.

Current net — Set bag net (behundi) — Fine-meshed jagat ber jal — Char ghera jal

Figure 2. Harmful types of gear used in *jatka* harvest.

the true catches of the marine sector may not be accurately reflected in FRSS catch statistics (Haldar 2004a). The average catch per mechanized boat per year was 16.7 t in 1983–1984, which appeared to increase to 42.3 t in 1998–1999 and subsequently decrease to only 6.9 t in 2001–2002.

Artisanal nonmechanized boat operations were investigated two years after the study of mechanized boats was carried out. The number was estimated to be 3802 (1985–1986). Almost the same numbers of boats (3509–3802) were recorded in subsequent studies until 1998–1999, when the number of such boats dramatically increased to 7177. Until 1999–2002, the numbers remained about the same. Before 1998–1999, only one net per artisanal nonmechanized boat was used, increasing to six nets per boat in 1999–2002 The average catch per nonmechanized boat ranged from 2.08 to 5.03, with an average of 4.1 t per year from 1983–1984 to 1988–1999, decreasing to 3 t at the beginning of 2000.

2.10. Seasons of hilsa fishing

Commercial hilsa fishing occurs in marine and riverine areas throughout the year, but the peak fishing season is September–October. The majority of the catch (60%–70%) takes place during the peak breeding season when 60%–70% of hilsa are sexually mature and ripe. The second peak fishing season is January–February in riverine areas. In the Bay of Bengal coast, off Cox's Bazar, the fishery extends almost throughout the year, but activity is significantly reduced during the monsoon months (June–August) because of the roughness of the sea. Hilsa fishing is closely related to the lunar cycle, as fishing intensity increases during the full moon and new moon periods.

2.11. Present management measures of hilsa

To sustain increased hilsa production, several management measures have been undertaken by the DoF, under the Ministry of Fisheries and Livestock (MoFL), based on the research findings of the BFRI. Among the different attempts, the most important initiatives have been conservation of *jatka* through imposition of bans on catching juveniles <23 cm from November to May, the declaration of five fish sanctuaries in the major nursery and spawning grounds of Padma-Meghna river systems and the protection of gravid hilsa from being caught for 11 days during the peak breeding season (Rahman et al. 2012).

2.12. Implementation of hilsa fisheries management action plan

The hilsa management action plan (HFMAP) has been implemented since 2003 with the aim of protecting *jatka* until they become large enough to undertake a seaward migration. The action plan specifies the activities and implementation strategy, ascertains the responsibilities of the relevant agencies and target communities and sets out a timeframe for implementation. The action plan involves the following measures:

- a comprehensive awareness raising program, including a riverine rally, advertisements in public media, distribution of leaflets and posters
- enforcement of fish protection and conservation acts, and a fishing ban for 11 days in major spawning grounds
- establishment and maintenance of a hilsa sanctuary with protection of hilsa habitats
- conservation of gravid hilsa for uninterrupted spawning and subsequent recruitment
- conservation of *jatka* and hilsa species diversity
- rehabilitation and promotion of alternative livelihoods among *jatka* fishers/collectors, together with accompanying incentives
- involvement of all stakeholders in the *jatka* protection program, including the MoFL, the DoF, the navy, the coast guard and district and *upazila* administration
- involvement of relevant district ministers and other public representatives
- development of a special task force (STF) by involving district and *upazila* administration
- review and improvement of a catch monitoring system of hilsa
- generation of funds to support a *jatka* protection and conservation campaign
- special operation for *jatka* protection and conservation
- regional initiatives, primarily a tricountry (Bangladesh, India and Myanmar) partnership, for hilsa management and conservation.

2.12.1. Special operation for *jatka* protection and conservation

Catching, transportation, marketing, selling and possessing juvenile hilsa (*jatka*) (<23 cm) are banned between 1 November and 31 May in Bangladesh under the Protection and Conservation of Fish Act–1950. The following arrangements have been made:

- involvement of all relevant agencies in the *jatka* protection program (MoFL, DoF, navy, coast guard, district and *upazila* administration, district and *upazila* level officers of the DoF)

- allocation of funds for the *jatka* protection program
- identification of a special operation area for proper functioning and coordination of the navy and coast guard
- formation of special task forces by the DoF and district and *upazila* administration
- implementation of awareness building programs
- rehabilitation of and AIGs for *jatka* fishers.

2.12.2. Declaration of hilsa sanctuaries

Five sites in the riverine-estuarine ecosystems in the coastal regions of the country have been declared as hilsa sanctuaries under the Protection and Conservation of Fish Act–1950 for effective conservation of *jatka* in major nursery areas and for the maintenance of fish biodiversity (Figure 3 and Tables 5 and 6). The total hilsa sanctuary area as declared is about 350 km long, covering 22 *upazila* in five districts.

2.12.3. Conservation of gravid hilsa to ensure uninterrupted spawning

Every year, the highest number of gravid and upward migrating hilsa are generally caught during the five-day period before and after the full moon, including the full moon day of *Barapurnima* in October (Ashwin). Thus, catching hilsa has been banned each year in a number of major spawning grounds during this the most vital breeding period. The tetragonal-shaped protection area covers four major spawning grounds with an estimated area of 6882 km^2 (Table 7).

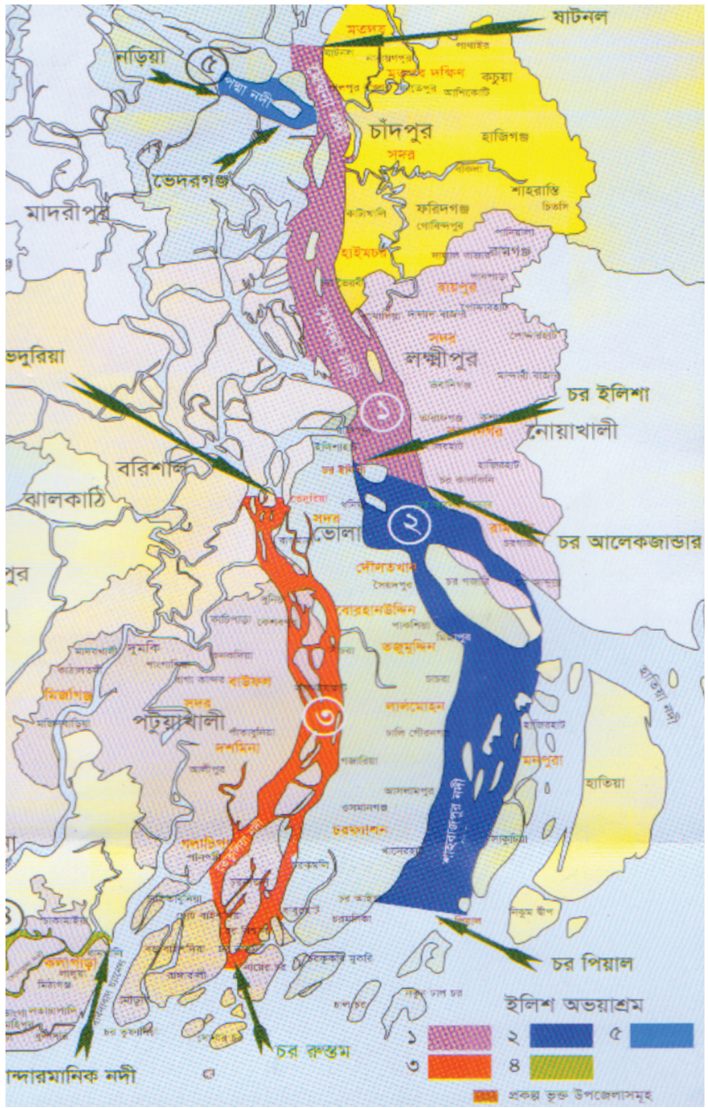

Figure 3. Different hilsa/*jatka* sanctuaries in Bangladesh.

Hilsa sanctuary area	Ban period
From Shatnol of Chandpur District to char Alexander of Laxmipur (100 km stretch of the lower Meghna estuary)	March to April
Madanpur/Char Ilisha to Char Pial in Bhola District (90 km stretch of the Shahbajpur River, a tributary of the Meghna)	March to April
Bheduria of Bhola District to Char Rustam of Patuakhali District (nearly 100 km stretch of the Tetulia River)	March to April
Entire 40 km stretch of the Andharmanik River in Kalapara Upazila of Patuakhali District	November to January
A 20 km stretch of the lower Padma River in Shariotpur District	March to April

Table 5. Five hilsa/*jatka* sanctuaries in Bangladesh.

Position	Sanctuary area with GPS point	Ban period
North-East	Kasikata, Vedorgonj, Shariatpur (23019.8′ N, 90032.6′ E)	March and April (2 months every year)
North-West	Vomkora, Noria, Shariatpur (23018.4′ N, 90028.8′ E)	
South-East	Beparipara, Matlab, Chandpur (23015.9′ N, 90037.7′ E)	
South-West	Tarabunia, Vedorgonj, Shariatpur (23013.5′ N, 90035.1′ E)	

Table 6. Location of new hilsa sanctuaries in the lower Padma River.

2.13. Key interventions for hilsa management based on HFMAP

The fishing ban creates suffering among fishers during the declared ban period. Fishers are thus compelled to continue fishing to survive. The DoF with its inadequate logistics and labor cannot ensure full compliance with fish protection measures within the sanctuary and spawning areas during the ban period. A study was undertaken by GEF on the impact of *jatka* fishing (DoF 2014). The study revealed an estimated 45% increase in hilsa landings in four major landing centers following implementation of the new management measures. From the above study, it is evident that effective enforcement measures in critical sites and during the critical breeding period of a species can help significantly increase production and biodiversity. The Government of Bangladesh has also recently taken five further initiatives to strengthen the ongoing hilsa management campaign.

1. Support to enhance hilsa sanctuary activities: The government has already established five sanctuaries in areas of hilsa and *jatka* abundance in the rivers of Bangladesh. Implementation of the Fish Protection Act–1950, massive awareness building efforts, highlighting the benefits of conservation of *jatka* and gravid hilsa, livelihood supports and rehabilitation of *jatka* fishers within the government declared sanctuaries and ban areas, etc. have all been accorded importance. The estimated allocation of funds for hilsa sanctuary management is about BDT 20 million per year. This program includes all 20 districts (91 riverine *upazilas*) where jatka are at risk of being overfished. The ongoing program mainly deals with activities to enhance production of hilsa rather than supporting livelihoods of poor fishers.

Districts under hilsa program (20): Chandpur, Lakhmipur, Bhola, Barisal, Patuakhali, Barguna, Pirojpur, Jhalkathi, Bagerhat, Faridpur, Manikganj, Dhaka, Munshiganj, Sariatpur, Madaripur, Rajbari, Narayanganj, Noakhali, Chittagong and Kishoreganj.

2. Training and support for AIGAs: Under this program, needs-based training/refresher courses and micro grants are provided to hilsa fishers to help them find AIGAs. An estimated 20,000 fishers (20 *upazilas*, with an average of 1000 fishers per *upazila*) primarily depend on fishing in sanctuary areas and could benefit. For example, through the AIGA scheme, fisher families can be provided with grant funding to purchase a rickshaw/van, sewing machine, goat, cow (for fattening) and/or other forms of support to begin a small business, such as net making, duck or poultry rearing, plant nursery, kitchen gardening or cage aquaculture.

3. Support of food grain: For livelihood sustenance, fishers are supported with food grains for 4 months during the ban periods. Total fishing bans are imposed in the defined areas through enforcement of relevant laws and rules by the appropriate authorities. Table 8 shows the details of food-grain distribution.

Position	Area	Ban period during peak spawning time
North-East	Mayani point, Mirersharai	5 days before and after the full moon (including the full moon day), which is first sighted in the Bengali month of Ashwin each year (it had previously been fixed as 15–24 October each year)
North-West	West Syed Awlia point, Tajumuddin	
South-East	Gandamara point, Kutubdia	
South-West	Lata Chapili point, Kalapara	

Table 7. Location of hilsa sanctuary in the hilsa breeding/spawning grounds.

Financial year	No. of *upazilas* (districts)	Food-grain distribution		AIGA program	
		Allocated amount (t)	No. of households	Allocated money (BDT '000)	No. of fisher households
2007–2008	59 (10)	4360	145,335	2000	16,985
2008–2009	59 (10)	5,730.08	143,252	200.00	18,355
2009–2010	59 (10)	19,768.60	164,740	500.00	14,746
2010–2011	85 (15)	14,470.64	186,264	517.00	6,869
2011–2012	85 (15)	22,351.68	186,264	588.00	7,500

Table 8. Details of food-grain distribution and the AIGA program during 2007–2012.

4. Awareness raising program: Massive awareness raising programs are now regularly carried out in *jatka* and hilsa overexploitation prone areas to develop awareness among stakeholders. The programs include the observation of *Jatka* Conservation Week, TV talk shows and trailers, poster/leaflet distribution, road and boat rallies, awareness meetings, workshops and seminars. Orientation courses for *upazila* and district level officers on *jatka* conservation are also carried out regularly.

5. Research and study: Provision is underway to conduct relevant research and studies on *jatka* and hilsa conservation and management in coordination with research organizations. Recent studies indicate that the hilsa found in the territorial waters of the three countries possibly belong to the same stock and thus require shared management. The gaps in hilsa biology, genetics of stocks, parental assignment, migratory pattern and triggering physicochemical parameters, food habits at different stages of its lifecycle, influence of salinity on growth, etc. are some of the research areas needs to be undertaken in Bangladesh and, if possible, in collaboration with the CIFRI of India.

2.14. Regional initiatives for hilsa management and conservation

Hilsa is a common resource of the Bay of Bengal, and three countries, including Bangladesh, India and Myanmar, harvest 90%–95% of global hilsa, but there is no regional stock management initiative. Therefore, sustainable production of hilsa requires intense management of the stock through regional/subregional collaboration throughout collective research work and sharing and exchanging information. The scope of collaboration includes the management of similar types of spawning and nursery grounds of hilsa, the development of marine parks/no-take zones, the abatement of pollution of common rivers and the development of a Bay of Bengal regional management plan.

2.15. Impacts of management measures on hilsa

2.15.1. Size, sex and composition of different groups of hilsa

During a riverine research cruise (2011–2012), the monitoring authority observed the availability of relatively larger (2-year plus) hilsa in fishers' catches at all landing points, as well as downstream of Chandpur district, Bangladesh. In the upper region, most of the hilsa were <30–35 cm, whereas more than 90% hilsa were >35 cm in downstream areas. Among captured hilsa, the proportions of males and females were estimated to be 31% and 69%, respectively. In the spawning ground areas (Monpura and Hatia), more than 95% of hilsa were >35 cm and almost all were capable of breeding. The findings reconfirm that these areas are hilsa spawning grounds.

2.15.2. Percentage composition of oozing/gravid hilsa

During the same research cruise, the percentage composition of mature/gravid hilsa (maturity stages V and VI) found in spawning grounds was higher than in adjacent areas because of the fishing ban in the spawning grounds.

2.15.3. Spent hilsa and spawning success

The research cruise found that the proportion of spent hilsa (36.27%) observed in the spawning areas was 72.5% higher than in 2002 (0.5%), indicating successful breeding of hilsa in the spawning grounds (Table 9).

2.15.4. Estimation of egg/fry production during fishing ban

An approximately eight–fold quantity of eggs and *jatka* were estimated to have been produced in 2011 than those in 2007–2008 after executing an 11-day fishing ban in the spawning grounds of hilsa during its peak spawning period. The successful breeding of hilsa and the positive impacts of the fishing ban are shown in Table 10.

Year	Percentage of spent hilsa	Percentage increase	Management strategies
2002	0.50	-	Traditional
2003	1.40	2.8	*Jatka* protection
2007	5.40	10.8	Sanctuary + 10 days fishing ban
2008	38.72	77.44	Sanctuary + 10 days fishing ban
2009	17.62	35.24	Sanctuary + 10 days fishing ban
2010	33.69	67.38	Sanctuary + 10 days fishing ban
2011	36.27	72.54	Sanctuary + 10 days fishing ban

Table 9. Percentage of spent hilsa before and after intervention.

During the experimental collection of spawn and juveniles, approximately 20- to 30-day-old fry were found in all surveyed areas in and around the spawning grounds. Many fry and juveniles of other fish species were also present, indicating a positive impact of the fishing ban on their reproduction.

2.15.5. Catch per unit effort of *jatka* in different rivers in different years

The abundance of *jatka* was higher than in previous years and was 189% higher than in 2005 (Figure 4).

The average increase in *jatka* abundance was 189%, with a sharp increase in the Meghna belt *jatka* sanctuary areas when compared with 2003 and 2004 data. This indicated that the complete fishing ban has a strong positive impact on *jatka* abundance. Similarly, a complete fishing ban for 11 days in the spawning grounds showed an increase in spent fish (36.3%) in 2011, while the huge number of hilsa fry and juveniles in and around spawning grounds indicated a positive impact on reproduction of hilsa. Hilsa production increased by 54.1% in 2011 compared to 2003 because of the implementation of key management measures.

After exploring the abundance of *jatka* in different major rivers, another *jatka* sanctuary has been established. The area of the new *jatka* sanctuary (ban period March–April) is located in the lower Padma River in the Shariotpur region (Table 6). Further investigation is ongoing to determine if additional sanctuaries are needed in more important hilsa spawning grounds.

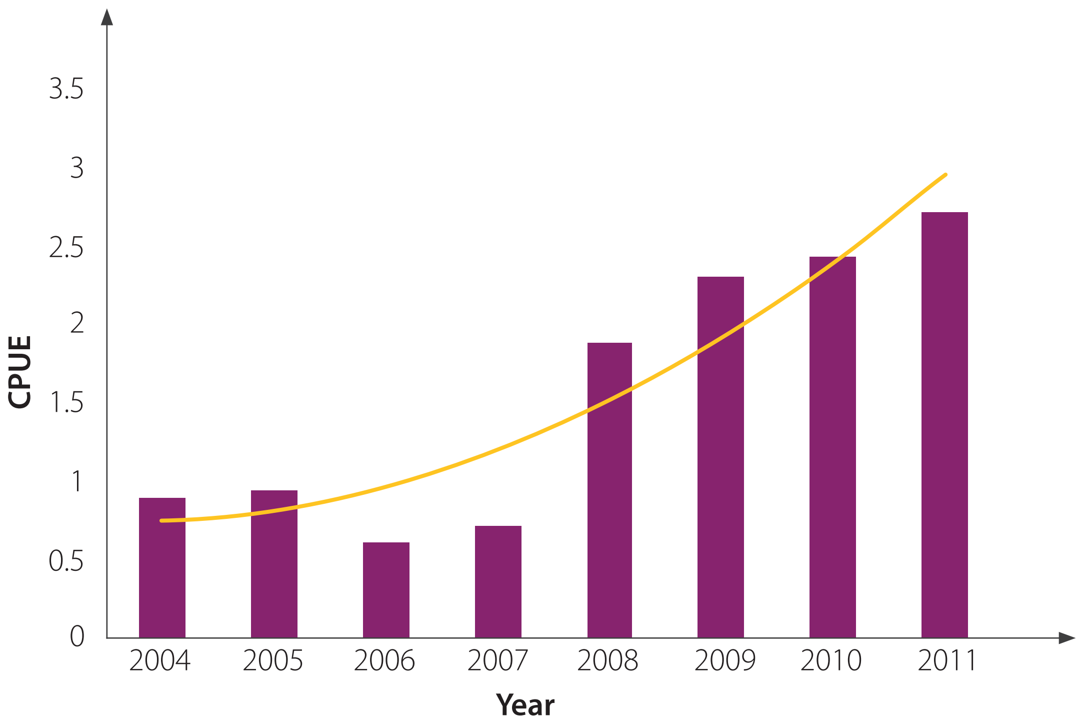

Figure 4. Increasing trend of CPUE of *jatka* in hilsa nursery grounds.

Period	Saved hilsa (crore = 10 million)	Total egg production (kg)	No. of fry (crore) (50% hatching)	Production of jatka (crore) (10% survival)
2007–2008	1.44	46,800	29,300	2,930
2008–2009	1.56	392,620	245,385	24,538
2009–2010	1.49	170,420	85,210	8,521
2010–2011	1.51	336,199	168,099	21,012
2011–2012	1.61	385,500	240,937	24,094

Table 10. Estimated hilsa egg/fry production during fishing ban.

2.16. Conclusions

To increase hilsa production and ensure sustainable fisheries, a number of management measures were undertaken by the MoFL and the DoF. The conservation of *jatka* and protection of brood hilsa by declaring fish sanctuaries in the major nursery and spawning grounds of the river and estuarine ecosystem for a certain period have proved to be the most successful initiatives. As a result, production of hilsa has gradually increased throughout the riverine, estuarine and marine ecosystems. Tri-country research partnership and cooperation between India, Bangladesh and Myanmar should be developed to ensure a sustainable management of this valuable renewable hilsa resource in the Bay of Bengal.

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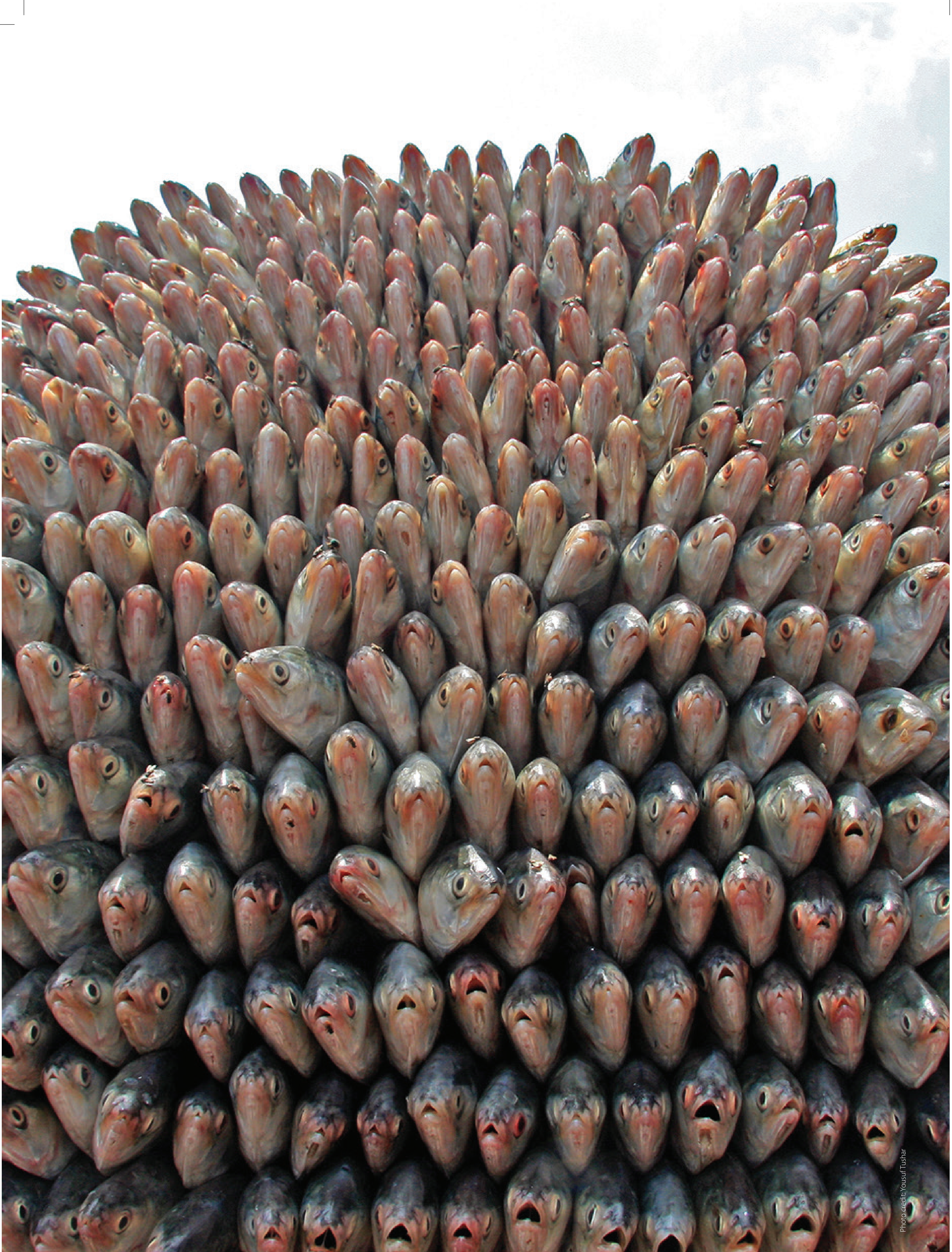

Pile of hilsa in Chandpur Borostation market.

3. Status of the hilsa fishery in India

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Abstract
Hilsa is found in the rivers of Eastern and Western India, namely the Ganges, Bhagirathi, Hooghly, Rupnarayan, Brahmaputra, Godavari, Narmada, Tapti and other coastal rivers. Currently, three species under the genus *Tenualosa*—*Tenualosa ilisha* (H. 1822), *T. toli* (V.1847), *T. kelee* (C.1829)—have been recognized from the estuaries and coastal waters of India. The hilsa fishery in India prevails mostly in the rivers of the east coast of the Bay of Bengal (Hooghly-Bahgirathi, Godavari, Mahanadi and Chilika) and in the rivers of the west coast of the Arabian Sea (Narmada and Tapti). As such, 90% of India's hilsa production comes from the Hooghly-Bhagirathi river system. Overall production of the species constitutes nearly 2%–3% of the country's marine fisheries potential and 5%–6% of its inland capture fisheries potential. The hilsa fishery fluctuates highly in Indian rivers and is dependent on various biological, climatological and hydrological factors of natural and human origin. As revealed in time-scale analyses of India's annual production figures, the hilsa fishery has declined in every river system, other than Hooghly-Bhagirathi distributory of the Ganges river system. Fishers involved in the hilsa fishery are facing livelihood problems as a result of poor and unsustainable catches. Intensive fishing in all water bodies needs to be controlled immediately. Fishing level should not exceed the Maximum Sustainable Yield (MSY) level so as to develop a sustainable fishery in the country. Therefore, strict conservation measures are needed to improve the hilsa fishery in the river-estuarine systems of India.

3.1. Introduction

Popularly known as hilsa, the Indian shad, *Tenualosa ilisha* belongs to the subfamily Alosinae of the Clupeidae family. The prized hilsa has established itself as one of the most important commercial fish in the Indo-Pacific region. It is widely distributed and occurs in marine, estuarine and riverine environments. The fish is found in the Persian Gulf, Red Sea, Arabian Sea, Bay of Bengal, Vietnam Sea and the China Sea. Its riverine habitat covers the Satil al-Arab and the Tigris and Euphrates of Iran and Iraq, the Indus of Pakistan, the rivers of Eastern and Western India, namely the Ganges Bhagirathi, Hooghly, Rupnarayan, Brahmaputra, Godavari, Narmada, Tapti and other coastal rivers, the Irrawaddy of Myanmar, and the Padma, Jamuna, Meghna, Karnafully and other coastal rivers of Bangladesh (Figure 1). The majority of hilsa that are caught (about 90%) are by fishers in Bangladesh, India and Myanmar.

Presently, three species under the genus *Tenualosa*, namely *Tenualosa ilisha* (Ham-Buchanan), *T. toli* (Valenciennes) and *T. kelee* (Couvier), have been identified from the estuaries and coastal waters of India. Habitat, migratory behavior, maximum age and growth differ from species to species. Since these species are highly prized, they are subjected to heavy fishing, which has led to decline in catches. Among the three species, only *T. ilisha* is the basis of a commercial fishery, the other two species, *T. toli* and *T. kelee*, being rarely seen in Indian waters.

Figure 1. Distribution of hilsa in the Indo-Pacific region.

Figure 2. Species of *Tenualosa* recorded in the Tapti estuary: (A)*Tenualosa ilisha*, (B) *Tenualosa toli* and (C) *Tenualosa kelee*.

3.2. Hilsa fishery in India, with special reference to the Hooghly-Bhagirathi river system

The hilsa fishery in India prevails mostly in the rivers of the east coast of the Bay of Bengal (Bhagirathi-Hooghly, Godavari, Mahanadi, and Chilka lake) and in the rivers of the west coast of the Arabian Sea (Narmada and Tapti). As such, 90% of the country's hilsa production comes from the Hooghly-Bhagirathi river system.

3.2.1. West Coast

3.2.1.1. Narmada River

The Narmada, the largest west-flowing river in India, originates in the Maikala highlands near Amarkantak in Shahdol District of Madhya Pradesh. Its drainage area is the northern extremity of the Deccan Plateau. Of its total length of 1312 km, it traverses Madhya Pradesh for 1077 km, forms boundaries between the Maharashtra and Madhya Pradesh, and Maharashtra and Gujarat (for 35 and 39 km, respectively), and flows through Gujarat for some 161 km before joining the Gulf of Cambay (Arabian Sea) near Bharuch (Gujarat). The Narmada River is fed by 41 major tributaries along its course, 22 from the south bank (21 in Madhya Pradesh and one in Gujarat) and the rest from the north bank (18 in Madhya Pradesh and one in Gujarat). Its total catchment area is 94,235 km^2. *Tenualosa ilisha*, contributes a sizable fishery (24.14%–31.6%) from the Narmada estuarine system, which is one of the most productive natural fishery resources in Gujarat state. During 1961–1970, the average catch in the Narmada was 380 t. Over the past 25 years, the hilsa catch has fallen in four of them (1987, 1992, 1994 and 2009) to such an extent that fishers' livelihoods have been threatened. Poor rainfall was the main cause in 1987, 1992 and 2009, while in 1994 a combination of excessive rainfall and low discharge from the Sardar Sarovar Dam (significantly reduced rainfall in the upper catchment) was to blame. Catches reached a minimum in 2004 (Figure 7).

3.2.1.2. Tapti River

The Tapti River, also called Tapi, is the other westerly flowing river in peninsular India. Rising from the Satpura Range, it flows westward through Madhya Pradesh, Maharashtra and Gujarat before joining the Arabian Sea at Duma near Surat (Gujarat). The total catchment area of this river is about 48,000 km^2. With a view to using huge quantities of rainwater to develop the regions of the lower Tapti valley and also to control flooding in Surat District, a weir was constructed on the river at Kakrapar at Mandovi of Surat District. During 2008–2009 and 2009–2010, hilsa catches in the Tapti River were less than 1 t, down from earlier reported catches by 55 t. However, during recent investigations on the Tapti estuarine system, a very large specimen of *T. ilisha* measuring 614 mm and 4.25 kg was recorded (Bhaumik et al. 2012). And in the Tapti river system, all three species of hilsa, namely *Tenualosa ilisha*, *T. toli* and *T. kelee*, have been observed.

3.2.1.3. Vallabh Sagar Reservior

The catchment of the Vallabh Sagar Reservoir (VSR) extends from longitude 73°32′25″ to 70°36′30″ E and from latitude 20°5′0″ to 22°52′30″ N. The dam is located some 29 km upstream of the Kakrapur weir. The total catchment area is 62,225 km^2. The catchment of the dam covers large areas of 12 districts in Maharashtra and Gujarat. The earthen side walls of the dam rise to a height of 80.77 m above full reservoir level (FRL), while the masonry dam is 68.68 m high. The area of the reservoir at FRL is about 60,000 ha. Ukai, a large multipurpose dam, has been constructed above the Kakrapur weir, on the border of Maharashtra and Gujarat. An anicut has also been constructed on this river in the district of Jalgaon (Maharashtra) near Adilabad.

Studies on the hilsa fishery in the VSR confirm that hilsa have adapted to the totally freshwater lacustrine habitat. In 1999–2000, hilsa varied in size from 172 to 331 mm TL and 59.2 to 340 g in weight. During 2002–2003, a multisized fishery of *T. ilisha* was evident. The size group encountered during this period varied from 130 to 285 mm in length and 15.12 to 202.77 g in weight. In September 2002, the abundant young *T. ilisha* ranged from 45 to 70 mm in TL and 0.73 to 3.20 g in weight.

Analysis of the annual fish catch data of the VSR revealed that annual catches of *T. ilisha* ranged from 1 to 52 t (0.06%–1.76% of total catch) from 1989–1990 to 1996–1997. The contribution further increased to 119 t (2.28% of total catch) during 1998–1999 and further to 934 t during 2000–2001. The lowest catch recorded in the VSR was 0.5 t in 2007–2008. During 2004–2005, 2006–2007 and 2010–2011, catches gradually increased to 7.35, 65.87 and 93.26 t, respectively. The maximum recorded fish production from the VSR was 934 t in 2001–2002. During the study, the multisized nature of the fishery was observed over the years, and the increasing contribution of hilsa in the annual catches of the VSR strongly indicate that an endemic population has thrived in this totally freshwater lacustrine environment (Bhaumik et al. 2013.)

3.2.2. East Coast

3.2.2.1. Brahmaputra river system

The mighty Brahmaputra, a mass of freshwater that travels through northeast India, rises from the Angsi Glacier in Tibet, on the northern side of the Himalayas. It runs for about 1250 km through Tibet, as the Yarlung Tsangpo River, before turning sharply southward to enter India through a number of great gorges near Tuting in Siang District of Arunachal Pradesh. Running for about 160 km in Arunachal Pradesh, as the Dihang/Siang River, it enters Assam northwest of Sadiya where it meets two equally important trans-Himalayan tributaries, Dibang (Sikong) and Lohit. After joining with these tributaries, the river becomes the Brahmaputra. Fortified by 41 main tributaries (25 on its northern bank and 16 on its southern bank), the river flows through the heart of Assam for about 740 km before entering Bangladesh, where it is called the Jamuna. After flowing for its last 480 km in Bangladesh, the river joins with the Padma (Ganges) at Goalando, which reaches the Bay of Bengal through the Meghna estuary. The total length of this river is about 3850 km, of which 900 km lies in India. The combined length of the river, including its 41 main tributaries in India, is about 4000 km with a catchment area of about 580,000 km^2 (195,000 km^2 in India) and an average water discharge of 510,450 m^3. Hilsa production from this river system was 11.113 t in 2006, 12.829 t in 2007, 7.554 t in 2008, 8.535 t in 2009, 2.464 t in 2010, 2.305 t in 2011 and 1.350 t in 2012.

3.2.2.2. Mahanadi River

The Mahanadi River rises from the Sihawa hills (near the village of Pharsia) in the southwest of Raipur District in Chattissgarh. With a total length of 857 km, in Chattissgarh, Madhya Pradesh and Odisha, it drains an area of about 141,600 km^2. After a brief run westward, it turns north and then eastward at Khagoni to reach Mahadeopalli, 140 km away, where it is dammed by the Hirakud Dam. After the Hirakud Reservoir, it runs east for 415 km in the state of Odisha before entering the Bay of Bengal.

Fish specimens collected from landing centers and fishing boats were identified and preserved for further studies all along the estuarine length. Hilsa (*T. ilisha*) was found as far as the Naraj Barrage, about 100 km upstream of the sea. The average annual catch of hilsa in the river during 1951–1960 was 310 t, which declined gradually to 298 t during 1961–1970 and to 112 t in 2001–2010.

3.2.2.3. Chilka Lake

Chilka Lake is a brackish water lagoon, covering 1100 km^2 of the Puri, Khurda and Ganjam districts in Odisha state on the east coast of India, at the mouth of the Daya River and flowing into the Bay of Bengal. It is the second-largest lagoon in the world. The lake catchment comprises a wide range of clays, silts, sand and gravel and shell banks, the major part of the catchment area being silt. Approximately 1.6 million t of sediment per year is deposited into Chilka Lake by the Daya River and associated streams. The north shore of the lake is part of Khordha District and the western shore is part of Ganjam District. Because of its siltation, the width of the barrier has fluctuated and the mouth of the sea has periodically been closed. The location of the mouth has also frequently shifted, generally toward the northeast. The width of the old channel to the sea, now reported to be about 100 m, is known as Magarmukha. A 32 km long outer channel connects the lake with the Bay of Bengal at the village of Arakhuda. A tropical monsoon climate prevails over the drainage basin area of the lake. The lake experiences southwest monsoons from June to September and northeast monsoons in November and December. The wind speed varies from 5.3 to 16 m (17 to 52 ft) per hour and predominantly comes from the south and southwest during the southwest monsoon period and from the north and northeast during the other months.

The lake is broadly divided into four zones—southern, central, northern and outer channels—on the basis of salinity values. The tidal influx of seawater during the monsoons is arrested by the strong influx of a large amount of freshwater from the northern and central zones. Salinity in the southern zone decreases during the post-monsoon period and in winter as northern winds facilitate the mixing of saline water with the rest of the lake. During the summer, intrusion of saltwater from the outer channel into the lake increases, since this is when lake water levels are at their lowest.

In 2000, the de-siltation of the channel connecting the lake to the sea and the opening of a new mouth to restore natural flows of water and salinity levels were carried out. These actions resulted in a notable increase in the lake's fish yield.

Chilka Lake in the east coast is a destination for hilsa because of the Daya River, which is rich in breeding and rearing habitats for the species. Hilsa in this system generally appear in two: peaks, during the monsoon season and winter. Geomorphological features of the connection between the sea and the river mouth and the Daya confluence itself significantly affect the migration and fishery of the species in the lake.

Decadal fluctuations in hilsa catches have been observed. During the 1970s, the average catch was 129.2 t. In 1980s it was 252.8 t, but declined to 62.8 t during 2001–2010. Data from the Chilka Development Authority shows that hilsa production was 170.8 t in 2007–2008, 11.5 t in 2008–2009 and 4.1 t in 2009–2010.

3.2.2.4. Godavari River

The Godavari River, the largest of the peninsular rivers and the third-largest river in India (next to the Ganges and Brahmaputra), is 1465 km long, from its origin near Triambakeswar in the Deolali hills near Nasik (Maharashtra) in the northwestern ghats to its tidal limits below Rajamundry (Andhra Pradesh).

The changes in the hydrobiological conditions in the river caused by the construction of anicuts may have influenced the migration of fish into the river. Chacko (1954) mentioned some changes that have taken place in the hydrobiological conditions of the river, the most important of which appears to be an increase in siltation and a reduction in the quantity of freshwater flowing downstream. The observation of Chacko and Dixitulu (1951) that in 1949 hilsa did not ascend the Godavari because of a reduction in floodwaters and silting of the river is significant in this respect. However, hilsa was found to be the prime contributor to the fishery during the monsoon season and early post-monsoon months, when the species contributes about 25%–30% of total fish landings. Godavari showed a drastic decline in hilsa catches. During 1941–1950, the average annual catch was 8250 t, declining to 5350 t during 1951–1960 and 26.99 t during 1961–1970. In the recent past, during 2010, the catch was recorded as 14.5 t.

3.2.2.5. Bhagirathi-Hooghly river system

Hilsa is the major component of the fishery in the Bhagirathi-Hooghly (also called Hooghly or, traditionally, Ganges) river system, accounting for 15%–20% of total fish landings. The annual catch of hilsa from the Bhagirathi-Hooghly river system has fluctuated greatly over the years (Figure 3). During the period preceding the construction of the Farakka Barrage (1957-1974), annual hilsa landings varied between 114 and 6573 t with an average of 1427.6 t. Increased yields were observed during the post-barrage period. The average annual harvest of hilsa was recorded as 2471 t from 1975–1976 to 1990–1991 and 6370 t from 1991–1992 to 1998–1999 (CIFRI annual reports). Hilsa landings in the Bhagirathi-Hooghly river system from 2000–2001 to 2010–2011 varied between 12,733 and 77,912 t. The observations on production trends for five decades indicate that every 10 years there is sudden increase in hilsa production, as is evident from Figure 3. Post-impoundment increase may in part be attributed to the higher freshwater discharges caused by water diversion at the Farakka Barrage through the Bhagirathi-Hooghly river system. Tremendous increase in fishing efforts from the 1990s onward, with the mechanization of fishing vessels exploiting hilsa stocks in the estuary mouth, have also contributed to the many-fold increase in hilsa landings. In general, 80%–90% of hilsa are captured during monsoon months (July–October). According to investigations carried out by the Central Inland Fisheries Research Institute (CIFRI) (Bhaumik 2010), the commercial hilsa fishery is based on a fish size of 300-480 mm in June-August, in the mid-range of 300-480 mm 320- 490 mm in September-November and in the lower

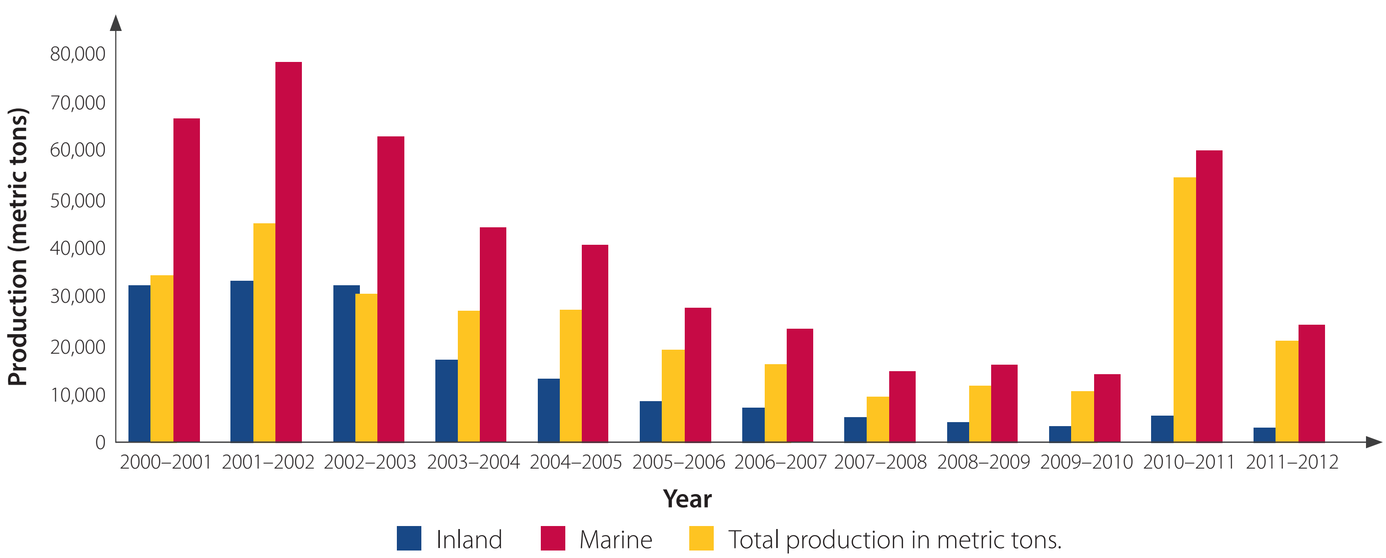

Figure 3. Production of hilsa in Bhagirathi-Hooghly river system.

range of 300-400 mm in January-March. The impact of the Farakka Barrage on hilsa fisheries is very evident upstream of the barrage, where in all the landing centers the contribution of hilsa to catches is almost negligible.

The state of West Bengal also imports on an average 5000 t of hilsa from the Padma River in Bangladesh to meet local demand.

3.3. Age and growth

The age and growth of hilsa in different stages was studied by Prashad et al. (1940), Jones and Menon (1951), Raj (1937), Dixitulu and Chacko (1962) and Pillay (1958). The growth of juvenile hilsa collected from the Hooghly estuary has been studied by De (1986 and 2001) and Bhaumik and Sharma (2012). The average growth of young hilsa after hatching was 28–32 mm at the end of 1 month, 48–63 mm after 2 months, 64–73 mm after 3 months, 74–83 mm after 4 months, 84–93 mm after 5 months and 94–102 mm after 6 months.

The age and growth of adult hilsa differed among water bodies. However, the rate of growth of fish can vary from one environment to another or in the same environment from year to year as a result of changes in food availability, density dependent growth factors, etc. (Table 1). Maximum fish size to date is 600 mm with females growing to a larger size than males. A fair degree of agreement can be seen between lengths and ages obtained by Pillay (1958), De (1986) and De and Datta (1990).

3.4. Maturity

The minimum size of hilsa at first maturity has been studied by many investigators (Table 2). By contrast, the stages of maturity of female gonads have been studied by only a few researchers: Pillay (1958), Mathur (1994), De (1980), Bhaumik (2011) and Bhaumik and Sharma (2012).

Table 2 shows that although females <300 mm rarely participate in spawning, a 208 mm female at the sixth stage of maturity has been recorded from the Hooghly River. The smallest mature females observed in the Hooghly estuary by De (1980 and 1986) were 341 mm long and weighed an average of 550 g, which is comparable to the hilsa of the Ganges, where the smallest mature females observed at Allahabad, Varanasi (Mathur 1964) and Godavari were 330, 310 and 370 mm, respectively (Pillay and Rao 1962). In almost all cases, the age resembles more than 2 or 3 years of maturity. In the Hooghly, higher values of the gonadosomatic index (GSI) of hilsa were observed from September to March with the peak in October (15.847), compared to a species average GSI of 10.2447 (De 1986 and 2001).

Hooghly estuary (Pillay 1958)		**Hooghly estuary (De 1986; De and Datta 1990)**		**Hooghly estuary (Bhaumik and Sharma 2012)**		**Northeast India, Hooghly estuary (Reuben et al. 1992)**		**Brahmaputra River (Choudhury et al. 1990)**	
Age group (yr)	Length (cm)	Age group (yr)	Length (cm)	Age group (yr)	Length (cm)	Age group (yr)	Length (cm)	Age group (yr)	Length (cm)
1.5	24.7–26.5	1	18.9	1	21.5	1	23.8	1	23
2.5	34.5–39.1	2	27.7	3	41	2	37.2	2	33
3.5	39.3–43.6	3	35.1	3+	44.8	3	45.6	3	41
		4	41.3			4	50.8	4	47

Godavari estuary (Pillay and Rao 1960)		**Chilka Lake (Jhingran and Natarajan 1969)**		**Chilka Lake (Ramkrishnaiah 1972)**	
Age group (yr)	Length (cm)	Age group (yr)	Length (cm)	Age group (yr)	Length (cm)
1	35.5	1	0.0–21.0	0	16.2
2	41.5	2	18.5–31.0	1	23.7
3	45.5	3	29.4–41.2	2	38.7
4	48.5	4	39.5–49.3		
5	50.5	5	48.8–56.0		
6	52.5	6	56.0–61.0		

Table 1. Age and growth of hilsa.

3.5. Fecundity

There is a wide range of variation in the fecundity of hilsa. In this study, the fecundity of 212 sampled fish (Table 4) varied with size. The amount of eggs in the mature ovaries of hilsa ranged from 44,002 (fish length 274 mm, weight 234.5 g) to 1,554,894 (fish length 403 mm, weight 855 g).

Minimum size at maturity		Water body	Investigator
Male (mm)	Female(mm)		
170	208	Hooghly-Bhagirathi	Bhaumik and Sharma (2012)
193	207	Ukai reservoir	Bhaumik et.al. (2012)
280	382	Godavari River	Chacko and Krishnamurthy (1950)
300	356	Godavari River	Chacko and Ganapati (1949)
216–254	267–305	Hooghly, Chilka and Mahanadi	Jones and Menon (1951)
160–170	190–200	Hooghly estuary	Pillay (1958)
----	266	Narmada River	Karamchandani (1961)
256	370	Godavari River	Pillay and Rao (1962)
----	341	Hooghly estuary	De (1980 and 1986)
200	350	Ganges River	Mathur (1964)
----	330	Ganges at Allahabad	Mathur (1964)
----	310	Ganges at Varanasi	Mathur (1964)
175–300	200–300	Chilka Lake	Jhingran and Natrajan (1966)
172	186	Chilka Lake	Ramakrishnaiah (1972)
360	420–430	Godavari River	Rajyalakshmi (1973)

Table 2. Size at first maturity attained by hilsa.

Sampling Station	Female						
	Length Range (mm)	Weight Range (g)	Maturity Stage (%)				
			III	IV	V	VI	VII
Farakka	245–440	120–1,130	27.42	1.59	15.03	22.96	32.79
Lalbagh	263–451	184–963	24.07	4.74	18.60	26.35	26.97
Nabadwip	244–437	159–912	33.58	6.12	16.66	14.40	30.03
Kalna	235–404	173–631	31.30	4.64	21.20	20.88	22.09
Tribeni	258–475	142–1,124	17.38	4.52	27.96	14.74	35.40
Hooghly Ghat	241–440	193.5–934	13.02	5.60	26.74	15.37	40.07
Baranagar	240–457	174–1,112	9.21	5.41	13.07	29.56	43.49
Godakhali	208–445	112–1,175.5	19.52	15.25	11.58	23.45	30.97
Nischintapur	250–378	105–604	27.45	16.45	7.97	12.96	36.05
Frasergunj	261–406	200–728	24.29	11.15	6.01	14.92	43.72

Table 3. Maturity profile of female hilsa (n = 457).

Total length (mm)	Percentage of sample	Weight (g)	Gonad weight (g)	Fecundity (nos.)
208–250	8.02	105–352	6.35–50	65,394–10,67,220
251–300	32.55	173–332	2.78–56.39	44,001–5,69,539
301–350	16.98	250–605	3.19–92.03	50,003–10,66,903
351–400	28.77	142–957	4.00–155.97	67,996–10,08,592
401–445	12.74	631–1,175.5	7.14–183.62	72,312–15,54,894
457–475	0.94	1,086–1,112	-136.00–149.27	13,99,984–14,28,663

Table. 4. Fecundity of hilsa (*T. ilisha*) (n = 212).

The numbers of ova increased with age while egg diameter, a measure of maternal provisioning, also increased with higher fecundity. While Pillay (1958) recorded fecundity in the range of 250,000–1,600,000 in fish measuring 253–481 mm in length from the Hooghly estuary, De (1986) found egg numbers ranging between 373,120 and 1,475,676 in fish of 334–522 mm TL. Swarup (1961) and Mathur (1964), while working on hilsa reproduction in the upper Ganges river system near Allahabad, recorded fecundity values as high as 289,000–1,168,622 in fish 315–506 mm long and 316,316–1,840,179 in fish 310–436 mm long. Bhaumik and Sharma (2012 recorded fecundity values as high as 2,949,750 from a large gravid female weighing 4.250 kg caught from the Tapti River. The fecundity of the species from various water bodies estimated by different researchers is presented in Table 5.

3.6. Migration and behavior

Hilsa normally inhabit the lower reaches of estuaries and the foreshore areas of the sea, characterized by the presence of subsurface dissolved oxygen, relatively low salinity levels, strong tidal action, high turbidity, heavy siltation and rich plankton growth (Pillay and Rosa 1963). It is well known that hilsa ascend rivers to spawn (Hora 1938; Pillay 1958; De 1986) and that spent fish as well as their progeny migrate downriver toward lower estuaries and coastal areas (Pillay 1958). Most hilsa stocks are anadromous, breeding much above tidal limits (Naidu 1939). Some stocks have also been found to remain permanently in freshwater stretches of rivers (Hora 1938; Hora and Nair 1940) while others spawn in tidal areas. There is no doubt that hilsa is a eurytolerant species that inhabits freshwater, estuarine and coastal waters in the Bay of Bengal.

Hilsa move on the surface in the foreshore region whereas in the river they move in deeper zones near the bottom. The species moves in shoals. The peak upstream migration of hilsa in most of the rivers in India generally coincides with the southwest monsoon season in July and August and continues up to October or November (Kulkarni 1951; Jones and Menon 1951; Pillay and Rosa 1963). In the Hooghly estuary, the period of migration is prolonged and extends through to winter (De 1986; De and Saigal 1989; De et al. 1994). Bhaumik et al. (2011) have observed migration up to February. The long-range migration of the species has also been reported from other large river systems of the country, namely the Brahmaputra (Pillay and Ghosh 1958; Pillay and Rosa 1963), Mahanadi (Pillay and Rosa 1963), Godavari (Chacko 1952), Krishna (Chacko 1952), Cauvery (Chacko 1952) and Narmada (Kulkarni 1954) as well as Chilka Lake (Jones and Sujansingani 1951). However, the migration of hilsa in these water bodies is now so greatly impeded by the construction of dams, weirs, anicuts and barrages (Jhingran 1991; Panickar 1954) that they are unable to reach their traditional breeding grounds.

In the Hooghly estuary, hilsa ascend only to spawn, and their progeny, generally after attaining 80–110 mm in size, start their downstream migration toward the coastal region, which commences in February and continues until June (De 1986; De and Saigal 1989; De and Sinha 1997; Bhaumik 2010). Young hilsa do not penetrate far into the sea, but move in shoals around estuarine and foreshore regions (Raj 1937). In the Brahmaputra River, the peak migratory season of the species is from May to July because of the earlier arrival of the monsoon.

Upstream migration is associated mainly with the state of sexual maturity as well as the volume of freshwater discharge from the estuary during and after the monsoon season. However, other factors such as rainfall,

Water body	Fish size	Fecundity (numbers)	Author
Hooghly estuary	208–475 mm	44,002–1,554,894	Bhaumik and Sharma (2012)
Ukai reservoir	207–420mm	30,097–92,070	Bhaumik et al. (2012)
Tapti River	614 mm	2,949,750	Bhaumik et al. (2012)
Hooghly estuary	253–481 mm	250,000–1,600,000	Pillay (1958)
Hooghly estuary	343–522 mm	373,120–1,475,676	De (1986)
Ganges and Yamuna rivers (near Allahabad)	315–506 mm	289,000–1,168,622	Swarup (1961)
Ganges River (near Allahabad and Varanasi)	310–436 mm	316,316–1,840,179	Mathur (1964)
Chilka Lake	353–515 mm	390,379–1,120,304	Ramkrishnaiah (1972)
Godavari estuary	401–548 mm	400,000–1,300,000	Pillay and Rao (1962)
Narmada River	452 mm	1,864,000	Kulkarni (1950)

Table 5. Fecundity of hilsa from various Indian water bodies.

current velocity, temperature, low salinity, turbidity, primary productivity and availability of planktonic food are likely contributing factors as well. Based on the study of extensive samples of fish for length frequency as well as sex ratio and the maturity condition of the migrant fish, two well-marked hilsa migration periods into the Hooghly have been identified: one during the monsoon season (May–October) and the other during the winter (January–February). In riverine areas, groups of large fish are abundant between May and October, declining to a minimum in December. The catch rates for the Hooghly reveal two peaks: one in May and the other in August. Fish of intermediate size are available throughout the year. The spring spawners that enter the river for spawning during January–March return to the sea during July–August, when they are caught in good numbers. The monsoon spawners that enter the river during September–October return to the sea after spawning, the spent fishes being heavily exploited during January–March. Similarly, the offspring of spring spawners journey downriver to the sea during November–January, while the offspring of monsoon spawners return to the sea during July–September. The return to the sea of the brood of spring and monsoon spawning hilsa is not as precise as the riverward migrations. Recruitment of juveniles to the marine fishery is observed for four to five months each year (July–January), peaking in October.

In Chilka Lake, the small- and medium-sized fish group, whose sizes range between 240 and 400 mm, support the fishery (Thingson and Natarajan 1969; Ramakrishnaiah 1972). The upstream migration of winter spawners and the downstream migration of summer spawners as spent fish intermingle at various locations and are exploited by the use of fishing gear of different mesh sizes.

3.7. Spawning

Various investigations of the reproductive biology of hilsa indicate that spawning is seasonal. In almost all major river systems and lagoons, namely the Hooghly, Ganges, Chilka, Tapti, Indus, Padma and Meghna, the hilsa spawning season is August–October. Rao and Pathak (1972) observed a peak in spawning activity in the Brahmaputra River during May–July. It has also been noted that mature hilsa migrate to Iraqi rivers to spawn during March–July.

Studies of the early growth rates of hilsa in the Hooghly estuary by De (1986), De and Saigal (1989), De et al. (1994), Bhaumik (2010) and Bhaumik and Sharma (2012) indicate a prolonged spawning season of the species during August–March, peaking in October–November and February–March. Note, however, that the various studies indicate a wide variation in the spawning seasons of hilsa in the same and different water bodies.

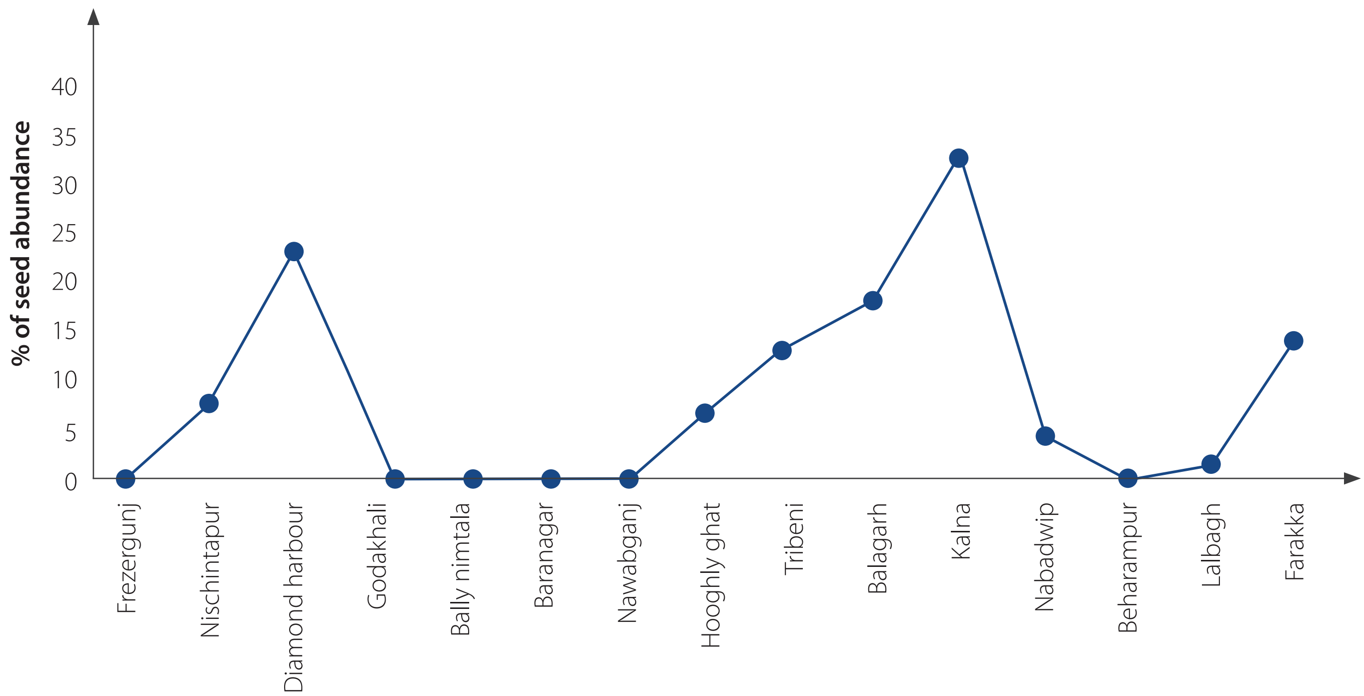

Figure 4. Seed abundance in the sampling sites.

Data on fry (26–30 mm) abundance has been used to determine spawning areas (Figure 4). During July–October, two distinct areas between Nishchintapur-Godakhali and Hooghly Ghat-Kalna were determined as likely breeding zones.

3.8. Fish catch under experimental fishing

Data on fish length, weight and sex from monthly experimental fishings at sample stations (total sample size = 1528 hilsa) is shown in Tables 6 and 7. Although when and how the fish were sampled are not mentioned, Table 6 reveals that as many as 43.4% of hilsa belong to the size group of 250–300 mm TL followed by 300–350 mm TL (22.5%). The smallest proportion (0.3%) were large hilsa, 450–500 mm. More males 250–300 mm in length were found during October, which corresponds with the peak breeding season, whereas females of this size group were more apparent in February.

The data obtained during the study (Table 7) indicates that 37.2% of hilsa captured weighed 150–250 g, 21.6% weighed 250–350 g, 13.2% weighed 350–450 g, 9.3% weighed 50–150 g, 6.2% weighed 450–550 g, 5.1% weighed 550–650 g, 3.9% weighed 650–750 g and 2.2% weighed 750–850 g. Only 0.07% weighed 1150–1250 g. The above observations show that 87.44% of the hilsa catch are <550 g, which paints an alarming situation of overexploitation.

3.9. Migration routes and breeding zones

Stretches between Nishchintpur (21°59.366'N, 88°13.026'E) and Diamond Harbour (22°3.242'N, 88°15.753'E) at downstream Hooghly Ghat (22°54.792'N, 88°24.098'E) and Kalna (23°10.542'N, 88°20.364'E) in the freshwater tidal zone and Lalbagh (24°5.243'N, 88°14.550'E) to Farakka (24°47.603'N, 87°54.565'E) in Bhagirathi River have been identified as likely breeding zones for hilsa (Figure 5). In 2011, monsoon breeding of hilsa was first observed around Kalna in July, then in the area of Lalbagh to Farakka during September and October. The breeding activities shifted downstream below Diamond Harbour following decreased river discharge and resultant low depths in the upper reaches of the river during September and October. Post-monsoon breeding, which varied in timing and intensity, occurred in all the breeding zones.

Length class (mm)		150–200	200–250	250–300	300–350	350–400	400–450	450–500
March 2011	Male	2	20	36	7	2		
	Female			32	9	11	4	
April 2011	Male	1	9	34	19	5		
	Female			4	16	6	10	1
May 2011	Male	2	9	7	39	37	2	
	Female		1	2	9	8	6	
June 2011	Male		6	18	57	42	3	
	Female		1	4	3	6	1	
July 2011	Male		3	13	38	22	2	
	Female			7	3	12	6	1
August 2011	Male	1	20	38	35	11		
	Female			8	3	7	7	
September 2011	Male		21	38	18	9	1	
	Female		3	20	5	17	5	1
October 2011	Male	1	32	70	15	6		
	Female		9	20	12	9	4	
November 2011	Male		10	23	13	10	5	
	Female			10	1	1		
December 2011	Male		3	47	4	5		
	Female			7	2		1	
January 2012	Male		16	59	2			
	Female		8	54	9	14	10	1
February 2012	Male		3	38	4	1	1	
	Female		2	74	17	18	11	
Total		7	176	663	340	259	79	4

Table 6. Lengths of hilsa by sex harvested at sample stations on the Hooghly River (n=1528).

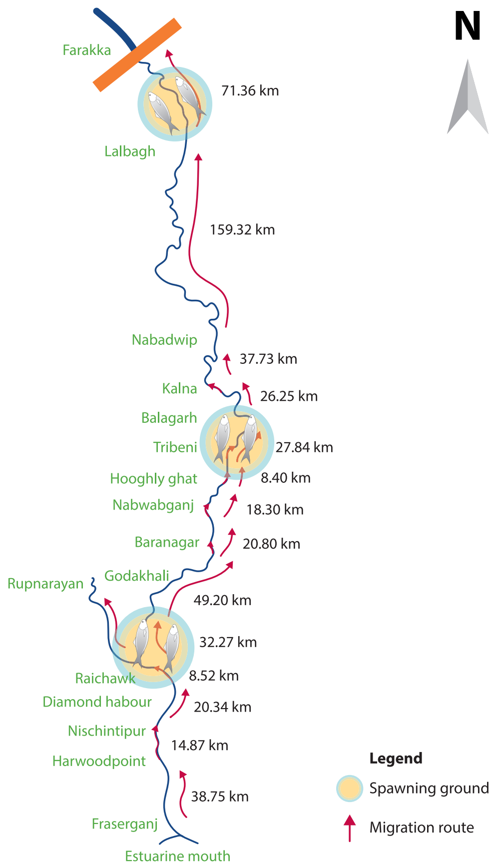

Figure 5. Migration route and breeding grounds of hilsa.

Weight class (g)		50–150	150–250	250–350	350–450	450–550	550–650	650–750	750–850	850–950	950–1,050	1,050–1,150	1,150–1,250
March 2011	Male	23	34	4	3	1	1	1					
	Female	2	18	14	3	6		4	5	2	1	1	
April 2011	Male	13	29	17	4	4	1						
	Female		4	9	7	2	1	10	2	1	1		
May 2011	Male	11	11	24	31	15	3	1					
	Female		2	8	4	3	4	3	1	1			
June 2011	Male	5	17	35	53	12	3	1					
	Female		2	4	5	3	1						
July 2011	Male	3	9	22	17	7	15	5					
	Female	1	2	3	4	4	4	4	1	1	3	2	
August 2011	Male	12	28	41	17	3	2	2					
	Female		5	6		2	2	3	5	2			
September 2011	Male	9	40	19	9	8	1		1				
	Female		12	11	2	2	11	4	4	4		1	
October 2011	Male	19	64	26	12	3	1						
	Female	1	10	20	5	7	3	4	1	2			1
November 2011	Male	5	23	7	11	3	7	2	3				
	Female		4	6		1	1						
December 2011	Male	1	41	11	4	2							
	Female		4	4	1			1					
January 2012	Male	11	62	3	1								
	Female	8	47	14	3	1	7	9	5	1	1		
February 2012	Male	9	32	2	2			1					
	Female	5	68	20	3	6	10	5	5				
Total		138	568	330	201	95	78	60	33	14	6	4	1

Table 7. Weights of hilsa by sex harvested at sample stations on the Hooghly River (n=1528).

The combined catch of fry and advanced juveniles showed two peaks in 2011: April and July (Figure 6). The catch of the advanced juveniles was more in the downstream area, between Godakhali and Nishchintapur. The percentage of fry apparent in the total catch was greater in the upper freshwater reaches.

3.10. Method of hilsa exploitation in India

3.10.1. Crafts and gear

The types of gear used in the exploitation of hilsa in inland and coastal waters of the Hooghly-Bhagirathi system vary in type and size (Swarup 1958; Jones 1959; Saxena 1964; Saxena and Chandra 1968; De 1980; Mitra et al. 1987). The most important types of gear are the gill net, boat seine and clasp or purse net. Gill and boat seine nets are commonly used in coastal areas, estuaries and the middle and lower stretches of the Ganges, while clasp nets (*sangla jal*) are mostly operated in upper stretches of the estuary and the Ganges river system. Moreover, Bandal fishing (a trap) was very common in the Ganges during peak fishing season. There are two types of gill nets: the drift gill net (*chandi jal*) and the set gill net (*nangar jal*). *Chandi jal* is one of the most important types of gear used in the exploitation of hilsa. It consists of several pieces of netting, each piece being 8–20 m long and 5–13 m high, depending on the characteristics of the fishing area. Generally, large drift gill nets are operated in the lower marine zone of the Hooghly estuary and in adjacent coastal areas. Mesh size generally varies from 60 to 100 mm, with consequent impacts on selectivity and catch size. Reuben et al. (1992) reported that smaller-sized *chandi jal* (drift gill nets made of nylon monofilament), with mesh sizes of 50–80 mm are also used in the coastal waters of the Bay of Bengal. In the Hooghly estuarine system alone, it has been estimated that there are in excess of 200,000 drift gill nets in operation (Mitra et al. 1987; De 1991). Presently, more than 5957 small mechanized and 1533 nonmechanized boats (DoF and WB 2012), most of which are equipped with drift gill nets composed of 100–500 separate pieces of netting (total length 0.5–2 km) are actively engaged in the coastal areas of West Bengal. Fishing activities are mainly confined to the marine zone of the estuary within 30–40 km of the shore. Inshore areas <50 m deep, in particular, are intensively exploited.

Table 8 depicts the number of licensed boats operating in the inland and coastal sectors, where hilsa constitutes the main catch. The mechanized boats vary between 9.5 (31 ft) and 11 m (36 ft) in overall length (OAL) and are fitted with 15 hp engines, while boats of 16–18 m (51–58 ft) OAL tend to be fitted with larger 105 hp engines. In estuarine and freshwater zones, only small nonmechanized boats are in operation.

3.11. Socioeconomic conditions of the fishers involved in hilsa fishing

A large number of fishers are engaged in exploitation of hilsa in the marine, estuarine and freshwater zones of the Hooghly-Bhagirathi river system. Approximately 21,000 fishers have been operating between Frazergunj and Raidighi (upper stretch), whereas some 5600 fishers have been operating in the freshwater zone, between Dakhineshwar and Farakka.

In the upper stretch, fishers exploit hilsa in groups by hiring mechanized boats, locally referred to as trawlers. As many as 70% of these mechanized boats are 17–18 m (57–58 ft) OAL and fitted with four to six cylinder engines (105 hp), while 30% are 9.5–11 m (31–36 ft) OAL, fitted with 15 hp one or two cylinder engines. Mechanized boats generally fish in the marine zone of the estuary within 30 km of the estuary mouth during monsoon months, but venture up to 60 km out to sea during the winter season. Each boat accommodates 8–11 fishers, who share the total catch among them. They pay 30% of sale proceeds to the boat owner, while 30% is spent on

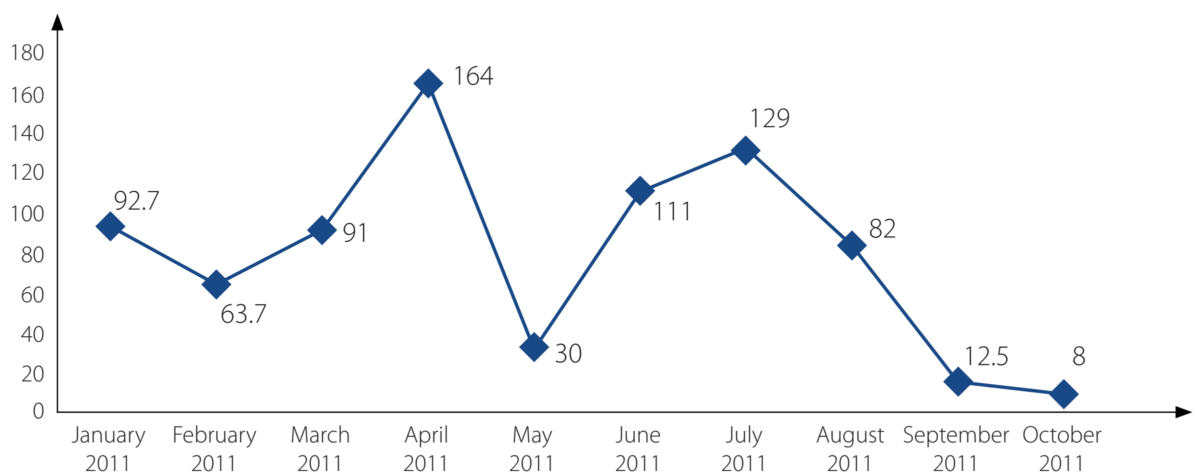

Figure 6. Catch per unit of effort of juvenile hilsa.

fuel as well as vessel and gear wear and tear and the costs of onboard food. The remaining 40% is divided among the co-fishers, the boat and engine drivers who are allocated 2% more than their fellow crew members. Gill nets of various sizes are primarily used to exploit hilsa. The income of individual fishers typically varies between INR 5000–8000 (USD 80–100) per month. Larger mechanized boats fish for 2–5 days whereas smaller ones go fishing daily. The vessels that go to deeper areas for 2–5 days have catches that average 200–400 kg per day during July–September, 100–200 kg during October–December and 50–100 kg during January–March, whereas boats operating daily have daily catches that average 50–70 kg during July–September, 30–40 kg during October–December and 10–20 kg during January–April.

In the lower stretch, fishers operate small boats, accommodating just one person or two people, and catch hilsa throughout the year. They mostly use small gill nets of various sizes and also sometimes a clasp trap (*shangla jal*). They catch on an average 1–5 kg/boat/day throughout the year. Income per person per month varies between INR 3000–6000 (USD 48–96).

3.12. Artificial fecundation of hilsa

During the late 1970s, Malhotra et al. (1969 and 1970) successfully bred hilsa by "wet stripping" in the Ganges River, some 50 km downstream of Allahabad. Panicker et al. (1985) also achieved success in propagating the fish at the VSR in Gujarat. De (1986), De and Sinha (1997) and Sen et al. (1990) have also successfully bred the marine stock of hilsa, collected from the lower stretch of the Ganges, downstream of the Farakka Barrage, by the wet stripping method. Hatchlings were reared for considerable periods in captivity.

3.13. Hilsa culture in confined water

It is evident from the culture experiments so far conducted in India (Table 9) that heavy mortality of larvae or fry has occurred under all types of rearing. The causes of mortality have been mainly attributed

Year	Mechanized			Nonmechanized		
	Purba Medinipur	South 24 Parganas	West Bengal	Purba Medinipur	South 24 Parganas	West Bengal
2002–2003	174	1,015	1,189	2	240	242
2003–2004	395	1,908	2,303	9	295	304
2004–2005	843	1,761	2,604	72	609	681
2005–2006	754	1,279	2,033	146	341	487
2006–2007	830	1,490	2,320	43	222	265
2007–2008	989	2,241	3,230	Not available	Not available	Not available
2008–2009	1,221	1,759	2,980	670	552	1,222
2009–2010	1,150	2,382	3,532	100	1,136	1,236
2010–2011	1,656	3,459	5,115	131	913	1,044
2011–2012	1,703	4,254	5,957	67	1,466	1,533

Table 8. Licensed fishing boats in operation in inland and coastal waters of the Hooghly-Bhagirathi system.

Author	Initial length/weight at time of stocking	Culture system	After rearing a period of	Growth attained
Pillay (1958)	50–80 mm 120–180 mm	Cemented cistern	9 months	Mean increment in length was 40 mm during the period
Malhotra et al. (1969, 1970, 1979)	2.5–6.0 mm	Freshwater pond	69 days 1 year 2 years 4 months	53.0 mm 155.0 mm 320.5 mm 345.0 mm
Bhanot and De (1984)	25–60 mm	Freshwater pond	1 year 2 years 2 years, 8 months	180 mm/125 g 310 mm/300 g 350 mm/ 425 g
Panicker et al. (1985)	20–25 mm	Vallabsagar reservoir	1 year, 5 months 1 year, 7 months	500 g 600 g
De and Sinha (1987)	3.5–4.5 mm	Cemented cistern	47 days	40 mm
Sen et al. (1990)	3.6–4.1 mm	Freshwater pond	4 months	80 mm

Table 9. Growth of hilsa in culture in India.

to poor water conditions in ponds and an absence of ideal food. The growth of hilsa from the various rearing experiments may not be much different from the natural growth rates estimated by Sujansingani (1957) and De and Dutta (1990) (Table 9).

3.13.1. System-wise analyses

The Bay of Bengal stock of hilsa is shared by Bangladesh, India and Myanmar, and the abundance of the species in all three countries is greatly influenced by the exploitation intensity and the available effective fishing area. In India, hilsa is most abundant in the Ganges river system but is also present in rivers such as the Mahanadi and Godavari on the east coast and Tapti and Narmada on the west coast. Hilsa also occur in Chilka Lake (east coast) during a certain period of the year. Overall production of the species constitutes approximately 2%–3% of the marine fisheries catch and 5%–6% of the inland capture fisheries catch of the country.

The hilsa fishery fluctuates highly in Indian rivers and is dependent upon various biological, climatological and hydrological factors of natural and anthropogenic origin. However, as is apparent from time series analyses of the annual production figures (Figures 6–10), please accept these since I could not do every river system,

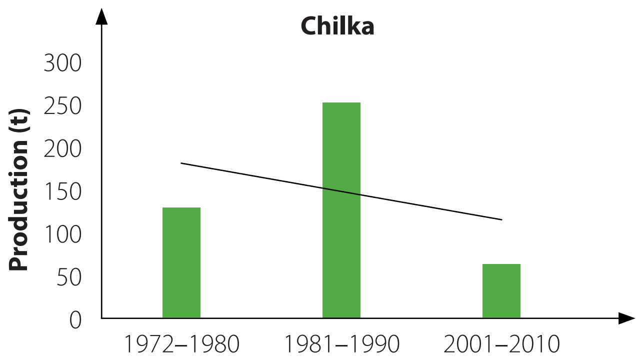

Figure 6. Decadal trend of hilsa in Chilka production.

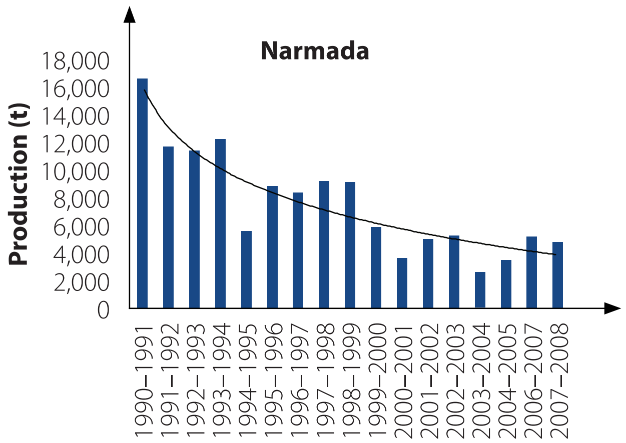

Figure 7. Decadal trend of hilsa in Narmada production.

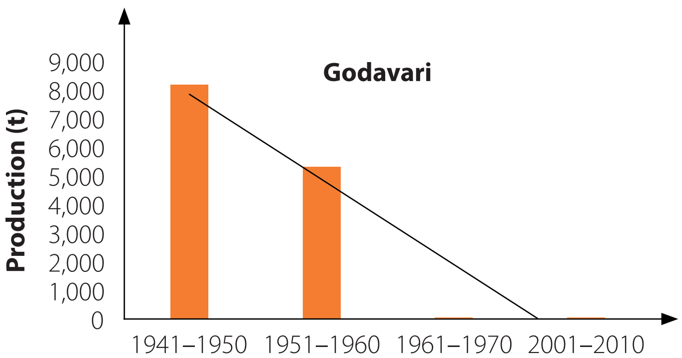

Figure 8. Decadal trend of hilsa production in Godavari.

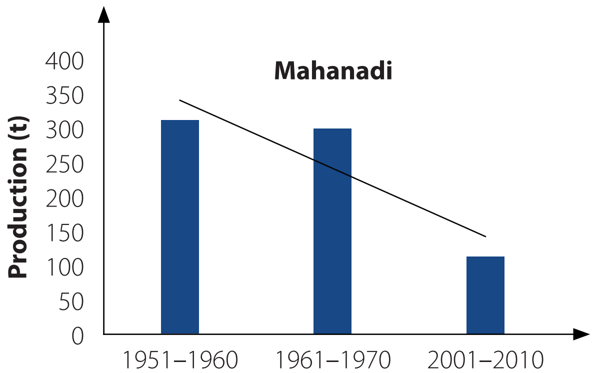

Figure 9. Decadal trend of hilsa production in Mahanadi.

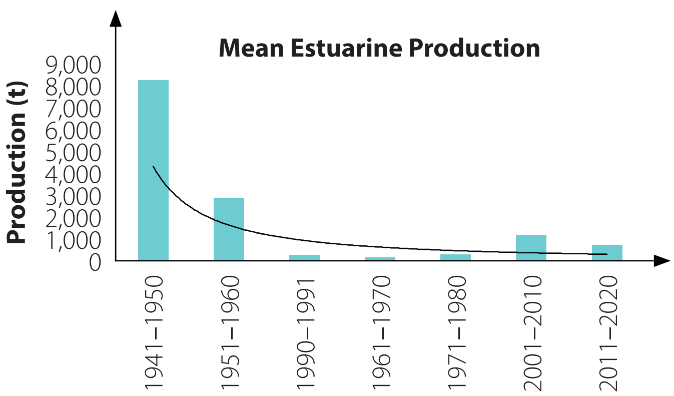

Figure 10. Overall production trend of hilsa in the estuaries of India.

except the Hooghly-Bhagirathi tributary of the Ganges river system, is characterized by a declining trend in hilsa catches.

In river-estuaries such as the Mahanadi, Godavari, Narmada and Tapti, the decrease in hilsa catches since the 1960s has been associated with the development of multipurpose river valley projects, with the resultant water holding and storage facilities profoundly affecting the river hydroecology. Both the resident fish species and the anadromous hilsa have suffered loss of breeding and nursery grounds. It goes almost without saying that the migration routes to freshwater habitats have been seriously impacted.

The Tapti is virtually devoid of commercial hilsa fisheries at the present time. The installation of the Vallabh Sagar Dam at Ukai and the construction of downstream causeways and weirs have changed the hydrological and hydrographical conditions of the river course to such an extent that they almost completely halt the upstream migration of hilsa beyond the estuary.

In Chilka Lake on the coast of the Bay of Bengal, hilsa, which were caught in large quantities during the early 1960s, had become almost nonexistent by the year 2000. Hydroecological barriers on the passage that connected the lake to the Daya impeded freshwater migration and thus production of the species in the system. Efforts such as the opening of a new lake mouth and dredging of the channel from the estuary mouth through the northern sector have partially reinstated the lagoon hilsa fishery in recent years.

The hilsa fisheries of the VSR on the Tapti River have developed an additional source of production for the species. Hilsa fry and fingerlings released periodically by the CIFRI and also the Gujarat State Fisheries Department during the 1970s and 1980s acclimated to conditions in the reservoir. Annual production of adult hilsa constitutes 2%–3% of the total reservoir fish yield. Production of juveniles are estimated to account for nearly 70% of "miscellaneous fish catches," resulting in some 6%–7% of the reservoir yield from hilsa alone (Figures 11–13).

Production of hilsa in the reservoir is mainly linked to hydrographical conditions. Reservoir levels and inflow of flood pulses influence breeding and recruitment success. The rate and pattern of precipitation in the catchment areas in Madhya Pradesh and Gujarat thus have an important influence on hilsa fisheries in the reservoir. The species breeds in two peaks: between mid-June and mid-August and again during November–January. While the maximum recorded size of reservoir hilsa is about 500 g, the mean size of adults fluctuates between 200 and 300 g.

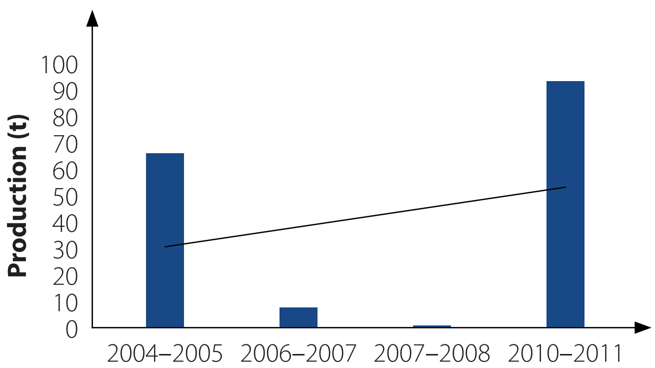

Figure 11. Adult hilsa production trend in VSR.

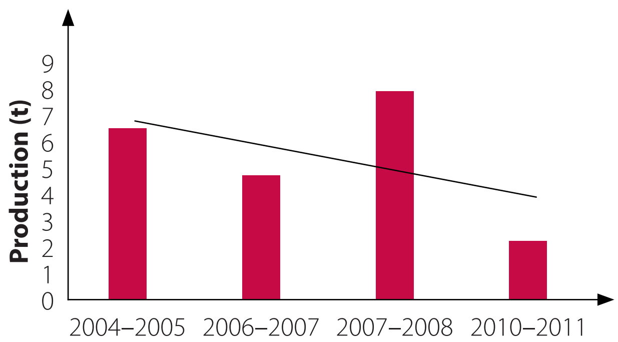

Figure 12. Juvenile hilsa production trend in VSR.

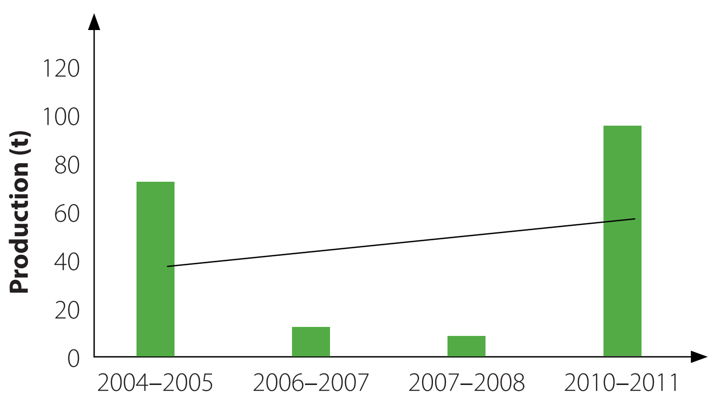

Figure 13. Total hilsa production trend in VSR.

The Hooghly, the only exception among the Indian estuaries, has been rejuvenated by the Ganges River discharge through the Farakka Barrage since the mid-1970s. The barrage plays a dual role, obstructing the migration passage of Hooghly hilsa to the upper Ganges while simultaneously expanding the habitat space for breeding and rearing of juveniles in the downstream Hooghly-Bhagirathi stretch of the Ganges river system. As a result of changes in habitat and the modernization of fishing methods, followed by intensified fishing, hilsa catches have seen as much as a 10-fold increase over the past five decades. However, in the recent past hilsa catches have been fluctuating, with an overall declining trend (Figure 16).

3.14. Issues, threats and remedies

3.14.1. Issues and threats

Hilsa is a great concern to the people of West Bengal and also for the state. Similarly, several other states where hilsa is popular are experiencing increased demand for the fish, while the fishers involved in hilsa fisheries are facing livelihood issues resulting from poor and unsustainable catches.

3.14.1.1. Decline in fisheries

Hilsa production is declining and failing to meet the increasing domestic demand of states such as West Bengal and Maharastra and the North-Eastern region. In recent years, about 5000 t of hilsa have been imported from Bangladesh each year by the Government of West Bengal to meet consumer demand, especially during festive occasions. Inadequate supplies have elevated the price of the fish to as high as INR 1000–1500 (USD 16–24) per kg. The Gujarat Department of Fisheries reports that the supplies of hilsa to the cities of Maharastra have decreased considerably.

The size of hilsa is also a matter of great concern since it has decreased markedly in the most productive river systems, such as the Hooghly-Bhagirathi stretch of the Ganges. Within three decades, the mean size has declined 10–15 mm in TL and 150–200 g in weight. Furthermore, huge quantities of juveniles are marketed in the state of West Bengal as miscellaneous fish (Mitra et al. 1998; Nath et al. 2004). The biomass of hilsa juveniles caught in the VSR in Ukai sometimes exceeds that of table-size fish in Gujarat (Gujrat Department of Fisheries, personal communication, 2012).

3.14.1.2. Habitat degradation and its impact

Breeding and rearing habitats of hilsa in most of the river-estuarine systems are threatened by rapid degradation caused by the commissioning of river valley projects. The geomorphological changes are associated with the construction of dams, barrages and anicuts, and they obstruct the migration of hilsa, resulting in sharp declines in fishery yields. Barrages and dams also impact the water flow requirement for spawning and migration. As reported earlier, hilsa used to migrate as far as Delhi through the Ganges River and have also been recorded from Agra and Kanpur. After the commissioning of the Farakka Barrage across the Ganges in 1975, hilsa migration upstream of the barrage became almost nonexistent since nothing was landed at most of the fish landing centers. The CIFRI has estimated a 92% reduction in the hilsa catch upstream of the Farakka Barrage. Even at Allahabad, where hilsa used to form a significant share of the total fish catch, it now forms only a small percentage.

Low river discharges reduce dilution and increase the retention period of inflowing contaminants, which, besides hindering migration, destroy the delicate eggs and larvae of adult hilsa. Various industries flank the Tapti and Narmada rivers on the west coast, and the water is contaminated with different toxicants. The biota, including hilsa, is exposed to such hazards.

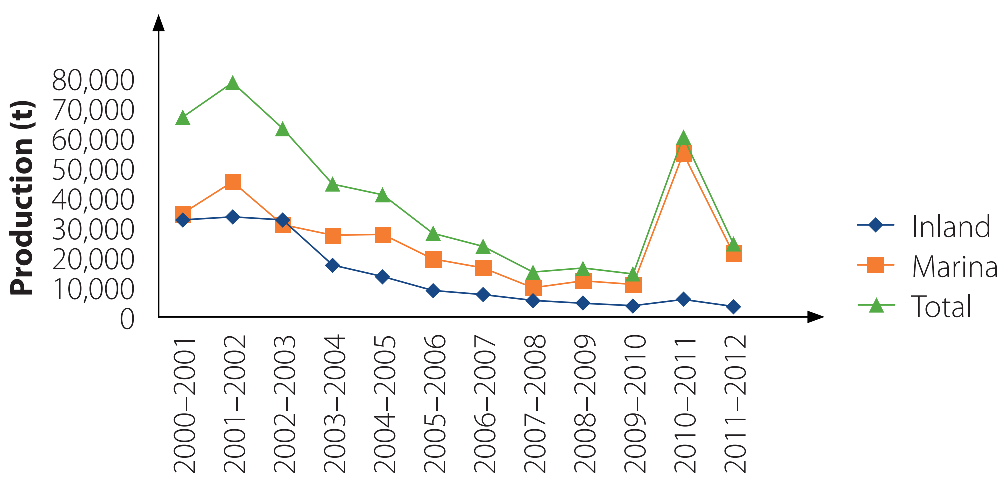

Figure 14. Please accept it Hilsa catch in Hooghly-Bhagirathi system.

3.14.1.3. Siltation in estuary mouth

The mouth of Hooghly estuary is gradually affected by siltation, resulting in the serious hindrance of hilsa migration into the estuarine system.

3.14.1.4. Irrational fishing pressure

Fishing pressure on hilsa in the Hooghly-Bhagirathi system has multiplied significantly as the number of mechanized fishing boats and sophisticated gill nets has increased since the 1980s (Mitra et al. 1998). The intensity of exploitation of juveniles by bag nets has also escalated without any control on mesh size, leaving no space for free upstream movement of hilsa at the estuarine mouth where such gear is used in the hundreds across the entire width of the river. In the VSR, juvenile hilsa are caught en masse by drag nets (*maha jal*) and dried for export to the northeast states of the country.

3.14.1.5. Overfishing

Fish catch trends in the Hooghly-Bhagirathi river system indicate a significant increase during the post-Farakka Barrage period, primarily from the many-fold increases in hilsa catches. Between 1998–1999 and 2002–2003, the average per annum catch of hilsa was 10,382.9 t, an impressive increase of 63.3% from the previous five years (6279.6 t). Between the 1960s and the past decade, however, the mean TL of hilsa declined from 356 to 325 mm or even less, which is a strong indication of overfishing.

3.14.2. Remedies

Hilsa has a wide transboundary distribution in the region of the Bay of Bengal and the Arabian Sea and thus warrants joint efforts from all stakeholders toward implementing conservation measures of its natural stock and responsible fishing of the resource.

3.14.2.1. Conservation

For conservation of natural stock, proper assessment of resources, including genetic stock structure, migration and population dynamics, warrants attention. The hilsa stocks on the west coast are inadequately known, and there is considerable scope for development of fisheries in this region. In the VSR, a nonmigratory population of the species is becoming established without any human intervention.
The hilsa fisheries in the reservoir have fluctuated enormously because of factors such as erratic reservoir hydrography, destructive killing of juveniles and heavy predation by large carnivores, such as freshwater shark, *Wallago attu*.

3.14.2.2. Fishing management

The open nature of hilsa fisheries in India is an impediment to the implementation of appropriate management measures. Capturing hilsa at the right size, time and location is essential, and the information to support such decisions needs to be shared with stakeholders. The CIFRI has investigated hilsa in the Hooghly-Bhagirathi system and has made available information that is essential to its proper management (Bhaumik and Sharma 2012). The importance of using gill nets with mesh sizes >100 mm and appropriate lengths has been shown in the Gujarat coast to maintain the size of hilsa caught above 1 kg. Similar approaches should be made for other hilsa resources, especially in the Hooghly-Bhagirathi system where the mean fish size is declining particularly rapidly.

3.14.2.3. Fish size

The size of marketable fish has to be logically determined and accommodate the concern of stakeholders. In the state of West Bengal fish >500 g are now the established target for commercial fishing. The exclusion of broodfish <500 g, when the first maturity stage usually occurs, would allow the stock to breed and contribute to population growth. It is estimated, for example, that for every t of 300–400 g females saved in this way some 250–300 t of >500 g adults would occur in catches after 2–3 years.

3.14.2.4. Juvenile fishing

This study reveals that hilsa have a prolonged breeding season, as evidenced by the occurrence of hilsa seed from August to May. This suggests that spawning is not strictly simultaneous for all individual hilsa migrating upstream to breed. Small juveniles are often caught in small-meshed bags and scoop nets during their migration toward the sea, especially November–May and sometimes up to July.

The estimated annual catch of these juveniles fluctuated between 41.1 and 151 t (average 85 t) during 1998–2010. Fish size ranged between 62 and 155 mm in TL and 2 to 28 g in weight. It has been estimated that a 50% reduction in juvenile fishing mortality has the potential to increase adult production by about 10%. Another estimate reports that if even 1% of juvenile hilsa could be saved, production of hilsa could be increased by 4000 t/year. Killing hilsa juveniles is prevalent in all systems. Bag nets account for the majority of the juvenile catch in river estuaries, while in the VSR the bulk are caught in drag nets. Restricting such nets seasonally and regionally would help boost the adult fishery appreciably.

3.14.2.5. Spawning season

In India, hilsa breed during the monsoon and post-monsoon season. They move in shoals toward breeding grounds using the lunar phases as cues. Regulating fishing for 3–4 days prior to and after the full moon and new moon phases from August to October and January to March is needed to protect the broodfish and allow them to breed freely. In the VSR, the breeding time is earlier than in the estuaries, where similar restrictions are needed for mid-April–mid-July and November–January.

3.14.2.6. Pollution

The largely uncontrolled discharge of industrial and domestic effluents in most river systems inhibits upstream migration and must be tackled.

3.15. Suggested interventions toward conservation of the hilsa fishery

The major breeding migration of hilsa begins in July and can extend until as late as February. As per a circular from the India government, an official fishing ban is also in force in the marine fisheries sector from 15 April to 15 June, but does not coincide with the hilsa breeding migration.

There is a need to enforce a legal mesh size of 100 mm, especially at estuary mouths, to control the exploitation of hilsa <500 g to allow them to breed at least once.

- There should be a strict ban on the capture of juveniles to conserve the fishery. Vigilance is required by law enforcement authorities to minimize the destruction of hilsa juveniles. As most of them begin their downstream migration in March–May after reaching 80–150 mm in size, a complete ban on the use of nonselective gear, namely bag or scoop nets, during these 3 months would allow the juveniles to migrate to the sea and maintain stock recruitment.
- Hilsa congregate near obstructions (barrage, anicuts, dams, etc.) during migration. Fishing should be prohibited in the vicinity of such obstructions.
- Breeding zones should be declared as sanctuaries during the breeding season when adequate compensation should be arranged for designated hilsa fishers.
- Hilsa fishers should be trained and participate in conservation activities to ensure the success of conservation programs.
- Improvements must be made to aquatic habitats, including perhaps more dredging of estuary mouths, thereby encouraging more spawners to migrate upstream.
- There should be a ban on trawling in the marine zones of the estuaries about 30 km from mouth of the estuary.
- Surveillance by the Territorial Coastal Guard is essential to stop the operation of foreign vessels in the Indian fishing areas.

Most destructive gear


Bag net in all the zones


Shooting net in saline zone


Veti/Vessel jal in FW zone


Small mesh gill net in all zones


Ber jal (Siene net) in FW zone


Charpata jal in all the zones

Figure 15. Major nonselective gear responsible for hilsa juvenile destruction in the Hooghly estuary.

3.16. Conclusions

There is an urgent need to promote the conservation of hilsa in view of the national interest in sustaining the prized fishery in the country. Intensive fishing in all water bodies must be controlled without further delay. Exploitation should not exceed Maximum Sustainable Yield (MSY) levels if a sustainable fishery is to be built in the country. The killing of juveniles and hilsa breeders must be prohibited and strictly enforced and public awareness programs implemented. To maintain sustainable yields and also increase production, regulation of selective fishing through changes to gear mesh sizes should be enforced. This will ensure that hilsa reach a length of <340 mm and a weight of <500 g and have a chance to escape and breed. To achieve this, the minimum mesh size of gill nets should be 100 mm. Therefore, strict conservation measures are warranted for improvement of hilsa fisheries in the river-estuarine systems of India.

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Illegal fishing of hilsa juveniles *(jatka)* in the Kirtonkhola River.

4. Hilsa fry and fingerlings for aquaculture

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Abstract
Hilsa production in Bangladesh rivers and territorial marine habitats of the Bay of Bengal has gradually declined since 2000. This has created interest in its potential for aquaculture in ponds or cages. In spite of interest among fish culturists and entrepreneurs as well as government efforts, hilsa culture has not yet been successful in either Bangladesh or India. The main challenge has been the sustained availability of hilsa fry and fingerlings at a reasonable cost and effort. Through an in-depth literature review, it was revealed that the Fisheries Research Institute of Bangladesh and Central Inland Fisheries Research Institute of India have made several attempts in breeding and culture of hilsa. However, only partial success has been achieved in breeding, while there has been no success in producing enough juveniles for aquaculture. Two major spawning seasons, September–October (peak in October) and January–March, were established based on the Gonado Somatic Index (GSI) values for hilsa and the presence of spent fish. Hilsa juveniles (*jatka* caught in *jagat ber jal*) could be kept alive in water for several hours by making an artificial pool on a pickup truck when transporting fry for nursery rearing. After the success of induced breeding of Chinese, American and Malaysian shad of closely related species, induced breeding of hilsa shad was tried in Bangladesh and India. Although induced breeding under hatchery conditions has been successful, its proper care at different embryonic stages remains a mystery. Efforts on onboard breeding and transporting fertilized eggs to hatcheries for fry production might be worth trying.

4.1. Introduction

Two species of hilsa, *T. ilisha* and *T. toil*, belong to the genus *Tenualosa* (they had formerly been assigned to the genus *Hilsa*), and one species, *Hilsa kelee/ kanagurta*, belongs to the genus *Hilsa*. All three species under two genera occur in Bangladesh waters. *Tenualosa ilisha* contributes more than 99% to the total fisheries production of hilsa. *T. ilisha* is born in freshwater, but brought up in both freshwater and marine water, while *T. toli* and *H. kelee* are truly marine. *T. toli* is a protandrous hermaphrodite (Blabber et al. 1996 and 2000). Earlier, considerable quantities of *T. toli* had been caught (about 6% of total landings at Cox's Bazar) in Bangladesh (Hossain et al. 1987). This species is now on the verge of biological extinction and needs special conservation efforts if it is to survive and thrive.

As a result of the implementation of the Hilsa Fisheries Management Action Plan since 2004, the decreasing trends of *T. ilisha* have been gradually reversed and production has increased after a major decline in 2000–2001. Even though production has increased, it is still unable to meet the high demand of the country's growing population, and, as result, prices are fast becoming beyond the reach of the majority of people. Although Bangladesh has successfully produced productive strains of carp, *pangasid catfish*, tilapia and shrimp for use in pond aquaculture, hilsa culture has not been commercially started in this country. It is widely believed that hilsa cannot be cultured in brackish water ponds, lagoons or enclosed water areas of large barrages. However, it has been demonstrated that a moderate growth rate of 2–2.5 cm per month can be achieved in freshwater pond culture up to the initial couple months (Rahman et al. 1997). Many farmers and entrepreneurs have shown interest in culturing this fish in captive conditions. The main challenge to meet the needs of farmers and entrepreneurs is the sustained availability of hilsa fry and fingerlings at a reasonable cost and effort. However, some related species like American shad and the Reeves shad have been shown to breed successfully through induction (Wang et al. 1997 and 1998). The Sarawark Development Institute (SDI) in Malaysia has succeeded in artificial breeding and pond culture of the *T. toli* and produced large quantities of fry and fingerlings in captive conditions (Blabber et al. 2001).

This chapter focuses on potential sources of hilsa fry and fingerlings, methods of production, nursery and larval rearing and transport to foster its future aquaculture in Bangladesh and in the countries within the Bay of Bengal region.

4.2. Sources of hilsa fry and fingerlings

Aquaculture in Bangladesh and elsewhere is dependent on the collection of fish eggs, fry and/or fingerlings from nature and/or induced spawning and fry and fingerlings reared in hatcheries. The options for hilsa are discussed briefly below.

4.2.1. Natural sources

Wild collection of natural eggs, fry and fingerlings of hilsa is dependent on the spawning season, spawning area, nursery area and season of fry and fingerlings availability and opportunity for live catching and transportation. Elaborate studies investigating these issues have been conducted in the past. Recent studies during the past decade have provided more accurate information.

4.2.2. Maturity and breeding seasons of hilsa

Conflicting views on the age at first maturity of hilsa existed for many years. Many earlier studies opined that hilsa mature at 1+ to 2+ years of age and at 20–35 cm TL (Pillay and Rao 1963; Mathur 1964; Shafi et al. 1978). However, Jones and Menon (1951) showed that male and female hilsa become mature at lengths of 22–25 cm and 22.5–30 cm, respectively, at their presumed age of >1 year in the Hooghly River, Mahanadi River and Chilka Lake. However, through the recent studies by World Bank Aquatic Resources Development, Management and Conservation Service (ARDMCS) and the Global Environment Facility (GEF), the minimum size of maturing female hilsa was 17 cm TL and 43 g (Figure 1) in the Tetulia River in Bangladesh. Males were also found mature at this size and milt readily released by applying mild pressure to the belly (Haldar 2004). Using von Bertalanffy's growth equation, the age of this size of hilsa was about 8 months. Thus, it seems that hilsa may become mature below 1 year of age, though the minimum size at first

Minimum size of maturing hilsa.

maturity varies depending on area, food availability and stock health.

Similar conflicting views also exist with regard to the spawning seasons of hilsa. Earlier, most studies claimed that hilsa spawn pretty much throughout the year, peaking in February–March and July/August–October (Hora and Nair 1940; Bhanot 1973; Shafi et al. 1982). The BFRI identified two major spawning seasons—September to October (peak in October) and January to March by observing hilsa Gonado Somatic Index (GSI) values. This was further confirmed by studying the availability of spent fish in the landing centers in 2003 (Table 1).

This data also confirmed that October is the peak breeding season of hilsa, followed by February, and that the fish do not breed throughout the year, though they carry eggs. Hilsa breeding is also highly influenced by the lunar cycle. The local fishers believe that most hilsa breed during the full moon of *Bara Purnima* (first full moon of the Bengali Ashwin month).

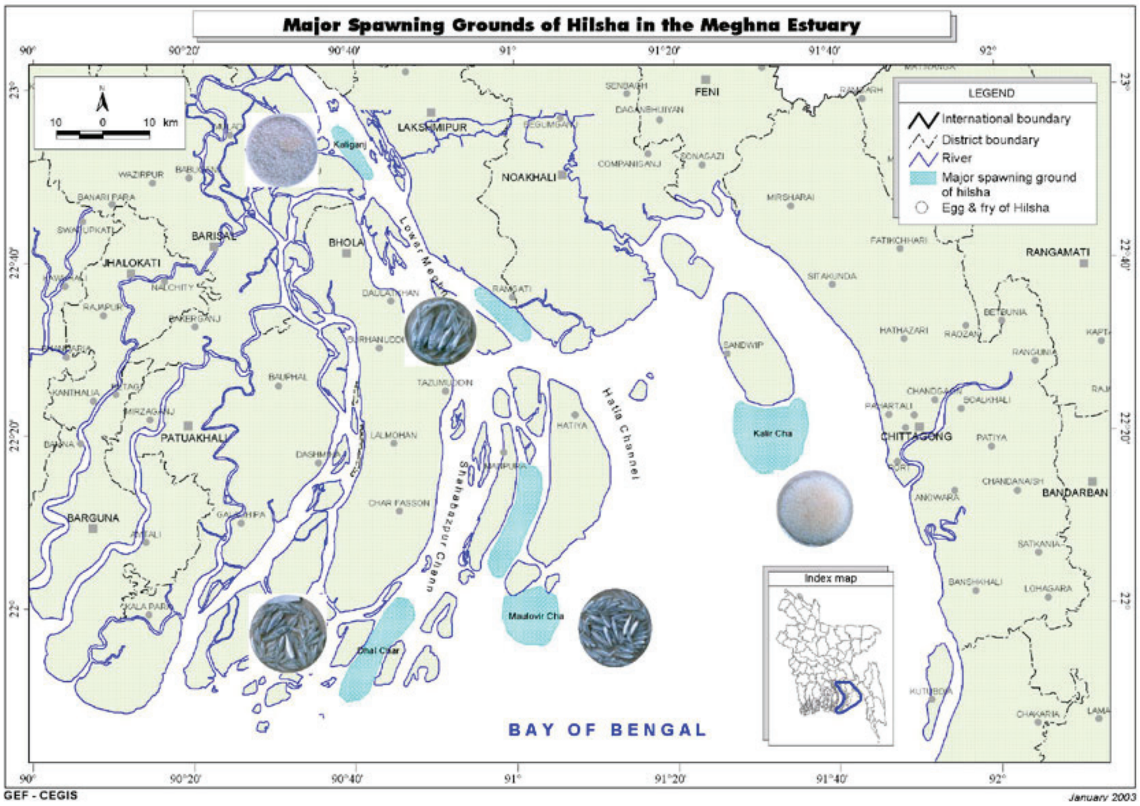


Figure 1. Hilsa spawning grounds and postlarvae availability area.

Month	No. of fish observed	No. of spent hilsa	% of spent hilsa
January	528	4	0.76
February	522	14	2.68
March	1,034	7	0.68
April	1,176	0	0.00
May	506	0	0.00
June	1,012	0	0.00
July	579	0	0.00
August	525	0	0.00
September	1,006	0	0.00
October	1,012	37	3.66
November	982	19	1.93
December	803	3	0.37
Total	9,685	84	0.87

Table 1. Number and percentage of spent hilsa landed at Ilisha ghat, Bhola, during 2003.

This was further verified by the GSI study (Table 2). However, depending on the water temperature and availability of plankton for food (most limiting factors) in the spawning ground, the peak breeding season may vary a little.

4.2.3. Spawning grounds of hilsa

Earlier studies indicated that hilsa spawn almost in all the major rivers of Bangladesh. Quereshi (1968) claimed that the lower Meghna River and its tributaries were the major spawning grounds. The BFRI, ARDMCS and GEF studies confirmed four specific sections of the lower Meghna River (Figure 1) as the main hilsa spawning grounds (Miah et al. 1999; Haldar and Islam 2003; Haldar 2004) by observing oozing hilsa onboard fishing vessels and collecting postlarvae. The areas are (1) the area surrounding Dhal Char Island (Charfashion, Bhola), (2) the area surrounding Monpura Island (Monpura, Bhola), (3) Moulvir Char Island (downstream of Hatia) and (4) Kalirchar Island (downstream of Sandwip). Similar surveys were conducted in the upper section of the Meghna River and its tributaries, but hilsa in postlarval stages could not be caught or found. Over the past 30 years or more, hilsa have been observed spawning in these areas, so it has been concluded that hilsa spawn in specific locality of the lower Meghna River, though there may be some more spawning grounds in other areas.

4.2.4. Scope of fertilized eggs or spawn collection from hilsa spawning grounds

Nair (1939) and Jones and Menon (1951) stated that they collected fertilized eggs and larvae of hilsa from the Hooghly River near the Pulta Water Works and from the Daya River at the confluence of Chilka Lake using a plankton net. However, subsequent attempts with other types of egg/spawn collection nets, at various places, depths (surface, middle, bottom area of spawning grounds and adjacent shoreline) and times (high, low and slack tide) were not able to collect any fertilized eggs or spawn of hilsa. The spawning grounds of the lower Meghna River are tidal, and high water velocities (10–20 km/h) and turbidity conditions prevail, especially during certain phases of the lunar cycle. It seems likely that immediately after ovulation, the eggs are widely dispersed by tidal currents, so collecting fertilized eggs or spawn from hilsa spawning grounds may not be possible for nursery rearing, as is practiced with the Indian major carp.

Although the collection of fertilized eggs or spawn

Larvae (top), fry collection (bottom).

Month	Date of sampling	GSI Value	Date of full moon	Date of new moon
July	08/7 25/7	7.0 27.5	31/7	01/7
August	15/8 31/8	33.0 21.2	29/8	16/8
September	20/9 30/9	29.1 20.0	28/9	13/9
October	18/10 31/10	20.7 33.0	28/10*	13/10
November	20/11 30/11	21.5 13.6	26/11	11/11
December	20/12	8.2	25/12	11/12

* Full moon of Durga Puja (*Bara purnima*)

Table 2. GSI value and corresponding date of full moon and new moon.

was not possible, 2- to 3-day-old postlarvae/fry of hilsa were caught from the shoreline of the rivers adjacent to the spawning grounds by *savar jal*, a typical conical set bag net used to catch fish fry (Figure 2). The highest numbers, 41 fry/minute, were caught from the Moulvir Char area, followed by 20 fry/minute from Dhalchar, Shahbazpur as part of the GEF studies (Table 3). In 2003, almost the same numbers of fry were also caught from the same places. Thus, it is possible that hilsa fry could be caught from the rivers adjacent to the spawning grounds and transported for nursery rearing in captivity.

4.2.5. Scope of fry and fingerling collection from hilsa nursery grounds

A wide variety of nets and gear is used for *jatka* collection, such as small mesh large beach seine (*jagat ber jal*), very fine mesh beach seine (mosquito net), small mesh synthetic gill nets (current *jal*), set bag nets, lift nets and submerged island encircling traps. Among them, the most efficient gear is the *jagat ber jal* and gill net. In an earlier study, of the total catch of 19,258 t commercial fishers caught about 50% of *jatka* using the *jagat ber jal* and 40% with gill nets. *Jatka* are mainly

Hilsa fry and fingerlings up to 22.9 cm TL, popularly known as *jatka*, are found in almost 100 rivers in Bangladesh from November to April or May. However, most (approx. 60%) are caught during March and April (Figure 2). Although *jatka* are more widely available, the bulk (95%) is caught in the lower Meghna River, between Shatnal of Chandpur and Ramgoti, Lakshmipur District. During March 2004, *jatka* were found to be 8.8–11 cm long with an average weight of 7–12 g (Haldar 2004). This size of *jatka* is suitable for transportation for nursery rearing. In April–May, the sizes and weights of *jatka* are higher.

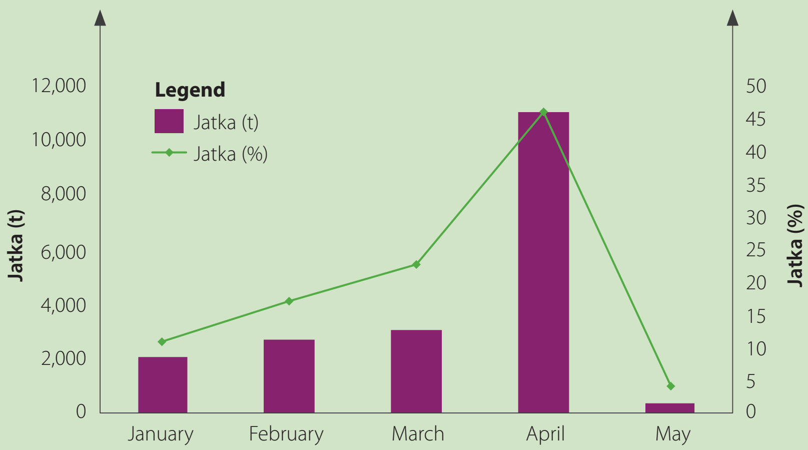


Figure 2. Peak period of *jatka* catch.

River name and place	GPS Location	Hilsa larvae/ fry caught		Fish larvae/fry caught		Remarks
		Nos./Min	Av. Wt. (mg)	Nos./Min	Total Wt. (mg)	
Meghna, Chandpur	23° 13′901″ N 90° 38′375″ E	-	-	10	20	
Meghna, Diara	23° 07′538″ N 90° 32′802″ E	2	20	-	-	-
Meghna, Kaligong	22° 51′942″ N 90° 38′612″ E	-	-	-	-	
Meghna, Ramgoti	23° 34′855″ N 90° 69′658″ E	3	3–4 days old	1,000	1–2 days old (larvae)	
Meghna, Hatia	22° 24′950″ N 91° 84′382″ E	-	-	-	-	-
Meghna, Moulvir Char	22° 26′626″ N 91° 02′582″ E	41	100	38	186	-
Shahbazpur Monpura	22° 20′887″ N 90° 59′153″ E	3	1–2 days old	-	-	-
Shahbazpur Dhalchar	22° 28′774″ N 91° 00′840″ E	20	1–2 days old	50	1–2 days old (larvae)	-
Shahbazpur Channel, Hatia	22° 19′784″ N 91° 03′810″ E	-	-	-	-	

Source: Haldar 2004.

Table 3. Results of experimental fry/larvae collection.

caught during dawn and dusk by *jagat ber jal* and gill nets. Although most of the *jatka* from gill net catches died immediately after being brought onboard the fisher's boat, *jatka* caught in *jagat ber jal* could be kept alive in water for several hours by making an artificial pool on the pickup truck, which seems to be the most suitable method for transporting hilsa fry for nursery rearing.

4.2.6. Transportation of hilsa fry and fingerlings

In 1988–1989 and 1997, live hilsa fingerlings of about 5–10 cm in length were collected from the *jagat ber jal* catches of commercial fishers and 100–150 fingerlings were placed in a 50 L rectangular fiberglass tank filled with river water. Fingerlings were transported from the Meghna River to the BFRI/RS at Chandpur (about 15 km away) to condition them to a hatchery pond. However, the fingerlings were stressed by the handling. They were swimming erratically, jumping and injuring themselves against the tank surface. Only a few survived the journey to the pond side. In later experiments, the fingerlings were transported using the same protocol, but rubber foam was used to line the inside of the tank while the upper surface was covered with wet cloths. Stress was thus reduced and a good number were carried to the pond site alive. However, poststocking mortalities were high, with only a few surviving for any length of time. The high mortalities may have been a result of light sensitivity (Pang and Teck 2001). Transport might be improved by lowering the water temperature through the addition of ice, thereby reducing the metabolic rate of the fingerlings. Anesthetics could also be tried, as is practiced with transport of other types of fish. The most recent experience of the BFRI/RS shows that fingerling mortality during transport can be reduced by transporting larger (>20.0 cm) hilsa fingerlings, at stocking densities of 5–10 fish per polythene bag (4–5 L water capacity), with oxygenation.

4.3. Hatchery origin of spawn, fry and fingerlings of hilsa

4.3.1. Induced breeding of hilsa

Induced breeding of hilsa under hatchery conditions (ponds) was conducted from March 1988 to February 1989 at the BFRI/RS in Chandpur. Fingerlings (mean length = 5.31 cm; mean weight = 1.25 g) were collected from the Meghna River and stocked at a rate of 2500 fingerlings ha^{-1} and reared for 12 months (Rahman et al. 1997). At this stage, the average length and weight of the fish reached 25.8 cm and 194 g (average of results from two ponds). Under pond conditions, some males matured, with milt becoming visible when mild pressure was applied to their belly. However, the females only reached maturity stages III and IV (BFRI 1994). Females must attain at least stage V or VI for induced breeding to be possible. The limiting factor for achieving full maturity of female fish may be water transparency, since hilsa breed in turbid water, natural food in water, dissolved oxygen and water current in the ponds. The program could not be continued further because of drought and the failure of the deep tube well supply, resulting in the death of the captive fish.

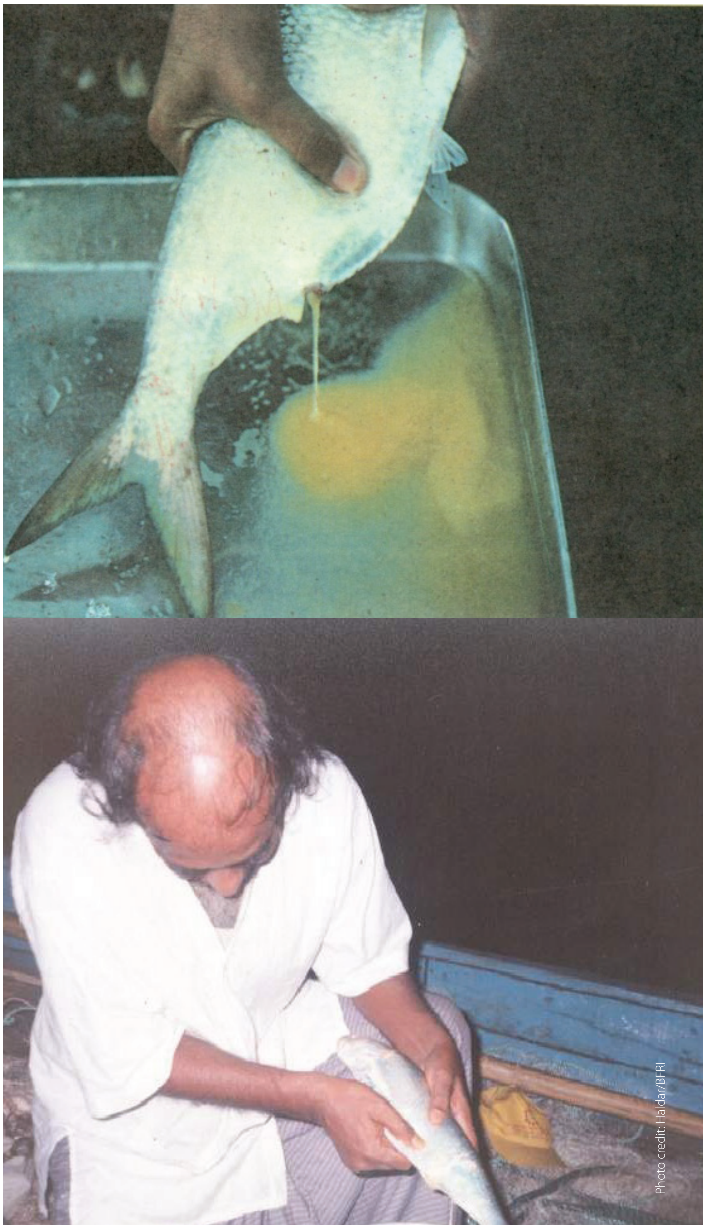
On the basis of the above results, it is proposed that induced breeding of hilsa might be achieved by mimicking natural spawning conditions in captivity. To obtain proper gonadal maturation, males and females should be reared in shaded large circular tanks to prevent direct sunlight. Turbid water conditions, strong currents and optimal water temperatures must also be provided. Furthermore, natural plankton may also be given to maturing adults. The use of hormones that stimulate gonadal maturation could also be tried. A broad-based research program would be necessary to search if it is at all possible to breed hilsa in pond conditions.

4.3.2. Breeding hilsa onboard fishing boats

During peak breeding season, a good number of female and male hilsa oozing eggs and milt, respectively, can be found in the catches of fishers. Some of these oozing fish remain alive for a few minutes after being taken onboard, particularly those caught with pocket gill nets (*kona jal*). Ripe hilsa are usually caught in the evening or late afternoon (16:00–18:00), suggesting that they spawn at night. Eggs and milt from these fish can be collected easily by stripping. Fertilization is readily achieved and the resultant fertilized eggs can be transferred to hatcheries where larval and nursery rearing of fry can take place. In an onboard experiment conducted by the BFRI in 1991, the fertilization rate of these endeavors was approximately 90%. Onboard breeding of hilsa was also carried out in 2004 under the World Bank-funded GEF studies with similar results (Haldar 2004). In many cases, ripe males in excellent condition were caught, facilitating the onboard collection and preservation of milt. The development of sperm cryopreservation techniques may help in the successful onboard breeding of hilsa.

4.3.3. Fertilization and transportation of fertilized eggs

Hilsa eggs may be fertilized, as is done with carp and other fish, following a wet or dry method. Immediately after eggs are stripped from females into an enamel plate, bowl or tray, a small volume of water is added to cover the eggs. For fertilization, milt is stripped from the males over the eggs and mixed well either using a feather or by gently agitating the tray or plate by hand. The fertilized eggs of the onboard breeding experiments in 1990 and 2004 were released into the river because there were no larval rearing or incubation techniques available. In 1995, the SDI bred *T. toli* onboard using very similar methods (Pang and Teck 2001), transferring the newly fertilized eggs in 20 L buckets and plastic bags filled with filtered water from the spawning site to the hatchery for larval rearing, fry and fingerling production.



Collection of eggs (tops) and milt (bottom) from hilsa.

4.3.4. Larval rearing of fertilized eggs in an incubation tank

While Bangladesh has no experience of larval rearing in incubation tanks, the SDI succeeded in larval rearing of the progeny from the onboard spawning. The following description comes from Pang and Teck (2001).

Soon after arrival at the hatchery, the fertilized eggs were transferred from the bucket or plastic bag into a 100 L plastic container filled with river water of 5–10 ppt salinity and provided with gentle aeration. The eggs were hatched within 15–18 hours at temperatures of 28°C–31°C. Hatching rate rates varied between 60% and 95%. Larvae were reared in a variety of 1400–4100 L circular and rectangular tanks at maximum densities of 25 larvae per L. Larval yolk sacs were absorbed within 5–6 days and the fry fed cultured rotifers. From the age of 14 days, they were fed a mix of *Artemia* nauplii and rotifers. Tanks were siphoned daily in the morning and 50% of the water was replaced daily for the first 6 days, 80% for the next 8 days and 100% from Day 15 onward, using filtered river water supplied by gravity from overhead tanks. Fine silt particles were added to the rearing tank to keep the water turbid (water transparency 80–100 mm) because *T. toli* larvae are highly sensitive to light and do not feed in clean water. Tanks were also covered with black netting to provide 50% light penetration. Continuous gentle aeration was provided to keep the silt in suspension in the water column and also to oxygenate the tank water.

Larvae were held in tanks for 20–70 days before being released to enhance riverine stocks or reared in nursery ponds. The survival rate of fry in the tank was 48%–72%. When the larvae were reared for longer periods in the tanks, mortality rates increased. From a study of the food and feeding habits of natural hilsa fingerlings, the feeding intensity was highest at 21:00 then from 00:30 to 01:30. In the morning (07:00–09:00), feeding intensity reduced (Areman et al. 2003). Thus, hilsa fingerlings should be fed in the evening and at night.

4.3.5. Nursery rearing of hilsa fry and fingerlings

Bangladesh has no experience with hilsa fry and fingerling rearing in nursery ponds except the earlier pond culture experiment conducted during 1988–1989, when 5.31 cm TL fingerlings weighing an average 1.25 g were stocked in two nursery ponds. After 12 months, the average weights of the fish were 119.28 and 267.33 g in the respective ponds. Although the growth rate of the fingerlings was satisfactory, high mortality (60%) occurred during transport and the subsequent survival rate was very poor. The SDI stocked 45-day-old fry in the nursery ponds and recorded an increase in length to 54–76 mm SL from 22–25 mm SL at stocking during a 55-day rearing period. The survival rate of the fingerlings was 50%–70%. The results suggested that nursery rearing of hilsa fry and fingerlings can be done in pond conditions but needs further investigation.

4.4. Breeding of American and Chinese shads

Wang and Pieree (1997) documented successful experiments carried out in China from 1963 to 1982, which led to attempts to rear Reeves shad (*Tenualosa reevesii*) from egg to adult in ponds and to domesticate broodstock for egg production. From 1987 to 1996, Wang and his team achieved success in domesticating Reeves shad (Wang et al. 1997). Domesticated parents were induced to spawn through the long-term use of hormones.

The Chinese trials showed a mean monthly increase in body length of Reeves shad up to 18.9 mm and a bodyweight up to 24.09 g. Growth varied with season and water temperature, being somewhat higher in early summer and late autumn when the mean water temperature was about 29°C–30°C. Growth rates were also positively correlated with the biomass of zooplankton in the pond. After eight months of extensive rearing in a large pond, mean bodyweight reached 496.3 g, and the output of it being intensively reared in two ponds reached to 1170 kg/ha^{-1} and 1087.5 kg/ha^{-1}, with a mean bodyweight of 203.3 g and 201.3 g, respectively. The experiments showed that artificial culture of Reeves shad in pond water was feasible.

Wang et al. (2003) further documented the findings on broodstock rearing and controlled reproduction of Reeves shad. The shad broodstock was held in captivity and induced to spawn with serial injections of luteinizing hormone-releasing hormone analogue (LHRHa), following GtH priming by implantations of 17-methytestosterone (T), combined with environmental manipulations. Induced maturation of 4-, 5- and 6-year-old females reached 83.3%, 87.5% and 100%, respectively, while fish in control treatments remained immature. During the gonadal development priming period, mean serum 17-estradiol levels in the T treatment were significantly higher than the LHRHa treatment and control fish. Gonadal development of females was suppressed when their mesenteric fat index was below 1.5% in April. The effective accumulating temperatures for female and male maturation were 3995 * 31.4 C/d and 2278 * 8.9 C/d, respectively. Two injections of LHRHa in combination with domperidone (DOM) and environmental manipulation were effective in inducing ovulation. About 800,000 fertilized ova were obtained (fertilization rate = 75%) in 1995 and 5000 fry hatched in 1996.

With respect to the artificial manipulation of American shad (*Alosoma sapidissima*), ripe males and females were caught in seines from their spawning grounds. The brood fishing took place at night, because ripe fish were found in considerable numbers at that time. The captured fish were taken onboard a boat and stripped immediately because they die quickly. Eggs and milt were caught in a pan and mixed with a little water and allowed to stand for a few minutes until impregnation was complete, which is signified by swelling of the eggs. The temperature of the water was then reduced by 10°C and the eggs transferred to hatching boxes and left. In 24 hours, the black eyes of the young fry were visible through the shell, and within 3 to 10 days all fry had hatched. The method is rapid, simple and inexpensive, and opened the window for shad culture (Roosevelt 2008). Hatching boxes were anchored in a stream, tied one to other. Eggs were collected and incubated by the hundred thousand, and in about a week the tiny but lively shad started swimming. Feed was given at this stage. The hatchlings were later stocked for rearing in a long narrow pond connected to the river.

Successful artificial propagation of Malaysian Terubok *Tenuoalosa toli* has also been reported, the resultant juveniles being used for restocking purposes (Kasim et al. 2012). According to staff at the Department of Agriculture, Malaysia has been successfully producing Terubok fry and fingerlings since 1996. The brood fish are wild caught spawners, with *in situ* spawning having been carried out onboard. The availability of live broods was identified as a challenge for large-scale operations.

From the above review, it appears that traditional shad hatching operations have largely depended on strip-spawning ripe fish, mostly as close as possible to the spawning grounds. In this method, adult fish are captured by gill nets and subsequently sacrificed during the collection of eggs and milt. The method, while simple, is often limited by the lack of ample supplies of ripe fish, especially when shad resources are seriously depleted.

To make artificial spawning a successful means of obtaining large quantities of fry and fingerlings for aquaculture, the rearing of hilsa/shad juveniles to sexual maturity must be achieved. While in the past few decades there have been several attempts to produce domesticated broodstock of hilsa and other shad species, neither hilsa nor indeed any shad species to date has been successfully cultured to sexual maturity and spawned artificially, possibly because of handling stress or low survival in captivity (Wang et al. 2003).

4.5. Impacts of migratory behavior for breeding/domestication technologies

The transition of adult hilsa from seawater to freshwater rivers to breed, as well as the fact that juveniles live in freshwaters for 5–6 months during nursing and feeding until they become pre-adults, provides both opportunities and challenges for domestication of this fish, its breeding and nursing and the development of grow-out technologies.

There are two options for mass production of hilsa seed: (1) growing broodstock under controlled conditions, or (2) collecting eggs from oozing females and milt from ripe males at the breeding ground. A further approach has been used for American shad to facilitate the survival of floating eggs by providing floating submersible trays and releasing the young offspring back into the water to maximize survival.

Broodstock, young fry/fingerlings or *jatka* can be collected from riverine nursery grounds at the mouths of the Meghna, Padma and other coastal rivers and streams, as well as inshore areas, and carefully carried in large portable tanks fitted with aerators to the nearest hilsa hatchery, yet to be established. The juveniles should be nursed and fed well with natural planktonic food organisms alongside supplementary prepared feed through a process of gradual adaptation. After 2–3 weeks of nursing, they can be released into deep (about 3 m) well-prepared green ponds. Rectangular ponds, modified to be longer than usual, are required so that the fish can undertake lengthy swims to and fro. Growth and the eating of natural food by fish should be carefully monitored.

After 1 year of culture at a lower stocking density (0.5–1 fish per m^2), growth performance, condition factors and gonadal development should be determined. If these are comparable to those of wild fish, this indicates that brood fish, capable of producing mature eggs and milt, might result at the end of the second year. As far as is possible, artificial currents should be generated during the monsoon season, in synchrony with the natural spawning season. Knowledge of hilsa migration will provide information on the nature and quality of water and food organisms that they prefer as juveniles and adults. Knowledge of the domestication of American shad as well as that of salmon may help in addressing the challenges of hilsa domestication. It is not yet established through research (a fact rather necessary to know) if hilsa have an absolute requirement for a saline environment during certain periods of their life to complete their lifecycle.

Knowledge of the migration of adult hilsa to the breeding grounds and identification of the grounds as well as the peak breeding period for a fortnight before, during and after the full moon in October, can be used for practical onsite breeding of ripe females and to collect milt from ripe males. Bangladeshi researchers from the BFRI as well as DoF fishery managers can readily identify both the breeding grounds and breeding times. Trained fishers using special gill nets can be employed to catch ripe females and to strip the eggs in mobile (plastic) hatchery tanks fitted onboard a boat or a research vessel equipped with an aeration device. Sufficient quantities of milt (2–3 males:1 female) should be added to the eggs and gently stirred. Within 12 hours, the tank must be taken to a hatchery and the fertilized eggs gently transferred into larger tanks with artificial aeration in place, sufficient to keep the water well aerated. After a successful 72-hour period of nursing, the yolk sacs will have been completely absorbed, and the spawn can be transferred to larger, green water tanks to which river phytoplankton and zooplankton have been added. *Artemia*, boiled egg yolks and soft-bodied zooplankton can also be administered as food after yolk sac absorption. Knowledge of breeding migration and feeding of nursery stages in rivers helps provide information for successful postspawning nursing in the hatchery. With the success of large-scale production of juveniles, the next steps of larval rearing in ponds can be carried out. The numbers of juveniles in each rearing pond should be gradually thinned out as the fish grow and are used either for restocking in rivers or for grow-out systems.

4.6. Conclusions

Since 2004, capture fisheries production of hilsa has increased significantly in Bangladesh, but it still cannot meet increased demand among ordinary people of the country. In the near future, the production of hilsa from the wild may plateau, with no further scope for increase, so there is an urgent need to explore alternative sources of hilsa production. Culture of hilsa in captive/semi-captive conditions may be an option. To culture hilsa in captive conditions, sources of fry and fingerlings are the limiting factor. Thus it appears that

- hilsa fry and fingerlings may be collected from natural sources but transportation techniques need to be improved;
- onboard breeding can be done and the fertilized eggs be transported to hatcheries for fry and fingerling production in captive conditions;
- fry and fingerling production techniques in captive conditions need to be developed;
- artificial or induced breeding is also possible and efforts should be made to produce more seed using this method;
- induced breeding techniques should be standardized through focused, coordinated research;
- to address the issues of captive culture of hilsa, broad-based research programs should be undertaken by the BFRI/RS in Chandpur;
- capacity building for hilsa breeding and aquaculture should be a priority.

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Hilsa fish in a Barishal fish market.

5. Food, feeding and nutritional requirements of hilsa

Authors

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Abstract

Hilsa is an anadromous fish that spends adulthood in marine habitats, breeds in estuaries and rivers, and grows through early stages in major rivers and their tributaries. Since the species spends different stages in different habitats, its food and feeding habits differ throughout the course of its lifecycle. Feed composition may also vary with season in response to the changing availability of food. A thorough knowledge of its food, feeding habits and nutritional requirements at different stages of its lifecycle is essential for sustainable management of hilsa and its aquaculture. From anatomical and histological studies, it was observed that the alimentary system of hilsa consists of a buccal cavity, a short pharynx, an esophagus, cardiac and pyloric stomachs, a duodenum, intestine and rectum. The gill rakers of hilsa act like a sieve and show little selective preference for any type of food or food particles. The diet of *jatka* includes both phytoplankton and zooplankton, and post-*jatka* hilsa feed mostly on phytoplankton. Adult hilsa feed on plankton and are generally referred to as planktivores. Mass culture of both green algae/diatoms and zooplankton of river and coastal origin could be promoted for hatchery operation, but a plant-based diet with fishmeal may be formulated for grow-out hilsa.

5.1. Introduction

Tenualosa ilisha (Hamilton), commonly known as hilsa, is a widely distributed Clupeid species inhabiting the coastal waters from the Persian Gulf, Pakistan, India, Bangladesh and Myanmar to North Sumatra and is found in the estuaries, rivers, brackish water lagoons and coastal marine areas of the Indo-Pacific region. It is most abundant in the Ganges-Brahmaputra drainage system of India and Bangladesh, forming one of the most important commercial species fisheries in the countries around the Bay of Bengal. The highly prized hilsa is currently under severe fishing pressure (De 2001). As a result, the abundance of hilsa has drastically declined in almost all major river systems, so there is an urgent need to initiate hilsa farming in confined waters for conservation of this species. A thorough knowledge of its food and feeding habits during different stages of its lifecycle is essential for the development of hilsa aquaculture.

5.2. Hilsa food and feeding

The food and feeding habits of hilsa have been a century-old topic of research for South Asian fisheries biologists and ecologists. Because of its migratory nature and widespread distribution, there have been very few studies investigating all of the stages of its lifecycle. Since the species spends different stages in different habitats, its food and feeding strategies can be expected to differ throughout the course of its lifecycle. Feed composition may also vary by season in response to the changing availability of food. Moreover, food preferences may be dependent on its growth stages, which can be broadly divided into larvae or young-juveniles, *jatka* and adult fish.

The pelagic young-juvenile stage is mostly confined to the rivers and the upper reaches of estuaries where young hilsa feed on both phytoplankton and zooplankton. Hora (1938 and 1940) observed that young hilsa (20–40 mm TL) mostly feed on diatoms and occasionally on crustaceans, while slightly larger specimens (<100 mm) feed on small crustaceans, insects and polyzoa. Hora (1938 and 1940) also inferred that young hilsa were benthic as well as pelagic feeders. Shafi et al. (1977) observed that juveniles were voracious eaters and bottom feeders and that its food and feeding habits change with increase in body size and seasonally.

Hilsa juveniles that have reached 40–150 mm TL are locally known as *jatka*, a stage similar to salmon smolt. *Jatka* live in the rivers or streams for about 6–7 months and then migrate to the sea at the onset of the monsoon season to mature, especially when the clear water of the rivers and streams begins to become turbid. *Jatka* prefer planktonic food, primarily phytoplankton, with small quantities of zooplankton. In a recent review, Rahman (2006) mentioned that the diet of hilsa varies with season and body size. Juveniles up to 20–40 mm TL feed mostly on diatoms and occasionally on copepods, *Daphnia* and Ostracods. *Jatka* (<100 mm TL) were found to feed on small crustaceans, insect larvae, chironomid larvae and polyzoa, while larger fish (<150 mm TL) included shrimp in their diet along with other organisms. De and Datta (1990) studied the alimentary tract and described the feeding adaptation of hilsa. No jaw teeth are present. Instead the species has fine gill rakers, a pharyngeal pouch, a modified stomach, which acts somewhat like a gizzard, and a moderately long intestine. Together, these indicate that hilsa has a planktivorous mode of feeding.

Adult fish live mostly in the sea, where they feed on marine algae. When they become adults, they migrate into rivers to breed. Reports on the feeding of adult hilsa during upstream migration are rather mixed. Pillay and Rosa (1963), Quereshi (1968) and Shafi et al. (1977) found that adult hilsa stop eating during upstream migration, depending on accumulated fat deposits for energy. Pillay (1958) and Haldar (1968) found no evidence of cessation or even any significant decrease in the feed uptake during upstream spawning migration. Narejo et al. (2005) in their studies of landlocked *Tenualosa ilisha* found that adults (138–328 mm TL) fed exclusively on phytoplankton with Bacillariophyta (diatoms) dominating the diet (70% by occurrence). Rahman et al. (1992) have also suggested that while the diet of *jatka* includes both phytoplankton and zooplankton, the diets of post-*jatka* hilsa include mostly phytoplankton. Narejo et al. (2005) did not quantify the maturity status of landlocked hilsa, but claimed that their observation could provide important insights into pond culture of this species.

5.3. Morphology, anatomy and histology of the alimentary canal

Very little work has so far been done on the morphology, anatomy and histology of the alimentary canal of *T. ilisha*, barring the accounts of Swarup (1959) from the Ganges River at Allahabad, Safi et al. (1976) from Bangladeshi waters and De (1986) and De and Datta (1990) from a freshwater stretch of the Hooghly estuary. Other fragmentary information on pyloric caeca, pharyngeal organ, gill rakers, morphological structure of the alimentary canal and bucco-pharynx of the species are available from the accounts of

Rahimullah (1945), Kapoor (1954), Dutta and Munshi (1960) and Khanna (1961 and 1962).

Swarup (1959) studied the morphology and histology of the alimentary canal of hilsa from the Ganges River near Allahabad. He described the alimentary canal as consisting of a buccal cavity, a short pharynx, an esophagus, cardiac and pyloric stomachs, a duodenum, intestine and rectum.

Buccal cavity: The lining of the buccal cavity consists of mucosa and submucosa. The buccal cavity is devoid of teeth but has a tongue supported by cartilage. Few goblet cells are present at the proximate end of the buccal cavity. The submucosal region is highly innervated.

Pharynx: The gill rakers and pharyngeal organ are present in the pharyngeal region. The gill rakers are long and slender and are closely spaced on the branchial arches and adapted to screen microscopic food particles. The pharyngeal organ consists of a pair of curved blind diverticula of the pharynx. Each diverticulum is again divided into a canal-like passage and a blind sac. The histology of the canal passage is similar to that of the pharynx and has no respiratory function. The pharynx wall is composed of four layers: inner mucosa, submucosa, muscle and the outer serosa. The mucosa here is rich in goblet cells and is thrown into folds.

Esophagus: In this region, the mucosal folds are thin and prominent compared to those in the pharyngeal region, where the folds are thicker. High numbers of mucus secreting goblet cells are present.

Cardiac stomach: The wall of the cardiac stomach is composed of same four layers as in the pharynx and esophagus. In this region, gastric glands are numerous in the posterior area but few in the anterior. The cardiac stomach functions as a reservoir for food.

Pyloric stomach: Among the four layers of the pyloric stomach, the highly developed muscularis layer is responsible for grinding food. Numerous gastric glands are present throughout the submucosal layer. Goblet cells are completely absent from the cardiac and pyloric parts of stomach.

Duodenum: Numerous intestinal diverticula or pyloric caeca open into the duodenum. Swarup (1959) recorded a concentration of pyloric caeca on the ventral and lateral side of the duodenum. The histological structure of the duodenum is almost similar to that of pyloric caeca. Few goblet cells are present in this region.

Intestine: The mucous layer of the intestine is provided with two kinds of cells: columnar cells, which are absorptive in nature, and mucus secreting goblet cells. The greatest numbers of goblet cells are found in the distal part of the gut (rectum).

De (1986) and De and Datta (1990) also studied in detail the morphology, anatomy and histology of the alimentary canal of hilsa from a freshwater stretch of the Hooghly estuary in relation to food and feeding habits. The striking features observed by the authors are described below in brief.

Morphology and Anatomy

The alimentary canal is described under two main divisions: (1) the buccopharynx, comprising the mouth, buccal cavity, pharynx and pharyngeal pouches, and (2) the gut, which includes the esophagus, oesogaster, cardiac stomach, pyloric stomach, pyloric caeca, a moderately long intestine and an undifferentiated rectum (Figure 1).

Buccopharynx: The mouth of hilsa is small and almost terminal in position. It is bounded by thin upper and lower lips and is slightly upturned, since the lower jaw is slightly longer than the upper one. The mouth opens into a laterally compressed buccopharyngeal cavity, which is narrower anteriorly and somewhat broader posteriorly. The floor of the buccphayngeal cavity is almost flat and a small immovable spoon-shaped tongue is present. The mouth is edentulous. There are four pairs of well-developed gill arches, each bearing gill filaments and rakers on its outer and inner surface, respectively. The numbers of rows of gill rakers are variable.

In adult hilsa, the gill rakers are numerous and have plate-like, fine processes. Each raker is differentiated into four zones, the innermost marginal layer possessing conical papillae. Neither the zones nor the papillae are fully developed in gill rakers of fish <50 mm TL. The characteristics of gill rakers of various size groups are shown in Table 1.

The presence of the pharyngeal organ in the posterior part of the pharynx is a striking feature of hilsa. This is a paired structure situated dorsal to the branchial arch. It consists of two parts: the canal passage and the sac. The inner lateral side of the canal passage is occupied by two rows of small-sized rakers as well as gill lamellae-like structures. The sac has a blind end.

Gut: The pharynx leads into the esophagus, which is a very short, narrow and moderately thick-walled tube. The innermost layer (mucosa) is provided with rows of longitudinally and densely arranged papillae of different shapes. The stomach is a typically V-shaped muscular tube that is divisible into two parts: a cardiac and a gizzard-like pyloric. The distal end of the pyloric stomach is highly muscular, spherical and resembles the gizzard of a bird. The inner wall of the cardiac and pyloric is provided with thick well-marked longitudinal folds. The volume of the pyloric stomach is much reduced and the innermost wall is provided with a thin cuticular lining.

The posterior end of the pyloric stomach leads into the mid-gut, which includes the anterior part of the intestine. Immediately behind the pyloric stomach, the anterior intestine is provided with numerous small caeca in the form of clusters that open into the intestine. The pyloric caeca are variable in number (several hundreds), the number varying with the size of the fish. The remaining part of the gut and hindgut forms a coiled tube of moderate length. The rectum is not well differentiated from the intestine. The intestinal wall is thin and the inside wall is characterized by faint transverse folding.

The liver is the largest organ associated with digestion, covering the entire stomach and a major portion of the anterior intestine. The liver is not differentiated into lobes. A diffused pancreas is scattered between the pyloric caeca and around the intestine. A gradual increase in the relative length of gut (RLG) value is also noted among fish of different length groups, from fry (59 mm TL) to adults (525 mm TL), varying from 0.86 to 1.87 (Table 2).

The gill rakers of hilsa are like a sieve and show little selective preference for any type of food or food particles. Adult hilsa feed on plankton and are generally referred to as planktivorous. Raja (1985) reviewed the food and feeding habits of hilsa and found general agreement on the food items of hilsa among a large number of researchers, working during the late 1930s to the 1970s (Hora 1938 and 1940; Hora and Nair 1940; Chacko and Ganapati 1949; Pillay and Rao 1962; Halder 1968 and 1971; Quereshi 1968; Shafi et al. 1977). The dominant food items are crustaceans (particularly copepods), diatoms (Bacillariophycae), green (Chlorophycae) and blue-green (Cyanobacteria) algae, organic detritus, mud and sand particles. Mazid and Islam (1991) noted that relatively large but immature hilsa preferred zooplankton and that *jatka* were voracious feeders. Rahman et al. (1992) identified 27 genera of phytoplankton and 12 genera of zooplankton in a post-*jatka* fish caught in the Meghna River. They further mentioned that hilsa gradually adopt a largely phytoplanktivorous diet with size. Rahman (1996)

Fish size (mm)	Number of fish examined	Maximum length of gill raker (mm)	Width of gill rakers (mm) (flattened side)	Density (number) of gill rakers per mm	Number of gill rakers 1st branchial arch (left side only)
44–54	6	1.40–1.50	0.05–0.07	12.80–15.20	150–158
86–88	5	2.25–3.00	0.10–0.12	10.40–11.20	176–183
127	1	4.12	0.15	8.80	222
362–392	5	12.50–13.25	0.55–0.60	4.00–4.50	361–384
448–465	5	14.75–15.62	0.75	2.90–3.40	371–391

Sources: De 1986; De and Datta 1990.

Table 1. Characteristics of gill rakers of *T. ilisha*.

Total length (mm)	Number of fish examined	Maximum/minimum value	Average
59–99	9	0.86–1.14	1.05
115–161	2	1.08–1.17	1.13
230–285	10	1.26–1.55	1.37
309–392	21	1.35–1.70	1.47
401–475	12	1.43–1.77	1.50
510–525	4	1.80–1.87	1.82

Source: De 1986; De and Datta 1990.

Table 2. RLG values of *T. ilisha*.

reported that juveniles are plankton feeders, ingesting blue-green and green algae, diatoms and desmids from among the phytoplankton and copepods, cladocerans and rotifers from the zooplankton. In a more recent document, the gut content analysis of adult hilsa has shown that algae constituted 41%–65% of the diet, sand particles 36.28%, diatoms 15.36%, crustaceans 1.89%, protozoa 1.22% and other miscellaneous items 0.41% (DoF 2005).

Southwell and Prashad (1918), observing a large number of empty stomachs, concluded that adult hilsa do not feed while ascending rivers to spawn. Pillay (1958) did not find any evidence of cessation or appreciable decrease in feeding during the spawning period, but most researchers have noted that the intensity of feeding decreased or completely ceased during the spawning migration (Pillay and Rosa 1963; Quereshi 1968). In Bangladeshi waters, Quereshi (1968) observed that hilsa appeared to feed only in the sea and stopped feeding while ascending the rivers, and that the fish were probably sustained by fat reserves accumulated during the marine phase of their lifecycle, which gradually reduced during the upstream journey.

Both adult and immature Reeve's shad (*Tenualosa reevesii*) feed mainly on zooplankton and small shrimp in Chinese coastal waters (Wang and Pierre 1997). Zooplankton is the main food source for juveniles of the riverine Pontic shad (*Alosa immaculata*), which migrates from the Black Sea to the Danube River to spawn. Similar feeding behavior has also been noticed among the Twaite shad (*Alosa fallax*), which is distributed from Iceland to Morocco and as far as east as the Baltic Sea. Adult Twaite shad do not feed in freshwater. Juveniles consume mainly *uniramia* (millipedes, centipedes and their relatives) in freshwater and zooplankton in the estuary (Aprahamian 1989). Peterson et al. (2001) assumed that the diet of the American shad (*Alosa sapidissima*) was likely to be determined by nutrient levels, the abundance and composition of the zooplankton community and food webs in large river systems such as the Columbia River.

5.4. Feed and nutritional requirements for broodstock, larval rearing and fingerling production

There is no published information on the nutritional requirements for broodstock, larval rearing and fingerling production of hilsa. However, experience from other species such as carp and salmon shows that it is necessary to meet the nutritional requirements of each stage of any fish in the production system. The large-scale production of microorganisms of animal origin, such as *Artemia*, rotifers or other soft-bodied zooplankton, preferably of riverine origin, are likely needed to feed hilsa larvae after absorption of the yolk sac. As the larvae develop into fry and fingerlings, they may need a mixture of zooplankton and phytoplankton, especially diatoms and green algae. It is thus likely that both algal and zooplankton production facilities will be required in association with any hilsa breeding and seed production systems.

To grow hilsa from fingerlings (>100 mm) to *jatka,* a rapid change in the quality and quantity of feed will be needed. *Jatka* are voracious feeders (Mazid and Islam 1991) that eat both zooplankton and phytoplankton that are abundant in large river mouths and estuaries. In enclosed systems, *jatka* may still need both zooplankton and phytoplankton at the same time as artificial feed gradually replaces their natural food. Since *jatka* preferentially feed on phytoplankton, a plant-based diet compounded from soya or maize and with small but adequate quantities of fish- or meat-meal may suffice.

Particular care is needed to ensure that hilsa brood fish get a sufficiently nutritious diet to ensure proper development and maturation of gonads and eggs. Hilsa live in the sea at this stage, where they feed on marine phytoplankton with small amounts (approximately 5%–10% by volume) of zooplankton in their diet. Since brood fish are large, it is likely to prove difficult to maintain broodstock feeding solely with natural food and would need formulated feed as well.

Feed prepared from feedstuffs of plant origin, such as soya or maize and rice bran, mixed with 10%–15% fishmeal or some other source of animal protein, fish oil and a vitamin premix will be required to make an appropriate broodstock feed. Incremental replacement of natural food with prepared feed will be necessary, though natural food should continue to be used as a dietary supplement to improve diet quality. A green water pond or recirculating system routinely fed with a prepared diet may help adapt hilsa broodstock to a controlled feeding regime. The level of fat deposition, gonad/sperm development and the conditions of the broodstock must be routinely monitored and compared to that of natural stocks to insure the proper growth and maturation. Feed development is likely to prove a key ongoing research commitment to understand dietary preferences as well as how diets perform with respect to growth and maturation of broodstocks, specifically the gonads and eggs, as well as for other stages of hilsa in aquaculture systems.

At the outset, efforts will be needed to develop both algal (green algae and diatoms) and zooplankton culture systems for sustained production of adequate quantities of natural food. Availability of the commercial *Artemia* should be ensured for hatchery operations. Commercial feed used in the culture of marine shrimp larvae and broodstock may form a useful guideline for developing feed for hilsa. Information on shad culture (American shad, *Alosa sapidissima*) and its feed composition may also help in the preparation of hilsa feed. Fishmeal and oil from animals of marine origin may be useful in the preparation of feeds for juveniles, *jatka* and broodstocks.

In summary, feed and feeding of hilsa are likely to vary at different life stages. There is a lack of thorough study of feed preferences at different stages of the lifecycle of this fish. The available literature shows that hilsa larvae and fry/fingerlings prefer zooplankton during the months in which they drift downstream toward the estuary. *Jatka* voraciously feed on both phytoplankton and zooplankton in the nursery grounds in the lower reaches of river mouths and estuaries. Adult hilsa, however, feed mostly on phytoplankton with a minor component of zooplankton, the diet also containing sand particles. Pre-spawning brood hilsa stop feeding, depending instead on accumulated fat deposits. Post-spawning hilsa have been found with full stomachs, often with detritus and bottom muds and sands, indicating that they feed well at this stage and on benthos as well as plankton.

De (1986) and De and Datta (1990) examined the stomach contents of 362 hilsa specimens 16–525 mm in length, obtained from a freshwater stretch of the Hooghly estuary from October 1981 to September 1984. Fry and juveniles were procured from October to June, since they were found in the freshwater zone of the estuary for that period only. The gut contents were analyzed both quantitatively and qualitatively. Feeding intensity was assessed by observing the degree of distension of the stomachs (Job 1940; Pillay 1952). The relative importance of various food items in the stomachs was calculated using the index of preponderance (Natarajan and Jhingran 1961).

$$Ii = \frac{ViOi}{\Sigma ViOi} X\ 100$$

where Ii is the index of preponderance and Vi and Oi are the volume and occurrence index of food item (i).

The quantity of food items found in the stomach is expressed both in volumetric and percentage occurrence terms. The order of preponderance of broad groups of the stomach contents of fry (16–50 mm), juvenile (51–116 mm) and adult hilsa (167–522 mm) examined are presented in Tables 3, 4 and 5.

Food analysis	**Volume (Vi)**	**Occurrence (Oi)**	**ViOi**	**Index of preponderance ViOi X 100 / ΣViOi**	**Grading**
Copepods	58.74	61.69	3,623.67	96.45	I
Cladocerans	15.63	4.56	71.27	1.90	II
Sand and mud	2.90	10.27	29.78	0.79	III
Organic matter	5.45	2.62	14.28	0.38	IV
Rotifers	1.12	6.48	7.26	0.19	V
Ostracods	14.83	0.48	7.12	0.19	VI
Blue-green algae	0.91	3.12	2.84	0.08	VII
Green algae	0.24	3.12	0.75	0.02	VIII
Diatoms	0.02	0.96	0.02	*	
Protozoans	0.01	0.24	-	*	
Nauplii	0.11	1.20	0.13	*	
Plant tissues	0.02	4.06	0.08	*	
Miscellaneous	0.02	1.20	0.02	*	
	100.00	100.00	Σ3,757.22	100.00	

Source: De 1986.
(= less than 0.01)*

Table 3. Index of preponderance of broad groups of food items found in the stomachs of hilsa fry (<50 mm TL).

Food analysis	Volume (Vi)	Occurrence (Oi)	ViOi	Index of preponderance ViOi X 100 / ΣViOi	Grading
Copepods	54.47	37.44	2,039.36	88.52	I
Cladocerans	12.28	9.22	113.22	4.92	II
Rotifers	3.43	9.53	32.69	1.42	III
Blue-green algae	3.47	7.76	26.93	1.17	IV
Sand and mud	2.83	9.06	25.64	1.11	V
Ostracods	14.10	1.75	24.67	1.07	VI
Organic matter	5.06	3.18	16.09	0.70	VII
Green algae	2.35	6.34	14.90	0.65	VIII
Diatoms	0.97	8.41	8.16	0.35	IX
Nauplii	0.74	1.59	1.18	0.05	X
Plant tissues	0.19	4.93	0.94	0.04	XI
Miscellaneous	0.11	0.79	0.09	*	
	100.00	100.00	Σ2,303.87	100.00	

Source: De 1986.
(= less than 0.01)*

Table 4. Index of preponderance of broad groups of food items found in the stomachs of juvenile (51–116 mm TL) hilsa.

Food analysis	Volume (Vi)	Occurrence (Oi)	ViOi	Index of preponderance ViOi X 100 / ΣViOi	Grading
Copepods	55.91	20.13	1,125.47	66.28	I
Organic matter	21.73	16.58	360.28	21.21	II
Green algae	5.97	13.02	77.73	4.58	III
Diatom	2.61	17.16	44.79	2.64	IV
Sand and mud	4.19	9.47	39.68	2.34	V
Rotifers	4.18	6.51	27.21	1.60	VI
Plant tissue	3.17	4.73	14.99	0.88	VII
Blue-green algae	1.04	4.73	4.92	0.29	VIII
Cladocerans	0.86	2.95	2.54	0.15	IX
Protozoans	0.19	2.95	0.56	0.03	X
Ostracods	0.06	0.59	0.04	*	
Nauplii	0.02	0.59	0.01	*	
Miscellaneous	0.07	0.59	0.04	*	
	100.00	100.00	Σ1,698.26	100.00	

Source: De 1986.
(= less than 0.01)*

Table 5. Index of preponderance of broad group of food items found in the stomachs of adult (>116 mm TL) hilsa.

5.5. Seasonal fluctuation in composition of food

Young stage: The volumetric and percentage occurrence in food composition of young hilsa reveals that copepods form a major part of the food items throughout the year. Among copepods, *Cyclops* were uniformly present from October to June. *Diaptomas* and copepod fragments also constituted a major portion of the food items. Among the cladocerans, *Daphnia*, *Moina* and *Bosmina* formed the highest percentage in terms of volume. Among the rotifers, *Trichocerca* was almost uniformly present from October to May. *Spirogyra*, *Lyngbya*, *Oscillatoria* among algae were consistently present in small quantities almost throughout the observation period, while other types of algae occurred casually in the stomach contents of young hilsa. Of the diatoms, *Melosira* was an important food item found in the stomach contents almost throughout the period of study, though in very low percentage volume terms.

Adult stage: Copepods and copepod fragments formed the bulk of food items throughout the year. *Cyclops* were present in the stomach contents during February–May and November but in volumetric percentage terms peaked in February (28.28%) and March (32%). Decayed organic matter was found in the stomach contents of adult fish throughout the year. The maximum and minimum percentages of organic matter by volume ranged from 45 in September to 7.50 in May and by occurrence 25% in September to 8.33% in May. *Spirogyra* and *Lyngbya* were among the most commonly occurring algae present in the stomach during most of the year. The maximum volumetric percentage of *Spirogyra* was 46.50% during January. The diatoms *Melosira* and *Synedra*, though negligible in both occurrence and volume terms, were present in most of months of the year, especially during winter and summer. Other groups of food items, such as rotifers, cladocerans and ostracods, were found occasionally in the stomach contents.

Food composition of different size groups: The percentage composition of food items both by volume and occurrence in fry, juvenile and adult hilsa is given in Table 6.

In hilsa, the absence of teeth and a masticatory apparatus in the mouth and pharynx, respectively, are well compensated for by a highly developed muscular gizzard-like pyloric stomach for crushing food, in addition to its normal function in digestion. While working on clupeid fish, Nelson (1967) found that the development of a gizzard may be considered one of a series of gut specifications, such as loss of teeth, development of a pharyngeal organ, well-developed gill rakers and a moderately long intestine, that indicate microphagous habits in a fish group. The intestine of hilsa is thin-walled and of considerable length. The intestine accommodates 10 bends and five loops. The increase in RLG (length of gut/length of body) value from 0.86 to 1.87 is a result of changes in food and feeding habits in the same environment (De 1986; De and Datta 1990). A similar RLG value for adult hilsa (1.72) was reported by Khanna (1961).

5.6. Feed formulation of hilsa for hatchery and grow-out

No attempt has been made to formulate or provide prepared feeds for hilsa at any of its lifecycle stages in Bangladesh or elsewhere. The experience of feed development for American shad, salmon and marine shrimp may be useful in the preparation of hilsa feed for juveniles to grow-out phases. Wiggins et al. (1985) studied the development, feeding, growth and survival of cultured American shad larvae. They observed that shad larvae experienced a difficult transition from endogenous to exogenous nutrition. The pre-larval stage of development lasted 5–6 days, characterized by the retention of the yolk sac. Feeding began on the fifth day when 22% of the larvae sampled had feed in the gut. There was a low incidence of feeding during the first 9–14 days of postlarval development when less than half of the fish sampled had feed present in their gut. The period of low feeding incidence paralleled periods of slow growth from 6–21 days of age, and high larval mortality occurred during 9–14 days of age.

Wiggins et al. (1985) also observed that larvae more actively sought feed after this period, became more efficient in feeding and that the incidence of feeding increased. Daily larval mortality returned to a level of <0.4% per day, and larvae again began to increase in length. First-feeding larvae selected *Artemia* slightly smaller than the mean length and width available, with greater rejection of large nauplii of 0.55 mm in length. There were dial variations in the incidence of feeding, with the peak feeding periods in the evening (18:00–21:00). The incidence of feeding was higher among larvae reared in continuous light. In another study, Wang et al. (1997) observed that the growth rate of Chinese Reeves shad, *Tenuolosa reevesii*, was positively correlated with the biomass of zooplankton in the rearing ponds.

Efforts may be made to develop mass culture of both green algae/diatoms and zooplankton of river and coastal origin as part of the hilsa hatchery system. At the same time, a plant-based diet for broodstock following the principles used in compounding marine shrimp feed may serve as a preliminary option for hatchery and grow-out feed preparation in Bangladesh. A complete feed system for hilsa may be economically less sustainable. Rather, a mixed fertilization and feeding regime, especially in the case of coastal pond aquaculture, may be a more viable option.

Size groups		Fry (16–50 mm)		Juvenile (51–116 mm)		Adult (167–522 mm)	
Food analysis		Vol.	Occ.	Vol.	Occ.	Vol.	Occ.
Diatoms	*Melosira*	-	-	0.72	3.02	1.87	7.10
(Bacillariophycae)	*Nitzschia*	0.01	0.72	0.06	0.47	0.01	1.18
	Navicula	-	-	0.03	1.43	0.05	2.37
	Asterionella	0.01	0.24	0.01	0.48	-	-
	Cymbella	-	-	0.01	0.15	-	-
	Synedra	-	-	0.05	0.63	0.63	3.55
	Cosinodiscus	-	-	0.07	1.27	*	0.59
	Pleurosigma	-	-	0.01	0.48	-	-
	Cyclotella	-	-	-	-	*	0.59
	Pinnularia	-	-	0.01	0.48	0.05	1.78
Green algae	*Spirogyra*	0.22	2.64	1.25	4.29	3.79	7.70
(Chlorophycae)	*Tribonema*	-	-	0.49	0.48	0.07	1.18
	Pediastrum	0.02	0.48	0.20	0.63	0.08	1.18
	Pleodorina	-	-	0.02	0.15	-	-
	Eudorina	-	-	0.06	0.48	0.96	0.59
	Scenedesmus	-	-	0.33	0.31	0.24	0.59
	Closterium	-	-	-	-	0.83	1.78
Blue-green algae	*Lyngbya*	0.10	0.48	2.55	4.45	0.38	2.96
(Cyanocateria)	*Oscillatoria*	0.42	2.16	0.04	0.63	0.35	1.18
	Aphanocapsa	-	-	0.02	0.15	-	-
	Ulothrix	-	-	0.01	0.15	-	-
	Coelosphaerium	-	-	0.01	0.16	-	-
	Microcystis	0.39	0.48	0.65	1.27	0.31	0.59
	Anabaena	-	-	0.19	0.95	-	-
Protozoans	*Perdinium*	0.01	0.24	-	-	-	-
	Euglena	-		-	-	0.10	1.18
	Ceratium	-		-	-	0.04	1.18
	Difflugia	-		-	-	0.05	0.59
Rotifers	*Trichocerca*	0.76	4.32	2.65	7.15	4.00	3.55
	Brachionus	0.02	1.44	0.54	1.43	0.12	2.37
	Keratella	0.33	0.48	0.24	0.95	0.06	0.59
	Polyarthra	0.01	0.24	-	-	-	-
Copepods	*Cyclops*	28.74	23.93	23.45	15.66	26.00	5.33
	Diaptomus	10.00	14.82	14.74	10.33	0.49	1.18
	Copepod fragments & eggs	20.00	22.94	16.28	11.45	29.42	13.62
Cladocerans	*Daphnia*	9.20	2.16	2.69	3.02	0.43	1.77
	Moina	0.57	1.68	3.85	3.18	-	-
	Bosmina	5.86	0.72	5.74	3.02	0.43	1.18
Ostracoda	*Cypris*	14.83	0.48	14.10	1.75	0.06	0.59
Nauplii		0.11	1.20	0.74	1.59	0.02	0.59
Organic matter		5.45	2.62	5.06	3.18	21.73	16.58
Plant tissue		0.02	4.06	0.19	4.93	3.17	4.73
miscellaneous		0.02	1.20	0.11	0.79	0.07	0.59
Sand & mud		2.90	10.27	2.83	9.06	4.19	9.47

Source: De 1986.
(= less than 0.01)*

Table 6. Composition of stomach contents by volume and occurrence for fry, juvenile and adult hilsa.

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Experimental hilsa aquaculture in earthen ponds at the BFRI/RS in Kalapara.

6. Status of hilsa aquaculture: A review

Authors

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Abstract

Indian shad, *Tenualosa ilisha* (H.1822), commonly known as hilsa, is one of the most commercially important fish species in South Asia. It is a Clupeid species that is widely distributed from the Persian Gulf to the Bay of Bengal and ascends the estuaries, rivers and brackish water lagoons of Indo-Pacific region. Recently, the abundance of hilsa has drastically dwindled in all river systems. Various factors have attributed to the decline of the hilsa fishery. There is thus an urgent need for the conservation of this species, with ranching and mass-scale production of seed for aquaculture being possible approaches. This chapter provides insight into the reproductive biology, artificial breeding, larval rearing and culture potential of the species in confined conditions.

6.1. Introduction

The family Clupeidae includes the most valuable food fish in the world. They are characteristically small in size, as most species are fewer than 250 mm in length. The maximum length record is 600 mm by hilsa shad, *Tenualosa ilisha*. The anadromous hilsa belongs to the subfamily Alosinae, family Clupeidae, order Clupiformes. Hilsa is a widely distributed species inhabiting the coastal waters of the Persian Gulf, Pakistan, India, Bangladesh and Myanmar to North Sumatra and ascending the estuaries, rivers and brackish water lagoons of the Indo-Pacific region. Although the species is well distributed throughout major river systems in India, it is most abundant in the Ganges-Brahmaputra drainage systems (Figure 1). Hilsa ascend the freshwater stretches of the rivers from coastal sea areas primarily for breeding (Hora 1938; Hora and Nair 1940; Jones and Menon 1951; Pillay 1958), thereby forming important lucrative fisheries in coastal areas, estuaries and river systems. However, the abundance of the species has drastically dwindled in almost all river systems of the country. A number of factors are responsible for the collapse of hilsa fishery: the construction of dams and barrages, which have obstructed the migration to natural breeding grounds, high rates of fishing pressure on hilsa in most stages of its lifecycle in both estuarine and riverine areas, alteration of physicochemical parameters of the river ecosystem because of industrial and domestic pollution, and increased water abstraction, resulting in reduced water flows and higher rates of sedimentation in rivers and habitat loss. The loss in habitat is directly related to the recruitment potential of the hilsa fishery. Therefore, the need of the hour is conservation of this species through reducing or stopping pollution and regulating water abstraction. Another means of treating the symptoms is mass-scale production. This is one possible approach to developing a pond-reared strain for potential aquaculture. Many scientists who have studied hilsa (Hora 1940; Pillay 1958) have suggested the possibilities of culturing the fish in confined water bodies. India's National Commission on Agriculture has also suggested that this species could be transplanted to coastal streams, comparing it with such transplantation of Atlantic and Pacific Salmon, though the case with salmon was not successful.

In view of the great national and international interest, as well as the enormous commercial importance of hilsa, there is an urgent need for hatchery development grow-out technology of the species. Although several attempts toward artificial spawning of hilsa have been made since 1908 (Wilson 1909; Southwell and Prasad 1918; Kulkarni 1950), the major breakthrough came during late 1970s (Malhotra et al. 1969; Mathur et al. 1979) in India. Against this backdrop, this chapter will review the studies so far carried out on breeding biology, artificial fecundation, larval development and rearing of hatchlings as well as problems and prospects of culturing the species from both Indian and Bangladesh perspectives.

Figure 1. Distribution of hilsa in major river systems of India and Bangladesh.

6.2. Breeding biology of hilsa

6.2.1. Maturity

Hilsa, *T. ilisha*, is gonochoristic. Unlike other *Tenualosa* sp., there is no evidence of sex change in *T. ilisha* (Blaber 2001), though Chacko and Krishnamurthy (1949) reported a single instance of hermaphroditism. The minimum size of hilsa at first maturity remains somewhat controversial. Current knowledge indicates that the size of sexual maturity attained by males varies from 160 to 400 mm and 190 to 430 mm for females (Table 1). The stages of maturity of female gonads have been studied by few researchers (Pillay and Rao 1962; Mathur 1964; De 1986), but reveal that females below 300 mm rarely participate in spawning. According to De (1980 and 1986), the smallest mature females observed in the Hooghly estuary were about 341 mm in length and 550 g in weight, comparable with the Ganges hilsa, where the smallest mature females, observed at Allahabad, Varanasi and Godavari, were 330, 310 and 370 mm, respectively. Thus, it was concluded that females below 300 mm rarely take part in spawning. Recent studies in the Hooghly estuary during 2010–2011 revealed that the smallest mature females were about 200–250 mm (Figure 2). Climate change associated environmental changes—for examples, in water temperature, salinity, flow regimes and other physicochemical parameters—over past three decades may be responsible. In the Hooghly River, Pillay (1958) reported that the smallest mature females were about 190–200 mm long and mature males 160–170 mm. Pillay (1958) also reported that the smaller-size groups of mature hilsa were 230–250 mm for males and 240–270 mm for females. Based on the value of the gonado-somatic index (GSI), De (1958)

Minimum size at maturity		Water body	Author
Male (mm)	Female (mm)		
300	356	Godavari	Chacko and Ganapati (1949)
280	382	Godavari	Chacko and Krishnamurthy (1950)
216–254	267–305	Hooghly, Chilka and Mahandi	Jones and Menon (1951)
160–170	190–200	Hooghly	Pillay (1958)
256	370	Godavari	Pillay and Rao (1962)
280	341	Hooghly	De (1980 and 1986); De and Sinha (1987)
200	310–350	Ganges at Allahabad	Mathur (1964)
175–300	200–300	Chilka	Jhingran and Natarajan (1966)
172	186	Chilka	Ramakrishnaiah (1972)
360	420–430	Godavari	Rajyalakshmi (1973)
210	320	Meghna (Bangladeshi waters)	Shafi et al. (1977 and 1978)
400	400	Bangladeshi waters	Dunn (1982)
-	415	Kuwaiti waters	Al-Baz (1993)

Table 1. The minimum size of hilsa at first maturity as observed by different researchers.

Figure 2. Matured female (ova stage V) from the Hooghly River.

reported that September–October was the peak breeding season for hilsa, commencing in August, while a short period of breeding activity recorded in the Hooghly estuary came in November to March.

6.2.2. Spawning

The spawning period of this species is seasonal, as with other Clupeid fishes. The spawning season occurs during July–August to October–November in most major river systems, lakes and lagoons, namely the Hooghly (Pillay 1958; Chandra 1962; De 1980; 1986, De et al. 1994), Ganges (Motwani et al. 1957; Nair 1958; Swaraup 1961), Chilka Lake (Jones and Menon 1951), Godavari (Chacko and Ganapati 1949; Pillay and Rao 1962), Narmada (Karamchandi 1961), Tapti (Karamchandi and Pisolkar 1976), Indus (Islam and Talbot 1968), Padma and Meghna (Quddus 1982; Quddus et al. 1984), though in the Hooghly estuary spawning extended up to February and March. By contrast, in the Brahmaputra River, the peak spawning season is from May to July (Rao and Pathak 1972). Moreover, Hora and Nair (1940) and Bhanot (1973) claimed that hilsa spawn throughout the year in the Hooghly, while Pillay (1958) opined that the species spawns intermittently but that it has two distinct breeding seasons and that the same fish does not spawn twice in the same year. Kotwal (1967) also recorded two spawning seasons from Chilka Lake while Mathur (1964) observed the same in the Ganges River.

Based on the histological studies of gonads in different months of the year, Nair (1958) reported that spermatogenesis and oogenesis start by the end of January and peak in March but that the majority of ova undergo reabsorption and artesia, retaining fully mature sperm in the testes. De (1980 and 1986) claims that hilsa spawn once per year, i.e. it has a definite spawning season and that mature ova are shed in a short duration. The prolonged availability of hilsa seed in the Hooghly from July–August to March–April and peaking in October and November suggests that the maturation process of ovaries among the females of ascending shoals was spread over a prolonged period (De et al. 1994). A similar prolonged period of spawning was also noted among hilsa spawning in the Godavari River (Rao 1969).

Job (1942) reported that the breeding period of hilsa varied with location somewhat because of differences in ecological conditions. It is well known that temperature plays a role in the development of gonads as well as in spawning. Nair (1958) reported that the spermatogenesis and oogenesis processes of hilsa were fully active when the temperature rose to 25ºC, though 30ºC inhibited gonadal development, while De (1986) reported that temperatures of 24ºC–29ºC were optimum for spawning. Although a number of spawning grounds have been reported in major river systems, it is likely that spawning sites vary from year to year. Blaber et al. (2001) reported that hilsa spawn in rivers, estuaries and on the coast of Bangladesh (though the proportion of fish spawning on the coast was perhaps lower), but the pattern differed from year to year. Studies carried out by the present authors during 2010–2011 found a higher percentage of hilsa juveniles among catches at two sites than elsewhere: Diamond Harbor and Kalna, between Farakka and Kakdwip in the lower part of Hooghly estuary (Figure 3).

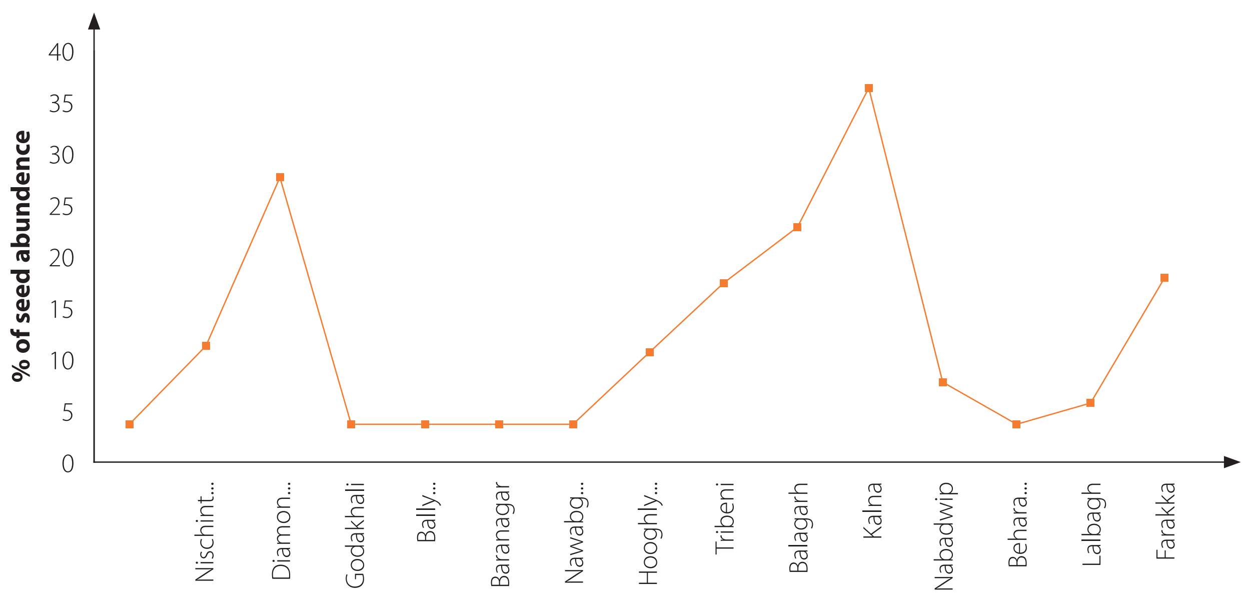


Figure 3. Sites showing peaks and crests of hilsa distribution in the Hoogly River.

6.2.3. Fecundity

Hilsa are prolific breeders. Depending upon the size of the fish, fecundity varies from 250,000 to 2,917,000 (Table 2). De (1986) reported that the number of mature eggs per g of bodyweight ranged from 502 to 1350 with an average of 1190, while the average number of mature eggs per gram of ovary weight was 7460. Pillay (1958), Swarup (1961) and Mitra and De (1985) have observed a linear relationship between fecundity and bodyweight.

6.3. Artificial propagation of hilsa: Attempts made from the Indian continent since 1909

Since 1909, several attempts have been made to artificially propagate hilsa. Wilson (1909) was the first to successfully fertilize hilsa eggs artificially at the lower anicut (dam) on the Coleroon River, a branch of the Cauvery River. In 1912, staff at the Madras Fisheries Department created a hatchery, based on McDonald Jars, for the mass production of hilsa hatchlings for ranching in South Indian rivers. However, no hilsa broodstock could be procured. Attempts by Raj (1917) also failed. Southwell and Prasad (1918) were able to fertilize hilsa eggs collected from Monghyr on the Ganges River, but the eggs failed to hatch. The Madras Fisheries Department shifted its hatchery to the Bezwada anicut on the Krishna River in 1926 and finally to Babburlanka on the Dowlaishwaram anicut on the Godavari River in 1934. However, all attempts proved unsuccessful. Kulkarni (1950) and Dixitulu and Chacho (1962) successfully bred the fish, but did not succeed in rearing the hatchlings beyond 2–3 days. Meanwhile, several researchers (Jones and Menon 1951; Motwani et al. 1957; Karamchandani 1961) recorded the early development of fertilized hilsa eggs based on natural collection from the Ganges, Hooghly and Narmada rivers. By the late 1960s and early 1970s, Malhotra et al. (1969 and 1970) and Mathur et al. (1974) successfully bred hilsa by stripping after collecting them ripe from the middle reaches of the Ganges River and were able to rear the hatchlings for two years in freshwater ponds. During 1980–1981, an attempt was made by Bhanot and De (1984) to culture the species in freshwater ponds by collecting fry from freshwater areas of the Hooghly estuary. They succeeded in rearing the fish for 32 months up to final weights of 350–450 g. More recently, De (1986), De and Sen (1986), Sinha (1987) and Sen et al. (1990) successfully bred hilsa by wet stripping ripe fish obtained from the lower stretches (downstream of the Farakka Barrage) of the Ganges River and successfully rearing the hatchlings in a freshwater pond system at Rahara farm in West Bengal for 4 months.

Artificial fecundation through hypophysation failed since it was not possible to keep the spawn/juveniles alive for any length of time. Moreover, all attempts based on the stripping method were only a partial success, being dependent on supplies of live, fully mature male and female hilsa procured from fishers.

6.3.1. Stripping and fertilization

Both wet and dry methods of stripping were adopted for fertilizing hilsa eggs. However, the wet method proved the most suitable for large-scale production of fertilized eggs. De (1986) and Sen et al. (1990) reported that the most favorable times for fertilization were afternoon and evening. Immediately after fertilization, the eggs start to swell and the color of the yolk turns light greenish yellow from its original light yellow. Some 15–20 min after fertilization, the eggs become almost colorless and reach 1.95–2.10 mm in diameter with an average of 2.02 mm. The eggs get very soft, smooth, nonadhesive and almost spherical in shape. They are almost demersal in nature in water, easily

River systems	Fish size (TL) in mm	Fecundity	Researchers
Hooghly estuary	253–481	250,000–1,600,000	Pillay (1958)
	343–522	373,120–1,475,676	De (2001)
Ganges (Allahabad)	331–490	321,579–1,447,450	Mathur (1964)
Ganges (Varanasi)	315–506	316,316–1,840,179	Mathur (1964)
Godavari estuary	401–548	400,000–1,300,000	Pillay and Rao (1962)
Narmada	2,100 g	1,864,000	Kulkarini (1950)
Padma	273–420	348,318–1,465,969	Doha and Hye (1971)
Meghna	380–520	380,000–1,820,000	Shafi et al. (1977 and 1978)
Indus	358–550	755,000–2,917,000	Islam and Talbot (1968)
Padma and Meghna	342–520	660,000–1,547,000	Quaddus et al. (1984)

Table 2. Hilsa fecundity estimated in different river/estuary systems.

buoyed and drift with the slightest current. The eggs have a wide transparent perivitelline space. The yolk is also roughly spherical with an average diameter of 0.88 mm (De 1986). As in other Clupeoid eggs, the yolk matter is segmented into numerous oil globules.

6.3.2. Embryonic and early larval development

The embryonic and larval development of hilsa has been studied in detail by many researchers (Kulkarni 1950; Malhotra et al. 1986; De 1986). The rate of cleavage and embryonic development vary depending on water temperature, with the incubation period being 18–20 hours at 28.5ºC (Kulkarni 1950), 18–20 hours at 23.5ºC–30ºC (Malhotra et al. 1986) and 18–21 hours at 24ºC–29ºC (De 1986). The embryonic and early larval development of hilsa studied by De (1986) and De and Sen (1988) are summarized in Figure 4, and the different stages involved during the incubation period is depicted in Figures 5 and 6.

First cleavage takes place 40 minutes after fertilization.

Morula stage is attained in about 3.5 hours followed by blastula and then gastrula in 5.5 hours.

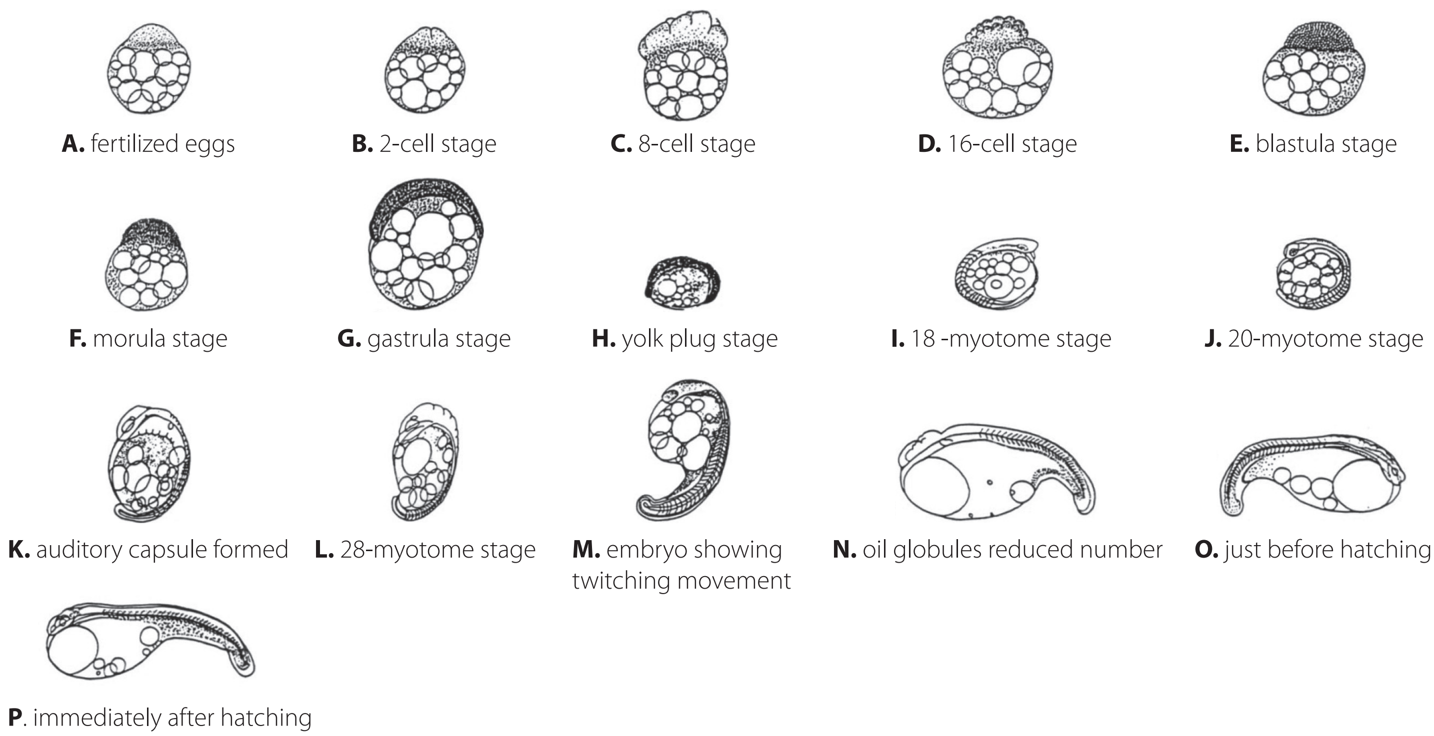
**Optics vesicles and myotomes appear in 10 hours.
The head and tail regions differentiate in about 10.25 hours.**

Auditory capsules develop in 13 hours.

Faint twitching movements occur after 16 hours.

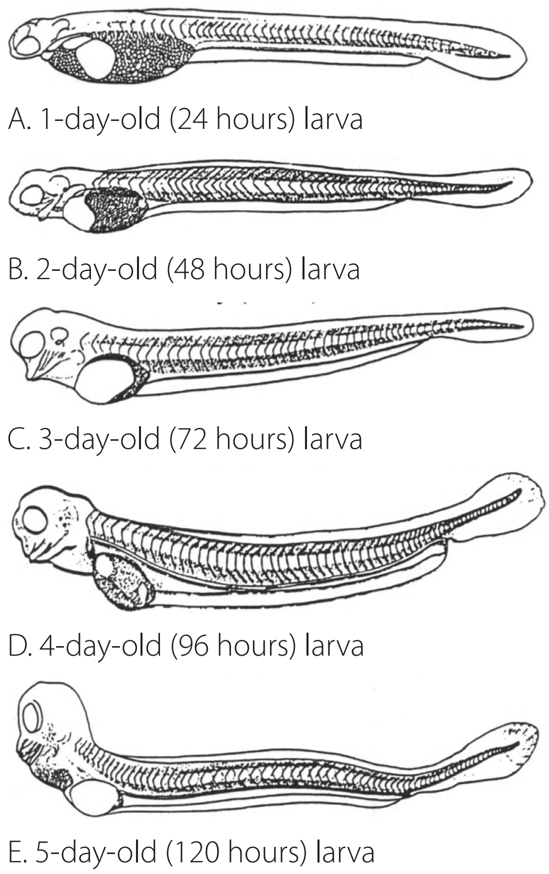
Hatching commences in 16–18 hours and completes in 20–21 hours at 24ºC–29ºC, with dissolved oxygen levels of 65–85 and a pH of 7.6–7.8.

Figure 4. The embryonic and early development of hilsa.



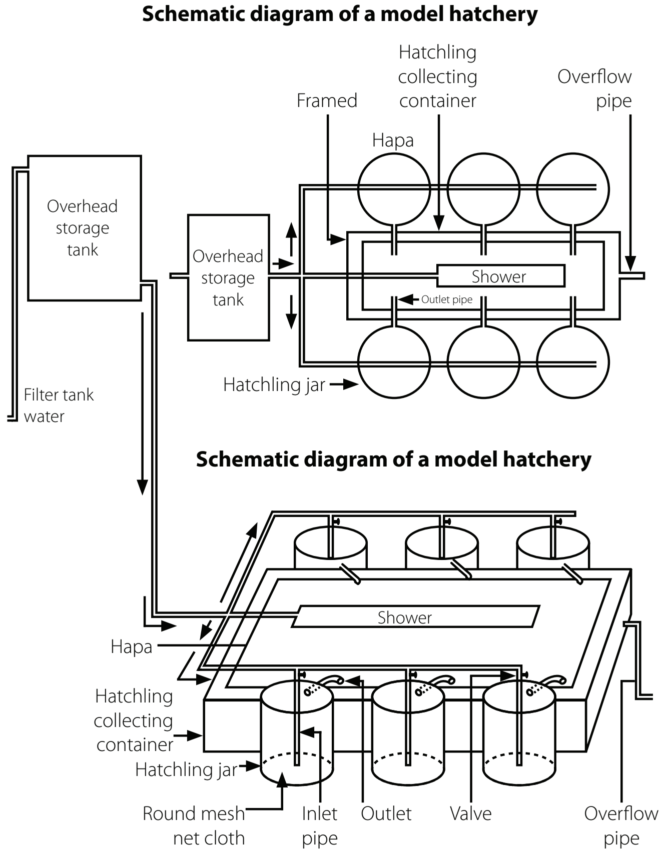
Source: De 1986.

Figure 5. Embryonic and early larval development stages of hilsa.



Source: De 1986.

Figure 6. Developmental stages of hilsa larvae from Day 1 to Day 5.



Source: De 1986.

Figure 7. Grid circular hatchery developed at the CIFRI, Barrackpore.

The newly hatched larvae are devoid of a mouth and pigmentation and generally remain on the bottom resting horizontally on their backs. At this stage, they measure 2.41 mm in length. Day-old larvae have an average length of 3.75 mm and possessed a tubular heart and paired pectoral fin buds. By Day 2, larvae measure 3.97 mm and the anus is now distinguishable. Eyes are enlarged and caudal fins are not yet regularly arranged. By Day 3, larvae measure 4.15 mm and are seen with mouths open. On Day 4, larvae measure 4.42 mm with the mouth opening shifted toward the terminal position. On Day 5, they measure 5.12 mm and the yolk sac is considerably reduced. After Day 5, the larvae start swimming actively. Complete absorption of the yolk sac is observed after Day 8. The details of the development stages, from eggs to larvae, are shown in Figure 5.

6.4. Hilsa hatchery at the CIFRI in Barrackpore, India

During 2000, the CIFRI designed a model hilsa hatchery and a circular grid hatchery for incubation, hatching and rearing of hilsa hatchlings. The model hilsa hatchery mainly consists of three units: an overhead tank, an incubation unit and a hatchling collection unit (Figure 7).

6.4.1. Overhead tank

Cleaned decanted river water is stored for the entire hatchery operation. The 5000 L tank is placed 4 m above ground level.

6.4.2. Incubation unit

This unit consists of a battery of circular 15 L glass jars, which are open at the top. The inner diameter of the jars is 30 cm. Each jar receives water from the storage tank through an aluminum or polyethylene pipe, which projects vertically to the mid-point of the jar. A mesh cloth, held in a circular frame with a diameter approximating the inner diameter of the jar, is fitted inside the jar horizontally a little below the opening of the outlet. The distal end of the inlet pipe, which is provided with uniform perforations all around, extends to near the bottom of the jar in such a way that the outflow of water from the bottom of the jar is in the form of a sprinkle. The top of the jar is fitted with a spout, which serves as an outlet for excess water.

6.4.3. Hatchlings unit

The hatchlings unit consists of a fiberglass tank provided with an outlet pipe, fitted with a framed fine mesh nylon cloth hapa and an overhead sprinkler. The fiberglass tank is used as a hatchling collection container. The outlet pipes of the hatching jars are placed in such a manner that the discharged water and hatchlings are collected in the filtered hapa fixed in the fiberglass tank. An overhead sprinkler sprays fresh and river water, augmenting the supply of oxygen and maintaining a gentle water circulation with a constant flow in the hatchlings unit.

6.4.4. Operation of the model hatchery

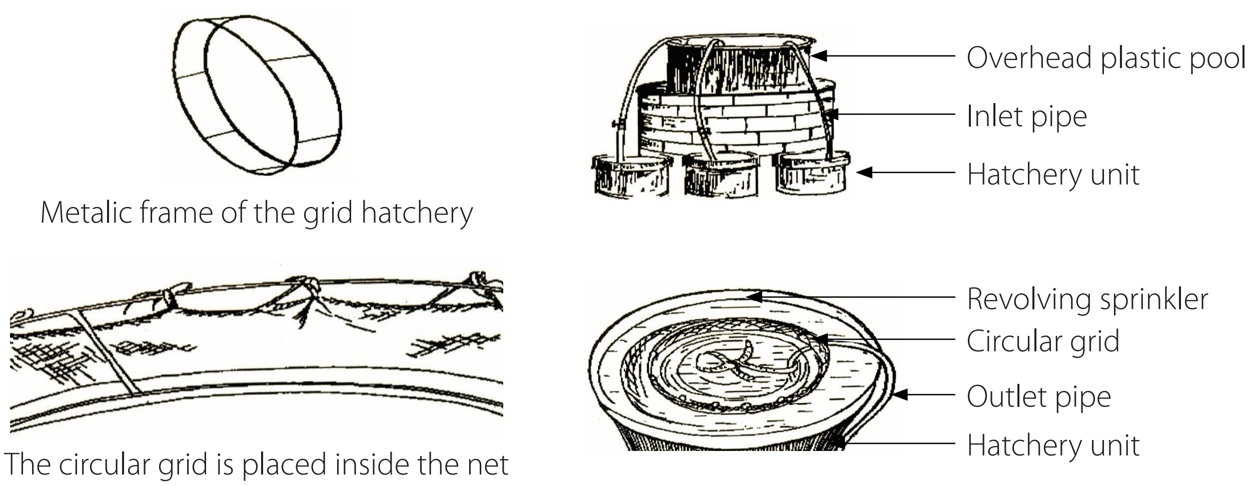
After repeated washing with fresh river water, the fertilized hilsa eggs are kept for some time in the stripping tray for water hardening and then released directly into the hatchling jars. At least 6000–8000 developing eggs can be kept in each jar containing 15 L of running water. The hilsa eggs are very soft, nonadhesive and demersal in nature. A very low rate of water flow must be maintained, sufficient enough to keep the eggs in buoyant conditions. After hatching, the postlarvae move vertically upward. Habitual upward vertical movement, coupled with similar movement of the water, facilitates the hatchlings' escape through the horizontally placed net cloth. Only unfertilized eggs and broken eggshells remain inside the hatching jars below the net cloth, and these are removed manually at the end of the hatching operation. The collected hatchlings are kept in the hatchling containers/units for 2–3 days before stocking in nursery ponds.

6.4.5. Circular grid hatchery

In addition to the model hilsa hatchery, the CIFRI has also designed and created a robust portable circular grid hatchery for incubating and hatching fertilized hilsa eggs (Figure 8).

The grid circular hatchery consists of a plastic pool 1.2 m in diameter and 0.9 m in height with a water outlet 0.15 m below the top, a revolving sprinkler and a circular grid. The grid is made of two rings of thick wire each 0.6 m diameter and attached to one another as shown in Figure 8. A circular net with 1.5 mm-size mesh at the bottom and 2 mm at the side is purposely made to suspend from the grid frame. The sprinkler with its inlet pipe from the overhead plastic pool is placed at the bottom of the plastic pool, which is filled with the water until it flows out through the outlet. The grid is now placed at the center of the plastic pool and kept 15 cm below the water surface by two supports, which hold the grid in position by means of four hooks fitted to the top of the grid, as shown in Figure 8. The grid of the hatchery unit is now ready to receive water-hardened hilsa eggs. The capacity of each unit in the hatchery complex is 1.5 lakh L (1.5 x 10^5 L) of water-hardened eggs. Eggs are gently placed in the grid, and a gentle circular current of water is maintained through the revolving sprinkler. Within 18–21 hours at 28ºC (27ºC–29ºC), the hatchlings emerge from the eggshells and find their way to the plastic pool through the side wall of the grid. The grid, along with the bad (unfertilized) eggs and eggshells are then removed from the hatchery unit. The overall percentage survival of hatchings is 50%–85%. Hatchlings are collected by lifting the hapa and thinning it out prior to rearing. Using this method, the hatchling survival rate is about 80%.

Comparable results for hatching rates of hilsa eggs in hapas established in rivers and in nursery ponds varied from 5% to 80% in riverine environments and 15% to 80% in nursery ponds Malhotra et al. (1969). The authors also observed that water chemistry played an important role in hatching success. A pH range of 7.4–7.6, Ca levels of 62.5–133 ppm and Fe concentrations of 0.6–2.2 ppm were most suitable. Greater hatching success, however, was observed when developing



Source: De 1986.

Figure 8. Grid circular hatchery developed at the CIFRI in Barrackpore.

eggs were incubated under laboratory conditions, with continuous and regulated flows of water (De 1986; De and Sinha 1987; Sen et al. 1990).

6.5. Culture of hilsa

6.5.1. Transport of hatchlings

The culture success of a species to some extent depends upon a reliable method of transport of hatchlings for stocking purposes. A series of experiments have been conducted on the transport of hilsa hatchlings using both open and closed systems. In the closed system, conditioned fry were packed in experimental polythene bags (16 L capacity) placed in a tin carrier with 4–5 L of sieved clear river water under pressurized oxygen. The number of fry packed ranged from 5 to 10/L of water. The duration of transport was 2–6 hours. In the closed system, under pressurized oxygen, high rates of mortality were observed. Almost 100% mortality was recorded when an anesthetic such as chloral hydrate was used at rates of 25, 50, 75 and 100 mg/L.

Conditioned fry were also transported in open plastic pools (capacity 200 L), for 6 hours without artificial aeration or oxygenation. Clean, filtered river water was used in all experiments conducted with this system, with the stocking density of fry varying from 1 to 4/L of water. The results were highly encouraging. Hilsa fry could be transported in a fiberglass tank at a density of about 800 fry in 200 L of water for up to 6 hours with a 60%–75% survival rate. The results were judged sufficiently encouraging to opt for an open system type of transportation for further rearing in well-prepared ponds.

6.5.2. Rearing and culturing hilsa in confined waterbodies

Several researchers have attempted rearing hilsa by stocking hatchlings obtained from both nature and artificial spawning (Table 10). To date, mass mortality of hatchlings or fry has been recorded, under all types of rearing conditions, because of poor water conditions and pond management, and the absence of ideal food. The change in habitat may also be to blame, as morphological or physiological changes occur in wild fry and fingerlings as they start to migrate from freshwater to saline water. Others claim that growth of hilsa in rearing experiments is not much different from natural growth rates (De 1986; De and Datta 1990). Further insights were gained by an experiment conducted at the CIFRI in Barrackpore through culturing hilsa in a 0.1 ha freshwater pond, which demonstrated the possibility of aquaculture for the species. Fry were collected from the upper stretch of the Hooghly estuary and stocked in the pond. Before stocking, the pond was cleared of existing fish fauna by applying mahua (*Madhuca longifolia*) oil cake at a rate of 250 mg/L. Lime was then applied at 200 kg/ha and no supplementary feed was provided. The growth rate was calculated bimonthly while physiochemical conditions of the pond water were determined monthly. Plankton samples were collected monthly between 09:00 and 10:00 in the morning for quantitative and qualitative analyses.

Author(s)	Material obtained for stocking	Culture system	Initial size	Rearing period	Growth attained
Pillay (1950)	Natural collection	Cemented cistern	50–80 mm	9 months	40 mm in length
Malhotra et al. (1969 and 1970)	Artificial breeding	Freshwater pond (100 x 90 ft)	2.5–6 mm	36 days 69 days 1 year 2 years 2 years and 4 months	41.0mm 53.0 mm 155.0 mm 320.5 mm 345.5 mm
Bhanot and De (1984)	Natural collection	Freshwater pond (0.1 ha)	25–60 mm	1 year 2 years 2 years and 8 months	180.0 mm/125 g 310 mm/300 g 350 mm/425 g
Sharma (1984)	Natural collection	Freshwater pond	100–400 g	1 year and 6 months	300–800 g
Panicker et al. (1984)	Artificial breeding	Vallabsagar Reservoir	20–25 mm	1 year and 5 months 1 year and 7 months	500 g 600 g
De and Sinha (1984)	Artificial breeding	Cemented pond (300 m^2)	3.5–4.5 mm	47 days	40 mm
Saha and Acharya (1990)	Natural collection	Freshwater tank	20 mm	5 months	121.1 mm
Sen et al. (1990)	Artificial breeding	Freshwater nursery pond (0.04 ha)	3.6–4.1 mm	4 months	80 mm

Table 10. Growth of hilsa in different culture conditions reported by different authors.

Gut contents of pond-reared specimens were analyzed. Hilsa fry (25–60 mm) were collected using a fine-meshed nylon drag net from the Hooghly estuary at Barrackpore and Dhatrigram, some 195 and 280 km, respectively, from the sea, and then transported using the open container method (De et al. 1986). Prior to stocking, fry were acclimatized for 1 hour. In total, 372 fry were stocked in 1980 and 621 fry in 1981, and the culture work continued for 2 years and 8 months.

The average length/weight of stick were 180 mm/125 g at the end of the first year of rearing and 310 mm/300 g at the end of the second. The survival rate was 30% at the end of Year 1 and 11% at the end of Year 2. At the end of the trial, after 2 years and 8 months, fry had attained an average length of 350 m and weight of 425 g, with a survival rate of 7%.

Experiments on rearing artificially produced hatchlings were also tried to determine growth and survival. The artificial breeding was done in the lower stretch of the Ganges River and 49,000 2- and 3-day-old hatchlings were transported from Farakka to Rahara Research Centre at the CIFRI, a distance of 300 km. The hatchlings were transported in open containers (without oxygen) at a density of 1000/L in clean, settled river water. Hatchlings were stocked in a well-prepared nursery pond (0.04 ha). Two months prior to stocking, the pond was cleared of unwanted fish and other harmful insects by applying mahua oil cake at 250 mg/L). After one month, lime was applied at 200 mg/ha, and Sumithion, a pesticide, was also applied at a dose of 0.5 mg/L to eradicate macroplanktonic fauna in the pond. Hatchlings were provided with finely powdered supplementary feed prepared with rice bran and ground nut oil cake at a rate of 5–10 g (1:1 ratio) once per day to supplement the natural food present in the nursery pond.

Several thousand fry survived for 30–35 days. Mortality started thereafter and by the end of second month most fry had died. A few fry were reared for 3 months and even fewer survived for 4 months. The stock attained average sizes of 30, 58, 65, 70 and 80 mm at the end of 27, 50, 75, 90 and 120 days of rearing in a pond, respectively (Table 11). While the same hatchlings stocked in a well-prepared cement cistern with supplementary feeding averaged 40 mm after 47 days of rearing all died thereafter. With a view to propagating hilsa in reservoirs, 500 fry (20–25 mm) obtained through artificial breeding were released in Yallabhsagar in October 1979. After 17 months of stocking, commercial fishers caught two hilsa specimens weighing about 500 g each, and one more gravid female hilsa weighing 600 g was caught just 2 months later (Panicker et al. 1982). The West Bengal State Fisheries Research Station, in collaboration with progressive farmers at Jaipur, made similar attempts at hilsa farming. Hilsa weighing 100–400 g were collected from natural sources and stocked in a well-prepared pond. Of the 190 hilsa liberated, only 80 specimens survived. After 1.5 years of culture, the stock had grown to 300–800 g in weight (Sharma 1984).

Expt number	Date of stripping	Hour of stripping	Size of male (g)	Size of female (g)	% of fertilization	Total production of hatchlings	Hatchling stocked	Size attained at the end of culture
1	16 October 1984	15:10	425–475	600	40	4,000	3 days old stocked in natural ponds	80 mm at the end of 4 months
2	16 October 1984	15:30	700	1,300	45	21,000	2 days old stocked in natural ponds	
3	16 October 1984	16:50	350-400	600	50	20,000	2 days old stocked in natural ponds	
4	16 October 1984	15:30	700	1,600	30	4,000	2 days old stocked in natural ponds	
Total						**49,000**		

Source: Sen et al. 1990.

Table 11. Results of experiments on artificial fecundation and rearing.

6.6. Attempts at hilsa aquaculture in Bangladesh

In Bangladesh, the increase in fishing pressure on both juveniles and adults, along with the loss of spawning grounds and obstruction of migratory routes by anthropogenic activities, has caused declines in the fishery in the upper reaches of rivers (Haldar and Rahman 1998; Rahman 2001 and 2006; Mome 2007). These factors, coupled with the large-scale transformation of fishing craft from artisanal to mechanized, and increasing demand for the fish by the rapidly increasing population have synergistically affected the abundance of the species in the rivers. On the other hand, catches from the marine environment seem to be increasing a little (Rahman 2006; Mome 2007). Given the situation, many fishery biologists and fishery managers have paid considerable attention to managing the species in both freshwater and marine environments. In Bangladesh, the HFMAP has been formulated and is being implemented, resulting in enhanced hilsa production. In addition, transboundary management initiatives among Bangladesh, India and Myanmar are being discussed under the auspices of the Bay of Bengal Large Marine Ecosystem (BoBLME) project. Hilsa fishery experts have considered artificial propagation and sea ranching as solutions for increasing production. Malaysia, for example, has successfully cultured and reseeded terubok *Tenualosa toli* in Sarawak (Pang and Ong 2001; Kashim et al. 2012). But the main impediments have been adapting the species to a confined environment where it can attain sexual maturity and thereby be induced to breed. In Bangladesh, the first approach to culturing hilsa in ponds was undertaken in 1988 through a project funded by the International Development Research Centre (Canada). Sporadic trials were then carried out at Chandpur Riverine Station via an Australian Centre for International Agricultural Research (ACIAR) project until 1996. Recently (2010–2012), another initiative has been undertaken to address obstacles and to study some biological aspects of hilsa in a confined environment, but the area of this science is still in the rudimentary stages.

6.6.1. Recent observations

This trial was carried out for 15 months (August 2010–October 2011) in three ponds at the BFRI/RS in Chandpur. The area of each experimental pond was 33 decimals (1335 m^2). Before the *jatka* were released, each pond was repeatedly netted to remove all fish, and rotenone was applied to remove other aquatic animals. Water levels were maintained at >3 m, 1.8–2.4 m and <1.83 m in the three ponds, respectively. Ponds were then limed (CaO) at a rate of 1 kg/40 m^{-2}. One week after liming, organic-inorganic fertilization was carried out to promote the production of phytoplankton and zooplankton. Fertilization and manuring were carried out fortnightly after stocking. Important physicochemical parameters—namely water depth, transparency, water temperature, pH, dissolved oxygen and free carbon dioxide of pond water—were monitored on each sampling date between 09:00 and 10:00. Mean length and weight of the fish samples were also determined on each sample date (07:00–08:00).

6.6.2. Sources, collection and transportation of fry

Hilsa fry (*jatka* <23 cm TL) were collected from the Meghna River *jatka* sanctuary areas. *Jatka* were harvested by shore seining at the eastern shallow bank of the Meghna near Chandpur. Live *jatka* were quickly transported by boat and a pickup truck in a 200 L trough and then in polyethylene bags filled with oxygenated water. The trough and bags were covered by a black wet cloth to reduce the effects of high temperature and light to which the juveniles were sensitive. Within 40 to 60 minutes, *jatka* were transferred to the ponds and released after acclimatizing in pond water for about 15 minutes. During transportation, the mortality rate of fry was approximately 53%.

Fry (*jatka*) transported in troughs and in polythene bags being covered by wet black cloth.

6.6.3. Growth performance of the transported jatka

The growth patterns of juvenile hilsa in a freshwater pond for 15 months are presented Figure 9. The mean initial TL and weight of fish at stocking were 16.0±7.0 g and 11.0±3.0 cm, respectively. After 15 months, the average TL and weight gained were 29.24±5.0 cm and 274.38±55.0 g. The survival rate was about 40% in the first pond and 54% in the second.

Several trials were made with juveniles harvested in the Meghna River and nursed and reared in ponds at the BFRI/RS in Chandpur. In all cases, growth performance was very poor in pond conditions. The growth of pond-reared hilsa was about 35% less than that of natural riverine hilsa. In all cases of experimental pond culture, survival rates were very low, varying between 25% and 40%. However, the taste of fish between the two sources, pond-reared and natural, was not so varied. A 10-member panel sampled cooked pond-reared and riverine hilsa of the same age group and found no discernable taste difference between the two.

6.7. Plankton diversity in ponds and rivers

Plankton diversity in *jatka*-reared pond water and natural riverine habitats were compared. About 2700–3500 plankton units l^{-1} were found in the hilsa ponds. There have been great differences between plankton varieties in the hilsa ponds and a riverine environment (Tables 12 and 13).

Some of the female pond-reared hilsa were sacrificed to investigate gonadal development after one year. They attained only the first stage of maturity, while river hilsa reached beyond the second (Figure 10).

Water quality of experimental ponds was within the normal range as experienced by the species and so was not much different from natural riverine habitats (Table 14).

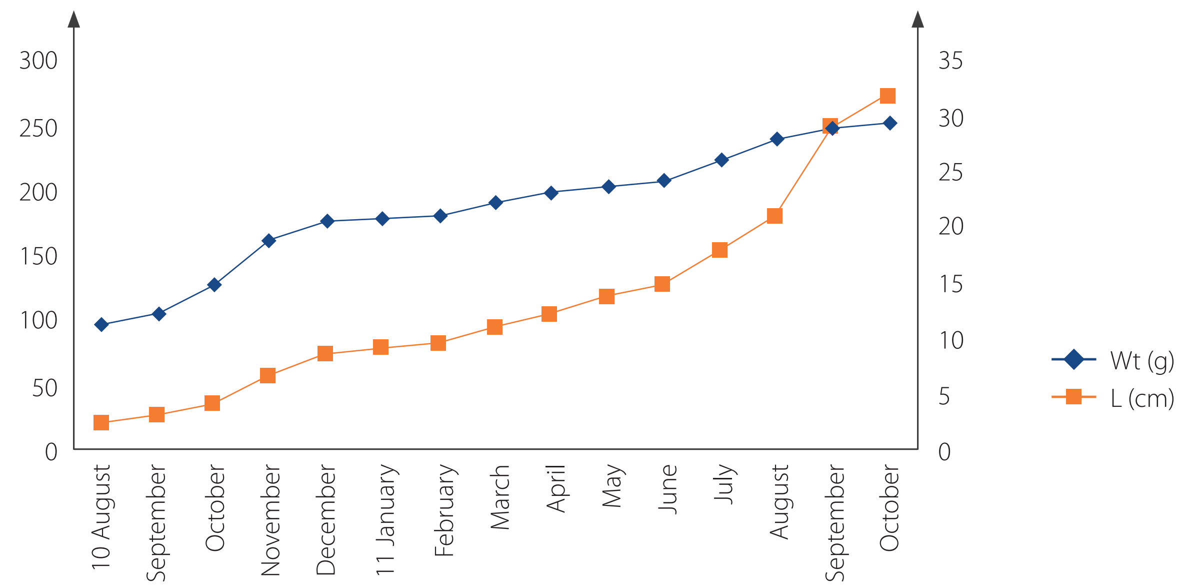
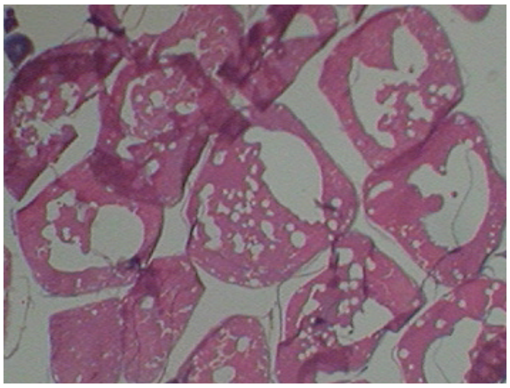


Figure 9. Changes in mean total length and mean weight of hilsa in experimental ponds.

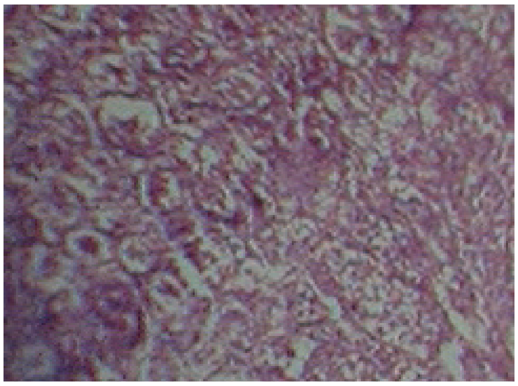
Plankton group	Family	Genera
Phyto-	Chlorophyceae	*Pediastrum, Scenedesmus, Spirogyra, Volvox*
	Myxophyceae	*Microcystis, Nostoc*
	Bacillariophyceae	*Amphora, Asterionella, Diatoma, Navicula, Nitzschia*
	Euglenophyceae	*Euglena*
	Xanthophyceae	-
	Dinophyceae	*Ulothrix*
Zoo-	Brachionidae	*Brachionus, Keratella*
	Cyclopidae	*Cyclops*
	Diaptomidae	*Diaptomus*
	Daphnidae	*Daphnia, other Nauplius*
	Sididae	*Sida*
	Testudinellidae	*Filinia*

Table 12. Diversity of plankton in experimental freshwater hilsa ponds.

Regarding fry production and aquaculture, although some improvements have been made in gamete collection from wild fish and also from captive broodstock in India and Bangladesh, the hilsa seed supply remains far below the requirements of a successful aquaculture program. Recent efforts by the BFRI for hilsa larval rearing are encouraging but need thorough revision and development of protocols and continued field experience. Before this popular but undomesticated aquaculture species can be grown commercially, there is a need to carry out extensive trials to improve spawning techniques, develop feed and improve husbandry at all stages.



River hilsa in the second stage.



Pond hilsa only in the first stage.

Figure 10. Gonadal development of river and pond hilsa after 12 months.

Plankton group	Family	Genera
Phyto-	Chlorophyceae	*Pediastrum, Spirogyra, Volvox, Spirulina, Gomphonema, Melosira*
	Myxophyceae	*Microcystis, Nostoc*
	Bacillariophyceae	*Amphora, Asterionella, Diatoma, Navicula, Nitzschia*
	Euglenophyceae	*Euglena*
	Xanthophyceae	-
	Dinophyceae	*Ulothrix*
Zoo-	Brachionidae	*Brachionus, Keratella*
	Cyclopidae	*Cyclops*
	Diaptomidae	*Diaptomus, Diaphanosoma*
	Daphnidae	*Daphnia, Bosmina, other Nauplius*
	Sididae	-
	Testudinellidae	*Polyarthra*

Table 13. Diversity of plankton in the Meghna River.

Parameters	Mean (Nursery)	Mean (Spawning ground)	Mean (Pond)
Air temperature (°C)	34.26± 2.44	28.75± 4.43	36.2±2.70
Water temperature (°C)	30.55± 0.64	28.06± 0.85	35.89±2.22
Dissolved oxygen (mg/L)	5.53 ± 0.51	5.77± 0.51	9.97±1.8
Free CO_2 (mg/L)	11.77±2.81	13.47±1.32	21±0.11
pH	8.07± 0.42	7.94± 0.48	8.5±7.25
Total hardness (mg/L)	78.00± 6.41	184.00± 6.01	117.72±4.45
Total alkalinity (mg/L)	70.33± 8.92	64.00± 8.32	117.92±10.5
SD transparency (cm)	47.72 ± 21.42	16.50± 20.23	-
Salinity (ppt)	-	1.20± 0.41	-

Table 14. Mean water quality parameters of experimental hilsa ponds, nursery and spawning grounds.

6.8. Conclusions

T. ilisha is the most important and prized edible fish in the Indian subcontinent, rich in omega-3 and omega-6 fatty acids and consumed by more than 250 million people across the globe. After recognizing the commercial importance of hilsa in 1951, the Indo-Pacific Fisheries Council (IPFC) of the Food and Agriculture Organization set up a hilsa subcommittee with representatives from India, Pakistan and Burma to carry out research on this fish for development of both capture and culture fisheries. Indian shad live in marine and coastal waters. The adult hilsa migrate from the sea to freshwater rivers to breed and the young return to the sea when they attain adulthood. Wild stocks of hilsa are in decline, largely because of hydrological changes in the major spawning habitats in the Ganges River watershed as a result of the construction of dams and barrages, as well as overfishing and habitat degradation. The consequences of the current situation are likely not only to result in the loss of a cultural icon for the people of Bengal, but also an important and nutritionally significant food fish, particularly for the poor. It is thus extremely pressing that a standardized breeding and culture protocol is developed to aid the conservation of the species and for income generation of millions through culture-based practices. In addition, this will also provide a new species for culture in regions of the Ganges Delta, which are increasingly affected by saline intrusion as a result of climate change.

Developing a new aquaculture species is always challenging and is a multifaceted process. It involves developing new technologies, including broodstock and hatchery management, live feed production, larval rearing and on-growing techniques. With several disciplines involved, a systematic and collaborative approach is needed for a better use of resources and to ensure success. Before a new aquaculture species can be grown commercially, there is a need to carry out extensive laboratory trials to improve spawning techniques, feed development and husbandry at all stages. Streamlining all these processes will enable the development of a successful aquaculture venture for commercial growers. Several experiments on artificial breeding for mass-scale production of hilsa seed have proved successful. The key difficulties remain with the grow-out or rearing phases of the species. Although some other key parameters, such as the water quality of the culture system and the appropriate quality of supplementary feed, particularly for hatchlings and fry, have been identified, it is essential to adopt a more holistic approach and to learn lessons from the farmed Atlantic salmon and cod industries. Broodstock management is the cornerstone of any aquaculture program because subsequent success of juvenile production is dependent on the production of quality gametes. Studies have shown that larval and juvenile growth and survival of finfish are affected by genetics (parental origin) and environmental conditions in captivity, i.e. management (Solemdal 1997; Kallio-Nyberg et al. 2000; Grindstaff et al. 2003; Fish et al. 2004; Green and McCormick 2005; Eriksen et al. 2006; Probst et al. 2006; Hansen and Puvanendran 2010). Therefore, mismanagement of broodstock will lead to inferior quality gametes and ultimately affect larval and juvenile growth and survival.

In conclusion, hilsa culture is in its early stages, and research and development efforts must be carried out on all life stages from larvae to broodstock in all aspects discussed above before any attempt to commercialize hilsa aquaculture. In particular, efforts must be directed toward understanding the different aspects of the biology of hilsa that are most critical to establishing commercial farming, namely reproduction, larval and juvenile development and growth. Regional collaboration with all stakeholders, including governments, research institutes, NGOs and the private sectors, is needed to work together toward the successful commercialization of hilsa aquaculture in South Asia.

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Photo credit: Mohammad Mahabubur Rahman/WorldFish

Hilsa in a basket, Bangladesh.

7. Population genetic structure of hilsa and prospects for genetic improvement: A review

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Abstract
The population genetic structure of hilsa (*Tenualosa ilisha*) has been studied using morphometric characterization, allozyme markers, Random Amplification of Polymorphic DNA (RAPD), Restriction Fragment Length Polymorphism (RFLP) and mitochondrial DNA Cytochrome *b* gene nucleotide sequence with varied results. The hilsa population of the Brahmaputra, Padma, Ganges and Hooghly rivers as well as the Feeder Canal in India did not exhibit significant genetic diversity to indicate the presence of a genetically unique stock in these regions. The phylogenetic relationship between the hilsa of the Bay of Bengal and the Arabian Sea using Cytochrome *b* gene sequence analysis found that they belong to two different clusters. Moreover, three genetically distinct populations of hilsa (riverine, estuarine and marine) seem to be present in Indian and Bangladesh riverine systems. Examination of a much large number of hilsa samples, from a broad range of sites throughout Bangladesh, based on genetics and morphology found them to belong possibly to the same stock of hilsa found throughout the Bay of Bengal. In addition, hilsa from Myanmar, Kuwait and Northern Sumatra in Indonesia were also analyzed. The samples from the Persian Gulf were found to be genetically different. Sufficient genetic variability is a prerequisite for any selective breeding program, since growth rate is the primary trait of selection for any fish breeding program. Genetic improvement of hilsa may be possible, provided standardized breeding and hatchery technologies are developed and moderate heritability for traits under selection is estimated.

7.1. Introduction

Hilsa shad (*Tenualosa ilisha*) is one of the most highly relished and economically important anadromous fish particularly in the countries of the Indian subcontinent, bordering the Bay of Bengal. The fish inhabits coastal region in the continental shelf, estuaries and freshwater rivers in Indonesia, Myanmar, Bangladesh, Pakistan, Kuwait, Iraq and Iran to the west of India in the Arabian sea and the Bay of Bengal (Pillay and Rosa 1963). In Bangladesh, hilsa is considered as the national fish. It forms major fisheries, contributing as much as 11% of national fish production (FRSS 2010). Moreover, hilsa is also extremely popular and highly valued in the Bengal region of India and supports a significant proportion of fisheries. The breeding migration takes place during the southwest monsoon, when mature fish migrate from the marine environment to the flooded freshwater inland rivers for spawning. The mass spawning migration of mature fish, alongside a number of immature young fish, for distances of up to 1200 km and 50-100 km, respectively, in upstream river systems is common in the Indian subcontinent (Hora 1941; Pillay and Rosa 1963). Since the early 1950s, different biological aspects of hilsa breeding and migration have been extensively studied. The upstream reaches of the rivers Meghna and Padma were rich in hilsa fisheries until 1972, but the fisheries have severely declined and are now primarily concentrated in downstream rivers, estuaries, coastal areas and the sea (Nurul Amin et al. 2004). Low water discharge from the upstream river, the Ganges, at the Farakka Barrage (in West Bengal of India) and consequent heavy siltation, indiscriminate exploitation of juveniles (*jatka*), disruption of migration routes, loss of spawning, feeding and nursing grounds, increased fishing pressure, etc, are all attributed as causal factors in the decline. Since the major source of income for poor fishers along the Bengal coast is from hilsa fisheries, promoting captive breeding of hilsa for restocking as well as aquaculture production is a potential alternative option for the future to compensate for declining wild catch trends and increasing demand.

Aquaculture is largely responsible for the increased fish production in a number of marine and freshwater species, total global fish production having increased from less than 5 million metric tons in the 1970s to as much as 90 million metric tons in 2014 (Yearbook 2016). In Norway, the leading producer of Atlantic salmon (*Salmo salar*), increases in aquaculture production were largely achieved through improvements in breeding and hatchery technology and the introduction of selective breeding programs in the early 1970s (Gjedrem 2012). Despite continued effort and research since the early 1950s, there has been limited success in the commercial breeding, hatchery management and aquaculture production of hilsa. However, recent initiatives at the CIFRI (India) and BFRI (Bangladesh) have resulted in some encouraging success in the artificial breeding and larval rearing of hilsa. Ongoing aquaculture trials of hilsa at these two institutes should now be upgraded to large-scale commercial production, with further standardization.

There are several approaches to genetic improvement of aquatic species, including hybridization and cross-breeding, chromosome manipulation, sex control, transgenesis and selective breeding (Lind et al. 2012). With the advent of controlled techniques for brood stock management, breeding and mass production of juveniles, the development of a national level centralized selective breeding program can be a possible model to support commercial aquaculture production. The domestication process selects fish that are best adapted to the conditions within which the fish are cultured, and selective breeding (genetic improvement) can improve traits of economic importance, such as growth and disease resistance (Gjedrem and Fimland 1995). Compared to the other approaches of genetic improvement, only selective breeding offers continued genetic gain, which is permanent and can be transmitted from generation to generation, and will benefit commercial aquaculture production (Ponzoni et al. 2007; Ponzoni et al. 2008), including that of hilsa. Genetic improvement programs help in the development of sustainable and profitable aquaculture production and utilization of limited feed, land and water resources. The review is composed of two parts. First, existing information about the genetic population and genetic structure of hilsa is evaluated. Second, a brief overview of available information on successful selective breeding programs for important fish species around the world is presented, with a view to formulating guidelines for the development of a selective breeding program for hilsa.

7.2. Population genetic structure

The genetic studies involving hilsa shad in India, Bangladesh, Iran and Iraq have focused primarily on population genetic structure analysis in order to interpret whether there is a single stock that uses all water systems (river, brackish and marine). The information on population genetic structure of a species helps to estimate the distribution of subpopulations in mixed fisheries and based on these distribution regulations may be required to regulate harvesting to protect weaker populations. Concerns over recent population declines have prompted implementation of management actions that prevent fishing during the breeding season in Bangladesh. Genetic analyses offer the potential to examine genetic partitioning between wild individuals from various locations for population assignment.

A knowledge of the genetic background of a species and its population structure is crucial for success in breeding, management and conservation programs in fisheries. Individuals with a high level of genetic variation have greater prospects in aquaculture in terms of higher growth rate, development, stress and diseases resistance (Carvalho 1993). Genetic variation at the species level helps to identify the taxonomic units and to determine the species distinctiveness that can provide essential information for conservation, systematic, ecological and evolutionary studies (Schierwater et al. 1994). Variation at the farmed population level provides insights into the levels of genetic diversity among such populations and their evolutionary relationship with wild relatives. The genetic variability within the population is extremely useful to gather information on individual identity, breeding pattern, degree of relatedness and distribution of genetic variation among them. Future research will rely mostly on the use of molecular genetics and associated technologies for genetic management and conservation, identification of quantitative trait loci and improvements of strains through marker-assisted selection (MAS). A variety of molecular biological tools are available for population genetic characterization of fish.

Genetic characterization of hilsa has been mostly carried out through morphometric characterization, use of allozyme markers, RAPD, RFLP and mitochondrial DNA Cytochrome *b* gene nucleotide sequencing. However, the results are inconclusive. An allozyme marker based study, using hilsa samples collected during the spawning period in the Ganges at five riverine locations (Brahmaputra, Padma, Ganges, Hooghly and Feeder canal), identified 26 loci encoding 15 enzyme systems of which 13 loci were found to be polymorphic (Lal et al. 2004). Despite the high level of polymorphism (31%-50%, most common allele <0.99) found in this study, samples from different locations did not exhibit significant genetic heterogeneity, indicating that there was only one overall panmictic (random mating) population in the Ganges river systems. In a similar study, Salini et al. (2004) reported five interpretable polymorphic loci using samples collected from nine sites within Bangladesh, and with no significant difference in allele frequencies observed within Bangladesh or within the Bay of Bengal (SE India and Myanmar), it was concluded that the population was likely to be panmictic. However, significant differences in allele frequencies were found when compared with samples from Kuwait and Indonesia, indicating the presence of genetically distinct populations in Bangladesh, Kuwait and Indonesian waters. In the same study, Indonesian and Indian hilsa showed more differences in morphometric and meristic characters than Kuwait hilsa; however, hilsa from Bangladesh could not be accurately classified. In agreement with Salini et al. (2004), Milton and Chenery (2001) used otolith microchemistry to study the stock structure of hilsa, and concluded that there was extensive movement and mixing of hilsa throughout Bangladesh, and therefore the population should be considered and managed as a single stock. On the other hand, in a different study, genetic variation among the individuals and groups in Bangladeshi waters revealed five polymorphic loci and contingency chi-square analysis showed that hilsa in Bangladeshi waters belong to more than one gene pool, rather than a single panmictic population (Rahman and Naevdal 1998). Genetic and otolith data both showed that hilsa from southeast India and Myanmar were not significantly different from fish collected in coastal areas of Bangladesh, and suggested that hilsa in the Bay of Bengal were a single stock. On the other hand, as with the allozyme studies, otolith chemistry showed differences between the hilsa of Bangladesh and Kuwait and between those from Bangladesh and Indonesia.

The populations of hilsa from different locations in the rivers Ganges (Beniagram and Lalgola), Yamuna (Allahabad), Hooghly (Nawabganj), Bhagirathi (Feeder Canal) and Narmada were analyzed using RAPD (Brahmane et al. 2006). The UPGMA dendrogram based on Nei (1978), genetic distance indicated the segregation of *T. ilisha* populations into two clusters. The populations from Allahabad, Beniagram and Lalgola from Yamuna and Ganges formed one cluster while the other cluster comprised populations from the Feeder Canal, Nawabganj on the Bhagirathi and Hooghly rivers and Bhadbhut (river Narmada). Rahman and Naevdal (2000) reported five polymorphic loci in hilsa samples collected from the Chandpur region (lower and upper Meghna and Dhaleswari rivers), Barguna region (Paira, Bishkhali and Patharghata coast), and the Bay of Bengal (near Cox's Bazar and the Chittagong coast). Significant heterogeneity was found between the Chandpur-Cox's Bazar and Barguna-Cox's Bazar population pairs, but no heterogeneity was observed between the Chandpur-Barguna population pair. Therefore, it was concluded that there are two gene pools of hilsa in Bangladesh waters. The results are in contrast to those of Dahle et al. (1997), who stated that there are three discriminating populations of hilsa shad in Bangladeshi waters: Chandpur (Meghna River), Barguna (brackish water, estuarine) and Cox's Bazar (sea water).

In another study, Brahmane (2008) studied the population genetic structure of hilsa in India using mitochondrial DNA Cytochrome *b* gene nucleotide sequence analysis. The study indicated that, there is a free flow of gene pool and mixing of hilsa between the Ganges and Hooghly rivers. Furthermore, the study revealed that the populations of the Ganges and Hooghly rivers belong to a single gene pool and every individual hilsa from the Ganges population has an equal chance of mating with individuals of the Hooghly population. The hilsa from the Ganges-Brahmaputra-Meghna estuary are biologically similar to those of the Hooghly-Bhagirathi estuary. Gene flow among basic genetic units is so extensive that the entire species in the Bay of Bengal region behaves as a single panmictic population, and there is no reproductive isolation that might result in genetic divergence. In a recent study, Behera and a coworker (unpublished data) analyzed hilsa samples collected from three different sites from the Ganges River (Bay of Bengal origin) and two sites from Nuapada and Ukai reservoirs (Arabian Sea origin) using mitochondrial DNA Cytochrome *b* gene sequence analysis. Phylogenetic analysis revealed that the hilsa of the Bay of Bengal origin and Arabian Sea origin formed two distinct different clusters (Figure 1).

Shifat et al. (2003), applying RAPD, analyzed the genetic variation of hilsa from the rivers Padma and Meghna in Bangladesh. The individuals of the two river stocks were grouped into two clusters in the dendogram assuming two different spawning stocks or races of hilsa shad in the two major Bangladesh rivers. In a preliminary study, Ahmed et al. (2004) analyzed the genetic structure of three populations of hilsa—Chandpur (Meghna river), Kuakata (estuarine water) and Cox's Bazar (Bay of Bengal)—using RFLP of mitochondrial DNA and observed a high level of polymorphic haplotypes (mean 0.958) in the three populations. Similarly, in a recent study, Mazumder and Alam (2009) examined genetic variability and divergence in two riverine (the Jamuna and the Meghna), two estuarine (Kuakata and Sundarbans) and one marine (Cox's Bazar) population of *T. ilisha*, and reported high levels of haplotype (0.882-0.967) and gene diversity (0.343-0.569), indicating high levels of genetic variation within and significant differentiations among the populations of hilsa. The UPGMA dendogram based on genetic distance resulted in two major clusters, although these were subsequently divided into three, corresponding to riverine, estuarine and marine populations.

The populations of *T. ilisha* that were studied were found to be in genetic equilibrium, which indicates that there is no apparent selection pressure on the population with regard to mitochondrial DNA haplotypes (Mazumder and Alam 2009). These authors observed significant p-values ($p < 0.05$) for population differentiation indicating nonrandom distribution of the composite haplotypes in the sampling locations. It also indicates that genetic exchange among populations was insufficient to prevent either genetic differentiation or structuring into genetically differentiated subpopulations in *T. ilisha* in Bangladesh.

Jorfi *et al.* (2008) studied population genetic structure of hilsa shad in Khouzestan waters, including the Karoon, Arvandrood and Bahmanshir rivers, as well as the Persian Gulf using the RAPD technique. The four

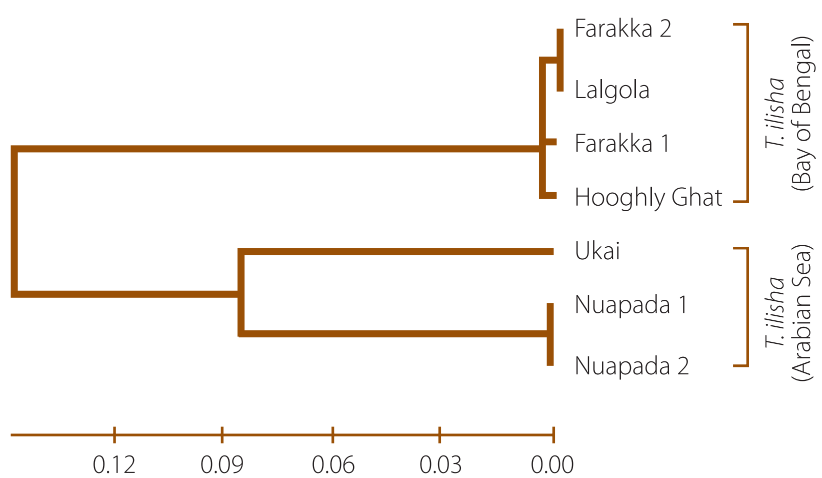


Figure 1. Phylogenetic tree showing two clusters of hilsa from Bay of Bengal and Arabian Sea.

samples were found to belong to two groups, one comprising the Karoon River and Persian Gulf and the other comprising the Arvandrood and Bahmanshir rivers, supporting the hypothesis that there are Iranian and Iraqi populations of this species; the fish from the Persian Gulf migrate to the Karoon River in Iran and the other populations migrate to the Tigris and Euphrates rivers in Iraq to spawn.

7.3. Prospects for genetic improvement

7.3.1. Knowledge from other selective breeding programs

The first documented selective breeding (genetic improvement) experiments in fish investigating furunculosis resistance in brook trout (*Salvelinus fontinalis*) was initiated in the US in 1919, where three generations of selection improved survival from 2% to 69% (Embody and Hayford 1925). In common carp (*Cyprinus carpio*), selective breeding experiments by Moav and Wohlfarth (1973, 1976) for fast growth rate conversely gave a positive response for negative growth rate, and the authors concluded that over-dominance plays a role in the heritability of growth rate in common carp and that there is no genetic variation in the trait. However, around the same time the response to selection for faster growth rate and inbreeding depression for growth in progeny after mating among relatives was reported in rainbow trout (*Oncorhynchus mykiss*) (Von Limbach 1969).

The successful modern day Atlantic salmon selective breeding programs began in the early 1970s with the pioneering work of Prof. Dr. Harald Skjervold and Trygve Gjedrem (currently Nofima, Ås, Norway) in Norway (at AKVAFORSK). The base population for the breeding program originated from fertilized eggs sampled from 40 Norwegian and Swedish rivers (Gjedrem et al. 2012). During the initial period, fish were selected for increased bodyweight at harvest, while later other traits, such as age at sexual maturation, survival, disease resistance and meat quality, were also included. A combined between-families and within-family selection scheme was followed to increase growth rate and reduce early sexual maturity, and family selection for improvement of disease resistance and product quality traits. In 1992, privatization of the breeding program led to the establishment of a breeding company, AquagGen AS, which continues to breed salmon using the material from AKVAFORSK (Gjedrem et al. 2012). The past 40 years of work in selective breeding of Atlantic salmon in Norway reduced the time to produce market-sized 4 kg of fish by half and reduced the feed consumption to produce 1 kg of salmon from 3 kg dry matter (in moist feed) to a mere 1.15 kg (dry pellets) (Gjedrem et al. 2012). The average genetic gain in growth rate from the first five generations of selection was 13%–15% per generation, while for early sexual maturity it was 3% units per generation (Gjedrem et al. 2012). The selection for increased growth rate led to a correlated response of 20% with respect to feed conversion efficiency, and hence improved feed retention of both protein and energy (Kolstad et al. 2005). In 2003, 97% of the total production of Atlantic salmon was based on genetically improved stocks, which indicates the importance of selective breeding in commercial aquaculture (Gjedrem et al. 2012).

A selective breeding program for Nile tilapia (*Oreochromis niloticus*) also contributed to large-scale aquaculture production around the world. The team of Dr. Roger Pullin (erstwhile ICLARM, now WorldFish), Trygve Gjedrem and Dr. Gideon Hulata formulated the selective breeding program, which began in 1986 with funding from the United Nations Development Programme (UNDP). Dr. Ambekar E. Eknath was appointed as project leader. To maintain the broad genetic variability in the base population, broodstocks were sampled from four farmed tilapia strains in the Philippines and four wild stocks imported from Africa. The project was called GIFT (genetically improved farmed tilapia). The initial breeding goal was for growth rate, and a diallel cross was used involving all the chosen strains. Five generations of selection conducted during the GIFT project had an accumulated selection response of 86% (17% per generation). At present at least 20 breeding programs for Nile tilapia are active around the world, and base populations for at least 10 of the programs originated from the fifth generation material of the GIFT project (Gjedrem et al. 2012). GIFT and other subsequent projects helped in the rapid increase in worldwide production of Nile tilapia from 115,212 mt in 1988 to 2.09 milion mt in 2008 (Yearbook 2008).

The knowledge and success of Atlantic salmon and Nile tilapia breeding programs laid the foundation for other species. In 1992, a family-based breeding program for Indian major carp, rohu (*Labeo rohita*), was started at the Central Institute of Freshwater Aquaculture (CIFA), India, in collaboration with AKVAFORSK. Initially the project was funded by NORAD (Norway). The overall response to selection achieved in growth rate of rohu was as high as 29.6% per generation (Gjedrem et al. 2012), and at present CIFA continues to breed rohu for growth rate and resistance to *Aeromonas hydrophila*. The breeding program for Pacific white shrimp (*Litopenaeus vannamei*) was started in 1995 at the Oceanic Institute, Hawaii with the involvement of AKVAFORSK. In later years AKVAFORSK was involved in other breeding projects for Pacific white shrimp in cooperation with CENIACUA in Columbia (Gitterle et al. 2005) and with Aquatec in Brazil. In one generation of joint selection, they obtained a genetic gain of 4.4% for harvest bodyweight and 12.4% for Taura Syndrome Virus (TSV) survival (Fjalestad et al. 1997). At present, there are about four breeding programs operating for Pacific white shrimp (Neira) and three for tiger shrimp (*Penaeus monodon*) (Rye et al. 2010). In 2001, a family-based national breeding program for the Atlantic cod (*Gadus morhua L.*) was started in Norway (at Nofima, Tromsø). The base population originated from brood fish sampled from different geographical areas along the Norwegian coast, and represented genetically distinct stocks (based on the difference in *Pan I allele*), namely, northeast arctic cod and coastal cod (south and north) (Pogson et al. 1995; Fevolden and Pogson 1997). So far, Atlantic cod has been selected for growth (weight at 2+ years old) and partially for resistance to *Vibrio anguillarum*. The average genetic gain after three generations of selection is ~10% per generation for growth rate (unpublished data). A separate family-based breeding program for Atlantic cod is also running in Iceland (ICECOD). In addition to the breeding programs discussed here, there are number of other ongoing breeding programs with various breeding goals worldwide (Table 1). However, growth rate is the primary trait of selection in all the breeding projects.

7.3.2. Heritability estimates

Heritability (narrow sense) is defined as the proportion of the total phenotypic variation of a trait that is explained by additive genetic (additive gene) effects (Falconer et al. 1996). Additive genetic variation and reliable heritability estimates are prerequisites for any selective breeding program (Bangera et al. 2011). Many heritability estimates are published for a number of traits in different species (Table 2). In general, body weight (growth rate) is the primary trait of selection, with a moderate heritability (0.20 to 0.46) in all species,

Species	No. of programs	No of families
Common carp	8	76
Rohu carp	1	60–70
Silver barb	1	-
Tilapia Nile	20	229
Tilapia red	4	125
Channel catfish	1	200
African catfish	1	70
Striped catfish	1	182
Atlantic salmon	13	280
Chinhook salmon	2	100
Coho salmon	4	133
Rainbow trout	13	226
European white fish	1	70
Turbot	2	60
Atlantic cod	3	110
European seabass	3	100
Sea bream	4	100
Freshwater prawn	2	82
Shrimp *P. monodon*	3	212
Shrimp *P. vannamei*	4	197
Abalone	3	210
Oysters	3	48
Mussel	1	60

Source: Gjedrem et al. 2012

Table 1. Number of important selective breeding programs for different species.

resulting in positive selection response. Other traits, such as sexual maturation, fitness traits (disease resistance, survival, etc.) and meat quality, show varied heritability estimates and have been incorporated in some species as selection criteria.

7.4. Strategies for selective breeding of hilsa

7.4.1. Base population

Sufficient genetic variability is a prerequisite for selective breeding, and valuable information can be drawn from population genetic studies (Vandeputte 2003). To form a base population, collecting genetically distinct strains of wild brood fish from different geographical locations ensures broad genetic variation. A simulation study by Holtsmark et al. (2006) concluded that more than eight populations in the base did not significantly increase genetic gain, and hence sampling from a larger number of subpopulations may introduce larger costs connected with sampling fish from numerous locations. Population genetic studies differentiating strains and populations of hilsa are limited. Although hilsa is largely an anadromous species, two other ecotypes (a fluvial potamodromous type and a marine type) have been putatively recognized (Raja 1985). From the rivers of Bangladesh, at least two genetically distinct strains of hilsa have been reported (Shifat et al. 2003; Mazumder and Alam 2009) and brood fish collected from these stocks could be used to form a synthetic base population for genetic improvement of hilsa. The breeding nucleus for hilsa should represent genetically and geographically distinct wild brood fish stocks collected from different habitats in India and Bangladesh.

7.4.2. Traits of economic importance

Selection for increased bodyweight (growth rate) has been the primary trait of selection in livestock and fish breeding programs. In almost all fish breeding programs for warm water and cold water fish species, with the possible exception of common carp (Vandeputte 2003), a positive response has been reported for growth rate, with an average genetic gain

Species	Trait	Average	Heritability	Reference
Rainbow trout	Bodyweight	3.4 kg	0.21	Gjerde and Schaeffer (1989)
	Fat	14.80%	0.47	Gjerde and Schaeffer (1989)
	Fillet yield	63.20%	0.33	Kause et al. (2002)
	Age of sexual maturity	-	0.12	Kause et al. (2003)
	Survival	-	0.16	Rye et al. (1990)
Atlantic salmon	Bodyweight	6.6kg	0.35	Rye and Refstie (1995)
	Fat	15.60%	0.3	Rye and Gjerde (1996)
	Texture	9.7	0.26	Refstie et al. (1999)
	Furunculosis resistance	-	0.48	Gjerde and Gjedrem (1984)
	Age of sexual maturity	-	0.2	Gjerde and Gjedrem (1984)
	Survival	-	0.08	Rye et al. (1990)
Atlantic cod	Bodyweight	~2.5kg	0.28	Bangera et al. (2011)
	Vibriosis resistance	-	0.16	Bangera et al. (2011)
	VNN resistance	-	0.68	Bangera et al. (2011)
Rohu carp	Bodyweight	440 g	0.23	Gjerde et al. (2004)
	Survival	-	0.16	Gjerde et al. (2004)
Tilapia	Bodyweight	181 g	0.34	Ponzoni et al. (2005)
	Survival	-	0.08	Eknath et al. (1998)
Shrimp	Bodyweight	16 g	0.17	Gitterle et al. (2005)
	Survival	-	0.04	Gitterle et al. (2005)
Oysters	Bodyweight	-	0.16	Evans and Langdon (2006)
	Bodyweight	24 g	0.28	Jarayabhand and Tavornyuikarn (1995)
Scallops	Bodyweight	-	0.46	Ibarra et al. (1999)
	Total weight	61 g	0.21	Crenshaw et al. (1991)

Source: Gjedrem and Baranski. 2009

Table 2. Heritabilties for different traits in aquaculture species.

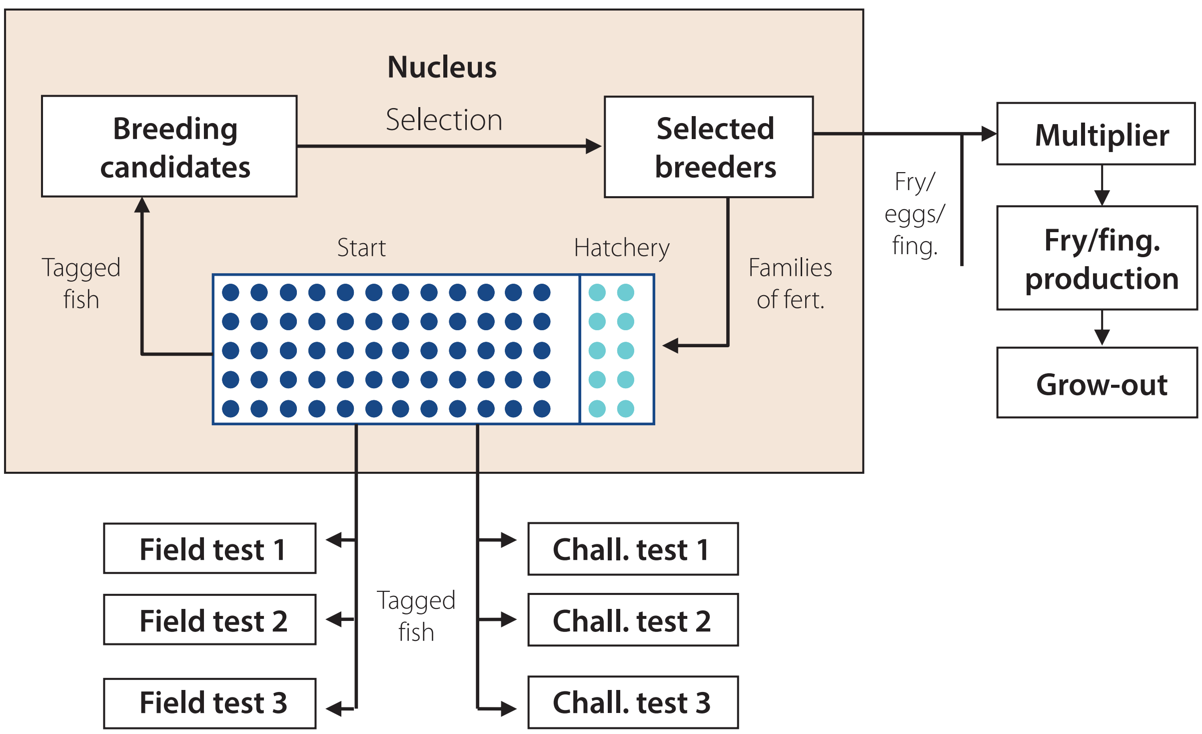
of 12.5% per generation (Gjedrem et al. 2012). When hilsa aquaculture becomes a reality, the market size of hilsa will likely be based on demand and price per kg. Usually, hilsa >800 g is considered the standard size and fetches higher prices in all seasons. Given the experience of selective breeding programs for other aquatic species, selective breeding in hilsa should focus on growth rate as the initial criterion, with other traits of economic importance being incorporated as breeding goals as the breeding program progresses. Nevertheless, moderate heritability estimates for growth rate (bodyweight) and other traits are prerequisites, and should be estimated before starting a breeding program.

7.4.3. Methods of selection

Methods of selection depend on many factors, such as the target trait for selection, ease of recording the trait in live animals, magnitude of heritability and reproduction capacity of the species (Gjedrem and Baranski 2009). Several selection methods are available for fish and shellfish species as discussed in Gjedrem and Baranski (2009), namely, selection based on pedigree information, individual or mass selection, family-based selection using measurements on full and half sibs and selection based on progeny performance. In most of the fish breeding programs around the world, a combined between-families and within-family selection scheme is commonly practiced (Gjedrem 2012), with the exception of common carp, where most of the breeding programs use mass selection techniques (Vandeputte 2003). In a family-based breeding scheme, information from ancestors add to the accuracy of genetic evaluation, and hence it is important to maintain good pedigree records (Gjedrem and Baranski 2009). Parentage assignments can be done using physical tagging (e.g. PIT tags) or by using genetic markers (e.g. microsatellites, Single Nucleotide Polymorphisms (SNP) markers etc.). Mass selection is usually advisable for small scale breeding programs as well as for small hatchery owners and possible only for the traits that can be recorded with live animals. For hilsa, depending on the budget, it is advisable to start with a family-based nucleus breeding program using physical tagging as information on genetic markers is still limited.

7.5. Structure of breeding program

Running a fish breeding program requires a detailed plan, and the technical activities of the breeding work require an extensive knowledge of the principles of quantitative genetics and selective breeding theory. A well-structured and advanced nucleus fish breeding design, similar to those followed for Atlantic salmon (Figure 2) and Atlantic cod (Figure 3), might usefully serve as examples for hilsa breeding. A typical breeding facility consists of broodstock management units (breeding candidates), facilities to breed fish (hand stripping or natural breeding), larval rearing facilities (start feeding units) where full-sib and paternal half sib family groups of the breeding candidates are reared separately until tagged, facilities for smoltification



Source: Gjedrem and Baranski. 2009

Figure 2. The main elements of a full-scale breeding program in fish.

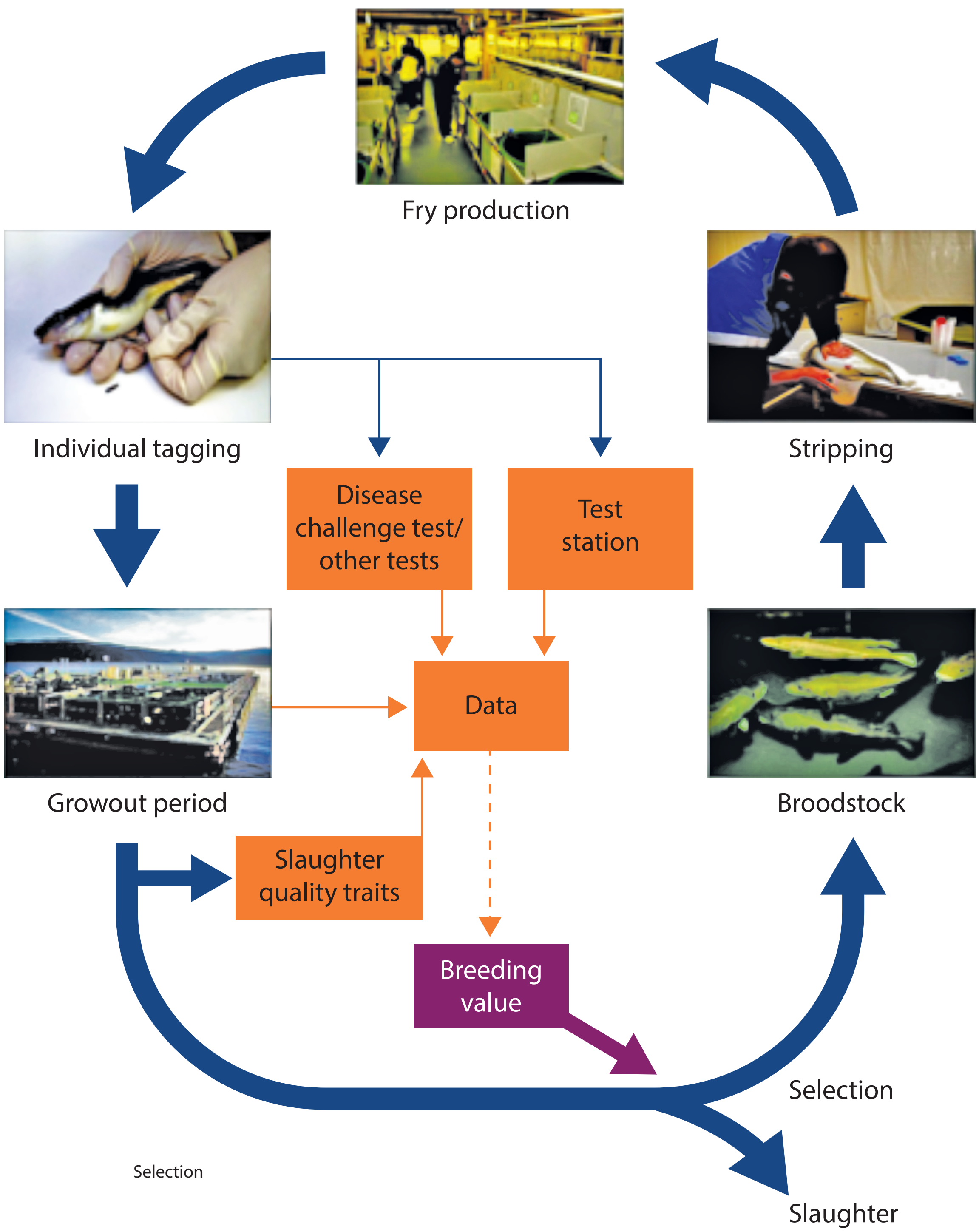


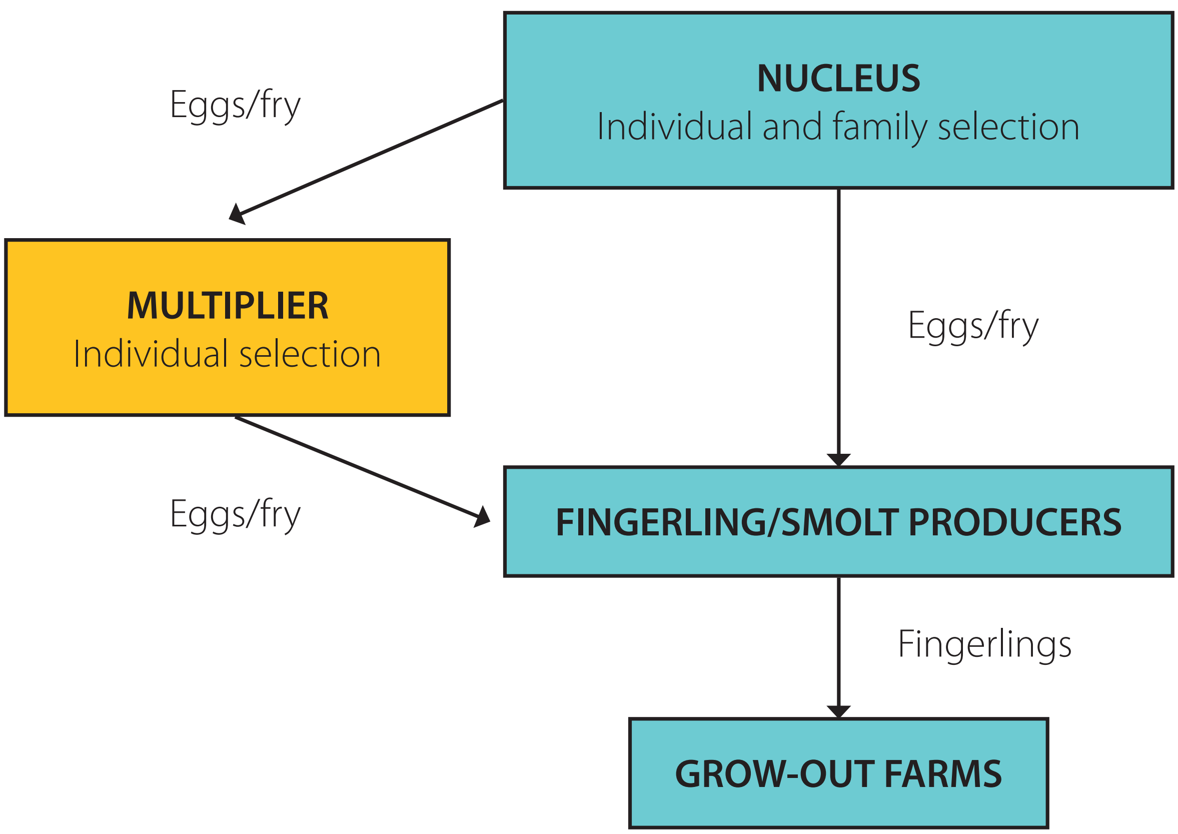
Figure 3. Different steps in a classic breeding program for Atlantic cod.

(freshwater to marine water) and a few open sea (or brackish water) facilities (cage, pen or ponds) for performance testing (e.g. bodyweight) of breeding candidates. Once the phenotypic records of the breeding candidates are available, final selection can be made using individual breeding values estimated from the mixed linear model-based Best Linear Unbiased Prediction method of Henderson (1975). In each generation, the level of inbreeding can be kept minimal using optimum contribution (OC) selection, which ensures maximum genetic gain (Meuwissen 1997).

7.6. Management of the breeding program

The success of a breeding program largely depends on collaboration among expertise from breeding technology, feed and nutrition, larval rearing, aquaculture, quantitative genetics and molecular biology. The data generated during the course of a breeding program should be properly analyzed with the help of a data analyst.

Dissemination of improved genetic material:
The purpose of investment, effort and benefit of genetic improvement is to reach fish farmers as early as possible in order to maximize the benefits of a breeding program. Depending on the fecundity of the species, the transfer and dissemination of genetic gain from the nucleus breeding unit to the farmers (industry) can be done either by direct transfer from the nucleus or by transfer via multiplier units (Gjedrem and Baranski 2009) as shown in Figure 4. The capacity of the nucleus breeding facility is also an important factor in deciding the dissemination strategy. For hilsa, where several partners are likely to be involved, it makes sense to develop a strategy to disseminate genetic material from selected multiplier units (usually private hatcheries) located in partner countries. The nucleus breeding station will supply eggs or fry from the most recent generation to private hatchery owners to use as brood fish. In the multiplier units (hatcheries), rigorous selection for bodyweight is followed in the selection of brood fish and the resultant fry produced supplied to farmers. Moreover, facilities at private hatcheries may serve as test stations where performance can be assessed to the benefit of all parties.



Source: Gjedrem and Baranski. 2009

Figure 4. Alternative routes of genetically improved material from a fish breeding nucleus to farmers.

7.7. Conclusions

Information on genetic population structure of hilsa shad (*T. ilisha*) from the Bay of Bengal and various rivers of Bangladesh and India revealed by allozyme, RAPD and RFLP of mitochondrial DNA analysis are inconclusive. According to allozyme analysis, there is only a single stock of hilsa in the Bay of Bengal and the rivers where the fish migrate to spawn. However, RAPD and mtDNA-RFLP analysis delineated riverine, estuarine and Bay of Bengal stocks as separate gene pools. Further detailed study of hilsa population genetic structure is therefore recommended, samples being systematically collected from throughout the species' distribution range and using more informative molecular markers such as microsatellites to resolve the issue.

Hilsa is an important fish of the subcontinent, particularly in Bangladesh and India. As fisheries in upstream rivers have declined greatly, the livelihoods of fishers, who depend largely on fishing hilsa in the rivers, are at stake. Overfishing, habitat loss due to siltation, construction of barriers obstructing the migration of the anadromous fish and climate change are believed to be responsible for the reduction in upstream fisheries. Because of increasing scarcity in the market, the price of hilsa has spiraled tremendously, making the fish unobtainable to low income groups. Therefore, in order to increase production, and thus geographic and economic access, it is imperative that a reliable captive breeding protocol be established for production of good quality seed for aquaculture and restocking. The artificial breeding of many marine and migratory fish has already been developed elsewhere. For example, artificial breeding protocols for the Chinese river shad (*Tenualosa revesii*), Japanese eel (*Anguilla japonica*), red seabream (*Pagrus major*), sea bass (*Lates calcarifer*) etc. are readily available. To avoid dependence on nature for fingerling collection for aquaculture, a massive program should be undertaken for large-scale production of hilsa seed through domestication and captive breeding. A detailed endocrinological study would help overcome the barriers to captive breeding of the species.

Once the artificial breeding protocol is established, a selective breeding program could be initiated to improve the growth rate and other economically important traits of the species. While breeding in captivity it should be ensured that no genetic deterioration takes place due to inbreeding and genetic drift. The base population should be established by collecting samples in sufficient numbers from different regions. Meanwhile, a reliable polymorphic molecular marker, preferably microsatellite and/or SNP, should be developed from *T. ilisha* for extensive genetic analysis of samples from its entire range of distribution to delimit the stocks and assess genetic variation. The markers can also be applied for marker assisted selection and for monitoring genetic change in captive populations. It is recommended that the genetic structure of the base population be analyzed beforehand so that the changes that take place in captive populations over time can be assessed with respect to the base population. Once a breed of superior performance is developed through selection, it should be disseminated to enthusiastic farmers for further multiplication and distribution for aquaculture. As mentioned previously a collaborative approach involving experts for captive reproduction technology, larval rearing, feeding and nutrition, aquaculture, quantitative genetics and molecular biology, can best ensure success of the project for genetic improvement of *T. ilisha*.

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Hilsa in market, Bangladesh.

8. Hilsa market trends in Bangladesh and India

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Abstract

Hilsa is highly popular among consumers on the Indian subcontinent. Through a market survey in the landing centers and markets in both Bangladesh and different states of India, it was revealed that the marketing system for hilsa is complex and involves various stakeholders, from harvesting by producers to selling to consumers. In spite of this complex market system, shorter distribution lines have been at affluent outlets, which deal among themselves comfortably. Bangladesh mostly relies on its own hilsa production from the country's rivers and marine habitats. India is not self-sufficient and thus used to import hilsa from Bangladesh through legal channels as well as illegal cross-border trade. Exporting hilsa to India and other countries has been temporarily banned to meet local demand. In traditional Bengali entertainment, serving hilsa to close family members and guests is almost an obligation. In addition, it has religious and cultural values, especially among Hindu communities. However, the market survey revealed that hilsa has become the fish of the elite as a result of dwindling harvests in both countries and its high market price. Fishers receive a low share of the price that consumers end up paying. It was found that retailers in hilsa value chain have a higher marketing margin than commission agents (*arotdars)* and wholesalers (*paikers*), but the net income of wholesalers is much higher than that of retailers because of transactions of greater volumes.

8.1. Introduction

Hilsa belongs to the genus *Tenualosa* of the family Clupeidae, order Clupeiformes. Locally known as *Ilish*, the fish is particularly favored by Bengalis especially to those who originated from Bangladesh. It is also a popular and premium fish in West Bengal, Orissa and Andhra Pradesh states of India. The soft and succulent taste makes it a luxury seafood. During the monsoon season, no grand meal is complete without hilsa in Bengal. A large-sized hilsa in the market weighs about 2.5 kg. Though basically a marine fish it thrives in estuarine and riverine environments. Its habitat covers the Satil Arab, the Tigris and Euphrates of Iran and Iraq, the Indus of Pakistan, the rivers of Eastern India, the Irawaddy of Myanmar, and the Padma, Jamuna, Meghna, Dhaleshwari, Karnafully and other coastal rivers of Bangladesh. Hilsa swim upstream as the inland stretches of these rivers are the breeding grounds for the fish. In India, the Hooghly, Ganges, Brahmaputra and Godavari rivers yield a rich hilsa catch during the monsoon. In Bangla Pradesh, hilsa is available in four regions—from Farakka to Konnagor, in the freshwater region; from Konnagor to Diamond Harbor, in the slope of the Ganges; from Diamond Harbor to Sandhead, in the distributaries region of the Bay of Bengal.

8.2. Hilsa market trends in India

8.2.1. Market survey

The survey team visited different reputed landing centers such as Chilka, Astarang, Paradeep, Kasaphal, Digha and Diamond Harbor in the Bangla of India and interviewed a number of small-scale fishers, the staffs and owners of fishing trawlers and boats, collection agents of exporters and small-time local wholesalers and retailers. They mostly focused on questions regarding catch and wholesale selling price. Some team members visited local and wholesale markets (Howrah, Bhubaneswar and Paradeep) for data on volumes, price and size of fish. They also interviewed retailers and consumers to collect data on price and size preference. The data compilation here was made on this basis.

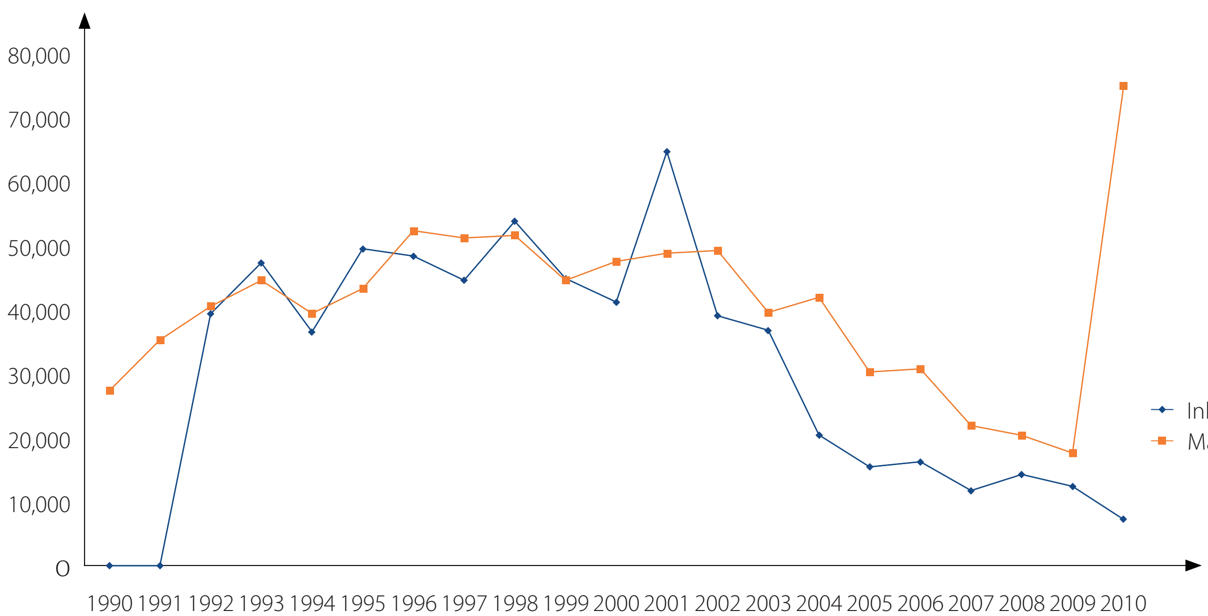
8.2.2. Domestic production

Of late, the production of hilsa in India has shown a declining trend. A recent International Union for Conservation of Nature sponsored study has revealed that the hilsa catch in Bangla Pradesh decreased from 80,000 to 20,000 t per year during the 10 years since 2001. Updated information from a CIFRI report shows that the hilsa catch in Bangla plummeted from 60,000 t in 2010–2011 to 18,000 t in 2011–2012 and they expect that in 2012–2013, the catch may fall as low as 7000–8000 t. The only recent exception to this trend was 2010, when around 60,000 t of hilsa were caught.

8.2.3. Indian import data

As per the informal market survey done by the study team, between July and September 2012, the consumption of the fish is almost 100 t per day in Bangla Prodesh alone, with 7% of the requirement fulfilled by imports from Bangladesh. The balance comes from catches at Digha and Diamond Harbor, Orissa, Gujrat and Mumbai.

India imports hilsa through legal channels, although the illegal trade is much larger, traders say, since it is cheaper and also much less complicated because



Source: FAOSTAT Database 2012.

Figure 1. Indian inland and marine hilsa production, 1990-2010.

they bypass customs checks. In 2011, according to the Department of Fisheries in Bangladesh, 5376 t of hilsa was exported to India alone out of total 8500 t exported in the fiscal year. The remainder went to the ethnic Bangladeshi markets in the Middle East, Europe and America. All of a sudden, on 31 July 2012 the notification came that the Bangladesh government has banned the export of not only hilsa, but all kinds of fish.

8.3. Quantity and size sold and prices

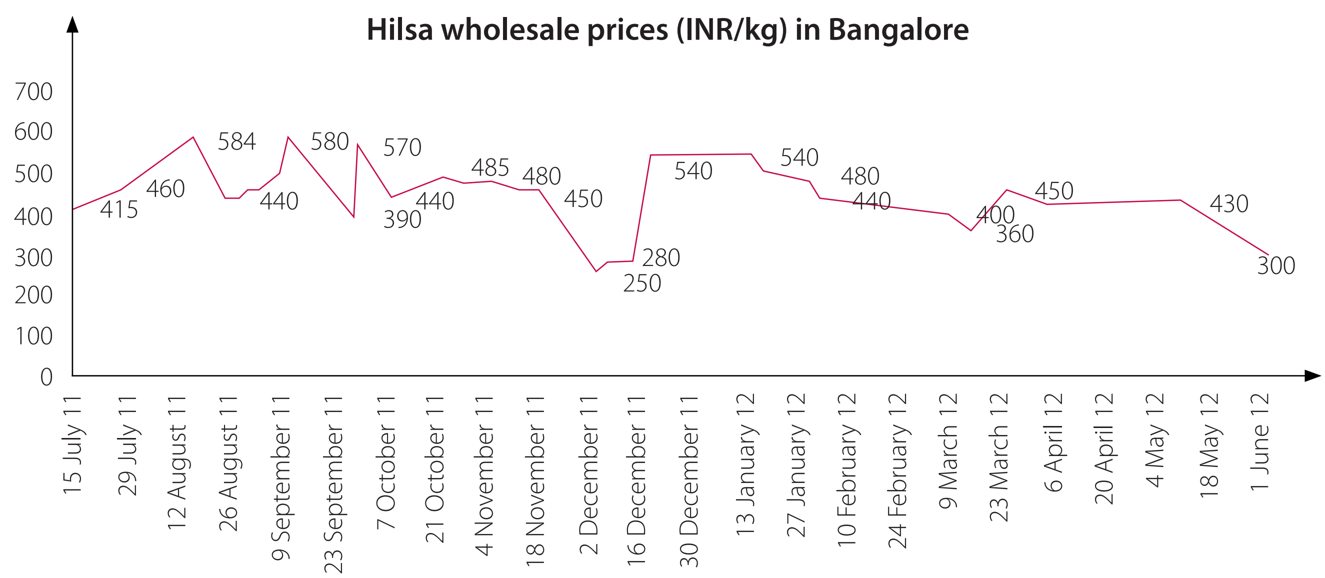
Bangla Pradesh (India): The recently imposed ban by Bangladesh on hilsa exports has adversely affected Bangla, where hilsa is a gastronomic delight of every Bengali as well as many states in India. The price of hilsa has skyrocketed and it has been selling between INR 900 and INR1500 (USD 14–24) per kilogram, making the product beyond the reach of ordinary people. According to a vendor report from Howrah fish market, the price of hilsa has soared because of the reduction in domestic production due to unstable monsoons, sharp declines in daily catches in both the Hooghly and Narmada rivers and declines of imports. Along the Hooghly coast although some fish are available from deep sea trawler personnel, supplies are not as abundant as previously and the price is almost INR 600–800 (USD 10–13) for 400–700 g fish and around INR 1200–1500 (USD 19–24) for fish >1 kg. In Kolaghat during early monsoon season, fish sizes range from 400 to 1000 g, but rarely more than 1000 g. In winter, sizes reach up to 600 g.

In August 2012, according to the local market report in Kolkata's Manicktala market, hilsa was selling at INR 1000-1500 (USD 16–24) per kg, depending on the quality and size. For the last two years a typical size hilsa (600–1000 g) was sold at an average price of INR 700 (USD 11) at the end of the season.

Orissa: In Orissa the scenario is the same. During the 2012 monsoon, hilsa was becoming increasingly scarce on the menu of lower- and middle-income groups with its price skyrocketing to INR 750 (USD 12) per kg. In the Chilka Lake area the situation is little better, as the local market secures only limited supplies of 400–800 g hilsa, retailing at INR 800–900 (USD 13–14) per kg. In the Paradeep area people are resorting to providing a cash advance to deep sea fish and are only likely to secure fish if there is a surplus to that consumed by the fishers. The price range is INR 1200–1500 (USD 19–24) per kg, irrespective of fish size.

Along the Astaranga coast, the hilsa catch is negligible and is no longer available to consumers, other than the fishers. Fishers say the fish are unavailable because of the absence of a northern wind. In Kasaphal as well as along the Digha coast, far fewer hilsa are being caught and the price range is around INR 700–1400 (USD 11–22) per kg, depending on size. The fish mostly go to Howrah and Darjeeling markets in West Bengal, making it unavailable to local markets.

Southern Indian cities: Southern Indian cities harbor many of the Bengali and northeastern people who love hilsa. To these cities, the vendors (wholesalers and retailers) source the hilsa from Howrah fish market and from Gujarat. The table below shows the wholesale delivery price for hilsa (500–1000 g) in Bangalore during July 2011–June 2012. The price range was INR 250–584 (USD 4–9) per kg.



Source: Spar Supermarket, Bangalore.

Figure 2. Wholesale delivery price for hilsa (500–1000 g) in Bangalore during July 2011–June 2012.

Consumer ethnicity*:* Bengalis, but also people from Odia, Assamees and other northeastern Indian states, are fond of hilsa. The fish is culturally suited to these people. Particularly in the rainy season hilsa is considered to be one of the best delicacies on the Bengali menu. There are many preparations of this fish. It can be fried, or made with soup (*jhol*), baked folded in banana leaf (paturi) or steamed with mustard (*bhape*). It also goes well with khichuri, as well as with panta or watered rice. In traditional Bengali entertainment, serving hilsa to close family members and honored guests for lunch or dinner is almost an obligation. Without this all other items, however rich, are considered inadequate. *Jamai Sasthi* without Ilish is unthinkable. In Orissa, there is an Odia proverb *"Chakiri kariba police and machha khaiba ilish,"* which means "the best job is police and the best fish is ilish." The estimated market is at least 120 million in India, plus migratory populations of the same ethnic origins overseas.

Consumer economic profile*:* Previously, hilsa was a fish consumed by the ordinary citizen during the monsoon season. The price of hilsa has skyrocketed recently after all-time low catches. However, with greatly elevated prices hilsa has become a fish of the elite class of Bengalis and other northeastern Indians. West Bengal accounts for most of the hilsa consumed, both the fish caught in India and those imported from Bangladesh. As a result of high prices and low availability, consumption has dropped dramatically. However, demand remains undiminished.

8.4. Availability and challenges faced by hilsa traders

The survey results conducted during the study period paint a dispiriting picture of the future of hilsa in India. At the time of the survey, India typically received a consistent volume of hilsa from Odisha and the West Bengal coast. However, during the survey year (2012) production was negligible. Thus, availability is the major problem confronting hilsa traders, the result of rapidly dwindling fish populations due to changing fishing patterns, over-exploitation, domestic and industrial pollution, the proliferation of barriers to fish migration (i.e. dams) and siltation.

Several years ago, markets in Kendrapara, Jagatasinghpur and its nearby areas were flooded with hilsa. But now such events are rarely seen due to the use of gill nets by fishers and the construction of dams and bridges in their migratory path, affecting the movement of fish during the breeding season. Industrial pollutants and decreasing freshwater flow through the Mahanadi River and its tributaries have also contributed to the declining population of hilsa, with the result that riverine hilsa is virtually unavailable to traders, while declines in hilsa catches from brackish water sources have resulted in great uncertainties the hilsa supplies at landing centers. It is thus difficult for traders to anticipate prices. With the exception of imported hilsa, local traders are not realizing much profit as the margins between purchase and selling price have fallen dramatically.

8.5. Preference of hilsa varieties by Indian consumers

The anadromous migration of marine hilsa into rivers results in changes in both fish physiology and, from the consumer's perspective, olfactory properties such as taste and small. The order of consumer preference is riverine, brackish water and marine source species. Fish from the Padma, Kasaphal, Chilka and Hooghly water bodies always attract a small price premium. To some, fish from the Ganges are tastier than from the Padma, as it is reputedly sweeter and softer. Bengalis in West Bengal share their hilsa obsession with Bangladesh, which has traditionally been the biggest supplier of the delicacy throughout the world. *Padmar ilish* or hilsa from the Padma River are believed to be even tastier than those caught in the Ganges, and its imports from Bangladesh have traditionally managed to help meet local demand.

8.6. Hilsa market trends in Bangladesh

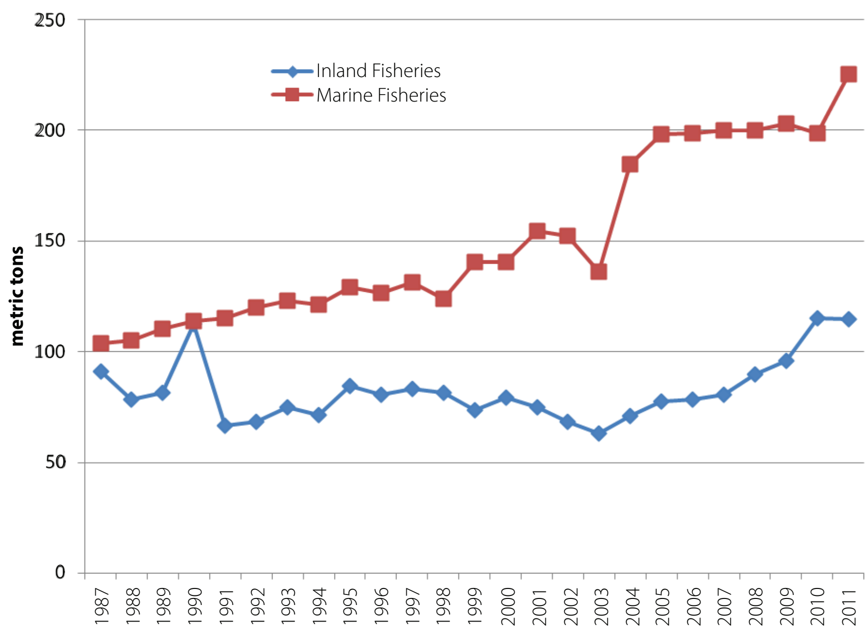
Hilsa is considered to be the national fish of Bangladesh. It contributes significantly to the national economy, accounting for approximately 1% of GDP, and employing an estimated 0.46 million people (Mome and Arnason 2007). The hilsa fishery is by far the largest single species fishery in Bangladesh. Until 1972, the hilsa fishery was restricted to the upstream portions of rivers, mainly the rivers Padma, Meghna, Dhaleshwari, Karatoya, Shitalakkya, Kushiara, Jamuna, etc. However, the fishery in the upstream areas has greatly declined since 1972 and is now mainly confined to downstream rivers, estuaries, coastal areas and the sea. Low water discharge from the Ganges River at the Farakka Barrage and associated heavy siltation, indiscriminate exploitation of juveniles (*jatka*), disruption of fish migration routes, loss of spawning, feeding and nursery grounds and increased fishing pressure have all contributed to a decline in the catch per unit effort in both the marine and river hilsa fisheries. As a result, hilsa fishing intensity has increased in downstream areas and especially in inshore waters where hilsa are presently most abundant (Mome and Arnason 2007). Despite declining catch per unit effort, Figure 3 indicates that total hilsa production increased substantially over the period 1987 to 2011 from 194,981 t to 339,845 t. However, the relative contribution of hilsa from inland and marine sources changed over this period from 47% and 53% to 34% and 66%, respectively, reflecting increasing pressures on the inland fishery.

Hilsa is marketed and consumed all over Bangladesh. According to Kleih et al. (2003), 88% of hilsa is marketed internally for domestic consumption while the remaining 12% is exported. Most of the catch is consumed domestically as fresh fish. A salted product, *lona ilish* is widely consumed in Bangladesh and Northeast India. Both dry-salted and wet-salted, along with controlled salt-fermented ilish products are produced in Chandpur, Vola, Barguna, Chittagong, Cox's Bazar and other coastal districts (Nowsad 2007, 2014). It is assumed that the technique for salt-preservation of hilsa was developed during periods of glut, as the high fat content of the fish makes it unsuitable for sun-drying. As there is no standardized method for *lona ilish* production, quality is variable and different grades are available in the market (Majumdar and Basu 2010). In recent days, mostly spent hilsa, along with those deformed from gill netting and those with of low quality, are used in salting (Nowsad 2014).

Ilish is the only species in Bangladesh that is commercially processed by salting. Two to three methods of salting are practiced as per demand in different areas. In Chandpur, Noakhali and Barisal-Barguna, both dry, wet and/or mixed salting are practiced, while in Chittagong and Cox's Bazar, a special type of salting leading to partial anaerobic fermentation is the preferred process. The catches that cannot be marketed as wet fish, because of a scarcity of ice or transport or as a result of low prices offered for spent fish, are only selected for salting during glut periods. Therefore, the salted-ilish product is 30%–50% cheaper in the market than the fresh hilsa of the same (Nowsad 2014). The value was compared between fish of equal-size by subtracting the weight of salt that adhered to the products, though salting removes about 25%–30% of the moisture from the body and adds similar weight through salt penetration (Nowsad 2007).

8.7 Hilsa exports from Bangladesh

Hilsa exports are an important source of foreign currency for Bangladesh. There is a huge demand of ilish in both national and international markets. Key markets include Bangla Province of India, and a number of countries in the Far and Middle East, the European Union, America and Australia, where there are populations of overseas Bangladeshis. In Europe, the US and some other countries, hilsa is available at Bangladeshi grocery stores (Mome and Arnason 2007). Every year, Bangladesh exports 6000–8000 t of ilish to India and other countries and earns around



Source: DOF Fisheries Statistical Year Book.

Figure 3. Total hilsa harvest from inland and marine sources in Bangladesh, 1987–2011.

BDT 500–600 million (DoF 2008). During peak season (August–October in 2006), on average 40 t of ilish were exported to India every day except Saturday and Sunday only through the Benapole border (Faruk 2009). Due to export pressure, in 2007 the local price of ilish in domestic markets went beyond the purchase price of the general people. Therefore, the Government of Bangladesh imposed a six-month ban on the export of ilish from 08 July 2007 to January 2008. Following the ban, the price of ilish in local markets was reduced by up to 30%–50% (New Age 2007).

Figure 4 shows the volume and value of hilsa exports between 2003 and 2011. In 2007, the export value plummeted due to a Government of Bangladesh imposed ban on hilsa exports. This ban was repeated once again in 2012 in an attempt to moderate price hikes during the Eid festival period.

Artisanal fisheries are by far the most important marine fisheries in Bangladesh. In 2006, about 93% of the marine catch came from the artisanal fishery, among which the hilsa fishery contributed over 41% of the catch. The catch from the artisanal hilsa fishery is sold directly to local agents. Traders buy fish at low prices from fishers located far from major urban centers. The traders visit different fish landing sites daily to buy fish and transport it to markets in major towns. The local price is dependent on the demand for fish and the distances of villages from major coastal towns. Hence, much of the variations in the price of fish are attributable to the cost of transportation. Prices tend to be lower farther away from the towns. Local agents supply the fish to the town market and some fish are transported to processing factories (Ahmed 2007; Mome and Arnason 2007).

Hilsa are graded according to two criteria: weight and location. Large fish weigh over 1 kg; medium fish weigh 0.8–1 kg; small fish weigh less than 0.8 kg. Fish are also classed as whether they are from riverine sources or from the sea. Hilsa harvested from rivers and from the sea are often differentiated in terms of price, with riverine fish usually fetching higher prices (Alam et al. 2012). In addition, the market price of hilsa depends on quality, season, market structure, supply and demand. Hilsa prices are known to follow a seasonal pattern, with demand peaking during festivals and not necessarily coinciding with bumper harvests. Prices also vary from market to market. Prices in town markets tend to be higher than in coastal markets due to a larger concentration of consumers and higher family incomes (Ahmed 2007; Mome and Arnason 2007).

This seasonal price fluctuation can be seen in Figure 5, which shows the retail price of hilsa over a 10-month period between October 2011 and July 1012, as recorded in 24 retail markets located in seven districts of Bangladesh (Bagerhat, Barisal, Faridpur, Jessore, Khulna, Mymensingh and Rangpur). This indicates a gradual upward trend in prices throughout the year for all three size grades of hilsa, increasing to a peak price of nearly USD 17/kg for 1 kg of fish during the month of May. Most of this peak can be accounted for by high prices in the markets in Barisal—the only one of the seven districts included in the survey that is a major hilsa landing site—during the month of May.

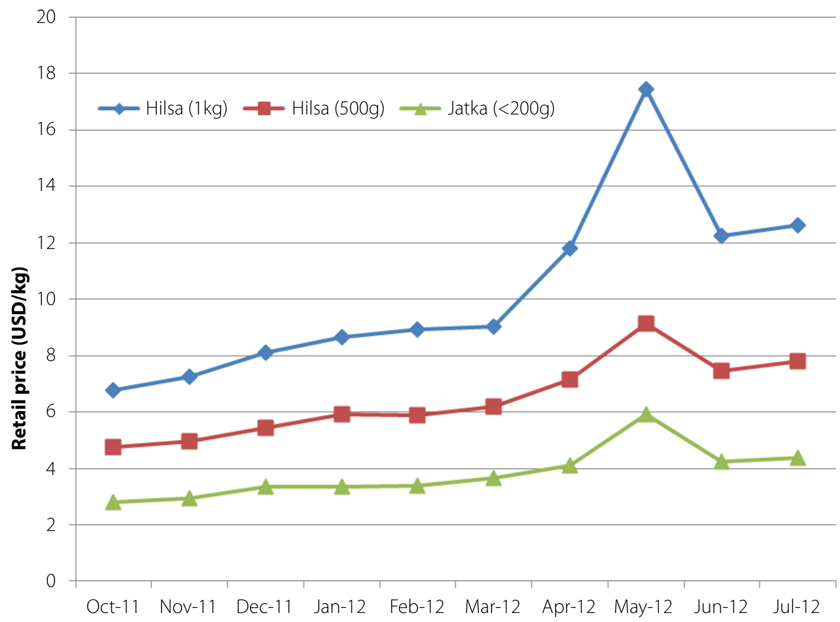
Source: FIQC DoF.

Figure 4. Hilsa exports, 2003–2011.

Marine hilsa fishing is organized by *arotdar* or *mohajon* (commission agents and organizers/suppliers of capital), who supply boats, nets and operating costs for fishing trips at sea. Many fishers work on a daily payment basis and do not have any ownership of the fish caught. The decision to sell is taken by *arotdar/mahajon*. As a result of their powerful position in the value chain, the major share (46%) of the price paid by consumers goes to *mohajon*, while fishers receive only 31% of the retail value. The market chain for hilsa and the proportion of the fish distributed along each marketing channel are illustrated in Figure 6.

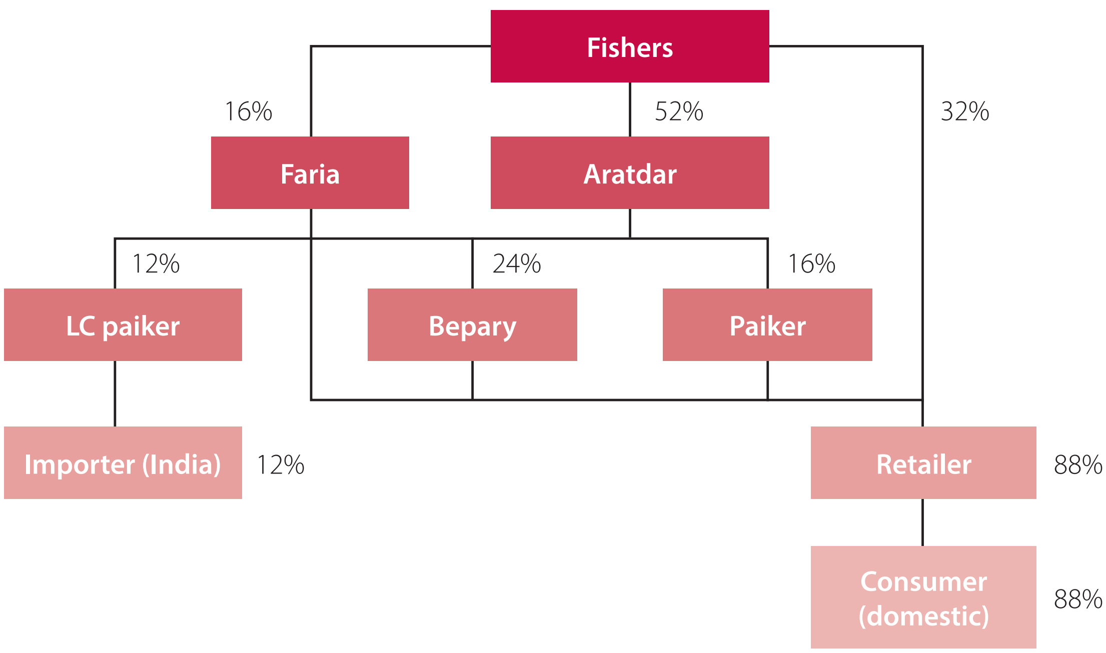
8.8. Share of consumer money among hilsa market actors in Bangladesh

Study on income and profit sharing among the fish market actors is rather scarce. The market value chain of river shad, *T. ilisha,* in two wholesale (Kawran Bazar and Showari Ghat) and two retail markets (Townhall market of Mohammadpur, Shah Ali market of Mirpur-10) in Dhaka was studied in 2009 under a BAU-Stirling University Joint MS program (Nowsad 2014). Ilish is a high valued popular species. Many types of market actors are involved in its lengthy market chain.



Source: unpublished WorldFish data.

Figure 5. Monthly variation in hilsa retail price by size grade, October–July 2012.



Source: adapted from data in Alam et al. 2012.

Figure 6. Hilsa marketing channels in Bangladesh.

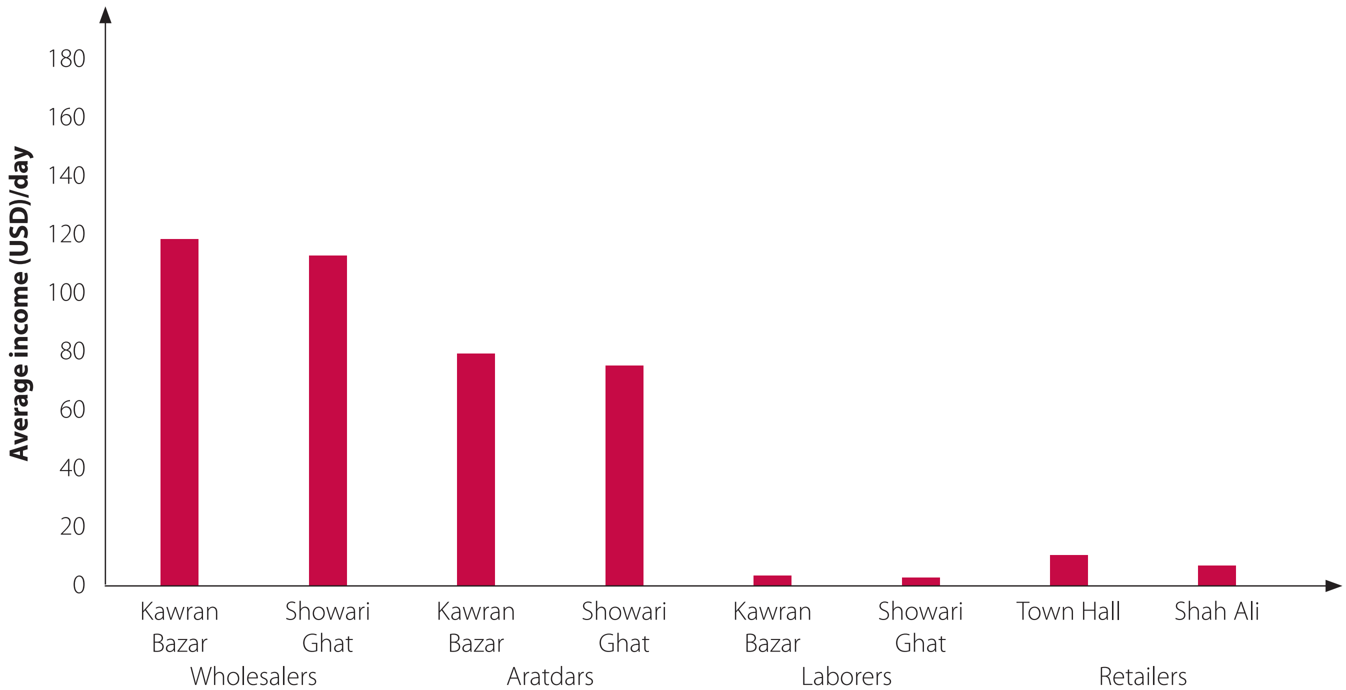
Therefore, the results of marketing margin and profit sharing in ilish may provide a glimse of the entire fish marketing scenerio of Bangladesh.

One study suggests that there are 400 *arats* in Kawran Bazar, where the net income of *aratdars* varies from USD 14.29 to USD 214.29 per day (Table 1). This is because in terms of trade volume the *arats* in Kawran Bazar are different is size. On the other hand, in Showari Ghat most of the *arats* are homogeneous in size, so the income variation is comparatively smaller here than that of Kawran Bazar.

More than 60% of wholesalers have an income higher than USD 100 where as only 12% of *aratdars* have the income more than USD 100. Most of the *aratdars* at Showari Ghat (90%) have the income level of USD 51-100. The income of retailers and laborers are significantly less than the income of wholesalers and *aratdars* (Figure 7).

The income level of around 30% of wholesalers in Kawran Bazar and Showari Ghat lies between USD 51 and USD 100. Over 60% of wholesalers have an income of more than USD 100 per day in both the markets. About 90% of *aratdars* in Showari Ghat have an income ranging from USD 51 to USD 100. Most of the *arats* at Showari Ghat are the same size, so their income is similar (Faruk 2009).

The income of laborers at Showari Ghat is comparatively lower than that of the income at Kawran Bazar, because there are large numbers of *arat* present in Kawran Bazar. The laborers have the



Source: Nowsad 2014.

Figure. 7. Comparative income of fish market actors in Dhaka.

Market operators	Markets	Average income /day($)	Standard Deviation	Maximum ($)	Minimum ($)	Number interviewed (n)
Wholesaler	Kawran Bazar	118.93	33.84	185.71	42.86	20
	Showari Ghat	112.94	25.32	142.86	71.43	16
Aratdar	Kawran Bazar	79.51	22.30	214.29	14.29	30
	Showari Ghat	75.46	14.58	114.29	57.14	23
Labourer	Kawran Bazar	3.57	0.87	5.36	2.14	30
	Showari Ghat	2.50	0.40	3.57	1.79	18
Retailer	Town Hall	10.19	1.89	14.29	7.14	30
	Shah Ali	6.76	1.10	8.57	5.24	10

Source: Nowsad 2014.

Table 1. Income of different market actors (per day/person in USD).

opportunity to serve a number of different *arat* in one day. In Showari Ghat, 94% of laborers have an income of USD 2.1 to USD 4. In Kawran Bazar, 30% of laborers have the income of less than USD 4 where as in Showari Ghat the percentage over USD 4 is zero.

In Townhall market of Mohammadpur, 93% of retailers have an income level of > USD 8, while in Shah Ali market of Mirpur, only 10% retailers have income of more than USD 8. Exactly 50% of retailers at Shah Ali market had an income level between USD 6.1 and USD 8 and a significant percentage had an income under USD 6. The retailers of Townhall market traded with more hilsa and earned more since the data was collected during August–September, the peak hilsa season. On the other hand, in Shah Ali market, the data was collected during November when the supply of fish was poor and hence income was less.

8.9. Hilsa marketing margin and profit

Marketing margin and marketing cost are usually used to estimate the profitability of different intermediaries. Total marketing margin is the difference between the selling price of the fishers, i.e. the buying price of wholesalers and the price paid by consumers. The price generally received by the fishers/fish farmers is much less compared to the price paid by the consumers. The highest average marketing margin received per kilogram of hilsa was found in retailers (USD 0.871 per kg) followed by wholesalers (USD 0.404 per kg) and then *aratdars* (USD 0.117 per kg) (Faruk 2009). Price per kilogram was calculated from the average price of each group. In the hilsa marketing system, the retailers buy fish from the wholesale market at a competitive price through auctioning. About 10 million people are living in Dhaka. The number of retailers are not sufficient to serve this huge number of people. They have the attitude to monopolize the market and charge a high amount from consumers. Therefore, they receive a significant marketing margin. The wholesalers buy fish from fishers at a comparatively lower price than in the market because they extend loans to them and fishers are bound to sell the fish to wholesalers. As a result, they gain a considerable margin of 10%. *Aratdars* have a fixed rate (3.5%) of commission on sales proceeds. They do not purchase fish from wholesalers, so in Table 2 their purchase price shown is hypothetical.

Although the retailers have a higher marketing margin than the commission agents (*aratdars)* and wholesalers (*paikers*), the net income of wholesalers is much higher than the net income of retailers (Table 2). The large volume of hilsa that the wholesalers sell in a day allows them to earn so much money.

8.10. Conclusions

Hilsa is very popular among consumers in the Indian subcontinent. It is one of the most important fishery export items of Bangladesh, so it is very highly priced in both local and international markets. The market actors also earn substantial profit from hilsa.

Hilsa markets remain in a complex situation in both India and Bangladesh due to the involvement of various stakeholders in the distribution chain. The typical distribution path is complex, although shorter distribution lines are seen due to the establishment of good supply and distribution chains and affluent outlets who have been found to deal among themselves comfortably.

Intermediaries	Particulars of Marketing	Price/kg (USD)	% of consumer purchase price	Marketing margin (%)
Wholesalers (*paikers*)	Purchase Price (PP)	2.835	67%	77-67 =10%
	Marketing Cost (MC)	0.029		
	Sales Price (SP)	3.240		
	Marketing Margin (MM=SP-PP)	0.405		
	Marketing Profit (MP=MM-MC)	0.376		
Commission agents (*aratdars*)	Purchase Price (PP) (Hypothetical)	3.240	77%	79-77 =2%
	Marketing Cost (MC)	0.029		
	Sales Price (SP)	3.357		
	Marketing Margin (MM=SP-PP) Commission Gained (CG=SP x 3.5%)	0.117		
	Marketing Profit (CG-MC)	0.089		
Retailer	Purchase Price (PP)	3.357	79%	100-79 =21%
	Marketing Cost (MC)	0.152		
	Sales Price (SP)	4.229		
	Marketing Margin (MM=SP-PP)	0.871		
	Marketing Profit (MP=MM-MC)	0.723		
Consumer Purchase Price		4.229	100%	

Source: Nowsad 2014.

Table 2. Margin and profit in hilsa marketing.

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Photo credit: Kingkar. Md Nahiduzzaman/WorldFish

Salted hilsa (*Nona Ilish*) in Boro Station fish market, Chandpur.

9. Nutritional values, consumption and utilization of hilsa

Authors

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Abstract

Hilsa shad, *Tenualosa ilisha* (H.1822), is one of the most important tropical fish in the Indo-Pacific region and has occupied a high position among edible fish because of its superb taste, mouthwatering flavor and delicate culinary properties. Hilsa is rich in amino acids, minerals and lipids because of its numerous essential and polyunsaturated fatty acids (PUFAs), which reduce the risk of heart disease, diabetes, cancer and obesity because of their very high levels of high density lipoprotein and low levels of low density lipoprotein. Hilsa is tastier during pre-spawning than post-spawning or maturing stages. Female hilsa grow faster, get bigger and are tastier than males of the same age group. Hilsa from riverine and estuarine environments are preferred to those from marine ones. Hilsa's unique taste has been attributed to the presence of many monounsaturated fatty acids (MUFAs) and PUFAs, namely oleic, lenoleic, lenolenic, arachidonic, eicosapentaenoeic and docosa-hexaenoeic acids. As a result of high market demand, this species is a good product to acquire foreign exchange. Therefore, postharvest handling, storage and transport are important factors to reduce postharvest losses. This chapter reviews the nutritional importance, consumption, postharvest handling, processing and use of hilsa as the most popular and commercially important food fish in the Indian subcontinent.

9.1. Introduction

Fish is one of the important sources of quality animal proteins, and its availability and affordability are better in regards to fish than other animal protein sources. Fish serves as a health-food for the affluent world owing to the prevalence of fish oils rich in polyunsaturated fatty acids (PUFAs), especially omega-3 PUFAs. It is also a rich source of nutrients for the people at the other extreme of the nutrition scale owing to its proteins, oils, vitamins and minerals and the benefits associated with the consumption of small indigenous fish (Bogard et al. 2015). Fish, especially saltwater fish, are often high in omega-3 fatty acids, which are associated with good cardiac health, and the inclusion of fish in a balanced diet is highly recommended by nutritionists (Nowsad 2014). This is conjectured to be one of the major reasons for the reduced risk of cardiovascular diseases among the Inuit (Bang et al. 1976). It has been suggested that the longer lifespan of Japanese and Nordic populations may be in part due to their higher consumption of fish and seafood. Oily fish is claimed to help prevent a range of other health problems from mental illness to blindness. Thus, fish has medicinal and therapeutic value and the health benefits of eating fish are now being increasingly understood (www. FISHupdate. com).

Five varieties of *Tenualosa* spp. (*T. toli* from Malaysia, *T. macrura* from Indonesia, *T. thibaudeaui* from Mekong, *T. reevesii* from Southern China and *T. ilisha* from Bangladesh, India and Myanmar) are found in tropical regions in Asia (Blaber et al. 1997), of which *T. ilisha* and to some extent *T. toli* and *T. kelee* are prevalent in Indian waters. Habitat, age, growth and migration habits differ from species to species. Among the five species, *T. ilisha* is the major component of fisheries in the Ganges-Brahmaputra-Padma river system. In the Hooghly estuary, hilsa, the state fish of West Bengal, accounts for 15%–20% of the total fish landing (Bhaumik 2010). Hilsa, the national fish of Bangladesh, contributes 11%–12% of total fish production and about 1% to GDP.

There are two bundles of muscles on each side of the vertebral column and each of the bundles is further separated into an upper mass above the horizontal axial septum and a ventral mass below the septum. In between the upper and lower bundle mass, along the axial septum, a thick sheet of dark muscles develops, spreading widely on the surface beneath the skin but extending conically up to the backbone (Nowsad 2010). Branched pin bones extend horizontally from the neural or hemal spines into the white muscle tissue. The abdominal parts of the lower bundles are devoid of pin bones. Because of its pin bones hilsa cannot be filleted. Most of the muscle tissue is white (65%–70%). White muscles have lower level of lipids, hemoglobin, glycogen and vitamins compared to dark muscles. The dark muscle, about 30%–35% of total muscle and located just beneath the skin, originates from the base of the caudal region and extends along the horizontal axial septum up to the cranium. The dark pigmentation apparent in the muscles is due to the presence of hemoglobin with myofibrillar proteins, called myoglobin. Dark muscles are generally devoid of pin bones and are characterized by higher levels of lipids, hemoglobin, glycogen and most vitamins. Dark muscle also contains more trimethylamine oxide and amino acids. The high lipid content of dark muscle in hilsa is important because of problems with rancidity. Dark muscle also inhibits the gel-forming ability of muscle tissue, which is an important characteristic of fish for heat-treated textured foods. The dark muscle primarily functions as a cruising muscle, for slow continuous movement, and is characteristic of migratory species (Huss 1988).

Due to the high lipid content, hilsa cannot be sun dried. The preferred method for short-term preservation is icing, while salting or salt-fermentation which is preferred for longer-term storage (Nowsad 2014). Some hilsa are also frozen. A few are smoked but, although previously available, are no longer found in the market (Nowsad 2007). High lipid content makes hilsa very susceptible to oxidative rancidity, along with rapid autolytic and bacteriological decomposition (Nowsad 2010). Proper handling and immediate icing of the fish are thus essential. Premium quality fresh hilsa has a silvery sheen, with a transparent watery mucus and pleasant odor. A reddish color is often found on the abdominal surface of each side of the fish in the market. Freshly caught fish do not have this color. The dark and associated surface muscles are supplied with enormous volumes of blood through networks of capillaries in order to supply sufficient oxygen and energy to facilitate continuous movement. The redness appears after death, when a portion of the hemoglobin molecule separates from the blood and floods the musculature beneath the skin; the redness, however, is not an indicator of quality deterioration (Nowsad 2010).

The present paper reviews the nutritional importance, consumption, postharvest handling, processing and use of hilsa as the most popular and commercially important food fish in the Indian subcontinent.

9.2. Nutritional value of hilsa

Fish contains proteins and other nitrogenous compounds, lipids, minerals and vitamins and very low levels of carbohydrates (Gopakumar 1997). The protein content of fish varies from 15% to 20% of live bodyweight. Fish proteins contain the essential amino acids in the required proportion and thus improve the overall protein quality of a mixed diet. The superior nutritional quality of fish lipids (oils) is well known. Fish lipids differ greatly from mammalian lipids in that they include up to 40% of the long-chain fatty acids (C_{14}-C_{22}) that are highly unsaturated and contain five or six double bonds; on the other hand, mammalian fats generally contain no more than two double bonds per fatty acid molecule. Fish is generally a good source of vitamin B complex, and species with high amounts of liver oils are excellent sources of minerals, such as calcium, phosphorous, iron, copper, selenium and zinc. Moreover, saltwater fish contain high levels of iodine. In fact, fish is a good source of all nutrients except carbohydrates and vitamin C. Some inland fish species such as singhi (*Heteropnestus fosslis*), magur (*Clarius batrachus*), murrels (*Channa* sp.) and koi (*Anabas testudineus*) are believed to have therapeutic properties (Mohanty 2011).

The importance of fish in providing easily digested proteins of high biological value is well documented. In comparison to other sources of dietary proteins of animal origin, such as chicken, mutton, pork and beef, the unit cost of producing fish is usually much lower. Fish also comes in a wide range of prices, making it affordable to the poor. An ordinary person can afford to meet the family's dietary requirement of animal proteins because (s)he has the option to choose from a fairly large number of fish species available. A portion of fish, even as little as 100 g, can provide one-third to one-half of one's daily protein requirement (Nowsad 2015). One hundred gram hilsa contains 22 g of protein, 19.5 g of lipid, 180 mg of calcium, and 250 of mg phosphorus, along with other nutrients (Mohanty et al. 2011). This explains how fish can play an important role in meeting food and nutrition security needs, especially in preventing protein-calorie malnutrition. In the past this has served as a justification for promoting fisheries and aquaculture activities in several countries. On a fresh-weight basis, fish contains a good quantity of protein, about 18%–20%, and all eight essential amino acids, including sulphur-containing methionine and cystein (Nowsad 2010).

A further advantage of eating fish is that, unlike meat, it contains very little saturated fat. The most important class of fat in fish is the omega-3 fatty acids. Hilsa is endowed with these valuable fatty acids and with lipids that play a major role in the physiological maintenance of body tissue. The fats found in hilsa are unsaturated, which is good for health. Cooked hilsa is known for its easy digestion and is also used during recuperation. Polyunsaturated omega-3 fatty acids (omega-3 PUFAs), Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) especially obtained from fish oil, are reported to have the potential to help cure coronary heart diseases, stroke, hypertension, cardiac arrhythmias, diabetes, rheumatoid arthritis, cancer and depression. It also improves brain development and the photoreception system. A 100 g of hilsa contain 22 g of protein and 19.5 g of fat. The highest fat content in hilsa (20%) was found in captured fish from the Mahanadi River mouth, while it was lower in Narmada catches along the Indian coast. The fatty acid profile of small pelagic fish of Sri Lanka have shown that the highest amount of saturated fatty acids (SFAs) in hilsa shad was 5844.5 mg/100 g of fish, where palmitic acid contributed 3345 mg/100 g of fish, as compared to other pelagic fish along the coast of Sri Lanka (Edirisinghe et al. 1998).

Nutrients	Value
Calories	309.58
Calories from fat	200.00
Protein	24.72 g/100 g
Total fat	22 g/100 g
Total carbohydrate	3.29 g/100 g
Vitamin C	27.22 mg/100 g
Calcium	204.12 mg/100 g
Iron	2.38 mg/100 g

Table 1. Nutritional value of raw hilsa.

The chemical characteristics of oil extracted from different body parts of hilsa show variations (Table 2). The saturated and unsaturated fatty acids present in hilsa oil are mainly myristic ($C_{14:0}$), palmitic ($C_{16:0}$), stearic ($C_{18:0}$), palmitoleic ($C_{16:1}$) and oleic acids ($C_{18:1}$). The free fatty acid (FFA) content (%) are initially low but increase rapidly on storage at room temperature (Salam et al. 2005).

The fatty acid composition of the oil from six different parts of hilsa show that the saturated fatty acids present in the oil are mainly myristic acid ($C_{14:0}$), palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$). The unsaturated fatty acids present in the hilsa oil are palmitoleic acid ($C_{16:1}$), oleic acid ($C_{18:1,\ n\text{-}9}$), linoleic acid ($C_{18:2}$), linolenic acid ($C_{18:3}$), arachidonic acid ($C_{20:4;\ n\text{-}6}$) etc. and are highest in hilsa eggs (Table 3) (Salam et al. 2005).

The fatty acid composition of different size groups of hilsa is given in Table 4. Analysis shows that medium-sized fish (800–1000 g) contained the highest levels of unsaturated fatty acids as well as omega-3 PUFAs (EPA ($C_{20:5;\ n\text{-}3}$) and DHA ($C_{22:6;\ n\text{-}3}$) and the lowest amount of saturated fatty acids. PUFA content was highest in small-sized hilsa (200–400 g); however, omega-3 PUFA content was lower and SFA content was higher in medium-sized fish (800–1000 g). In large-sized fish (1400–1500 g), although the omega-3/omega-6 ratio was highest, quantitatively they contained the lowest amount of PUFAs and highest amount of SFAs. Thus, on the basis of fatty acid profiles, medium-sized hilsa is best, followed by small, from a human health and nutrition perspective. Myristic acid ($C_{14:0}$) was the dominant SFA in small and medium-size hilsa whereas palmitic acid ($C_{16:0}$) was the dominant SFA in large-sized fish. The highest amount of stearic acid ($C_{18:0}$) was found in large-sized hilsa. However, there is no significant difference in stearic acid content between small and medium-sized hilsa. Oleic acid ($C_{18:1;\ n\text{-}9}$) was found to be the major monounsaturated fatty acid in all three size groups (Mohanty et al. 2012a). Oleic acid is a clinically important unsaturated fatty acid with great therapeutic value. It has been reported that oleic acid suppresses over-expression of the oncoprotein (Her-2/*neu*-coded) p185Her-2/neu in vitro, higher levels of oleic acid in breast tissue being linked to influencing the outcome of breast cancer (Menendez et al. 2005).

Parameters	Body parts					
	Dorsal	Ventral	Caudal	Egg	Liver	Brain
Saponification value	194.00	194.00	192.00	180.28	180.76	182.24
Iodine value	101.30	102.00	101.40	100.22	126.40	80.70
Peroxide value (m.eq.O_2/kg oil)	8.00	8.60	8.00	9.28	10.00	7.00
Acid value	4.28	4.16	4.30	7.16	12.00	8.72
% FFA (as oleic)	2.14	2.08	2.15	3.58	6.00	4.36
Unsaponifiable matter (%)	1.66	1.58	1.82	4.60	3.72	7.00

Table 2. Chemical characteristics of hilsa fish oil extracted from different body parts.

Fatty acids	Body parts					
	Dorsal	Ventral	Caudal	Egg	Liver	Brain
$C_{14:0}$	5.44	5.70	5.50	6.60	5.90	7.24
$C_{16:0}$	24.70	25.30	24.86	26.40	27.08	22.00
$C_{18:0}$	6.20	6.32	6.30	5.70	5.00	4.00
$C_{16:1}$	13.00	12.30	13.11	14.00	12.00	12.18
$C_{18:1}$	28.32	28.00	28.40	29.78	29.44	26.08
$C_{18:2}$	1.16	1.10	1.02	2.18	2.20	0.92
$C_{18:3}$	0.92	0.96	0.92	0.90	1.08	0.82

Source: Salam et al. 2005.

Table 3. Fatty acid compositions of hilsa oil extracted from different body parts.

Fatty acid	Small (200–400 g)	Medium (800–1000 g)	Large (1400–1500 g)
	(% of total fatty acids)		
Saturated			
8:0	0.05±0.04 a	0.03±0.03 a	0.03±0.01 a
10:0	0.06±0.02 a	0.05±0.01 a	0.02±0.01 b
12:0	0.41±0.01 a	0.37±0.23 a	0.09±0.03 b
13:0	0.24±0.25 a	0.05±0.01 a	0.02±0.01 a
14:0	38.78±0.12 a	37.77±0.02 b	9.67±0.48 b
15:0	1.69±0.04 a	1.48±0.01 b	0.34±0.12 c
16:0	0.81±0.05 a	0.21±0.06 a	38.26±0.05 c
17:0	0.82±0.03 a	1.05±0.03 b	0.19±0.05 c
18:0	0.24±0.02 a	0.26±0.06 b	8.86±0.16 b
20:0	0.62±0.06 a	0.67±0.03 b	0.20±0.02 c
22:0	0.48±0.09 a	0.45±0.02 a	0.22±0.09 b
24:0	0.43±0.02 a	0.44±0.04 a	0.11±0.05 b
ΣSFA	44.64±0.09 a	42.82±0.07 b	57.99±0.15 c
Monounsaturated			
14:1	0.26±0.05 a	0.18±0.08 a	0.07±0.04 b
15:1	0.08±0.02 a	0.05±0.02 a	0.01±0.01 b
16:1n-7	0.06±0.01 a	0.48±0.05 b	0.22±0.06 c
17:1	0.25±0.08 a	0.29±0.09 a	0.07±0.05 b
18:1n-9	26.55±0.51 a	30.66±0.19 b	25.42±0.25 c
20:1n-9	3.47±0.06 a	2.27±0.36 b	1.23±0.40 c
22:1n-9	0.38±0.06 a	0.64±0.02 b	0.09±0.04 c
24:1	0.55±0.13 a	0.78±0.05 b	0.20±0.13 c
ΣMUFA	31.60±0.19 a	35.36±0.20 b	27.59±0.18 c
Polyunsaturated			
18:2n-6	0.66±0.12 a	0.88±0.03 b	0.29±0.45 a
18:2tr	2.66±0.11 a	1.84±0.66 b	0.88±0.09 c
20:2n-6	0.13±0.02 a	0.12±0.03 a	0.03±0.02 b
22:2n-6	0.07±0.01 a	0.07±0.01 a	0.15±0.04 a
18:3n-3	2.61±0.06 a	2.23±0.04 b	0.59±0.13 c
18:3tr	0.86±0.16 a	0.68±0.05 a	0.74±0.72 a
20:3n-6	1.11±0.06 a	0.14±0.004 b	0.08±0.04 b
20:3 and 21	0.13±0.02 a	0.17±0.03 b	0.03±0.09 c
20:4n-6	4.66±0.03 a	4.14±0.06 b	1.21±0.33 c
20:5n-3	2.49±0.03 a	2.87±0.09 b	8.22±0.25 c
22:6n-3	8.41±0.01 a	8.95±0.03 b	2.02±0.42 c
ΣPUFA	23.78±0.08 a	22.11±0.25 b	14.75±0.39 c
Σω-3	13.51±0.09 a	14.06±0.05 b	10.83±0.68 c
Σω-6	6.62±0.12 a	5.36±0.09 b	1.76±0.37 c
EPA+DHA	10.90±0.03 a	11.83±0.09 b	10.24±0.57 a
Σω-3/ Σω-6	2.18±0.26 a	2.62±0.04 a	6.41±1.86 b
ΣPUFA/ΣSFA	0.54±0.01 a	0.52±0.02 a	0.25±0.02 b
AI	3.02±0.01	2.77±0.03	2.25±0.55
TI	0.62±0.01	0.59±0.01	1.18±0.02

Source: Mohanty et al. 2012a.

Table 4. Fatty acid composition of different sizes of hilsa.

9.3. Changes in proximate and fatty acid composition of hilsa

The spatial variations in the proximate composition of hilsa during migration from the Bay of Bengal to the Meghna river system were monitored for their nutritional value (Moniruzzaman et al. 2015). The results showed that the proximate composition of hilsa flesh varied widely and followed a gradual decrease in moisture (67.16%–62.48%) and increase in protein (16.29%–19.44%), fat (13.84%–14.67%) and ash (1.23%–2.45%) contents. The eggs of hilsa were found to be nutritionally valuable as they contained higher protein (15.62%), fat (18.23%) and ash (2.67%) contents.

Hilsa from the major landings sites of Chittagong and Khulna in Bangladesh showed that proximate compositions varied among body tissues (Shamim et al. 2011). Protein content was estimated to be 20.56%, 21.89% and 21.33% in the dorsal, ventral and caudal portions of hilsa obtained from Chittagong, and 20.87%, 20.40% and 20.50% in the dorsal, ventral and caudal portions of hilsa obtained from Khulna. Highest protein and fat contents were recorded in the ventral portion of fish from the Chittagong region (21.89% and 20.28%, respectively).

The nutrient composition of hilsa varies among the tissues and eggs of young, spent, mature and gravid hilsa based on upward migration and habitat (Moniruzzaman et al. 2014). Protein content in flesh was found to increase, while fat content decreased with the migration in the Meghna river systems from the Bay of Bengal. Lipid content was found 1.2 times higher in eggs than the flesh of hilsa in both sea and freshwater environments, with distinctly higher values observed in upward migration (Moniruzzaman et al. 2014).

The proximate composition of hilsa was also found to change during its anadromous migration in the Godavari River of India (Rao et al. 2012). Although changes in protein content during anadromous migration were not very conspicuous, wide variation in fat content was observed (Table 5). The fat content of marine hilsa was 12.4%, increasing to 17.3% in brackish water hilsa, gradually decreasing in Godavari hilsa (14.51% to 8.78%). The results suggest that hilsa gains significant fat content in the brackish water environment. This is in contrast to other anadromous fish, which accumulate fat in the marine environment and do not feed during their migration up river.

The Godavari hilsa showed decreasing fat content with time. It is likely that fatter fish move first from the brackish water location to the Godavari barrage. Hilsa must accumulate energy reserves during their growth phase in the form of lipids, mainly as triglycerides, which are catabolized to provide the energy necessary for anadromous migration and spawning. Jonsson et al. (1997) reported a decrease in lipid content during the course of upward migration of Atlantic salmon (*Salmo salar*).

Spatial variations in the fatty acid profile of hilsa during migration from the Bay of Bengal to the Meghna river systems in Bangladesh were also monitored (Moniruzzaman et al. 2015). Oil samples of flesh and eggs of hilsa collected from different landing stations from the sea to the banks of these rivers were analyzed to determine their fatty acid composition by Gas Chromatography (Table 6). Significant variations in different fatty acid groups, viz., saturated (44.57%–46.34% monounsaturated (36.52%–39.44%) and polyunsaturated (15.12%–18.91%) were noticed. Palmitic acid was found to be the predominant saturated fatty acid. The amount of omega-3 PUFAs was higher than that of omega-6 PUFAs in oils of hilsa collected from the Kirtonkhola and the Meghna Rivers. However, the amount of omega-3 PUFAs was lower than that of omega-6 PUFAs in oils of hilsa collected from the Payra River. The omega-3/omega-6 and omega-6/omega-3 ratio ranged between 0.76–1.18 and 0.85–1.31, respectively. On the other hand, the ratio of UFA/SFA, PUFA/SFA, and PUFA/MUFA varied

Proximate composition	Marine	Brackish water	Freshwater			
	June	July	August	September	October	November
Moisture (%)	63.5	62.31	64.63	66.3	69.29	66.64
Protein (%)	22.69	18.14	19.92	21.53	20.15	22.38
Fat (%)	12.4	17.38	14.51	11.18	9.83	8.78
Ash (%)	1.43	1.68	1.03	1.15	0.73	1.66

Source: Rao et al. 2012.

Table 5. Changes in the proximate composition of Godavari hilsa during anadromous migration to the Godavari River from June to November.

from 1.16-1.24, 0.33-0.42, and 0.38-0.52, respectively. Hilsa eggs were found to contain distinctly higher contents of unsaturated fatty acids (42.9%), where PUFA (27.7%) is 1.82 times higher than MUFA (15.2%). Likewise, omega-3 (19.47%) in eggs of hilsa is 2.36 times higher than omega-6 (8.24%). The results show that nutritional composition of freshwater hilsa changes during migration and the hilsa from the Meghna River appeared to be better than the other river and sea sources.

Changes in saturated and unsaturated fatty acid content during migration of Godavari hilsa in West Bengal were observed (Table 7). The SFA content was lower in Godavari hilsa (24.98%) than in brackish water (36.76%) and marine hilsa (36.03%). The higher SFA content apparent in marine and brackish water hilsa is thought linked to preparations for migration. Even though the total unsaturated fatty acid (USFA) content of marine hilsa (63.98%) and brackish water hilsa (63.14%) is similar, marine hilsa have higher MUFA levels (52.57%). PUFA content showed an increasing trend, with the lowest levels in marine (11.41%) and highest in freshwater hilsa (26.87%). PUFA content was higher in freshwater hilsa. The results suggest the transformation of fat, toward PUFA, during the migration of hilsa. PUFA was formed at the expense of either MUFA or both SFA and MUFA. PUFAs are integral constituents of cell membranes. The migration of hilsa from saline marine environments (30–35 ppt) to the low salinity brackish water or zero salinity freshwater environments changes the osmotic balance of the cells. Increased PUFA is necessary to reorganize the composition of vital membrane to maintain homeostasis (Rao et al. 2012). The change in fatty acid composition toward PUFA may be a physiological mechanism to cope with the changes in the salinity of water experienced during migration. The study showed that Godavari hilsa is a nutritionally rich fish with adequate amounts of protein, minerals and fat. Increases in PUFA were observed during the anadromous migration of hilsa. The nutritional composition of freshwater hilsa from the Godavari River appears to be superior to that of marine hilsa from the Bay of Bengal (Rao et al. 2012).

Constituents %	**Fish flesh**			**Eggs**
	Payra River, Patuakhali	**Kirtonkhola River, Barisal**	**Meghna River, Chandpur**	**Meghna River, Chandpur**
SFA	45.44	46.34	44.57	57.1
UFA	54.56	53.66	55.43	42.9
MUFA	39.44	37.9	36.52	15.2
PUFA	15.12	15.76	18.91	27.7
omega-3	6.55	8.53	10.23	19.47
omega-6	8.57	7.22	8.68	8.24
omega-3/omega-6	0.76	1.18	1.15	2.36
omega-6/omega-3	1.31	0.85	0.87	0.42
UFA/SFA	1.20	1.16	1.24	0.75
PUFA/SFA	0.33	0.34	0.42	0.48
PUFA/MUFA	0.38	0.42	0.52	1.82
DHA/EPA	0.74	3.04	1.07	0.36

Source: Moniruzzaman et al. 2015.

Table 6. Fatty acid profiles of flesh and eggs of hilsa, *Tenualosa ilisha*, collected from three riverine landing stations of Bangladesh during lean period (January–February 2014).

Hilsa origin	**SFA***	**USFA***
Marine	36.03	63.98
Brackish water	36.76	63.14
Freshwater (Godavari river)	24.98	75.02

*All values are expressed as % of fatty acid/total fatty acids

Table 7. Changes in the SFA and USFA during migration of hilsa from marine water to freshwater from June to November (Rao et al. 2012).

The crude fat content of hilsa increases with fish size at 6.74%–9.43% for small, 8.94%–12.56% for medium-sized and 11.25%–17.87% for large fish (Table 8) (Mohanty et al. 2012a). Substantial seasonal differences were also observed in all three size groups. Fat content was highest during July–October and lowest during November–February.

The physiological role of dietary proteins is to provide substrates required for the synthesis of body proteins and other metabolically important nitrogen-containing compounds. Therefore, the content of the nutritionally indispensable amino acids in food proteins is usually the primary determinant of nutritional quality of protein (Mohanty et al.

Size/Season	July–October	November–February	March–June
	(g/100 g of wet muscle)		
Small (200–400 g)	9.43	6.74	7.56
Medium (800–1000 g)	12.56	8.94	9.91
Large (1400–1600 g)	17.87	11.25	14.73

Source: Mohanty et al. 2012a.

Table 8. Seasonal variation in crude fat content of hilsa.

Amino Acid	Small (200–400 g)	Medium (800–1000 g)	Large (1400–1500 g)
	(% total amino acids)		
Essential			
Threonine	ND	6.32 ±0.17a	7.10 ±0.03a
Valine	6.58 ± 0.81a	6.35 ± 0.21a	5.80 ±0.81a
Methionine	3.30 ±0.29a	1.63 ±0.10b	2.72 ±0.02c
Iso leucine	5.35 ±0.12a	6.20 ±0.21b	4.69 ±0.58a
Leucine	9.25 ±0.33a	9.33 ±0.35a	8.03 ±0.06b
Phenylalanine	4.16 ±0.14a	3.71 ±0.42b	3.43 ±0.38b
Histidine	6.31 ±0.10a	5.47 ±0.41b	5.94 ±0.21a
Lysine	3.22 ±0.03a	2.35 ±0.25b	10.15 ±0.05c
Arginine	1.25 ±0.13a	0.94 ±0.03b	0.72 ±0.01c
∑EAA	39.42	42.3	48.58
Non-essential			
Aspartic acid	10.48 ± 0.04a	11.25 ±0.40b	10.21 ± 0.06c
Serine	6.56 ± 0.13a	7.02 ±0.31b	5.99 ±0.13c
Glutamic acid	15.16 ± 0.47a	15.39 ±0.22a	13.06 ±0.06b
Glycine	8.46 ± 0.39a	9.01 ±0.21b	8.22 ±0.25a
Alanine	9.34 ± 0.28a	9.59 ±0.15a	8.45 ±0.04b
Tyrosine	1.92 ± 0.54a	1.39 ±0.16a	0.84 ±0.16b
Proline	0.20 ± 0.05a	1.34 ±0.39b	0.91 ±0.10b
Cysteine	0.32 ± 0.03a	0.95 ±0.04b	2.11 ±0.06c
∑NEAA	52.44	55.94	49.79
EAA/NEAA	0.75	0.76	0.98

Values are shown as average ± standard deviation.
ND- not detected, EAA- essential amino acid, NEAA- non essential amino acid

Source : Mohanty et al. 2011.

Table 9. Total amino acid profiles of *Tenualosa ilisha*.

2014). Hilsa is rich in amino acids (Table 9), which are the building blocks of protein. In fact, essential amino acids (EAA) must be obtained from the diet, while non-essential amino acids (NEAA) can be synthesized from other sources in the body. The most prevalent amino acids are histidine, glutamic acid and aspartic acid, composition ranging from 5.47%±0.41% to 6.31%±0.10% in small hilsa, 13.06%±0.06% to 15.39%±0.22% in medium-sized hilsa and from 10.21%±0.06% to 11.25%±0.40% in large hilsa (Mohanty et al. 2012a). Total amino acid levels, in percent proximate analysis terms, range from 0.20%±0.05% to 15.16%±0.47% in small hilsa, 0.95%±0.04% to 15.39%±0.22% in medium-sized hilsa and from 0.72%±0.01% to 10.21%±0.06% in large hilsa.

A high plasma EAA-to-NEAA ratio is considered to be an index of positive protein nutritional status (Swendseid et al. 1963). A ratio of EAA to NEAA of about 0.70 indicates high quality protein content in fish (Bandarra et al. 2004). Hilsa contained a EAA/NEAA ratio between 0.80 and 0.90, based on season (Mohanty et al. 2014). The highest value of EAA/NEAA ratio was so far recorded in squid roe (0.93) and the lowest in sea urchin roe (0.65).

The paramount importance of hilsa from a nutrition point of view is further enhanced by the presence of minerals. Micronutrients play a major role in the metabolic activity of the human body, by serving as co-factor of enzymes. The macro minerals (Na, K, Ca, Mg) and trace minerals (F, Cu, Zn, Mn) are present in hilsa in good amounts (Table 10) when compared to other fish species.

Fish is a rich source of vitamins, particularly vitamins A, D, E in fatty fish species, as well as thiamine, riboflavin and niacin (vitamins B1, B2, B3). Vitamin A from fish is more readily available to the body than that from plant sources. Fatty fish also contain more vitamin A than fish with low fat levels. The vitamin content of medium-sized hilsa (Ganguly et al. 2015) is given in Table 11.

9.4. Musculature and the case for nutrigenomics

Study of the physical structure of fish is important in order to understand the nutrition profile and quality changes of fish during handling, transportation, processing, storage and heat treatment. Nutrigenomics is the study of the effects of foods and food constituents

Minerals	Concentration (mg/100 g wet weight)
Macro minerals	
Na	63.07±5.11
Mg	38.33±8.12
K	695.13±17.25
Ca	119.03±14.56
Micro minerals	
Mn	0.28±0.03
Fe	3.06±0.72
Cu	0.31±0.06
Zn	0.96±0.09

Values are shown as average ± standard deviation

Source: Ganguly et al. 2015.

Table 10. Mineral content in medium-size hilsa.

Vitamins	Concentration	
	(µg/100 g)	IU/100 g
A	712.93±0.59	2,376.43
D	133.6±0.60	5,344.0
E	841,545.45±0.47	925.70
K	1,163.85±0.62	-

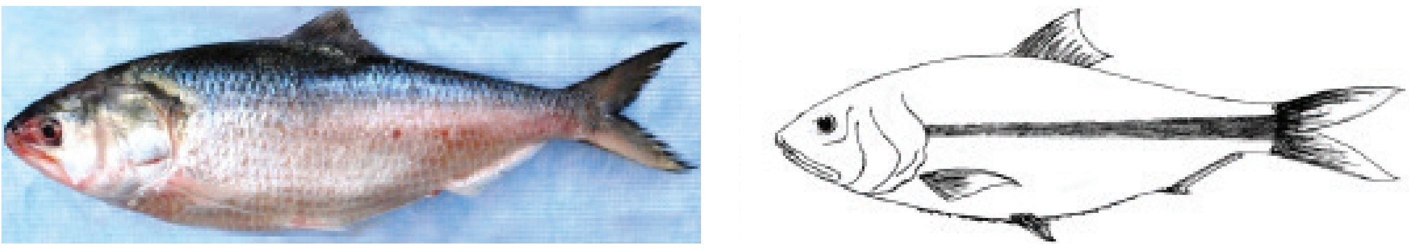
Source: Ganguly et al. 2015.

Table 11. Fat-soluble vitamin content of medium-size hilsa.

on gene expression that provides a molecular understanding of how common chemicals in the diet affect health by altering the expression of genes and the structure of an individual's genome (Muller and Kersten 2003). In fact, nutrigenomics is a type research focusing on identifying and understanding molecular-level interaction between nutrients and other dietary bioactive components with the genome (Astley 2007). Nutrigenomics can be described by the influence of genetic variation on nutrition, by correlating gene expression with a nutrient's absorption, metabolism, elimination or biological effects. By doing so, nutrigenomics aims to develop rational means to optimize nutrition with respect to the subject's genotype (Ries and Castle 2008).

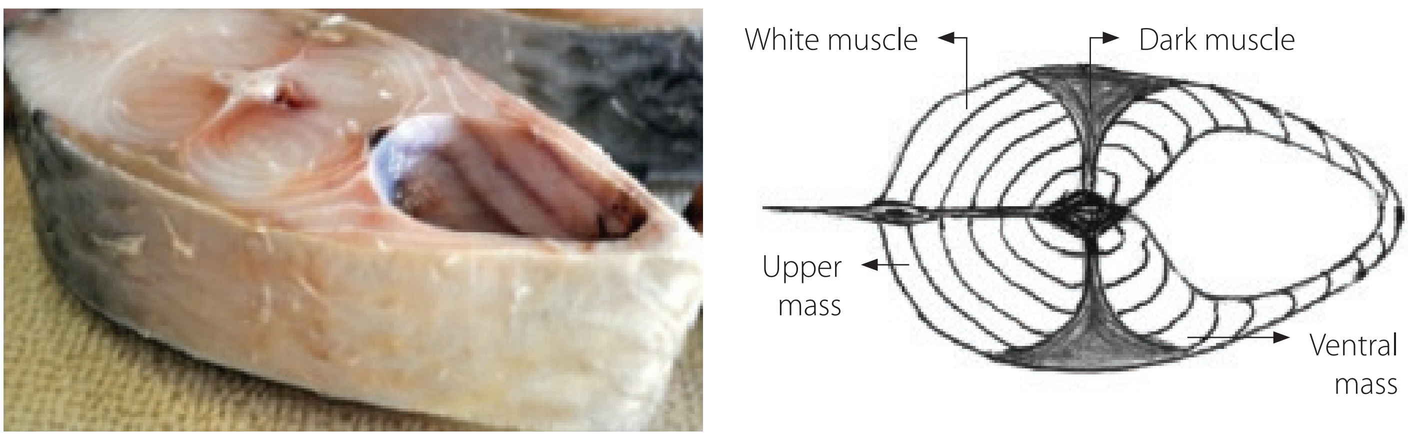
Like other teleosts, in hilsa there are two bundles of muscles on both sides of the vertebral column, and each of the bundles is further separated into an upper mass above the horizontal axial septum and a ventral mass below the septum. Between the upper and lower bundle mass, along the axial septum, a thick sheet of dark muscles develops, spreading widely on the surface beneath the skin but extending conically up to the backbone (Figure 1 and 2). The bundles of muscles, especially the upper bundles, are characterized by the presence of large Y-shaped branched pin bones. Pin bones extend horizontally from the neural or hemal spines into the muscle tissue. The abdominal portions of lower muscle bundles are devoid of pin bones. The presence of pin bones precludes hilsa from filleting. Patience is needed to separate cooked flesh from bones, which may deter people unfamiliar with hilsa from eating the fish for the first time.

There are two types of muscles: white muscle and dark or red muscle. Most of the muscle tissue is white (65%–70%). White muscles are full of pin bones and have lower level of lipids, hemaglobin, glycogen and vitamins than dark muscles. White muscle is used for sudden, quick movements needed, for example, to escape from a predator. Hilsa has 30%–35% dark tissue of brown or reddish color. The dark muscle is located just beneath the skin and originates from the base of



Curtsey: Nowsad 2010.

Figure1. Hilsa, *Tenualosa ilisha*. Mature female *Tenualosa ilisha* (left). Sketch of hilsa showing distribution of dark muscles along the lateral line (right).



Curtsey: Nowsad 2010.

Figure 2. Skeletal musculature of hilsa. Transverse cut at mid-region showing musculature (left). Sketch showing the distribution of dark and white muscles (right).

caudal region and extends along the horizontal axial septum to the cranium. The dark muscle color is due to the presence of myoglobin. Dark muscle, generally devoid of pin bones, is characterized by higher levels of lipids, hemoglobin, glycogen and most vitamins and usually contains more trimethylamine oxide and amino acids than white muscle. From a physiological point of view, the high lipid content of dark muscle in hilsa is important because of problems with rancidity. The dark muscle primarily functions as a cruising muscle for slow continuous movement (Huss 1988).

Skeletal muscle is the largest organ system in fish and represents the primary edible part. In fish, the skeletal muscle constitutes 34%–48% of total bodyweight (Addis 2010). Muscle composition contributes strongly to perceptions of quality as a food. Texture, elasticity and water holding capacity, all features highly related to quality, are dependent on the number and integrity of muscle fibers (Johnston 1999). The number of muscle fibers recruited during growth is dependent on a number of factors, including fish strain, diet, exercise training and temperature (Addis 2010). Muscle proteins are an important repository of much of the biological information. Since the proteins, not the genes, directly take part in various metabolic processes and physiological activities, depending upon whether it is a structural protein, an enzyme, a signaling molecule or growth factor or a defense protein (immunoglobulin), they can potentially provide most, if not all, of the vital information on the organism (Mohanty and Mohanty 2004; Mohanty et al. 2005; Ohlendieck 2011). All the proteins expressed by a cell, tissue or organ comprise the proteome. The study of the proteome is referred to as proteomics. Proteomics is functional genomics, meaning it focuses on the 10% of genes (or gene products) that are expressed/functional; about 90% of genes are not expressed and are, therefore, not well understood. It is a highly powerful tool in protein analysis, which supplements gene sequence data with information about where, in what ratios and under what conditions proteins are expressed.

Proteomics is an unbiased and technology-driven approach for the comprehensive cataloging of entire protein complements and represents an ideal analytical tool for the high-throughput discovery of protein alterations in health and disease (Hochstrasser et al. 2002; Martin et al. 2007). Mass spectrometry-based proteomics is concerned with the global analysis of protein composition, post-translational modifications and the dynamic nature of expression levels. The generation of large data sets on protein expression levels makes proteomics a preeminent hypothesis-generating approach in modern biology (Ohlendieck 2011). Aiming to better understand proteome alterations, it is vital to have a "reference proteome map" for a specific tissue and species, and the muscle proteome map may in fact represent a general "fingerprint" of the fish species (Figure 3. Mohanty 2012;) (Mohanty et al. 2009; Ohlendieck 2011).

Tenualosa ilisha is a commercially important food fish species and enjoys high consumer preference. Proteomics analysis of muscle is an important approach for gaining insight into the comparative muscle physiology and biochemistry under normal and patho-physiological conditions (Yi et al. 2008). Skeletal

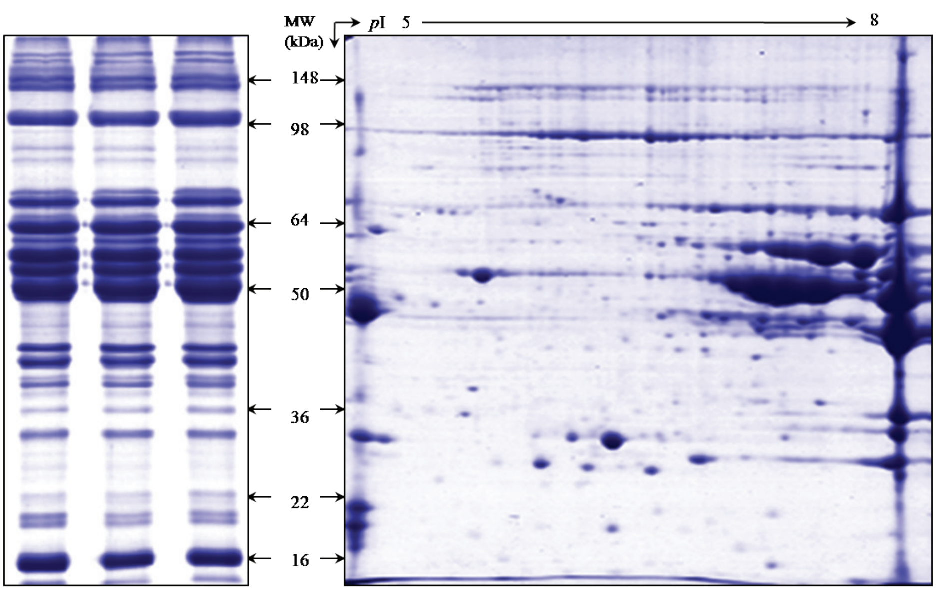


Figure 3. 1- and 2-Dimensional Gel Eectrophoresis profiles of *Tenualosa ilisha* white muscle protein extract. 12% Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) profile and 2-D gel electrophoresis profile. (Mohanty 2012).

muscle proteomics will also help to establish the global identification and biochemical characterization of the muscle-associated proteins including those associated with flesh quality (Mohanty et al. 2015). For example, as in hilsa, it is reported that medium-size fish contain higher levels of omega-3 PUFAs like EPA and DHA than small and large fish. The muscle/liver proteomics and transcriptomics can explain why it is so by showing the gene expression levels and abundance of the enzymes elongases (EC 6.2.1.3) and desaturases (EC 1.14.99.5) (Mohanty et al. 2012a). Thus, hilsa muscle proteomics and transcriptomics need to be studied in detail to understand the nutrigenomic aspects of this important food fish for optimal use of the health benefits associated with consumption of hilsa.

9.5. Hilsa for betterment of human health

The fatty acids present in fish oil are currently being championed as beneficial for human health (BNF 1992). The most efficient way to add these important oils to one's diet is to take at least two/three servings of fatty fish per week. Hilsa is a highly preferred food fish in Kolkata, India, and is always in great demand due to its taste and other culinary properties. Comparing the fatty acid profile of hilsa with other marine fishes, we found that omega-3 and EPA + DHA content of hilsa 14.06%–11.83% is higher than that of Indian mackerel 11.2%–6.42% (Marichamy et al. 2009). Moreover, the omega-6 content of hilsa (5.36%) is also higher than that of herring (2.93%) (Huynh et al. 2007) and Atlantic salmon (3.2%) (Blanchet et al. 2005). A single 40–45 g portion of hilsa consumed four times per week amounts to a weekly consumption of 160–180 g. Hilsa of 400–900 g (i.e. medium size) are the most widely available size in local fish markets and contain 1.55 g of EPA + DHA per 100 g of fish meat. Thus, 2.48–2.79 g of EPA + DHA are consumed per week, equivalent to a daily intake of 354–398 mg of EPA + DHA against a daily requirement of 650 mg of these two omega-3 fatty acids (National Institute of Health, as reported by Mohanty et al. 2012a). However, the projection of consumption pattern is for the peak seasons, when hilsa is plentiful in the market. In conclusion, hilsa can be a good means of providing PUFAs, especially the omega-3 fatty acids. However, a word of caution is need for affluent consumers who can afford to eat hilsa ad libitum. As mentioned earlier, and as has been reported by other workers (Rahman and Salimon 2006), hilsa contains relatively high amounts of SFAs (42.82%), as a result of which it has a relatively high atherogenic index and thrombogenic index (TI). Moderate consumption is best (Mohanty et al. 2012a).

The effect of eating hilsa in hypercholesterolemic subjects revealed that although the species is fatty and contains cholesterol, it may reduce blood cholesterol level. A study by Quazi et al. (1994) showed that after 10 months of eating 100 g of hilsa per day, serum total cholesterol level fell from 285.1 to 244.6 mg/dl (14.2% decrease) in hypercholesterolemic subjects. The fall in total cholesterol was exclusively due to a fall in LDL-cholesterol. Serum triglyceride and serum HDL-cholesterol increased in the experimental subjects by 12.5%. On the other hand, serum total cholesterol, HDL-cholesterol, LDL-cholesterol and triglyceride levels remained unchanged in control subjects. Both in control and experimental subjects there were no changes in bodyweight or blood pressure during the study period.

9.6. Why hilsa is called *Macher Raja*

Hilsa is considered one of the tastiest fish due to its distinctly soft, oily texture, superb flavor and mouth-feel. The fish is called *Macher Raja* in Bengali, which means the "king of fish." The unique tastiness of hilsa is reviewed by Nowsad (2012, 2014).

The human tongue recognizes four basic tastes as sensory responses in different taste buds, viz., sweet, sour, salty and bitter (Keller 1985). The sweet taste is sensed at the tip of the tongue, the salty taste at the tip and edges, the sour at the edges and the bitter at the deep back. Bitterness takes longer to perceive and tends to linger. Flavor is perceived when volatile flavor compounds stimulate the olfactory fibers in nasal air passages. Mouth-feel occurs at a variety of nerve endings in the oral cavity. When tasting, human sensory organs perceive not only the four basic tastes, but also experience warmth, cold, pain, tactile and pressure sensations. When food is taken into the mouth, all the sensations are usually recognized to verify the degree of tastiness (Keller 1985).

Konosu (1979) and Konosu and Yamaguchi (1982) reviewed the taste of fish and shellfish and concluded that there is an enormous variety of flavor compounds that vary according to species and biological conditions. The nucleus of taste and flavor in fish is constructed by the synergistic effects of glutamic acid and nucleotides along with sodium and chloride ions. The core flavor is enhanced by other taste active amino acids, mainly taurine and arginine, and nucleotides and inorganic ions. Peptides, organic bases, organic acids and sugars are also responsible for the characteristic taste of some fish species. Flavor volatiles, lipids, fatty acids and glycogen play a further important role in the resulting overall flavor. Konosu and Yamaguchi (1985) found large amounts of the dipeptide anserine in the muscle tissues of salmon and proposed that it plays a significant role in its taste. Various taste-active compounds for different taste attributes in fish are shown in Table 12.

Taste attributes of hilsa are compared with another very popular, tasty fish: Atlantic salmon (Table 13). Both fish are rich in nutraceutical compounds, very high in amino acids, minerals and vitamins, compared to many other freshwater or marine fish. Hilsa is lower in omega-3 FA but higher in omega-6 FA. On the other hand, Atlantic salmon is higher in omega-3 FA and lower in omega-6 FA. The only difficulty in swallowing hilsa is its high content of intermuscular pin-bones, but the flesh is very soft and oily. It tastes like marshmallow when placed on the human tongue by removing pin-bones, because of its characteristic fat particles, but are uniformly distributed throughout the tissue cells. It has a superb taste and mouth-watering flavor that subsides the difficulty of separating bones from the flesh while eating.

The unique taste of hilsa has often been attributed to the presence of certain fatty acids, including steareic and oleic acid and many of the polyunsaturated fatty acids (omega-3, omega-6), such as lenoleic, lenolenic, arachidonic, eicosapentanoeic and docosa-hexanoeic acids (Mohanty et al. 2011, Nath and Banerjee 2012, Rao et al. 2012). While it is a widespread assumption, the correlation between fatty acid content and the tastiness in hilsa has not been studied. It was mentioned earlier that hilsa is regarded as at its tastiest just before spawning than during post-spawning or maturing stages. During pre-spawning, the lipid content of female hilsa varies from around 16% to 22% (Mohanty et al. 2011; Rao et al. 2012). Riverine hilsa, especially those from the Padma River, are regarded as having a superior taste to those captured from the marine environment. A number of researchers have also claimed that a substock of hilsa exists in the Padma River, although the consensus is that a single stock of hilsa occurs in the regions shared by Bangladesh, India and Myanmar (BoBLME

Tastiness	Reasons	Reference
General taste and flavor	Glutamic acid, nucleotides, Na+, Cl-	Konosu 1979
Core flavor	Free amino acids: Taurine, argenine	Konosu 1979
Pertinent to taste	Peptides, organic bases, organic acids and sugars	Konosu and Yamaguchi 1982
Pertinent to flavor	Flavor volatiles, lipids, fatty acids and glycogen	Konosu and Yamaguchi 1982
Atlantic salmon (*Salmo salar*)	Anserine: all 5 species of Atlantic salmon are rich in anserine	Konosu and Yamaguchi 1985
Hilsa (*Tenualosa ilisha*)	Lipid-fatty acid-SFA-USFA (MUFA, PUFA)	Mohanty et al. 2011; Nath and Banerjee 2012; Rao et al. 2012

Table 12. Taste-active components for different taste attributes in fish.

Attributes	Hilsa	Atlantic salmon
Texture	soft, oily	tender
Taste	superb	excellent
Mouthfeel	like marshmallow	chewy
Flavor	mouth-watering	nice
Pin-bone	many small pin-bones	none or a few pin bones
Culinary importance	considered a delicacy	not considered a delicacy
Health benefit	many	many
Nutraceutical traits	omega-3 FA -lower; omega-6 - FA higher rich in amino acid, minerals and vitamins	omega-3 FA higher; omega-6 FA lower, very rich in amino acid, minerals and vitamins
Ritual importance	used in Hindu rituals	not known
Social value	highly esteemed	highly esteemed

Source: Nowad 2012.

Table 13. Comparison of taste attributes between hilsa and Atlantic salmon.

2011). Ahmed et al. (2004) found a distinct genetic difference between Chandpur-Kuakata and Cox's Bazar populations of *T. ilisha*. The substock of the Padma River is more likely to be rich in characteristic taste-active compounds that impart a distinctive flavor to the population.

The taste and flavor of many fish can be greatly influenced by food and feeding behavior (Connell 1975; Love 1992). The muscle of marine fish that have fed on the planktonic mollusc *Spiratella helicinia* are often described as having a petrol-like off-flavor, while the larvae of *Mytilus* spp. confers a bitter taste to herring (Connell 1975). The texture, color and flavor of fish flesh depend on food and feeding habits (Tangeras and Slinde 1994). The nature of habitat where it lives also influences the taste of muscles (Huss 1988). Tastes of cultured fish, including pangas (*Pangasius hypophthalmus*), climbing perch (*Anabas testudineus*) and Indian major carps can differ greatly from wild counterparts due to the type and quantity of supplemental feed administered. The unique taste of hilsa is widely attributed to the environment where it grazes and/or to the feed it consumes (Rao et al. 2012). While at sea hilsa remains short and thin, but when it enters freshwater its growth increases. Hilsa feeds on plankton, mainly blue-green algae (cyanobacteria), diatoms, copepods, cladocerans, rotifers and organic detritus (Hora and Nair 1940). The stomach of spawning hilsa was found to contain considerable amounts of mud and sand as well (Pillay 1958). Hilsa filters planktons but also forages on muddy bottoms in marine and brackish water environments (Rao et al. 2012). However, feeding reduces or even ceases as it migrates upstream from brackish waters to freshwaters (Pillay 1964) and instead is sustained by accumulated body fat. Thus, the fat content decreases as the fish migrates from sea to brackish water and then riverine environments. Hilsa with greater body fat reserves migrate faster and lose fat more rapidly in the rivers. Reduced fat levels in riverine fish makes the flesh softer. During spawning migration in low salinity waters, SFAs (fat deposits) are converted first into MUFAs and then into PUFAs. As fish such as hilsa, Atlantic, chum (*Oncorhynchus keta*) and sockeye (*O. nerka*) salmon migrate into freshwaters the greater the proportion of body fat is converted into PUFAs (Jonsson et al. 1997; Magnoni et al. 2006; Sasaki et al. 1989). The changes in tissue fat content and type are likely associated with changes in flavor, which is why, for example, the abdominal part of hilsa is believed to be tastier than the dorsal area, where both lipid content and level of unsaturation are higher (Salam et al. 2005; Shamim et ai. 2011). PUFA content was found to be lowest (11.41%) in marine hilsa and highest (26.87%) in freshwater hilsa (Rao et al. 2012). The transformation of SFAs and MUFAs into PUFAs is thus believed to be key important in determining the taste of freshwater hilsa. Furthermore, among PUFAs, the quantity of DHA (C22: 6ω3) was found to be 5.4 times higher than that of EPA (C20:5ω3) content in Godavari River hilsa, while they were present in smaller quantities in brackish water hilsa. In freshwaters, due to changes in osmotic pressure associated with reductions in salinity from 30–35 ppt salinity to almost zero, fish take in more water through the mouth, gills and skin to produce and expel increased volumes of urine. Thus, the musculatory system of the fish becomes relaxed, muscle cells become soft and flexible and the fat-protein intermolecular adjustment changes. As the fish swim up river, they flex their muscles, further contributing to loss of body fat and changing organoleptic properties (Mondal 2012). PUFAs act as integral components of cell membranes, helping the animal to cope with the changed osmotic balance in freshwater systems. Any off-flavors that may have accumulated in muscle tissues in marine/brackish water habitats tend to be eliminated in freshwaters. All these factors combine to impart a unique taste and flavor in hilsa flesh and make it the *Macher Raja* – the king of fish.

9.7. Consumption and utilization of hilsa

9.7.1. Postharvest handling of hilsa

Since hilsa is a high-lipid content, rapidly perishable tropical fish, proper handling is necessary to control and slow down spoilage so that this popular high-priced fish can reach the consumer in good condition. Because the flesh can rapidly deteriorate if treated badly, it is extremely important to handle this fish very carefully during all stages of transportation, retail distribution, processing, preservation and marketing.

Fishing gear determines the initial quality of harvested fish (Nowsad 2010). In Bangladesh, the crafts and gear for harvesting of hilsa differ from place to place and season to season. The most effective and popular gear used to harvest medium to large-size hilsa in marine and brackish waters are drift gill nets, lift nets (*veshal jal*), and seine nets (*jagat ber jal*). Small mesh monofilament gill nets, locally called *current jal*, are mostly used to catch juvenile hilsa in the river mouth, estuary and brackish waters. Nets are usually made of synthetic and monofilament fiber. Besides gill nets and seine nets, hilsa is also caught by set bag net, *shangla jal*, and *khora jal* or *veshal jal* (lift net). Usually motorized boats, locally called "trawlers," are used to catch hilsa in the sea and river. Motorized boats use inboard engines with capacity ranging from 18 to 65 HP. Generally, three types of motorized boats are operated in the estuarine and brackish water hilsa fishing areas. Small fishing boats operating in the estuary or near shore have a maximum of 4 crew on board. Some boats make a voyage for 3–4 days at sea with 5–8 crew, while large boats with a 65 HP engine sail for 10–15 days with crew numbering from 15 to 18. The boat owners generally hire fishers to catch fish against a pre-set share of the catch. Big merchants (*mohajons*) give cash loans and boats/nets to the fishers against the promise to sell the fish to them at tangibly lower than market prices. *Mohajons*/commission agents deploy collectors (*bepari*) to collect fish, which they then sell in wholesale markets. Traders purchase hilsa through the commission agents and transport them to big cities where they are re-auctioned through second commission agents to the retailers. Hence the quality of hilsa also depends on the capital flow, input and infrastructures and the awareness and attitude of market actors.

Until a few years ago hilsa were landed in major landing centers in most of the main rivers in Bangladesh (Haldar et al. 2004). During inundation, when flood water over-spilled river banks, huge numbers of hilsa left the rivers and found their way to *beels* or *haors* (Mazid et al. 2005). Most of those hilsa were caught and marketed locally within a few hours and did not require much care for quality. Upward migration of hilsa has since declined. Haldar et al. (2004) found hilsa and *jatka* only in 100 downstream rivers in Bangladesh. Over-exploitation has further aggravated the situation. The landing of hilsa is now confined to the lower shore areas of the Meghna River, Tetulia, Kalabodor, the downstream reaches of the Arial Kha River, the estuary of the Dharmagonj and Nayabhangani Rivers, other estuaries and coastal areas of Bangladesh (Hasan 2009). In contrast to freshwater landings of hilsa, marine landings have increased (DoF 2011). Hilsa is landed almost year-round in many landing centers at Teknaf, Cox's Bazar, Bashkhali, Chittagong, Hatia, Patharghata, Kuakata and Rangabali coasts and Khulna BFDC Ghat (Nowsad 2010).

When hilsa is harvested also determines its quality. Although they migrate up rivers during May–October, hilsa are also caught in small quantities more or less throughout the year in estuaries and brackish water areas. The main harvest time of hilsa is during August–October. Nearly 60% of hilsa are caught during this time, with a lesser season between May and June (DoF 2011). The fishing season varies from area to area. Fishing in the rivers starts at the beginning of the southwest monsoon and continues for up to 2–3 months after the monsoon has finished. Winter fishing is limited, starting in December and continuing up to March (Haldar et al. 2004). In the northern region hilsa is caught during summer and in the eastern region it is caught in the winter months. Dunn (1982) disagreed, saying that there are three peak seasons: one around February, another in June, with the major peak in September. Due to the very hot, humid climate, hilsa caught in Bangladesh requires proper handling and adequate icing. As it commands a very high price in both domestic and international markets, great care is generally taken in postharvest handling and marketing, unless a sudden glut catch occurs, overwhelming the supply of ice and other facilities (Nowsad 2010). Glut catches occur once or twice in a year, mostly during September–October.

Handling of hilsa on-board fishing vessels, at landing stages and in the different stages of distribution and marketing is more or less adequate (Nowsad 2010). This is partly because of greater awareness but it is mostly due to the high market prices. The price of inputs such as ice and fish boxes is high and adequate transportation is costly, but traders do not hesitate to pay because the extra cost can easily be recouped through additional price-hiking. While this applies to the big traders and suppliers who dominate the hilsa market, the handling of hilsa by small fishers and fish traders is often not up to the mark.

Lack of awareness and skill often creates real problems when fishers do not know how to look after their harvest from different gear. Fish caught in *current jal* (large drift nets) and other gill nets spoil rapidly as they struggle during capture. Juvenile hilsa caught in the coast and river mouths by monofilament *current jal* are most susceptible to spoilage. In hotter months, if not immediately put on ice, these fish spoil within a few hours of hauling. Field studies have revealed that traditional icing methods are often adequate for market size hilsa, except during glut catch when the supply of ice often cannot meet demand (Nowsad 2010).

In the traditional hilsa fishery of Bangladesh, fish are bulk-iced in the fish holds of motorized artisanal fishing boats. The size of fish holds depends on the size of boat. Generally, it varies from 3 x 2.4 m with a depth of 1.2–1.5 m in 18 HP engine boat to 3.8 x 3.0 m with a depth of 1.8–2.1 m feet in a 65 HP engine boat. Fish are stock-piled with ice in the holds. Large holds may be divided into sections using boards supported by stanchions. During glut catch, when the fish holds are full, because of the pressure of the huge quantity of fish and ice from the top, the fish at the bottom of the fish hold deteriorate rapidly, despite being iced. To overcome these problems, small boxes made of plastic or steel and/or empty plastic drums are increasingly used to keep hilsa in the hold. This type of icing is limited to only hilsa and other high-priced species in coastal and marine fishing.

Large fishing boats operating large gill nets (8–10 t capacity) stay at the sea for about 10–15 days. Small boats (0.5–1.5 t capacity) return to the land within 2–4 days. The boats generally carry less block ice than their capacity due to the high price of ice and the uncertainty of catching fish. For example, a large boat typically carries about 70–80 blocks of ice, each weighing 75 kilograms, which is insufficient to keep 6–8 t of fish chilled for 10–12 days. Most of the time fish holds are not full, so the quantity of ice carried does not compromise the quality of icing, except in glut catches, which occur on only a few occasions at the peak of the fishing season.

In Bangladesh, hilsa are iced in different types of containers and transported in many ways (Nowsad 2010). The majority of the hilsa are transported in bamboo baskets of different shapes and sizes, with or without *hogla* (aquatic plant *Typha elephantina*) mat or polythene cover and with sufficient ice. Transport of fish by bamboo basket can be up to several hundred kilometers and the content from a few kilograms of fish to several hundred kilograms. Quantities of 180 to 250 kilograms are often transported between districts in large bamboo baskets extended by up to 1 m in height using split bamboo and polythene gunny sacks. When two such baskets are placed on top of one another and transported for several hundred kilometers by truck, fish quality deteriorates badly.

Locally made large ice boxes stacked on top of one another on trucks are now used by innovative traders to carry fish from Khulna, Jessore, Chittagong, Cox's Bazar and other places. The boxes were initially designed to preserve ice blocks and unsold fish in the market to sell on the next or subsequent day (Nowsad 2007). They were referred to as community ice boxes since five community traders would share use of a single box. The technology has been successfully adopted over time in the bulk transportation of fish (Nowsad 2011).

Hilsa landed on the Barishal, Barguna, Patharghata, Kuakata and Sundarban coasts are mainly transported by waterway in country boats. Open boats are partitioned into several semi-insulated rectangular sections with or without wood boards, *hogla* mats or polythene sheets. Sometimes, styrofoam sheets are placed bewteen the wooden boards. The sections are lined with polythene sheets and filled with alternate layers of hilsa and ice. The sections are covered with a final layer of ice, polythene and hogla mats. Generally, fish landed in riverine stations such as Chittagong, Pathaghata, Chandpur or Showari Ghat of Dhaka are transported in this way.

Hilsa are thus transported by plastic drums, steel half-drums, country boats, sacks of hogla mats and woven plastic, polythene sheets, aluminium containers with or without lids, wooden, fiberglass or plastic crates, styrofoam boxes and ice boxes. Postharvest conditions of wet fish, along with consumption of harvested fish, are shown in Table 14. Hilsa was found to be nicely handled postharvest, along with other high-valued species like prawn, shrimp and pomfret.

About 68% of harvested hilsa are consumed as wet fish. Hilsa is brought to retail markets on ice and displayed for sale on large circular aluminium trays or galvanized iron sheets surrounded by ice. Fish not on display are kept in ice boxes or bamboo baskets wrapped with polythene with ample crushed ice around the fish. The fishmongers or *nikeries* are careful to try and maintain quality in order to attract buyers and secure best possible prices. Premium quality fresh hilsa is shiny silver in appearance, with transparent mucus film and a pleasant odor. The reddish or pink coloration, absent in fresh caught fish but sometimes seen on the ventral surface of fish in the market, does not indicate any deterioration in quality of the hilsa.

9.7.2. Postharvest loss in wet hilsa

Hilsa is a high-lipid, high-protein fish, which has 30%–35% dark muscle with relatively high levels of lipids, hemoglobin, glycogen, vitamins, trimethylamine oxide and amino acids. These characteristics make hilsa prone to spoilage at ambient temperature. Onset of rigor occurs within 15 minutes of death and the fish achieves full rigor within 2 hours at ambient temperature (33°C). Rigor lasts for 15–16 hours (Haque et al. 1997), after which decomposition of nitrogenous compounds leads to an increase in pH in the flesh and spoilage starts with autolysis and bacterial action in association with oxidation of lipids. As the fish is carefully handled by placing on ice during transportation and marketing, spoilage or quality deterioration is not significant in hilsa.

Loss of quality of wet hilsa was determined at different steps throughout the distribution channel (Table 15). A model, based on the sensory method of Howgate et al. (1992), was developed to standardize sensory data by chemical and microbiological quality indicators for greater accuracy (Nowsad 2010). Assessments were conducted at different steps along major distribution channels throughout the country for an entire year (March 2009 to February 2010) to determine seasonal and spatial variations in quality loss. At every distribution step, at least five samples of fish and three individual measurements per sample were assessed. Field data collectors traveled with the hilsa, from the point of harvest or landing along the value chains via primary and secondary commission agents to transporter/wholesalers and retailers and vendors, assessing deterioration in quality of the same fish or lot of fish at different stages.

In establishing quality loss, the distance of the consumer market from point of origin was taken into account and the average loss due to handling in hotter and colder months determined. No loss of quality was observed at the fisher, landing center or commission agent stages in primary fish markets. Losses in quality of 2% and 5% in wet fish destined for consumer markets were, however, observed at landing centers and *arotder* (wholesalers) (Table 15). This may be due to the unavailability of ice or transport in glut season catches. Uddin et al. (1999) reported significant loss of hilsa during periods of glut, mainly in August–September. During this period, most of the substandard hilsa are salted. Hilsa destined for salting suffer substantial losses while they are in the hands of fishers (14%) or at landing centers (43%).

9.7.3. Freezing of hilsa

Both *jatka* and medium-sized hilsa from glut catches are frozen into blocks on-board mechanized trawlers. Small hilsa are packed in polythene gunny sacks and frozen into large, 40–60 kg blocks. Frozen blocks of small hilsa and *jatka* are stored in land-based cold storage units and sold in domestic markets throughout the country at relatively low prices. Low-income people are the major buyers of frozen small hilsa. When sold in rural and urban markets, thawing of large blocks is not adequately carried out. Muscle distortion, torn heads, loss of opercula, burst bellies, etc., were observed as quality deteriorated (Nowsad 2010).

Hilsa exported to foreign countries are frozen whole, mainly in batch type air blast rack freezers as semi-IQF (Individual Quick Freezing) produce. Air blast spiral freezers and contact plate freezers are also used. Hilsa quality deteriorates when stored frozen for long periods of time due to oxidation of lipids and disintegration of myoglobin along the lateral line. Oxidation of fish lipids occurs slowly, even during frozen storage (Clucas and Ward 1996).

Semi-IQF of hilsa: On receipt of a consignment of iced medium-large premium quality hilsa, fish are weighed, washed, re-iced, dressed, washed again with chilled chlorinated (5–10 ppm) water (4°C) and reweighed. Hilsa is not gutted but processed whole for a semi-IQF product. Freezing plants that freeze white fish are equipped with air blast freezing equipment.

Fish groups	Pretreatment (% practice)				Icing BCM (% practice)[1]	Process pattern	Market pattern	% consumed as wet fish[2]
	Sorting	Gutting	Washing	Dressing/ filleting				
Giant prawn	97±1	Nil	95±3	Nil	87±9	Fre/Fro	Dom/Expt	19±9
Hilsa	97±2	8±2	77±18	Nil	88±3	Fre/Fro/Salt	Dom/Expt	68±5
Pomfret	98±0	Nil	87±12	Nil	91±4	Fre/Fro	Dom/Expt	33±8
Bombay duck	22±9	Nil	82±3	Nil	38±5	Fre/Dry	Dom/Expt	27±7
Ribbon Fish	27±4	Nil	87±4	Nil	42±8	Fre/Dry	Dom/Expt	14±4
Jewfish	65±12	Nil	86±5	Nil	72±12	Fre/Fro/Dry	Dom/Expt	18±7
Tuna/Mackerel	69±11	Nil	75±7	Nil	47±7	Fre/Fro	Dom/Expt	68±4
Sea bass	78±13	Nil	65±2	Nil	69±6	Fre/Fro/Dry	Dom/Expt	73±5
Penaeid shrimp	100	Nil	100	Nil	92±3	Fre/Fro/Dry	Dom/Expt	16±9

[1] Icing BCM: Icing before consumer market
[2] Estimated from interview checklist, RRA and RMA data. (Source: Nowsad 2010)
Fre: fresh; Fro: frozen; Dry: drying; Fer: fermentation: Dom: domestic; Expt: export
Data Source: RRA, SWOT analysis and questionnaire interview of the current study

Table 14. Postharvest situation of wet fish in Bangladesh.

Any water adhering to fish after washing is removed by fan. Fish are then transferred to stainless steel pans or racks placed on the freezer pipes of air blast freezers and frozen at –30 °C for 6 hours. Plants that exclusively process shrimp generally do not have batch or continuous type air blast freezer facilities. Dressed hilsa processed in shrimp/prawn processing plants are usually either frozen on the wire mesh of spiral freezers or, in the case of plate freezers, are frozen separately on freezing trays. Fish are then individually glazed, bagged and packed in 20 kg cartons under grades ranging from 10/12 to 20/22, the grade referring to the number of fish per 20 kg cartons. Hilsa are also sometimes packed as 1000 g+, 1200 g+, etc. Cartons are packed in durable polythene bags and stored frozen at –25°C.

9.7.4. Salting of hilsa

Salting is a means of preserving fish, whereby the water content is reduced through the penetration of salt into the tissues, inhibiting the activities of spoilage microorganisms. Salt inhibits the growth of microorganisms by drawing water out of microbial cells through osmosis. Concentrations of salt up to 20% are required to kill spoilage bacteria (Clucas and Ward 1996).

9.7.4.1. Dry salting of hilsa

In dry-salting, solar salt and turmeric powder are sprinkled over the dressed and cut fish. In large commercial applications, large quantities of salted fish are piled up in a circle in a large room. In small-scale operations, salt-treated fish are kept in bamboo baskets or perforated tins and the exudates are allowed to drain through the bottom holes. Fish are first scaled and the fins and gills removed. The fish is then cut transversely, from the dorsal to the ventral, by a sharp knife or *boti* so that the remaining pieces of flesh (0.75–1.0 cm thick) stay attached at the abdominal "keel bone" region. Sometimes a triangular piece is removed from the neck in order to enlarge the spaces between the pieces of flesh and to facilitate the concentric spreading of fish into piles. This also helps ease the mixing and penetration of salt and the removal of exudates. The gut is removed but the head is left intact with the body.

Salt is added to the fish, especially to the gills and mouths, the eyes and abdomen and in between each piece of flesh. One part salt is used to four parts fish. In addition to solar salt, a small amount of turmeric powder is used to develop a color in the product and to aid preservation.

Fish	Month	Distance to market (km)		
			Fishers/Farmer	Landing center
Hilsa (wet fish)	August–September	400–500	-	2±0.4
Hilsa (dry salting)	September	70–150	14±3	43±5
Rui	February–July	150–400	-	-
Catla	February–August	150–340	-	-
Mrigel	February–July	150–350	-	-
Kalibaush	February–July	150–400	-	-
Grass carp	March–July	150–350	-	-
Silver carp	March–May	150–400	-	-
Tilapia	February–May	150	-	-
Pangas	June	400–450	-	-
Bombay duck	January–April	250	3±0.2	4±0.8
Ribbon fish	December–February	50	8-10	10-14

Source: Nowsad 2010.

Table 15. Percentage of quality loss of fish in different stages of the distribution channel.

Fish is stored in piles in the case of large commercial production or in bamboo baskets and steel containers for small-scale production. In both cases, dry-salted hilsa are kept for 3–6 months to allow full development of sensory properties. Contamination can occur at every step of dry salting and neither the salt used nor the salting method itself is hygienic. In a study by Nowsad (2010), the raw material used was found to be stale, more than 60% of the raw material was no longer deemed fresh (Table 15) and hence the overall quality of the final product was found not to be good.

9.7.4.2. Wet salting of hilsa

In this method the fish is dressed, as with dry salting, but the head is removed. The dressed fish is either cut into small chunks or kept intact and salted either in brine or in dry solar salt. For brine salting, whole fish or fish pieces are kept in a saturated brine solution. Further salt may be added at this stage to counteract dilution of the brine by blood, slime and other exudates.

Where dry solar salt is used, fish are kept in a leak-proof tin container in alternating salt and fish layers, with a final layer of salt on top. The vessel is covered and kept for a few weeks in a cool, dry place. The exudates from the fish body due to salt penetration dissolve the surrounding salt, forming a concentrated salt solution in which the fish are bathed. Ripening occurs within 7–10 days. In both wet salting processes, the water, blood, slime and other exudates cannot drain away but instead contribute to the brine solution, thus forming a complex biochemical high salt mixture that probably helps to develop the characteristic texture, color and flavor of the wet-salted product. The keeping quality of wet-salted hilsa was found to be longer than that of dry-salted products (Nowsad 2005).

9.7.4.3. Salt fermentation of hilsa

Airtight pots are kept underground for 2–3 months and before filling with fish are prepared by polishing several times with mustard oil and then subsequently sun-dried. Turmeric powder is sometimes used with salt during fermentation. Semi-fermentation of the fish tissue takes place as the muscle softens, but the fish remains intact for 2–3 months and develops its characteristic texture and flavor.

9.7.4.4. Underground salting of hilsa

Undressed, unwashed hilsa is cut longitudinally along the base of the dorsal fin from the lumbar region to the cranium. For this purpose, the fish is kept flat on a uniform surface and the tip of a sharp knife is inserted through the base of the dorsal fin into the abdominal cavity. The knife is extended, parallel to the work

	% Loss*[1]				
	***Arotder*–1**	**Transporter/Piker**	***Arotder*–2/Processor**	**Retailer**	**Fish vendor**
	5±2	-	7±2	9±2	19±4
	-	-	61±7	-	-
	-	4±2	6±0.4	16±4	19±3
	-	3±2	4±3	12±3	17±2
	-	6±1	7±1	11±3	16±2
	-	4±1	8±2	9±2	12±3
	-	3±2	12±3	12±2	14±0.5
	-	3±0.1	4±2	13±3	15±3
	-	5±2	11±0.5	16±2	13±2
	-	-	4±2	7±3	10±4
	-	11±1	17±2	19±2	-
	20% in drying yard				

surface, forward to the cranium and backward to the tail and the entrails removed through the dorsal opening. The fish remains intact along the ventral line. Salt is put inside the fish and into the abdomen through the dorsal opening and additional salt is pressed into the gills, eyes and mouth and on the surface of the body. A chamber (0.6 x 0.6 x 0.9 m) is typically excavated in the earthen floor of a shed where rain water cannot enter. The inside of the underground chamber is lined with a mat of split bamboo, locally called *chatai,* and a polythene sheet. Salted fish are carefully layered in the lined chamber and generous amounts of salt added between layers. When the chamber is filled with fish, it is covered by a final layer of salt and a mat placed on top. The top of the chamber is sealed with a clay layer (0.3 m) and stones, wood–blocks or bricks are placed on the surface to press down on the fish. The top of the chamber is maintained at a height of 0.3–0.5 m above the floor. The open shed environment (no sides) also keeps the underground hold cool and dry. The exudates from the fish are absorbed by the surrounding soil. After 1–1.5 months, the flesh becomes slightly reddish and off-flavors due to pre-processing spoilage disappear with the development of a characteristic attractive flavor. The final product is flatter, wider and longer than the unsalted one.

9.7.4.5. Salt fermentation of hilsa in baskets

Salting in underground chambers generally requires a large quantity of fish. To process small catches, however, hilsa are salted and aged by semi-fermentation in bamboo baskets instead of earthen chambers. Hilsa is prepared in the same way as for the underground chamber method and kept in layers in polythene sheets surrounded by ample salt. Finally, the polythene sheet is sealed and the package kept in a woven bamboo basket for 1.5–2 months. A small mat covers the basket and heavy stones or bricks are used to press down on the fish inside the basket to release exudates. The surrounding polythene sheet is punctured at the bottom to allow drainage of exudates. The product is opened after 1 month and more salt added if required.

9.7.4.6. Maturing or ripening in salted fish

Maturing or ripening is a physico-biochemical process whereby a characteristic texture and flavor develop in the salted product due to complex autolytic, enzymatic and microbial action. In neither dry nor wet salting does salt uptake and water removal continue indefinitely; sodium and chlorine ions form a water binding complex with proteins which exerts

Curtsey: Nowsad 2010.

Figure 4. Aging of hilsa after dry salting in Chittagong.

an endosmotic pressure that eventually balances the exosmotic pressure due to the surrounding brine. Under this state of equilibrium, which occurs within 8 to 15 days of salting, depending on the species and size of fish, maturing or ripening occurs in salted products (Horner 1992). Having lost up to 20% of its weight through exosmosis of water to the brine, hilsa regains its original weight through salt uptake within 10–12 days. The enzyme responsible for maturing is derived mainly from the digestive system of the fish, the fish muscles and bacteria growing on the fish and in the salt. The products of proteolysis and lipolysis are also predominant in the ripened products. Lipolysis and oxidative rancidity play an important role in the flavor development of salted fish products. The products of Maillard browning reactions also make a significant contribution to the flavor of wet-salted fish (Jones 1962); in dry-salted hilsa, however, any browning is undesirable and can render the product unfit for sale.

Various researchers have studied the quality of ripened products produced in different ways in order to improve the traditional hilsa salting practice. Siddiqui (1993) found that the shelf life of salted hilsa packed in polythene bags and preserved at 4°C was of better quality than those kept at room temperature. Khan (1993) studied the changes in physical, biological and microbial quality of dry-salted, wet-salted and sun-dried and salted hilsa prepared in laboratory conditions and found that the combined curing method of sun drying and salting produced a more attractive yellowish color with hilsa's characteristic odor than that produced by traditional and other laboratory methods. When he compared four types of salted products, Mustafa et al. (2012) found the order of quality to be mixed salting, followed by dry salting, pickle salting and then brine salting. Rahman (1996) found a considerable loss of lipids during salting, in addition to moisture loss, but essential amino acids were found unchanged. Salted hilsa showed significant variations in the amino acid profiles in the finished product compared to that of raw hilsa, as shown in Table 16 (Majumder et al. 2005). This may be due to the formation of derivatives of amino acids,

Amino acids	Raw hilsa	Salted hilsa	% Loss during ripening
Aspartic acid	9.93	7.27	26.7
Threonine	4.11	3.31	19.4
Serine	3.37	2.67	20.7
Glutamic acid	16.59	11.21	32.4
Proline	0.99	0.72	27.2
Glycine	4.59	4.51	1.70
Alanine	6.34	5.03	20.6
Cysteine	0.68	ND	100
Valine	4.65	3.66	21.3
Methionine	1.56	1.44	7.70
Isoleucine	4.04	3.10	23.2
Leucine	7.91	5.70	27.9
Tyrosine	1.58	1.57	0.63
Phenylalanine	4.09	2.88	29.6
Histidine	3.58	1.86	48.0
Lysine	11.52	3.72	67.7
Arginine	4.39	3.49	20.5
Tryptophan	1.17	1.05	10.2

Source: Majumder et al. 2005.

Table 16. Amino acid composition (mg amino acid per 100 g protein) of salted hilsa.

such as amines and gluconeogenic substances. Lysine was greatly reduced, while cysteine was not present or detectable in the finished product.

9.7.4.7. Problems associated with salting of hilsa

Hilsa is a dark-fleshed, high lipid species. Icing is an effective short-term preservation method for the fish. Sun drying cannot be used because of atmospheric oxidation or rancidity problems. Long-term chilling and freezing are not useful due to the degradation of texture in the dark muscles. Considering the compositional characteristics of the species, comparative advantage and acceptability of different fish preservation methods, the socioeconomic condition and food habits of local consumers, salting seems to be the most appropriate method of preserving hilsa. The following problems, however, are associated with the process and the products (Nowsad 2010):

- Producers do not follow the regulations regarding public health and sanitation.
- During glut periods, only those fish that are spoiled or partially spoiled and cannot be sold in the fresh wet fish market are used for salting.
- Neither the fish nor the fish pieces are washed before salting in most cases.
- The raw material is contaminated by pathogens or other bacteria during scaling, gutting, dressing and processing by unclean knives, containers and other equipment.
- Low quality solar-salt is used, which inhibits the development of good texture, attractive color and good flavor in the product.
- The salt-to-fish ratio is not adequately maintained, often resulting in rancidity in dry-salted fish.
- Excess salting can denature protein, thereby impacting on the sensory and biochemical properties of the final product.
- In wet salting, pieces of flesh often float on the surface of the brine, thereby coming in contact with the air and becoming rancid.
- Semi-fermented hilsa is not always adequately protected in underground chambers. Rainwater and mud enter and insects and rodents attack and spoil or contaminate the products.
- Packaging and storage are inappropriate and unhygienic. Rancid off-flavor often develop in products kept in baskets for a long time.

9.7.4.8. Postharvest loss in salted hilsa

Postharvest losses were estimated in two types of salted products, dry-salted hilsa and wet-salted hilsa (Nowsad 2010). In both cases, 60% of the raw material deteriorated in quality. Pre-processing (handling, washing) and processing (dressing, chopping, salting, piling, etc.) losses ranged between 5% and 7%. Quality losses in final products were 65.6% and 67%, respectively, in dry- and wet-salted hilsa. Wet-salted pieces of flesh were found floating on the surface of the brine in salting containers, becoming rancid due to contact with the air, a likely cause of the comparatively higher qualitative losses associated with wet salting. No quantitative losses were found during packaging of wet-salted hilsa and transportation, storage and marketing losses were minimal (2.5%, 2.8% and 2.3 %, respectively). Thus, total losses in wet-salted hilsa were only 7.6%. It is thought that the comparatively low losses may be due to the reduced chances of drying out the product during processing and post-processing, compared to dry salting. Quantitative losses in dry-salted hilsa were 23.2%. Storage and marketing losses alone were estimated at 12.2% and 5.4%, respectively.

9.7.5. Smoked hilsa

With the current reductions in catch and the increased availability of ice, the extent of smoking of hilsa has been reduced significantly. The higher prices paid for wet fish may be another reason for the marked reductions in smoking. Indeed, the product is no longer found in the market. However, local people in Teknaf still prepare this delicate dish at home for their own consumption. The brilliant color and delicious flavor have made it one of the most cherished food items and delicacies of this area.

Smoking process: Fish are scaled and gutted, then thoroughly washed with clean seawater. Fish are then split along the dorsal line to expose the flesh, keeping the fish intact along the ventral line. After treatment with salt (3%–6%), split fish are secured between two triangular split bamboo frames, so that they are easy to handle and turn on the fire and ensure uniform smoking. Triangular, fine mesh frames made of split bamboo are sometimes used for small hilsa. The framed fish are secured to a narrow-meshed smoking rack made of split bamboo in such a way that the anterior split portion of the fish receives smoke directly. The smoking rack is placed 0.8 m above an earthen oven fueled with local wood. No flame, only smoke, is allowed, and any fire breaking out being stopped immediately. Flames burn the flesh and cause a brittle texture to the muscle, which separates from the bones. Smoking results in a firm but elastic textured product relished by consumers. Green or semi-green wood is used to generate intense smoke. Smoking is a two-step process. In the first step, smoking is carried out for 4–5 hours. However, to ensure best quality and a longer shelf life, the product is again smoked for 2 hours 2–3 days after first smoking. As a result, the bones soften. The final product is bright red inside, while the skin remains transparent. Products are stored and marketed still within the smoking frames, which are kept in large open-mouthed split bamboo baskets, locally called *lai*.

Field studies suggest that memories of smoked hilsa have already been lost because of the availability of ice and the development of other low-cost improved preservation methods (Nowsad 2007). Improvements in quality and better packaging and marketing would probably be necessary for smoked products to regain their importance in the competitive market. Attempts have been made to produce smoked hilsa as a ready food item. Smoked hilsa made from 10% salt and garlic resulted in a better product than fish treated with 10% salt, garlic and coriander, and only 10% salt. The proximate composition of smoked hilsa is 39.65% moisture, 25.65% protein, 24.85% fat, 3.5% ash and 16.2% salt (Hossain et al. 2012).

9.8. Hilsa consumption

Fish is not only important for human nutrition; it is also part of the Bengali culture. Fish demand remains unmet, and average per capita fish consumption is still below recommended dietary levels. Despite the recent dramatic increases in aquaculture, the pattern of fish production and the relative importance of different species have remained relatively unchanged during the last decade. In many developing countries, official national statistics on per capita fish consumption are commonly based on the total availability of commercial fish in the country and do not include the consumption of many small and non-commercial fish species obtained from artisanal and subsistence fisheries. It is widely believed that actual per capita fish consumption is higher than the national average reported in official statistics (Dey et al. 2005).

Fish consumption in Bangladesh varies across income groups. For example, the monthly consumption of the bottom income quartile is only 1.10 kg/capita, which is less than half that of the highest quartile group. Fish consumption also varies across different types of consumers. Urban consumers appear to have the highest fish consumption (1.96 kg/capita/month), followed by producers (1.92 kg/capita/month) and rural consumers (1.69 kg/capita/month). As for specific species, the highest consumption is of assorted small fish, accounting for 29% of total fish consumption. This is followed by Indian major carps (22%) and exotic carps (21%). The shares of the other species are as follows: hilsa (9%), live fish (7.6%), tilapia (4.7), shrimp and prawn (4%), and high-valued species (3%). The pattern of per capita fish consumption varies seasonally, consumption being in inverse relation to average fish price.

When consumption is disaggregated further by origin and species, some interesting patterns emerge. Medium-sized freshwater capture species and hilsa (including *jatka*) are the first and second most important categories of fish, being eaten in large quantities by consumers in all income groups.

9.9. Conclusions

The oily fish hilsa is known worldwide for its unique aroma and distinctive flavor, which is deemed delicious by many South Asian people. Hilsa is very favored also because of its easily digestible proteins (amino acids), the presence of omega-3 fatty acids, triglycerides, vitamins (vitamin D, vitamin A and some members of the vitamin B family) and minerals such as selenium, zinc, phosphorus, calcium and iron. Like salmon, hilsa is a rich source of omega-3 fatty acids, such as EPA and DHA, although the PUFA content is lower than that of salmon. Hilsa is also known for its appetizing and culinary properties. The highly nutritive and culinary properties of the species thus amply justify the adage *macher raja ilish*. This also makes hilsa a strong candidate for aquaculture and justifies the urgency in standardizing the breeding technology and management practices for this prized fish for early domestication. Additionally, the nature and extent of exploitation need to be studied in order to reduce pressure on stocks of juvenile hilsa and brood hilsa. Efforts need to be made to diversify the range of value-added hilsa products and to ensure that the fishing communities get their due share of profits from their catches, so that they can build resilience to adapt to the situation of dwindling catches from the Padma and Meghna rivers and estuarine systems.

Note: Data on postharvest handling and processing of hilsa was a product of a research project funded by FAO titled Post-Harvest Loss Reduction in Fisheries in Bangladesh: A Way Forward to Food Security (FAO-NFPCSP-PR#5, 2008). Some of the data used in this paper was generated under the Outreach Activity on Nutrient Profiling and Evaluation of Fish as a Dietary Component (ICAR-FSD-OA#3) (BPM), sponsored by the Fisheries Science Division of the Indian Council of Agricultural Research.

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Ilish chattar in Bhola.

10. Social, cultural and religious importance of hilsa

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Abstract

Since ancient times, fish has been an important food in Bengal and surrounding states. Its importance in the diet has been described in many religious scripts in Indian culture, even before Christ. Bengalis love fish and their cultural identity is often summed up in the traditional saying, *Machche Bhate Bengali* ("fish and rice make Bengalis"). Among the rich aquatic biodiversity, hilsa's position as a food is paramount and it is thus referred to as *Macher Raja* ("the king of fish"). In many Bengali-Hindu families, two hilsa fish are bought on special auspicious days (e.g. during *Pujas*). It is considered auspicious to buy two hilsa during *Dussera* and also on the day of *Saraswati Puja*, which takes place in the spring, and on the day of *Laksmi Puja*, which takes place in autumn. Hilsa holds an esteemed position in Bengali culture, especially in weddings and *Jamai Sashti*. A *Jamai Sashti* meal is never complete without at least one hilsa dish. It is said that there are more than 100 ways of cooking of hilsa; no other fish is prepared in so many different ways. There is a rich tradition of catching hilsa based on experiences passed down from generation to generation. Fishers believe that hilsa are attracted to the surface of the water by the light during full and new moons and can be readily caught in huge quantities. Cultural measures have been implemented to conserve hilsa, and breeding the fish has been secured by imposing cultural norms, such as forbidding eating it during breeding.

10.1. Introduction

From ancient times, fish has been considered as one of the best food items by the people of Bangladesh, West Bengal and other states of India. In recent years, because of increased awareness of health issues, the importance of fish in a balanced diet has been increasing. The activities based around the production, harvesting, marketing and trading of fish play a major role in income, employment and livelihoods of millions of people, especially in this part of the world.

People's preferences for fish depend on taste, flavor, shape, color, place of production and availability. Bengalis love fish, and their cultural identity is often summed up in the traditional saying *Mache Bhate Bengali* (rice and fish makes Bengalis). Among the diverse and rich aquatic biodiversity, hilsa's position as a food is paramount and it is thus referred to as *Macher Raja* (the king of fish). Hilsa's place as favorite among Bengalis has been further secured through the myriad ways of preparation of the fish and its use in ceremonial festivals such as pre-marriage events, wedding ceremonies and afterward, during the celebration of Bengali New Year, *Pahela Boyshakh* and in the celebration of religious festivals, especially among Hindu communities. Thus, hilsa is important socially, culturally and religiously to the Bengali people of Bangladesh, West Bengal and Indian states such as Orissa, Bihar and Assam.

Ironically, as discussed elsewhere in this book, the production and availability of hilsa have seriously declined in recent years, as its price has become so high that people of average and low income groups can no longer afford to buy and enjoy this delicious fish. Furthermore, it is claimed that the taste and flavor of hilsa has deteriorated due to the deterioration of water quality in the rivers. Bengalis are unhappy that hilsa is no longer within their means, and that even when they are able to eat it, it does not taste as it once did.

10.2. Fish in mythology

The ancient Indian treatise on statecraft, the *Arthashastra*, written some 2350 years B.C.E., mentions that reservoirs were stocked and managed as fisheries, that fishers were taxed and that fish was so plentiful it was sometimes used as agricultural manure (Hora 1948b). Ashokan epigraphical material from a period shortly after the earliest form of the *Arthasastra* confirms the importance of fish. Edicts written on stone pillars (the Pillars of Ashoka) are found in at least six places throughout the Mauryan Kingdom of the Northern Indian subcontinent. They name the fish and other animals that must be protected during breeding and provide a list of other measures to limit the taking of fish and/or their careless slaughter (Hora 1950; Thapar 1961). Aquatic animals named include the Gangetic shark (*Glyphus gangeticus*), the Gangetic eel (*Monopterus cuchia*), the Indian freshwater dolphin (*Platynista gangetica*), the skates (family Rajidae) and the puffer or porcupine fish (*Tetraodon patoca*) (Hora 1950). Such concerns may reflect Ashoka's philosophy of non-violence in the propagation of his dhamma, but they also highlight the importance of fisheries and fishery products. Indeed, Thapar (1961) has commented that this edict most probably reflects the difficulty the emperor experienced in banning the catching of fish because of its importance during the Mauryan period. Furthermore, Buddhist texts such as the Jatka tales, provide further support to the picture of widespread fisheries. In one place, for instance, fishing communities comprising a thousand families in Kosala are referred to (Hora and Saraswati 1955).

Hora and Thapar both hold the view that the evidence for widespread fisheries is also an indication that fish was widely used as food. Hora draws evidence from the *Arthashastra* that "fish was relished as an article of diet" (Hora 1948b), while Thapar (1961) talks of fish as "an important item of diet in Mauryan times." On the evidence of the Jataka tales, Hora and Saraswati (1955) claim the following:

> Fish eating was widely prevalent and highly esteemed in the days of Jatka tales. Even ascetics enjoyed fish dishes [no. 234]. ... Ajivikas, a religious order of naked ascetics, are also said to have a fish diet [no. 94]. Women are regarded as having a particular yearning for fish ... [no. 419].

Hora and Saraswati (1955) also point out, moreover, that the tales even provide practical culinary advice:

> One of the usual modes of preparing fish for eating was to roast it in the embers. We have evidence, too, of fish being dressed and richly cooked, each kind in a different manner.

In discussing the *Ramayana*, Hora (1952) also points to the fact that the heroes of the epic receive advice on cooking fish on the shores of Lake Pampa:

> Laksmana is advised to have the scales cleared and the fishes roasted in an iron pan over the fire. In Aranyakanda, Rama and Laksmana are advised to cook rice and fish with salt and red pepper on reaching an asrama on the west bank of the Pampa Lake.

By the time of his 1953 paper on the *Sruti* and *Smrti* literature, Hora was in no doubt about the importance of fish in the general diet:

> References to fish in the Srutiss and the Smrtis are only casual. Though they are few and far between, they reveal to a considerable extent the part played by fish in man's affairs in those early days in India. It shows also that for the Hindus, most of who are now vegetarian, fish then formed an important item of food.
>
> Apart from general allusions to fish here and there, we have references to specific types of fish in different contexts. Chiefly, it is in connection either with the sraddhas (i.e. ceremonies where food is offered to the manes and is actually consumed by Brahmana priests) or with certain forbidden foods that the different types of fish are mentioned.
>
> When it is not forbidden, certain species are shown preference over others, either for higher merit or for their greater food value. Again, when meat does form a part of offered food, fish is often declared superior to flesh of other animals.

Hora (1953) stated that it can be safely concluded that during the period 2600 to 1800 B.C.E., fish was generally considered to be a valuable article of food among Hindus, though certain species or kinds of fish, for one reason or another, were forbidden to be eaten. Among those regarded suitable for eating, there was a regular gradation in quality or value. The *Smritis* contain contradictory statements about the use of fish as food, which shows the working of the social, religious and political influences by which taking of any kind of animal flesh became a taboo afterward (Hora 1953).

Das (1931) dealt with the ways in which fish were associated with two important social areas of Hindu custom: marriage and the rituals of *sraddha*, the obsequies during which offerings are made to the deceased or to the manes collectively. Marriage, he noted, was invariably connected with fish in every part of the then Greater Bengal province. In the ceremonies which preceded marriage in the Hindu custom, fish were invariably among the items sent to the houses of both the bride and groom. In Eastern Bengal, now Bangladesh, the items sent for *adhibasa* "always include a pair of fish with scales," generally one larger than the other; in Western Bengal, now Bangla Province of India, fish were sent for *gaye-halud* "the ceremony of smearing with turmeric paste" (Das 1931). In the Muslim custom in Bangladesh and Bangla Province of India, sending fish to each other's family is the symbol of social dignity, heritage and wealth. In Hindu custom, however, the start of marriage is marked with fish, which is regarded as an auspicious article throughout the ceremony and even later in life (Das 1931). Das (1931) identified the following events:

- When the bride enters the house of her husband for the first time, she accompanies him carrying a fish in her hand.
- Until the symbolic marriage tie is untied, the couple must invariably have fish as part of their diet.
- During married life, a woman whose husband is alive, must try to eat fish every day.
- Every month on the third day of her menstruation, when she is ceremonially purified by ablution, a woman should consume fish, although only on that day.
- When a woman whose husband is living comes to the house of her husband from that of her father, she should have fish as part of her diet, on that day at least.
- Whenever a woman is taken from her husband's house to her father's, or vice versa, the party should always bring at least fish and betel leaf as presents.

In fact, wealthy peoples may continue such exchanges of presents even later on, such presents acquiring special social significance:

> The articles of food sent on these occasions are never wholly consumed by the families to which they are given but are distributed among all the families who collectively form the samaj (community) and also to friends (Das 1931).

Within this context, "the force of the prohibition" of fish to Hindu widows became very clear (Das 1931). Das noted, fish was also an important marker of particular phases of the *sraddha* ceremonies. During the period of mourning, mourners were required to observe certain taboos:

> The period of mourning depends on the caste of the family and is characterized by total abstention from fish, meat, eggs, some kinds of pulses, onions, etc. Sons and the wives are to wear special mourning dress while all agnates are not to cleanse their clothes, shave their beard or crop hair, etc. These taboos on food are 'removed in a ceremony known as matsyamukhi' (fish-eating ceremony). On this day, which falls on the first ceremonially suitable day after the Sraddha ceremony, all the relatives, especially the agnates, sit together at

a feast when fish is served, for the first time to the observers of the taboos. The nearest agnate belonging to the superior grade of agnatic kinship, and preferably older in age, puts a piece of fish from his own plate on that of the chief mourner and this ends the period of taboos for all concerned. Thus fish here serves as an emblem of all the taboos taken together and the partaking of it removes all other taboos automatically (Das 1931).

Fish is also featured among the offerings made to the departed soul in the *adya sraddha* and to the ancestors in the *abhyudhayika sraddha*. Among Brahmins, cooked food, including fish, was offered, sometimes to be eaten by the *agradani* (a class of degraded Brahmins who receive gifts at funeral rites); among non-Brahmans, uncooked fish is offered and is taken away by the *agradani* (Das 1931). Das noted that in some parts of Bengal "a piece of burnt fish is offered to the *preta* [corpse] at the time of the *Adyasraddha* ceremony" (Das 1931).

Das argued that an examination of the "customs surrounding fish in Bengal," which he had outlined, would show that these could not be associated with the Vedic Aryans. Fish used in the marriage ceremony occurred in parts not prescribed by the "sacred literature"; fish in the *sraddha* was also "dissociated from the Brahminical rituals" and observed only as "a social custom". Later, he adds the point that when the *Dharmasutras* began, at a quite late date, to introduce certain exceptions to the rule prohibiting fish-eating, thereby allowing consumption of certain kinds of fish, they appear to be the result of the need to make concessions to popular tastes in those regions outside the "original Midlandic zone" to which their influence had been extended and where fish-eating was accepted more widely (Das 1932). He was convinced, therefore, that fish was not introduced into the religious and social rites of Bengal by what he calls the "bearers of Midland culture" (Das 1931).

10.3. Hilsa: The cultural icon of Bengal

10.3.1. Meaning of hilsa fish in Bangla

Ilish: 'Il' means getting into water/inside the water and 'ish' means ruler/master/king. Thus, the meaning of ilish stands for "the king of water" whereas other meanings in this regard used are oily, glittering. Thus, oiliness vis-à-vis the taste of flesh is not only favored by Bengalis, but its oil also is very palatable when consumed with rice.

10.3.2. Various names of hilsa

In Bangladesh, hilsa is known as *Ilish Maach*, simply *Ilish* or *Ilsha*, while the juveniles are called *jatka*. In India, hilsa is known by various names in different states. In Bangla Province, hilsa is known as *chandana ilish, khoera ilish, zaitka ilish* (small), *khoka ilish, ilish gouri, phasa ilish* and *mukhpora ilish*. In Assam it is known as hilsa; in Gujarat as *palla, chaski* and *chaksi*; in Bihar it is known as *ilsha* and in Odisha it is known as *illishi*. Furthermore, it is also known as *kajal gouri, ganga, jal tapi* and *mukhopriya*.

10.3.3. Myths exists among the fishers associated with hilsa fishery

Fishing of hilsa is prevalent and is based on the experiences passed down from generation to generation. The first and foremost attributes that hilsa fishers need is the courage and patience to endure the sometimes fierce motion of the sea and an understanding of tidal movements and lunar periodicity. Knowledge is transmitted via the culture of hilsa fisheries. Among the many beliefs that have accumulated in the fishing culture are that winds blowing from the east bring shoals of hilsa, which can be exploited in huge quantities, and where the water appears grayish-red, huge catches of hilsa can be obtained. Fishers also believe that during full and new moons, hilsa are attracted to the water surface by the light and can be readily caught in huge quantities.

10.4. Cultural and religious aspects of hilsa in Bengali life

10.4.1. Religion

Hilsa is the most popular fish among the Bengalis living in both parts of Bengal. In many Bengali-Hindu families, two hilsa fish (*Jora Ilish*) are bought on special auspicious days, such as some pujas. It is considered auspicious to buy two hilsa during *Dussera* and also on the day of *Saraswati Puja* (The Goddess of Learning), which takes place in the spring and on the day of *Laksmi Puja* (The Goddess of Wealth and Prosperity), which takes place in autumn. The custom is mainly prevalent among Hindu-Bengalis, some of whom give hilsa as an offering to the goddess Lakshmi, without which the *puja* is sometimes thought to be incomplete.

Apart from its prominence in the Bengali culinary world it also holds a much esteemed position in Bengali culture. *Jamai Sashti* is a festival where the son-in-law (daughter's husband) enters the house and is feted and fed with various fish dishes. A *Jamai Sashti* meal is never complete without at least one dish of hilsa (*ilish*), and a pair of ilish (*jora ilish*) is considered especially auspicious on certain occasions.

Fish, apart from its role as food, is also associated with piety. In Hindu culture, fish is widely used during *Saraswati Puja* (*Jora ilish'er bhog*, food of paired *ilish*). In the famous Kali Temple in Kolkata and in Dhakeshwari in Dhaka fish is offered to Devi Kali. Fish is often considered as Lakshmi according to Hindu tradition. In Bengal, before leaving their homes people like to see a fish, as it is considered to be a symbol of luck. In some Hindu-Bengali families, large hilsa are bought as a part of the engagement rituals in pre-wedding ceremonies. Hilsa also appears on the menu in wedding ceremonies.

10.4.2. Festivals

Pohela Boishakh is the Bengali New Year and it is observed in both Bangladesh and the Bangla state of India. Each year Bengali communities celebrate *Pohela Boishakh* in a befitting manner and the special dish is *panta ilish* (fermented rice and hilsa). *Pohela Baishakh* has been the greatest festival in Bangladesh and many of the programs of the day, including the *"Mongol Shovajatra"*, have been recognized by the international community as world heritage events. The *Mongol Shovajatra* is a mass procession that takes place at dawn on *Pohela Baishakh* in Bangladesh that features gigantic replicas of birds, fish, especially the national fish hilsa, animals and other motifs. The procession is organized by the teachers and students of the Faculty of Fine Arts of the University of Dhaka. It is considered as an expression of secular identity of the Bangladeshi people, uniting the country irrespective of class, age, religious faith or gender. On 30 November 2016 the *Mongol Shovajatra* was selected as an intangible cultural heritage by UNESCO at its 11^{th} session. In 2017, the traditional *Mongol Shovajatra* was brought out in the West Bengal, now the Bangla province of India.

A wide range of Bengali hilsa dishes is associated with *Ranna puja* or *Arandhan*. The dishes must be prepared beforehand, as no fire can be lit on the day.

Bhai phota is celebrated on the second day after *Kali puja* or *Diwali* festival in Bengal. Hindu-Bengalis consider *Bhai phota* as one of the prominent festivals, representing the bond of love and affection between brothers and sisters. In this festival Hindu families make and serve sweets and hilsa fish dishes.

Another festival is *Bastu puja* or *Veet puja* that the Hindu community arranges it for the well-being and peaceful environment of a newly made house or opening of new house. On this occasion, hilsa dishes are preferred for dinner.

Some Hindu families practice the eating of *shadh* or favored foods toward the end of pregnancy in the belief that it helps the mother-to-be able to produce a healthy child. Fine rice, *payesh* (rice cooked in milk, sugar and cardamom) and fish (mainly hilsa) are among the most favored food items.

The festival of *Chaturanga ilish* is observed every year in Chandpur district city, Bangladesh. This festival is organized by the Chaturanga Cultural Organization. The festival is observed for three days, where the main elements of the program of events include a competition of hilsa fish recipes and art competition on *ilish*. The festival cultural program may also include folk music, debate, dance and drama.

The DoF under the Ministry of Fisheries and Livestock of the GoB observes a "National Fisheries Week" in a festive mood every year from the middle to the end of July during the peak of fish breeding in order to create and improve awareness at all levels of the fishery stakeholders for promotion of production, conservation, processing, marketing and export. Various promotional activities are organized at central and local government levels, in academia and research organizations, public and private organizations, development agencies, etc. National Fisheries Week observance has been a social revolution for the decades and in commemoration, the DoF publishes a national souvenir highlighting the events along with the most updated fishery information of the country.

10.5. Hilsa dishes and their preparation in Bengali culture

One of the main reasons that Bengalis anticipate the monsoon season is that this is the only time they see lots of their favorite shiny silvery hilsa fish in the market. Bengalis are famous for their love of the fish and the many ways in which it is cooked. No fish is prepared in more ways than *ilish*, for which it is said that there are more than 100 ways to cook the fish. It may be simply fried in mustard oil to form the basis of a quick and simple meal accompanied with steamed rice which has been drizzled with *ilish* scented oil, or time taken to prepare *ilish paturi*, where hilsa is cooked with spices and coconut, wrapped in plantain leaf. *Shorshe ilish* (*ilish* cooked in green chili and spiced with mustard gravy) is time-consuming to prepare but universally popular. *Ilish paturi* (hilsa cooked with various spices and coconut wrapped in plantain leaf) or a very light aromatic hilsa dish with eggplant and potatoes are also both popular. hilsa is also fried, steamed, roasted in banana leaves or boiled in a sweet and sour tamarind gravy. If that is not enough, then the *macher muro* (fish head) can be fried and cooked with Malabar spinach to produce an excellent *pui shaker ghanto* or *charchari*. The delicate hilsa roes are either fried and used as relish to accompany hot rice or are cooked with *amchur* or raw mangoes to make a very tasty chutney.

There's a popular joke that goes *Illish vaja khete moja garam garam hole*, which means "ilish fry is very tasty to eat if it is readily fried," which is the reality in Bangladesh. *Garam ilish vaja* (readily fried hilsa slice) and *khichuri* (rice cooked with pulses) are also very popular dishes.

Shorshe llish is a dish of smoked hilsa with mustard-seed paste, which has been an important part of both Bangladeshi and Bengali cuisine. *Ilishi maacha* is a curry made with ginger, mustard and garlic paste in tomato seasoning in Orissa style in the Oriya cuisine.

A large number of delicious dishes are prepared with hilsa as a major ingredient and are given by their Bengali name in an annex to this chapter.

10.6. Hilsa fish conservation

There is a custom that Bengalis should purchase a pair hilsa on the day of *Vijay Dashami* (October), after which they will not eat hilsa until *Basant Panchami* in February, when again, they will purchase a pair of hilsa. This allows hilsa to breed unmolested during the major breeding season. Bengali culture has thus practiced conservation of hilsa over many centuries.

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Annex

The following is a list of Bengali fish dishes featuring hilsa:

Ilish macher jhuri, Ilish macher chechki, Ilish macher vuna, Ilish basanti, Anaras ilish, Kanchkala ilish, Ilish kachur ghanto, Dab ilish, Ilish jhuri bhaja, Ilish biriyani, Narkel dudh ilish, Sarshe ilish, Ilish bhapa, Ilish paturi, Ilish tel jhol, Ilish ghanto, Jeera ilish, Ilish dum posto, Ilish macher roast, Grilled ilish, Lebupatar karamcha ilish, Ilish chalkumro, Ilish chhachra, Ilish makhani, Dhakai ilish paturi, Ilish baati chachchari, Ilisher jhol, Masala ilish, Ilish korma, Ilish chakka, Doi ilish, Roasted ilish, Ilish fry, Ilish dum pukhat, Batar ilish, Bin tel ilish, Doi ilish dum, Ilish bhate, Tomato ilish, Sabuj ilish salad, Ilish maacher pata fry, Ilish doi korma, Dudh ilish, Ilish maacher maalai curry, Ilish maacher tak jhal, Ilish macher soup, etc.

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