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Tropical Hilsa Shad (*Tenualosa ilisha*): Biology, Fishery and Management

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Abstract

Tropical hilsa shad, which is an anadromous fish migrating from the sea to spawn in freshwater river, constitutes an important fishery in some Asian and Middle East countries, particularly in Bangladesh. But historical information on hilsa biology and ecology has confronted the scientists and policy makers with research and management challenges. We have reviewed both the old and recent findings on the hilsa fishery to document the status of knowledge and potential gaps, necessary to know for formulating a more effective fishery management plan. Thus, there has been a decline in hilsa catch in the riverine system associated with shift in fish migration routes, indiscriminate harvesting of brood and juvenile fish, and degradation of habitat. Specifically, riverine hilsa catches peaked in 1960s, declining thereafter, and became relatively abundant in marine waters since 1990s. Biological data indicated that hilsa goes through multiple reproductive cycles, therefore, a comprehensive understanding of reproductive biology, recruitment by various cohorts, stock abundance and habitats across the life cycle are necessary to accurately impose fishery regulatory measures, such as fishing ban in spawning season in Bangladesh. Moreover, domestication initiative is important for artificial seed production and mariculture development of hilsa that can not only offer economic return to small-scale farmers but also reduce the growing pressure on capture fishery. Importantly, the arrangement of co-management is found ideal as fishermen, scientists and managers can work jointly to improve the regulatory processes and to sustain the hilsa fishery overtime.

Keywords: Bangladesh, conservation, domestication, hilsa shad, management, mariculture

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INTRODUCTION

Hilsa shad (*Tenualosa ilisha*, Hamilton 1822) is a tropical anadromous species distributed from the Sumatra to Kuwait, ascending the rivers from marine habitats of the Bay of Bengal, Arabian Sea and Persian Gulf (Al-baz & Grove, 1995; Blaber, 2000; Arai & Amalina, 2014). Since the early 1900s, hilsa has been a great societal and economic interest, and harvested in large quantities from the rivers of Ganges, Brahmaputra, Meghna, Irrawaddy, Mahananda, Godavari, Krishna, Cauvery, Indus, Shatt Al-Arab and Euphrates (Hamilton-Buchanan, 1822; Day, 1878; BoBP 1985; Jafri, 1988; BoBLME 2012). Unfortunately, the riverine catch of hilsa has declined due to closure of migration routes by dams/barrages, degradation of habitats, indiscriminate harvesting of broods and juveniles, and climatic variability (Miah, 2015; Dutton et al., 2018). As a result, hilsa became relatively abundant in the wider areas of Bay of Bengal, indicating a significant increase of marine catch in Bangladesh, Myanmar and India (BoBLME 2012; ECOFISH-Bangladesh 2017; FAO 2017). The annual catches of hilsa in Bangladesh is 0.5 million tonnes that fetches US$2 billion, and provides livelihoods to 0.5 million fishermen and 2.5 million people in the value chain and distribution (Islam et al., 2016a; Porras et al., 2017; Dutton et al., 2018).

Fish habitat is clearly a shifting mosaic over years to decades, and perhaps even centuries, particularly in laterally unstable rivers (van der Nat et al., 2003). Accordingly, spawning behaviour of hilsa varies in terms of both time and location in the rivers of the Bay of Bengal and Arabian Sea due to fluctuations in rainfall, upstream runoff, sediment input, and/or variation in habitat types. Over the past decades, hilsa is the subject matter of hundreds articles published in scientific journals, magazines, books and news portals. Yet, fundamental knowledge in spawning biology, induced breeding, rearing juvenile in sea cages or ponds, ecological drivers, habitats across the life cycle, and the spatial dynamics of hilsa are not readily available. Therefore, for the fishery management data (e.g. prey and predators interaction, spawning season, migration route) managers and policy makers used to rely upon expert opinions and obscure extrapolations. This is hindering the formulation of a well-planned and scientifically viable hilsa management scheme, either at local or regional levels.

Several studies have provided a broader picture of hilsa fishery management practices in different contexts (BoBLME 2012; Puvanendran, 2013; Pomeroy et al., 2016; IUCN 2017; Dutton et al., 2018). One study revealed that regional hilsa stocks is currently over exploited and need to reduce fishing mortality for maximizing the biological recruitment. Moreover, emphasis is placed on protection of the spawning and nursery grounds, reducing juvenile catches and regulatory compliance to rebuild the depleted hilsa stocks (BoBLME 2012). However, a comprehensive knowledge surrounding the hilsa fishery remains unknown. In this paper, the fishery history, biological aspects and distribution range of hilsa are discussed. Then, management, socioeconomics and sustainability of hilsa fishery are critically reviewed to identify the knowledge gaps. Finally, areas of research needs and recommendations are proposed in line with current exploitation, management and conservation status of the fishery.

FISHERIES HISTORY

Since the early 1900s, the administrators, philosophers, naturalists and scientists have been fascinated by hilsa due to its taste, euryhaline behavior, distant migration capability and high economic contribution as the single largest fishery to the society (see Bloch, 1795; Schneider, 1801; Russell, 1803; Hamilton-Buchanan, 1822; Day, 1878). The range of hilsa migration covers a distance of about 1,920 rkm (river kilometer) up to Delhi through the Yamuna tributary of the Ganges River (Hora, 1941; Motwani et at., 1957; Swarup, 1959; Quereshi, 1968), 825 rkm up to Mandalay through the Irrawady River (Day, 1873), 780 rkm up to the Tezpur of the Brahmaputra River (Pillay & Ghosh, 1958; Rao & Pathak, 1972), 410 rkm of the Hooghly (Day, 1889; Jones, 1957; Pillay, 1958; BoBP 1985), 50 rkm in the Godavari (Chacko & Dixitulu, 1951; Pillay & Rao, 1963; Rao, 1969; Rajyalakshmi, 1973), 275 rkm in the Meghna (Quereshi, 1968; Shafi et al., 1978), 420 rkm in the Padma (Quereshi, 1968), 1,000 rkm up to Multan in the Indus (Aitkin, 1907; Jafri, 1988), and 180 rkm in the Euphrates (Al-Dham, 1977; Al-Dubakel, 2011) (Figure 1). However, construction of barrages and dams without fish passages on various rivers, for example Farakka barrage on the main stem of Ganges river, reduced the riverward migration range of hilsa (Jafri, 1988).

The riverine contribution of hilsa from 1956-1957 to 1961-1962 was 94% and at that time the marine contribution was only 6% (Ahsanullah, 1964). In 2015, a total of 387,000 tonnes hilsa was landed in Bangladesh with shares of 65% marine catch and 35% riverine catch. While, 25,129 tonnes hilsa catch of India were represented by 82% marine catch and 18% riverine catch (Figure 2). Importantly, the lion share of hilsa landings dominantly contributed by the river Padma during 1930s and 1960s, suggesting the importance of freshwater as hilsa habitat. However, during 1990s onwards hilsa fishery moved to the downstream rivers (e.g. Meghna River ecosystem), showing a significant increase of nearshore and marine catches (Table 1). A declined riverine hilsa catch has been attributed to a combination of factors such as the closure of migratory routes, river siltation, overfishing, indiscriminate harvesting of broods and juveniles, use of fishing nets with small mesh sizes, mechanization of fishing, increasing numbers of fishermen and efforts, aquatic pollution and climatic variability (Dutton et al., 2018).

BIOLOGY

Age and growth

Knowledge of the age and growth, i.e. the data on recruitment, longevity, mortality and fluctuations in fishery, is essential for developing a rational harvesting plan and shaping up sustainable fish stocks. The length of new born hilsa larvae is 2.3-3.1 mm (Kulkarni, 1950) and the monthly average size for the first 6 months is shown in Figure 3 (Hora & Nair, 1940; De, 1986; Bhaumik & Sharma, 2012). Hilsa reached about 30-35 cm and 1-1.5 kg in size by two years of age, with maximum length reported to be 65.6 cm (Halder & Amin, 2005). According to Halder (2004), hilsa attain its maximum length of 58 cm at 6.5 years of age. Pillay & Rao (1963) designated the modal lengths of 35.5, 41.5, 45.5, 48.5, 50.5 and 52.5 cm corresponding to +1, +2, +3, +3, +5 and +6 age groups, respectively. Annual growth (total length) of the hilsa in Bangladesh waters, based on the back calculated length using polynomial relationships between the total length (cm) and age (year) are presented in Table 2. Studies suggest that female hilsa grow faster than male and caught more frequently in catches with individuals >40 cm (Pillay, 1958; BoBP 1985; Rahman & Cowx, 2006). In general, growth of hilsa varies from one ecosystem to another or in the same environment due to changes in ecology, habitat characteristics, food availability, population size and density dependent growth factors. Mome & Arnason (2008) has estimated natural mortality and showed high mortality rates for the whole stock in Bangladesh, especially for the first cohort (half year) as listed in Table 3. Even with high natural mortality rate, few hilsa older than 4 years are left in the stock. Therefore, Mome & Arnason (2008) considered the life span of hilsa is up to 4 years that corresponds to 8.5 year cohorts.

Maturity and reproduction

At present, a 22-day fishing ban has been imposed in the month of October for safe spawning of hilsa in Bangladesh. To be successful with this kind of management, data on size at first maturity, and the onset and duration of spawning season are extremely valuable for which understanding of fish reproductive biology is important. Different studies have found conflicting views about minimum size of hilsa at first maturity. In Bangladesh, Halder (2002) reported that hilsa matures at age 7-8 months when total length is 19 cm. According to Mome & Arnason (2008), hilsa at <6 months old remains immature, 6-12 months attains 80% maturity and at >12 months full maturity. In India, Jhingran & Natarajan (1969) reported maturity in 20-30 cm females and in 18-30 cm males, while Ramakrishnaiah (1972) defined length classes of 19, 29 and 34 cm as maturing, ripening and spawning, respectively. The peak gonadosomatic index (GSI) of hilsa was recorded in October, June and February and thus, the major spawning takes place in October-November, and a subsidiary spawning in June-July and January-March in the Meghna ecosystem (Hossain, 1985). There are two peaks of GSI values in July and February in the Indus River, indicating two different breeding seasons (Narejo et al., 2008). Spawning occurs in May-June in Kuwaiti coastal waters (AL-Baz & Grove, 1995; Roomiani et al., 2014), and it is February-March in the Shatt Al-Arab (Al-Dubakel, 2011).

Hilsa is an oviparous (produce eggs that develop and hatch outside the maternal body) and iteroparous (reproduce more than once in lifetime) fish like as other clupeid species. The diameter of ripe eggs by different studies ranged 0.70-0.75 mm (Jones & Menon, 1951), 0.89 mm (Pillay, 1958) and 0.76-0.87 mm (De, 1980). The eggs and spermatozoa are released into water in close proximity to support external fertilization, and the fertilized eggs are buoyed up and drifted by water currents (Kulkarni, 1950; Bhaumik & Sharma, 2012). Egg production is correlated to age or size of the fish (Table 4) as found to occur in other aquatic species. Currently, there is limited information on the reproductive biology of hilsa and this demands further investigation on maturity, hormone concentrations in blood and sex reversal aspect using the same sampling protocol throughout the major river basins. This data are essential for estimation of size at maturity and correct timing of spawning season, and to know how many mature and active individuals are contributing to offspring production and their subsequent management aspects.

Life cycle

The productivity of a fish over its life cycle is determined by the cumulative production in each life stage. Thus, availability of a species in the right place at the right time in its lifetime can have significant consequences on the fishery productivity (Naiman & Latterell, 2005). Oxbow shaped turbulent pools in the estuaries and rivers with favourable ecological characteristics support the spawning of hilsa. Major spawning grounds of hilsa include the Meghna ecosystem in Bangladesh (Hossain et al., 2014b), Hooghly-Bhagirathi river system in India (Bhaumik & Sharma, 2012), Ayeyarwady delta in Myanmar (Than & Lay, 2008; Tezzo et al., 2014), Indus river delta in Pakistan (Narejo et al., 2008), Shatt Al-Arab and Euphrates in Iraq (Al-Dubakel, 2011; Mohamed et al., 2012) and Kuwaiti coastal waters in the Persian Gulf (AL-Baz & Grove, 1995; Roomiani et al., 2014) (Figure 1). Hilsa fry is found in the downstream of rivers and nearshore coastal waters (Ghosh & Nangpal, 1970; Hora, 1938), while the juvenile disperses in the upper and lower estuaries (Milton, 2009; Hossain et al., 2014c). Water quality parameters suitable for different life stages of hilsa are shown in Table 5. Hossain et al. (2016) reported that hilsa population in the northern Bay of Bengal (Bangladesh) primarily inhabits marine waters and migrates to freshwater for spawning. But, there is exception to this behaviour as - (i) a small subset of the population completes its life cycle within freshwater and does not migrate to sea at any stage in its life cycle, and (ii) a different subset uses nearshore coastal and/or sea habitats and relies on downstream estuarine waters for spawning without migrating to freshwater (Figure 4). The latter notions need to be validated scientifically to manage the hilsa fishery even more sustainably. Moreover, information on the movement and distribution of hilsa beyond the continental shelf is inadequate to determine the extent of their seaward migration and fishing potential at offshore marine areas. Thus, range of hilsa migration with spatial and temporal distribution across the lifecycle needs to be determined comprehensively.

Hilsa-less tributaries enrich hilsa-bearing rivers

Major rivers for the hilsa habitat are the Meghna, Ayeyarwady, Hooghly, Indus, Shatt Al-Arab and Euphrates, where the streams or tributaries are mainly hilsa-less but are rich with small indigenous species. Water flow, nutrients and organic matters that form habitat attributes in hilsa-bearing rivers originated from these tributaries that maintain ecosystem functions and source of food to resident organisms (Hossain et al., 2007). For instance, the crisscrossed hilsa-less tributaries of the lower Meghna deltaic region of Bangladesh have an intimate relationship with surrounding land-based activities such as, agriculture, wet meadow, human settlement, and mangrove ecosystems that play important roles on aquatic habitat (Figure 5). Many tributaries in the Meghna deltaic region may be wet on only rainy months (June-October). Similarly, many do not support habitat for fishes although they possess planktonic organisms, benthos, amphibians and reptiles with life cycles that have both aquatic and terrestrial stages (Naiman & Latterell, 2005). These narrow and shallow tributaries occupy the headmost position in a drainage network, but are influenced by semi-diurnal tidal characteristics (Hossain, 2001). Even where hilsa is absent, these tributaries are closely coupled to the adjacent crop fields and villages, and are particularly influential in regulating and processing inputs of energy, nutrients and organic matters. These inputs contribute material to riverine food webs (Ahsan et al., 2012) and shape the structural characteristics of hilsa habitat in estuarine and marine ecosystems. Thus, hilsa-less tributaries are hilsa habitat in much the same way as the rivers.

Prey and predators

It is essential to understand predator-prey relationships for ecosystem-based management. Predators can influence the dynamics of prey populations by controlling survival, growth, size structure and distribution, while prey can equally control predator populations. Adult hilsa is plankton feeder (Chacko & Ganapati, 1949; Mohamed et al., 2012; Dutta et al., 2014; Hossain et al., 2014b; Hasan et al., 2016). Absence of teeth, efficient filtering gill rakers, pharyngeal organ, and modification of stomach into gizzard in hilsa dictate the food item size and feeding preference (Jafri, 1987). The prey species of hilsa include algae, diatoms, copepods, cladocera, protozoans, rotifers and the larvae of bivalve and gastropods (Hora, 1938; Jones & Menon, 1951; Pillay & Rao, 1963; Hasan et al., 2016). Jones & Sujansinghani (1951) mentioned that the spent specimens appear to feed at the bottom, whereas young ones seem to be mid-water feeder. Data on hilsa predators are limited, the likely candidates are the tertiary consumers (such as big carnivorous fish: shark, tuna, mackerel, catfish, freshwater shark) of a marine and river food chain who prey on adult hilsa (Figure 6). The larvae and juvenile hilsa are assumed to be consumed by medium to small carnivorous fish such as seabass and snakehead. However, the analysis of gut content of piscivorous species living in the habitats of hilsa can provide novel information on prey-predators interactions.

MANAGEMENT AND SOCIOECONOMICS

Fishery status

Several studies have carried out the stock assessment of hilsa from different water bodies (Table 6) using length data in FiSAT (FAO-ICLARM stock assessment tools). This approach is not rigorous and thus the estimated exploitation rates are highly uncertain and would not form the basis of management decisions in most cases (BoBLME 2010). However, alternative assessment options including life history based modeling approaches like Leslie Matrix models, age-structured integrated assessments, and Surplus Production based assessments need to develop and examine. BoBLME (2012) reported that regional hilsa stock is overfished and recommended to reduce fishing mortality for maximizing the biological yield. Global hilsa catch data is limited, the shares of Bangladesh, Myanmar and India are 76%, 15% and 4%, respectively, whereas the remaining 5% is contributed by other countries/regions (e.g., Iraq, Iran, Kuwait, Malaysia, Indonesia, Thailand and Pakistan) (BoBLME 2010; FAO 2015; Miah, 2015; Islam et al., 2016a). In general, marine catch of hilsa is 72% and the river catch shares 28% (Figure 7). The maritime zones of Bangladesh, Myanmar, India, Iran and Kuwait are suitable for marine catch, and the habitats of Meghna, Hoogly, Indus, Irrawaddy and Euphrates are suitable for river catch.

Typical hilsa fishing gears include drift gill, fixed gill and seine nets. Gear characteristics as well as length, breadth, mesh and mode of operation depends on water current, depth, tidal phase, seasonality and weather condition (Table 7). Drift gill net moves with water current, whereas fixed gill net is set in specific location of the river/sea. The seine net encircles shallow water areas to trap school of hilsa and other fishes (Figure 8). Recently, there is an increase in the efficiency and capacity of hilsa fishing in Bangladesh. For instance, the drift gill net in operation is two times long and four times more powerful than it was in 1980s, and the number of fishermen has also increased. Annual total catches of hilsa in Bangladesh varies irregularly, either increased or decreased in the subsequent years since 1983. But, a maximum of 32%, 18%, 11%, 29%, 8% and 26% increase was reported in 1985, 1989, 1994, 2003, 2010 and 2017, respectively. A maximum decrease of 20% and 10% was noted in 1990 and 2002, respectively (DoF 2014; FAO 2017). An increasing trend in total catch since 2004 is the outcome of well-enforced seasonal ban in fishing hilsa brood and juvenile stocks, though segregation of individual initiative's role in the catch of an anadromous species is difficult. Hilsa is a highly preferred edible fish to millions of people living in the Asia and the Middle East countries due to its taste, flavor and delicate culinary properties (Alam et al., 2012; Panhwar & Liu, 2013; Miah, 2015; Almukhtar et al., 2016). The market demands of high quality fish in the Middle East, Europe, North America, Japan and Australia has stimulated the hilsa price in recent years. For example, price of hilsa in retail markets of Bangladesh is US$10-12 per kg for individual weight 800-1200 g, and the price increases to US$20-25 per kg for fish weighing >1500 g. About 75% of harvested hilsa in Bangladesh is consumed locally and the remaining 25% is exported, and the pattern is similar in other countries, India and Myanmar (Kleih et al., 2003; Hossain et al., 2014a; Sahoo et al., 2016).

Management and conservation initiative

Bangladesh government and international agencies has taken several initiatives on hilsa biology, management, conservation and livelihoods of fishermen that enhanced hilsa catch (Figure 9). In Bangladesh, a decline in hilsa catch by 9,121 tonnes (= 3.97% of catch) in 2001 and 21,561 tonnes (= 9.77% of catch) in 2002 had a negative impact on the livelihoods, cash income and food security of fishing communities. Several protection and conservation measures have been undertaken since 2003 to enhance the size of hilsa population and improve the socioeconomic conditions of fishermen. The Hilsa Fisheries Management Action Plan (HFMAP) was undertaken to protect jatka (= hilsa juvenile, <160 mm length) through the development of an implementation strategy, and identification of the responsible agencies and target communities within a specific management timeframe. HFMAP involved in public meetings, riverine rallies, awareness raising campaign, media coverage, distributing leaflets and posters to protect jatka, enforcing the fish protection and conservation acts, establishing hilsa sanctuaries, a two-three week banning of fishing in major spawning grounds, and offering alternative livelihoods for fishermen as cash incentives. It is believed that jatka protection programme has had a positive effect, since hilsa catch increased by 56,806 tonnes (= 28.54% of catch) in 2003 and 20,024 tonnes (= 7.83% of catch) in 2004. Although no rigorous evaluation of the impact of HFMAP on catch size was carried out, the conservation programme has been expanded to a wider area since 2005 (Siddique, 2009; Islam et al., 2016a). The project was granted BDT 188 million (= US$ 2.4 million) at its inception in 2008 and implemented in 59 upazilas under 10 districts (Barbier, 2012) that has subsequently increased to 224,102 households in 91 upazilas under 15 districts in 2013-14 (Islam et al., 2016a). Consequently, a ban on catching, transporting and selling of juvenile hilsa from

November to May in each year has been legislated. During the ban period, households of hilsa fishermen are given monthly 40 kg rice since 2013 (Islam et al., 2016a). Table 8 shows the initiative of annual food grain distribution and alternative income generation programme among fishermen households undertaken during 2008-2014. However, no such conservation activities are known to be practiced in other hilsa catching countries.

While community-based fisheries management (CBFM) for inland waters is well established in Bangladesh, CBFM specific to hilsa fishery is limited (Pomeroy et al., 2016). The Empowerment of Coastal Fishing Communities for Livelihood Security (ECFC) project by the Food and Agriculture Organization (FAO) of the United Nations demonstrated some success in applying this model, but further efforts are needed to develop and institutionalize CBFM model in marine system (UNDP/GoB/FAO 2003). Although policy statements promote CBFM for hilsa, these have not been translated into formal instruments or implemented. As a matter of fact, there remains a legal barrier to the local and indigenous peoples' right of accessing to coastal resources as the state does not allow these rights, being fisheries and forests resources are owned and maintained by the government (Roy, 2001). Therefore, based on the analysis of natural resources and relevant tenure arrangements, Roy (2001) emphasized to extend the concept of community-based property rights and management to coastal and marine areas.

Recently, the United States Agency for International Development (USAID) funded Enhanced Coastal Fisheries in Bangladesh (ECOFISH-Bangladesh) is one of the major inputs to co-management strategy for hilsa fishery (ECOFISH-Bangladesh 2014). The interim progress report of ECOFISH-Bangladesh highlighted the importance of close working relationship among stakeholders (such as Department of Fisheries, NGOs, WorldFish, Bangladesh Navy, Coast Guard, Riverine Police and fishing communities) as key to building a common vision and local capacity for co-management infrastructure (ECOFISH-Bangladesh 2017). ECOFISH-Bangladesh established joint forces of Hilsa Ghat Groups (HGGs), Hilsa Conservation Groups (HCGs), Community Saving Groups (CSGs) and Community Fish Guards (CFGs) for effectively working in hilsa conservation. HGGs and HCGs look after compliance with hilsa fishing ban periods and gear restrictions, whereas CSGs is working solely with women's by giving out 'soft loans' for income diversification, i.e. net making, tailoring, duck and goat rearing, and vegetable gardening (ECOFISH-Bangladesh 2017). The CFGs initiative promotes a strong desire to be 'self-police' rather than to be enforced by the authorities. That motivation has been important to catalyzing more consistent enforcement for restricting hilsa fishing during ban periods and for building closer cooperation between villagers and law enforcement agencies.

Livelihood diversification is an attempt by individual and/or household to find new ways to raise income and reduce vulnerability. In order to sustain the hilsa fishery, both on-farm and off-farm activities (Table 9) need to be introduced during the fishing ban periods to enhance cash income, employment, and to meet household food and protein demand. Moreover, education and skill development training for professional diversity and interest-free loans from the bank are pre-requisites to maintain livelihoods by the fishermen in their villages (Hossain et al., 2013). The alternative income generation programme is already introduced, but the outreach is limited to a small number of households (Badhon, 2016; Dewhurst-Richman et al., 2016; Islam et al., 2016a). In 2009-2010, support for alternative income generation involving ~US$ 4 per household was given out to 4,388 households in 59 upazilas under 10 districts. In the following two years the coverage and amount have been increased gradually, although the quantity of food grain, amount of cash incentives and number of recipient households need to be increased for implementing the laws of hilsa fishery successfully, especially during ban periods.

In India, hilsa fishery is managed by the state rather than by the central government, suggesting that there is less capacity and resources to actively implement management measures (BoBLME 2010). There is currently no control on fishing effort and small mesh nets used to catch hilsa juveniles. An annual fishing closure in the Indian marine waters has been declared from 15 April to 15 June, but the relation of this initiative with hilsa fishing or hilsa spawning season is unclear (BoBLME 2010). Moreover, main spawning and nursery areas of hilsa are not yet identified and mapped in India which is a prerequisite to formulate management measures for improving hilsa fishery as Bangladesh. Although hilsa fishery, by now, has expanded over the Rakhain basin along the Myanmar and Thailand coasts, there is limited catch data or export statistics in that context (BoBLME 2012; BoBLME and SEAFDEC 2015). Myanmar has exported 17,952 tonnes hilsa valued at US$ 39.53 million in 2009 (FAO 2012). However, there is no scientific study on hilsa fishery, thus it is difficult to comment on the status of hilsa in Myanmar and Thailand (BoBLME 2010). Interestingly, Myanmar has undertaken a registration scheme for all the small fishing craft, and this model can be useful for Bangladesh and India where no such scheme exists. Recently, a road map for hilsa fishery management plan has been laid out among Bangladesh, India and Myanmar (BoBP-IGO 2008), where scientific networking among Bangladesh, India, Myanmar and Norway has now been established for jointly developing and managing the hilsa fishery (Puvanendran, 2013).

Mariculture development

To date, domestication (= a condition wherein the lifecycle, breeding, care and feeding of an organism are controlled by humans) has not been successful for hilsa, despite efforts made on artificial fertilization and larval development. Collecting viable broods from the river/sea is a limiting factor as the fish dies immediately after catching it (Pillay, 1955; Sahoo et al., 2016), though the first author observed live hilsa for 2-4 hours after catching (https://youtu.be/B3xg0Q8GfDs) at the Meghna ecosystem. Rearing of hilsa fry in open freshwater ponds has also been attempted in India and Bangladesh with little success in growth and survival rate (Bhanot & De, 1984; Sharma, 1984; Sen et al., 1990; Milton, 2010; Rahman et al., 2012). However, cage farming in Bangladesh holds great promise as 17,296 km^2 water bodies, such as the islands of Bhola-Manpura-Hatiya (Figure 10), are suitable for hilsa grow-out in captivity by obtaining juveniles from wild (Hossain & Hossain, 2016). This activity can offer economic benefit to the small-scale farmers and more importantly will reduce growing pressure on capture hilsa fishery (Sarker et al., 2018). In view of wider interests (national and international) and huge commercial importance, there is an urgent need for developing hatchery and grow-out technology of hilsa. Critical research gaps include water quality and nutritional (live and artificial feeds) requirements, understanding the smoltification process, and broodstock management (Sahoo et al., 2016). In this connection, knowledge from the successful domestication and breeding of American shad (*Alosa sapidissima*), Chinese shad (*T. reevesii*) and Atlantic salmon (*Salmo salar*) can be useful.

Condition of the hilsa fishermen

Hilsa is a fundamental component of the quality of life and wellbeing of Bangladesh, including some parts of Myanmar and India in a similar manner to cod (Kurlansky, 1997), salmon (Montgomery, 2003) and other leading fish species that underpin the economy, food security and cultural identity of long-established riverine and coastal communities. The Government of Bangladesh has undertaken hilsa protection and conservation initiatives to improve the socioeconomic conditions of the fishermen. For this purpose, a ban period is imposed on hilsa broodstock fishing during spawning season in October and on juvenile fishing from November to May. To compensate the fishermen incentives of food grain and alternative income supports have been introduced (Islam et al., 2016a; ECOFISH-Bangladesh 2017). It is recognized that such initiative has had a positive effect, since hilsa catch increased from 351,223 tonnes in 2012-13 to 496,417 tonnes in 2016-17 (Dutton et al., 2018). However, the allocated incentive to each fishermen household at the event of ban period seems inadequate. Also, malpractices are common in the distribution channel, such as providing allocation to the fake fishermen, offering reduced quantity of rice and not following the delivery schedule (Dewhurst-Richman et al., 2016). Thus, for instance, the incentive can be in the form of cash money via bank transfer in order to get rid of the transportation costs and distribution loss, and to guarantee fishermen trust and satisfaction.

Recently Enhanced Coastal Fisheries (ECOFISH) project has selected 15505 beneficiaries belonging to poor fishing communities of 123 villages who are involved in hilsa conservation through AIG (alternative income generation) supports, skill development trainings and savings schemes. The activities of AIGs include fish farming, vegetable cultivation, duck and goat rearing, pebbles making, and swing cloths (ECOFISH-Bangladesh 2017). Specifically, the 'one voice for the hilsa's community' scheme by ECOFISH has made strong progress by establishing hilsa sanctuaries as well as developing community resilience (= improved savings, livelihoods and coping strategies) towards climate related shocks and stresses (Sharifuzzaman et al., 2018). Major driving forces behind this success are incorporated into the concerted efforts by stakeholders, such as government officials, fishing community, moneylenders-cum-traders, NGOs, law enforcement agencies, academia, researchers and local government units. Further integration among science, policy, resilience and climate change adaptation options can build up the overall progress. Moreover, it is equally important to understand the relationship between fisheries and resilience from the view point of non-consumptive valuation study (Dewhurst-Richman et. al., 2016). Thus, other than economic benefits and rice subsidies by the government (Islam et al., 2017), there are additional non-cash benefits like social recognition, enhanced capacities and access to government/non-government services, and opportunity for local entrepreneurship - all of which needed to explore for strengthening the socioeconomic conditions of hilsa fishermen.

SUSTAINABILITY OF THE HILSA FISHERY

Ecosystem approach

Ecosystem-based management has been a prominent topic in the field of natural resource management for decades that have gained momentum in marine management initiatives and more specifically in fisheries resources (Long et al., 2015). The ecosystem-based fisheries management (EBFM) is a systematic approach of managing fisheries in a geographically designated area that contributes to the resilience and sustainability of the ecosystem and recognizes the physical, biological, economic and social interactions (Hossain et al., 2017). EBFM seeks to account for the interspecies biocommunication with each other, with the environment and with humans. The approach involves community participation, reliance on scientific research and advice, conservative catch quotas, gear restrictions, comprehensive monitoring and enforcement, temporal and spatial distribution of fisheries, habitat conservation areas, and other biological and socioeconomic considerations (Witherell et al., 2000). Unlike many South and Southeast Asian nations where there is a long history of experience in EBFM and related fields (Olsen et al., 2003; Osgood, 2014; Staples et al., 2014), Bangladesh has only recently started to pursue that type of biodiversity and coastal resources management, and coastal resilience approaches (Pomeroy et al., 2016; van Brakel et al., 2018). Similar approaches with cohesive structure can be adopted by hilsa producing countries/regions.

The 7th five year plan background paper of the Government of Bangladesh (source: http://www.plancomm.gov.bd/wp-content/uploads/2015/02/19_Strategy-for-Ocean-and-River-Resources-Management.pdf) has emphasized developing the coastal and marine fisheries following conservation and sustainable exploitation approaches. Therefore, restoration of lost habitats, prevention of further habitat degradation and restocking of rivers can be promising for the conservation of hilsa. There are five sanctuaries in the riverine-estuarine ecosystems of Bangladesh to serve the purpose of hilsa conservation (Islam et al., 2014; ECOFISH-Bangladesh 2017; IUCN 2017). Also, several marine protected areas (MPAs) are in the process of being declared to maintain marine biodiversity and fish stocks at sustainable levels (Hossain et al., 2014d). Co-management or the joint management of the commons can be an ideal option for implementing EBFM and/or MPA fruitfully. For example, the Tetulia River management area in Bangladesh (Figure 11) comprises parts of two districts, multiple sub-districts and many fishing villages, and this kind of multi-stakeholder involving resource management is already in practice, such as fishery governance in the Philippines (Pomeroy et al., 2010) and inland or freshwater fishery/wetland management in Bangladesh (Sultana & Thompson, 2012). In the estuarine system, the geographical distribution of villages around common water bodies may mean that the catches in each village are heavily dependent on the activities in neighboring villages. So, co-operation between the different villages is the key to achieve management goals. This is particularly true for Bangladesh where, in many cases, more than one village is expected to be involved in the management of inland and marine resources. This requires particular skills in communication and co-ordination, therefore, intermediate management units may be more difficult than only managing the fishing community. Basic understanding of the distribution of species and their life cycles must be taught to local communities through the citizen science approach to ensure that learning is two-way. For instance, ecological links among the key species in the maritime zone of Bangladesh can be earmarked for EBFM plans (Figure 12). The diagram may not represent all of the ecosystem connections for all of the species; however, it provides an idea of how these species impact one another and what factors need to be considered when formulating the plan.

However, under the co-management arrangement, a fishery will need to be managed at various nested scales through fishery management units. A fishery management unit is the area to be managed, and the units should be formulated according to spatial interactions in the riverine/estuarine/marine environment, fishing communities and fish stocks. At a minimum, three categories or levels of fishery management units may be trialed:

a) CBO level – smallest management unit composed of clusters of several adjacent fishing villages to which the rights and authority have been allocated to use and manage local fish stocks, and to regulate access to a specific water area.
b) *Upazila* level (intermediate area) – fishery coordination committees composed of two or more CBOs represented by an *upazila* committee involving CBO leaders and government officials.
c) Ecosystem management level – this is based on hilsa fishery ecosystems with a management body responsible for coordinating the community management areas in one of the existing hilsa management units/areas (this may include parts of more than one district, a geographic area larger than the *upazila*).

Transboundary cooperation

Hilsa of the Meghna estuarine ecosystem is a mixed population occurring across the Bay of Bengal region, signifying that Bangladesh, Indian and Myanmar are most likely sharing some same fish stocks (Milton & Chenery, 2001). Based on this notion, which requires further validation, an integrated transboundary (= across one or more international boundaries) management plan with neighbouring countries is essential to sustain the common hilsa stocks by protecting their spawning and nursery grounds, and establishing marine park for no-take hilsa (BoBLME 2011, 2012). Therefore, Bay of Bengal countries with hilsa fishery should actively cooperate with each other and develop joint hilsa management strategy. Similarly, Kuwait, Iran and Iraq can jointly manage the Persian Gulf stocks, and hilsa of the Indus River and adjacent northwest India by India and Pakistan, if the fishery is to be managed sustainably (Salini et al., 2004). Interestingly, hilsa population of the Sumatra (Indonesia) and Perak River (western Peninsular Malaysia) is found to be genetically distinct (Milton & Chenery, 2001; Arai & Amalina, 2014). Therefore, further study is necessary to understand the biological and ecological aspects of hilsa with their population structure and dynamics across the region in order to ensure sustainable exploitation (Salini et al., 2004). Indeed, adequate monitoring, surveillance and enforcement of fishery regulations need to be considered as essential aspects for making the transboundary initiative effective.

Monitoring, control and surveillance

The existing fisheries laws and policies have not been properly implemented and non-compliance is common (Islam et al., 2016b; Murshed-e-Jahan et al., 2014). Lack of adequate monitoring, control and surveillance (MCS) is reported to affect the sustainability of aquatic biodiversity and ecosystems in many countries. MCS capacity is constrained due to lack of knowledge, skills and abilities related to compliance and enforcement among practitioners at the local level that can only encourage illegal fishing activities. To address it, training and mentoring activities should be carefully tailored to fill specific gaps and to deal with specific needs within national and sub-national units. Strengthening resource use rights is an important approach to creating incentives for local fishermen to be part of an effective MCS. Fishermen who have enforceable rights are more likely than others to be engaged in the management of resources. In general, barriers to be addressed include the existence of cultural and social constraints related to enforcement activities that might strain social, familial, political, or professional relationships, lack of effective partnerships with external agencies and local leaders, and insufficient financial support and workforce for compliance and enforcement activities. Specific activities may include strengthening the strategic focus and effectiveness of public education and outreach efforts, assessing the effectiveness of current information and outreach campaigns, increasing law enforcement capabilities and effectiveness with respect to legal and tactical procedures, providing supplemental and advanced training, developing community-supported enforcement efforts, and creating local enforcement alliances.

Marine reserves

Marine reserves (MRs) can enhance the sustainability and resilience of marine ecosystem health and fisheries resources. In 2014, Bangladesh has declared 1,738 km^2 marine protected area in the Swatch-of-No-Ground (SoNG-MPA) for the protection of threatened cetaceans (i.e. dolphins, whales), turtles, sharks, rays and other marine species (UNEP/CBD 2016). In 2000, an MR area (698 km^2) was also established in the Middle Ground and South Patches of the northern Bay of Bengal as 'absolute no take, no go zone'. Additionally, two marine parks have been established in the Saint Martin's coral reef island and Khulna Sundarban mangrove forests. India has ~12,300 km^2 MPA (= >0.5% of EEZ) and Myanmar has ~340 km^2 MPA (= ~0.01% of EEZ) (BoBLME 2012). But, to what extent those MPAs/MRs are relevant for the protection and conservation of hilsa stocks is not known. Fisheries stakeholders need to be consulted and involved in all stages of the conception, formulation and implementation, preferably through co-management, of any new MRs. This balance of establishing MRs alongside building an understanding of the benefits to the fishery is an important component of establishing an effective governance regime.

Researchable issue

It is useful to initiate a data-prospecting and data-recovery effort for the catch composition of hilsa since 1950s. This kind of analysis can provide valuable insights into the hilsa spatial dynamics, as unplanned water control structure on the rivers is known to affect the abundance and distribution of hilsa. Some habitats, such as the southeastern rivers in Bangladesh including the Feni, Muhuri, Karnafully, Sangu, Matamuhuri, Bakhkhali and Naaf rivers are not known to be suitable as hilsa spawning grounds (Hossain et al., 2016), but the reason behind the fact need to be uncovered with scientific interpretation. To develop hilsa mariculture, domestication of hilsa for seed production is necessary together with identification of suitable cage farming sites for increasing the hilsa production. Moreover, development of geo-spatial models can be useful to know suitable habitats of hilsa across the life cycle (Hossain et al., 2016). This type of model requires information on river/sea bathymetry, water current, primary productivity, turbidity and habitat data specific to life stages.

Some other novel methods, such as, transects of $^{87}Sr/^{86}Sr$ isotope ratios in otoliths (Milton & Chenery, 2003), allozymes and morphometric analysis (Salini et al., 2003), and distinctive trait of the parasite fauna (Alam, 2001) can provide information about the seasonal movements and residency of hilsa. Additionally, electronic or genetic tagging may constitute interesting and powerful alternatives to investigate the hilsa population structure and estimate mortality rates. Moreover, some common questions about hilsa are to be answered, for example, (a) where hilsa disperses after leaving the freshwater ecosystem and where adult lives in the offshore, (b) whether hilsa exhibit homing fidelity, and (c) whether hilsa is semelparous (= single reproductive) or iteroparous (= multiple reproductive cycles) over the course of its lifetime, or both patterns exist among the population. Additionally, climate change issues (= extreme events, sea level rise, ocean acidification and hypoxia) are unavoidable in coming days, thus resilience and adaptation to impacts of climate change on the hilsa fishery must be taken into account focusing fisheries science, technology, society and economy (Chowdhury et al., 2012). Importantly, relevant local/regional academia and research institutions should be involved in coordinated research programs to avoid reinventing the wheel.

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Table 1. Catch data of hilsa from the Meghna River at Chandpur and Padma River at Goalunda (Bangladesh), and Ganges River at Allahabad (India)

Year	Landing			Reference
	Meghna River (tonnes)	Padma River (tonnes)	Ganges River (kg/km)	
1937	457	-	-	Das (1985)
1938	299	-	-	

1939	976	-	-	
1940	826	-	-	
1967	-	2,875	-	
1968	-	2,323	-	
1969	-	9,409	-	
1970	-	6,089	-	
1971	-	-	-	
1972	-	921	-	
1973	-	12,014	-	
1974	-	2,435	-	
1997	57,532	2,278	-	Huq (2006)
1998	57,327	2,308	-	
1999	51,086	2,242	-	
2000	47,340	2,363	-	
2001	41,473	1,462	-	
2002	39,904	1,058	-	
1950s	-	-	1,344	Vass et al. (2008)
1960s	-	-	1,168	
1970s	-	-	529	
1980s	-	-	665	
1990s	-	-	333	
2000s			362	

Table 2. Annual growth of hilsa in Bangladesh waters (source: Rahman & Cowx, 2006)

Sex	Total length of hilsa (cm)						
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Both sex	19.2	27.5	34.7	40.8	45.8	49.7	52.5
Male	19.5	27.3	33.9	39.2	43.2	46.0	47.5
Female	19.1	27.9	35.5	42.0	47.4	51.7	54.8

Table 3. Basic biological data of hilsa (source: Mome & Arnason, 2008)

Age (year)	Base year cohort no. (million fish)	Individual weight (kg)	Biomass (1000 tonnes)	Natural mortality	Fishing mortality	Maturity rate
0.5	24928.00	0.05	1271.30	4.00	10.50	0
1.0	456.60	0.27	124.00	0.64	1.64	0.80

1.5	88.60	0.62	55.20	0.64	1.64	1.00
2.0	17.20	0.97	16.80	0.64	1.64	1.00
2.5	3.30	1.35	4.50	0.64	1.64	1.00
3.0	0.60	1.71	1.00	0.64	1.64	1.00
3.5	0.10	1.92	0.20	0.64	1.64	1.00
4.0	0.00	2.14	0.00	0.64	1.64	1.00

Table 4. Fecundity of hilsa in different habitats

Habitat	Length (cm)	Weight (g)	Egg numbers	References
Hooghly estuary	25.3-48.1	–	250000-1600000	Pillay (1958)
Upper Ganges River	31.5-50.6	–	289000-1168622	Swarup (1961)
Padma-Meghna Rivers	22.5-48.3	–	900000-2000000	Qureshi (1968)
Meghna River	38.0-52.0	–	382702-1821420	Shafi et al. (1977)
Padma-Meghna Rivers	33.0-51.0	–	600000-1500000	Quddus (1982)
Hooghly River	33.4-52.2	–	373120-1475676	De (1986)
Padma River (Gaulunda)	26.6-51.1	536-1925	179000-1302000	Moula (1992)
Meghna River	28.7-52.3	–	226000-1931000	Rahman et al. (1998)
Bangladesh	17.1-41.5	–	108500-1993846	Blaber et al. (2001)
Coastal water (Bangladesh)	39-51	800-1700	1030951-1940620	Saifullah et al. (2004)
Meghna River (Ramgoti)	35.5-47.0	448-1300	135600-1703200	Haldar (2004)
Padma River	35.0-55.7	600-1775	558700-1867000	Akter et al. (2007)
Bangladesh	44.5	1100	2286000	DoF (2008)
Hooghly-Bhagirathi Rivers	40.1-44.5	631-1175	72312-1554894	Bhaumik & Sharma (2012)

Table 5. Ecological parameters of hilsa across the life cycle (Hossain et al., 2016)

Characteristic	Life stage				
	Egg	Fry	Juvenile	Adult	Brood fish
Temperature (ºC)	22-25	25-26	24-27	21-25	21-24
pH	6.0-7.5	6.0-7.5	6.0-7.5	6.0-7.5	6.5-7.5
Salinity (‰)	0	0-1	0-2	0-30	0-2
Turbidity (mg/l)	50-75	55-102	55-102	65-106	40-65
Water current (m/s)	0.10-0.15	0.10-0.16	0.17-0.21	0.18-0.22	0.18-0.22
Dissolved oxygen (mg/l)	5-6	5-6	5-6	4-6	5-6
Depth (m)	1-4	4-6	5-20	5-100	5-10
Timing (month)	Oct-Nov	Nov-Jan	Feb-Apr	May-Sep	Sep-Oct

Habitat	River/estuary	River/estuary	River/near shore	River/sea	River/estuary

Table 6. Study results on the population dynamics of hilsa

Region	Fish length (cm)	L∞ (cm)	K	ø	Z	F	M	E	Reference
North Arabian Gulf, Kuwait	14.0-57.0	52.5	0.36	3.00	1.20	0.80	0.40	0.67	Al-Baz & Grove, 1995
Northwest Arabian Gulf, Iraq	25.0–58.0	60.5	0.32	3.07	1.28	0.66	0.62	0.52	Mohamed et al., 2001
Bangladesh waters (♂)	20.0-46.0	51.5	0.53	3.14	3.08	2.07	1.01	0.67	Halder & Amin, 2005
Bangladesh waters (♀)	20.0-52.0	65.6	0.51	3.34	2.87	1.95	0.92	0.68	
Bangladesh waters		58.5	0.71	3.28	2.61	1.39	1.22	0.53	Ahmed et al., 2008
Northwest Arabian Gulf, Iran	20.0-39.0	42.2	0.78	3.16	4.53	3.24	1.29	0.72	Hashemi et al., 2010
Northwest Arabian Gulf, Iran	-	42.7	0.77	3.14	2.55	1.80	0.75	0.70	Roomiani & Jamili, 2011
Bay of Bengal, India	15.5-41.5	47.8	1.90	3.64	1.98	0.73	1.25	0.37	Dutta et al., 2012
Indus River, Pakistan	18.0-31.9	31.5	1.55	2.13	2.89	0.68	2.21	1.00	Panhwar & Liu, 2013
Northwest Arabian Gulf, Iraq	12.2–48.0	61.5	0.28	3.02	1.66	1.11	0.55	0.67	Mohamed & Qasim, 2014

L∞= asymptotic growth, K= growth rate, ø =growth performance index, Z= total mortality rate, F= fishing mortality rate, M= natural mortality rate, E= exploitation rate

Table 7. Type of hilsa fishing gears in the Meghna estuary, Bangladesh

Gear	Length (m)	Width (m)	Mesh size (cm)	Fishermen no.	Seasonality
Drift gill net	1000-1500	10-12	8-10	10-12	Apr-Nov
Fixed gill net	1000-1200	8-10	5-7	4-6	Nov-Apr
Seine net	1000-1500	5-8	2-5	7-8	Nov-March

Table 8. Distribution of food grain and cash incentives to fishermen households (source: Habib, 2014)

Financial year	No. of upazila (no. of districts)	Food grain distribution		Alternative income generation programme	
		Allocated amount (tonnes)	No. of households	Allocated money per household (US$)	No. of households
2008-09	59 (10)	5730	143,252	-	-

2009-10	59 (10)	19,769	164,740	3.91	4388
2010-11	85 (15)	14,471	186,264	6.67	6869
1011-12	85 (15)	22,362	186.264	7.56	7785
2012-13	88 (16)	24,748	206,229	1.68	1743
2013-14	91 (15)	35,856	224,102	1.51	1165

Table 9. Alternative income generation activities for livelihood diversification

On-farm activity	Off-farm activity
Integrated fish-poultry-livestock farming (well-designed for waste containment and recycling)	Handicrafts/showpieces making (doll, fish, hand fan, hat, etc.)
Cage or pen aquaculture of commercial fish species (hilsa, tilapia, carp, barb)	Bamboo and cane handicrafts making (basket, stool, chair, etc)
Mud crab fattening and live marketing in domestic and export markets	Tailoring and embroidery (indigenous, traditional dress)
Small-scale aquaponic (combined culture of fish and vegetable in water) food production	Fish processing and preparing value added products (such as fish drying, salting, smoking, icing, packing)
Organic production, such as vegetable production with compost (locally called 'kechosar')	Eco-tourism, catering service
Homestead vegetable gardening, small-scale dairy farm (2-5 cows for milk)	Small-scale enterprise development, such as improved cooking stove (ICS) preparation, pottery, weaving, etc.
Road/embankment side fruit (high yielding mango, lichi, guave, kul/plums, papaya, banana) gardening	Rickshaw/van pulling (for passenger and goods), vehicle/boat driving, diesel engine repairing, cell phone servicing
Mangroves/plant nursery	Boat making/repairing, net mending

Figure captions

Figure 1. Spatial distribution of hilsa shad and its main migration routes (black arrows). The main spawning grounds (dark line areas) are assumed to be located in the rivers/estuaries of the Bay of Bengal and Arabian Sea.

Figure 2. Hilsa catch data from the river and marine waters of Bangladesh and India (data source: FAO 2017)

Figure 3. Average size (total length) of hilsa for the first six months in Hoogly-Bhagirathi River, India

Figure 4. A schematic representation of the life cycle of hilsa shad (source: Hossain et al., 2016).

Figure 5. Hilsa-less tributaries of Meghna deltaic region, enlarged (left) to show ecosystem functions in a typical tributary

Figure 6. Hilsa food web in the marine and estuarine ecosystems of Bangladesh

Figure 7. Marine and river catch data of hilsa

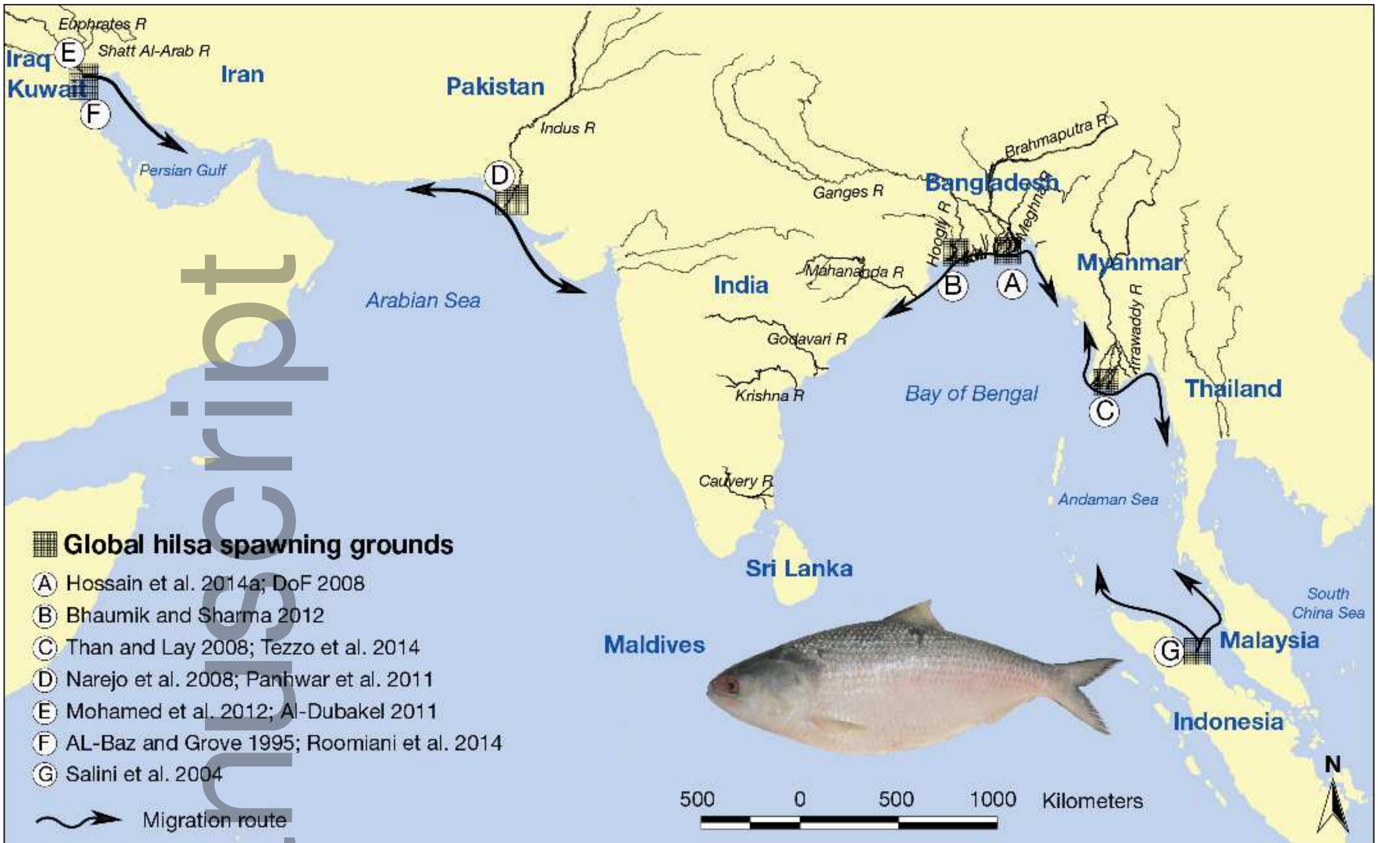
Figure 8. Hilsa fishing gears in the Meghna River estuary, Bangladesh (inset: a silver shinny hilsa)

Figure 9. Major initiatives taken by the government of Bangladesh and international agencies for hilsa protection, conservation, management as well as livelihood resilience of fishermen

Figure 10. Potential hilsa mariculture sites along the Bhola-Manpura-Hatiya islands of the Meghna delta, Bangladesh

Figure 11. Schematic representation of possible multi-tier co-management arrangement for managing the hilsa fishery and coastal ecosystem in Bangladesh

Figure 12. EBFM plan for key species in the maritime zone of Bangladesh



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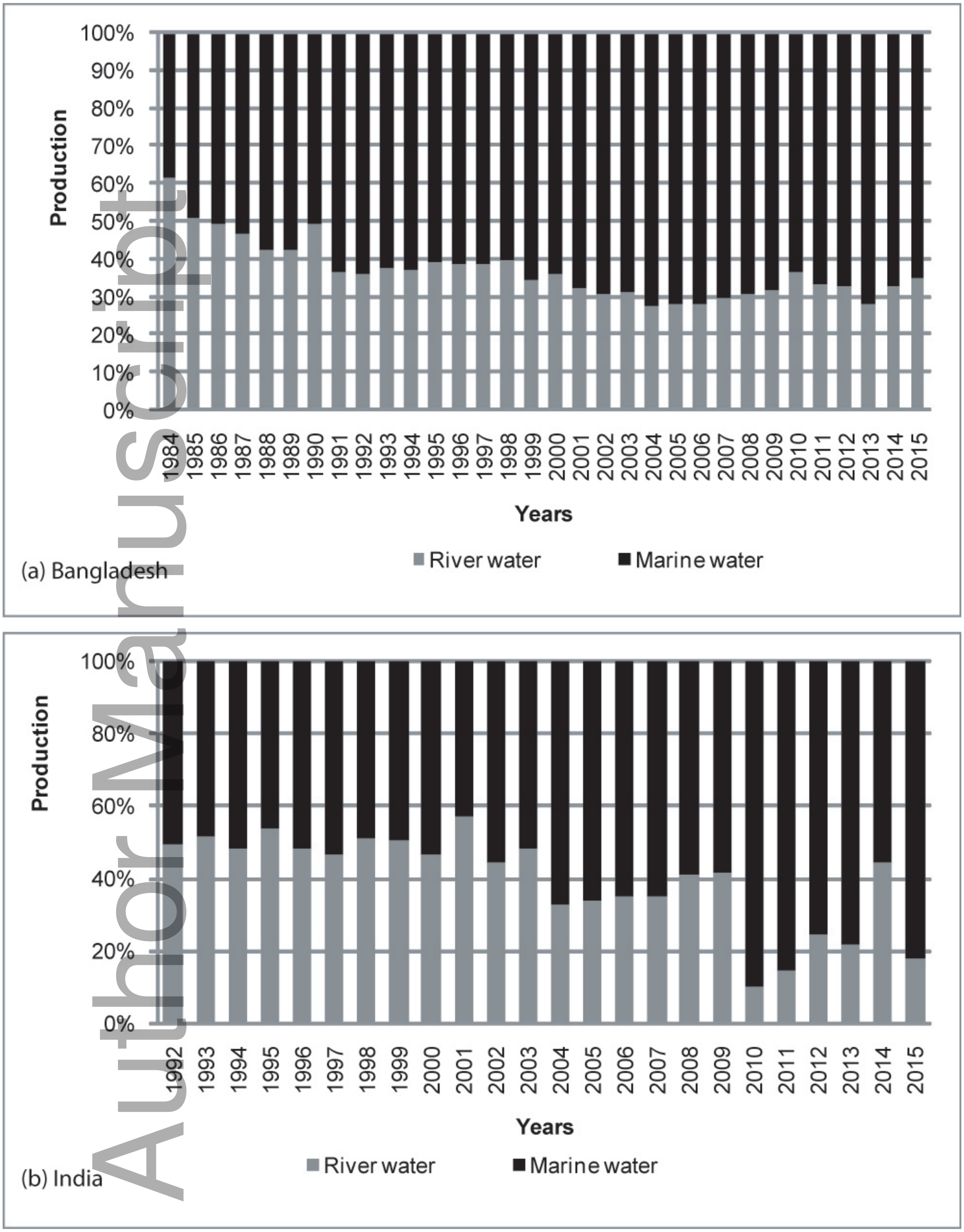

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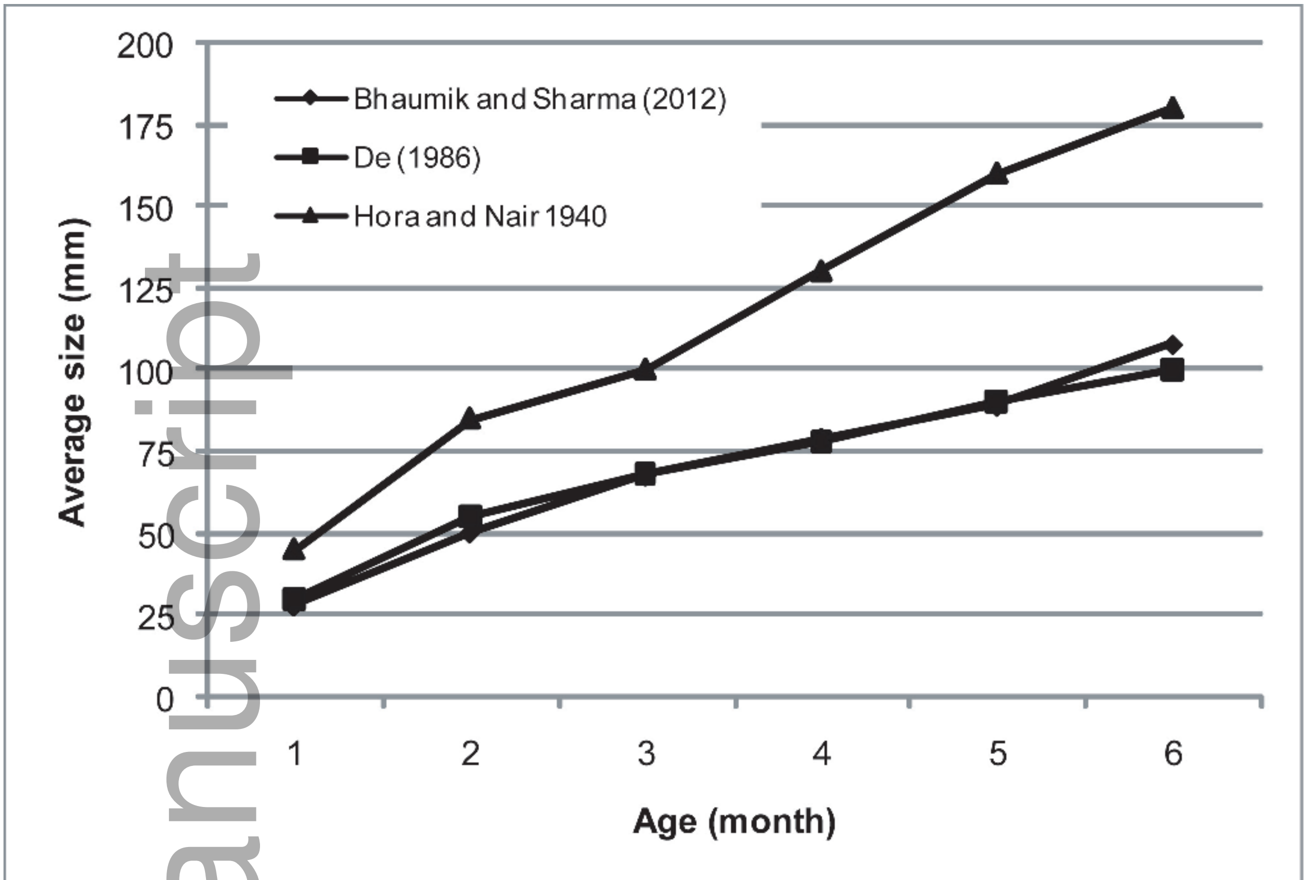

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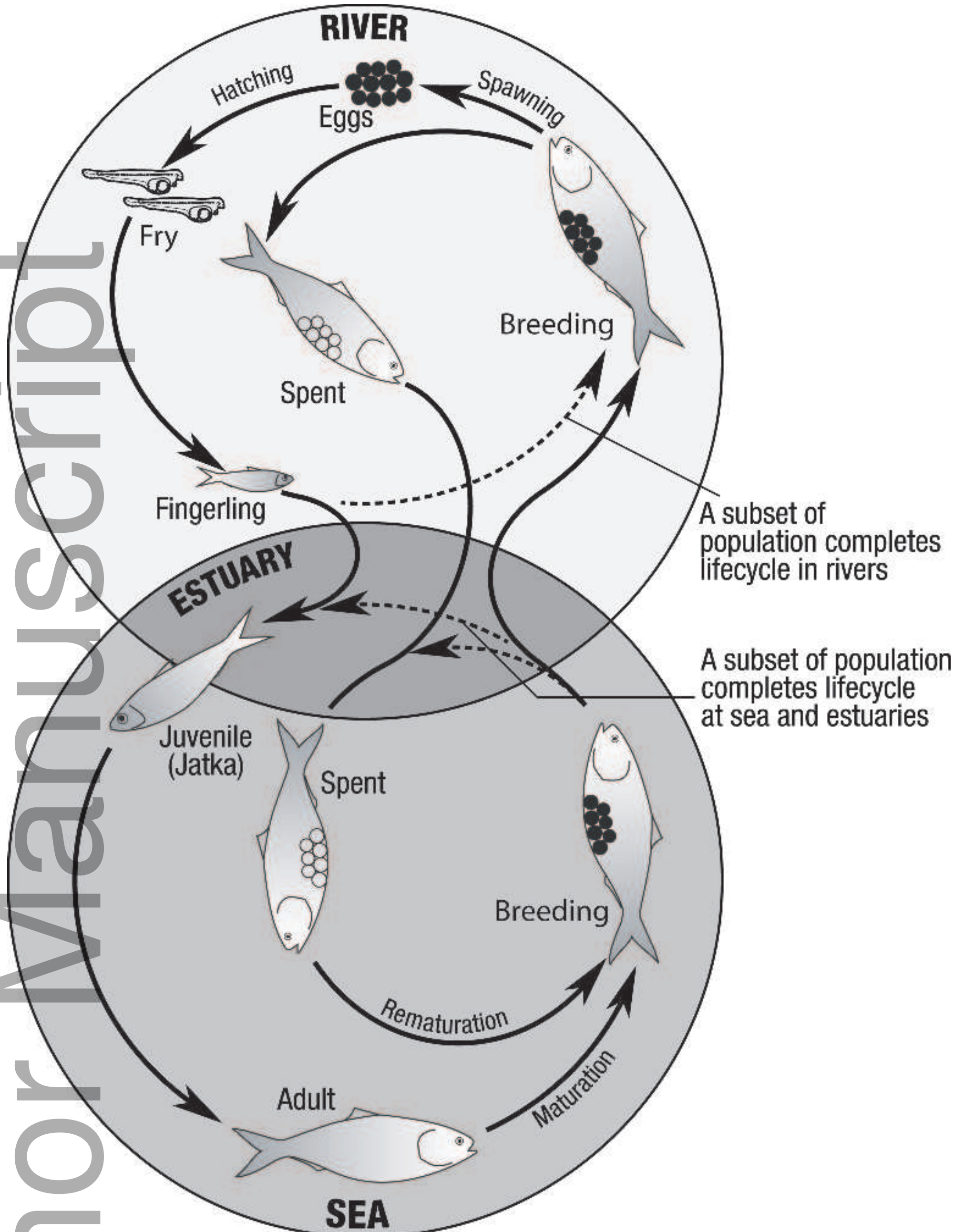

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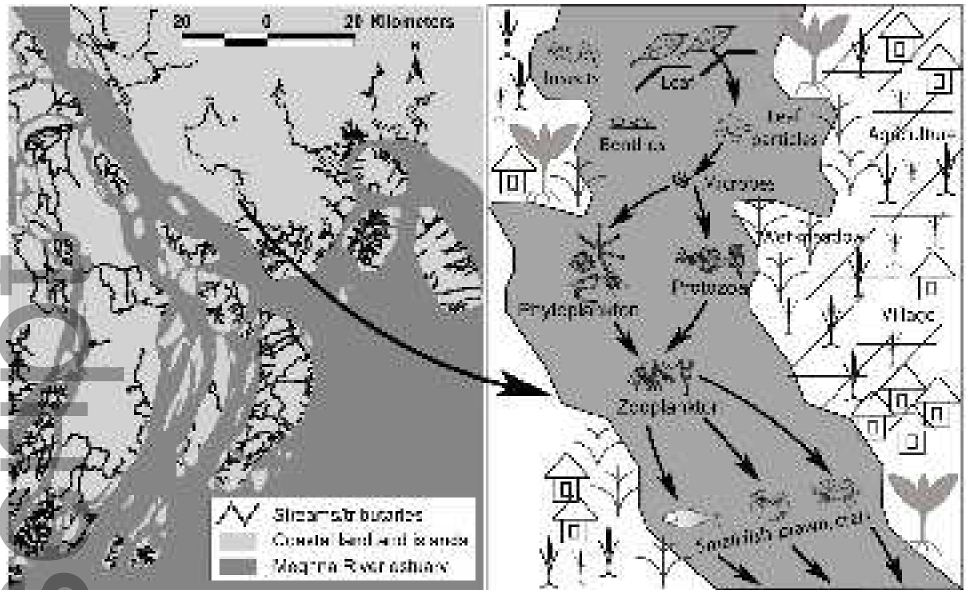

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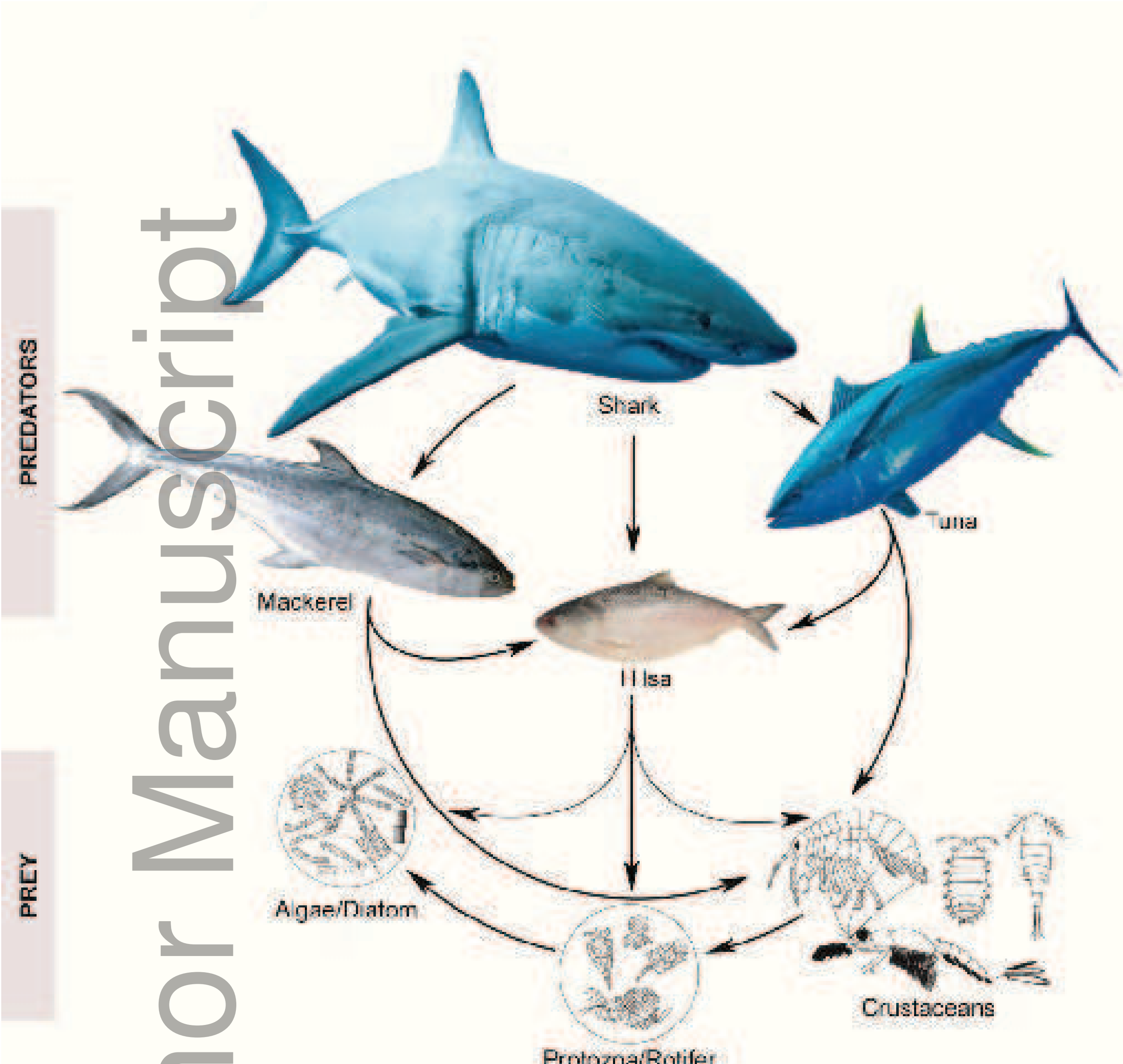

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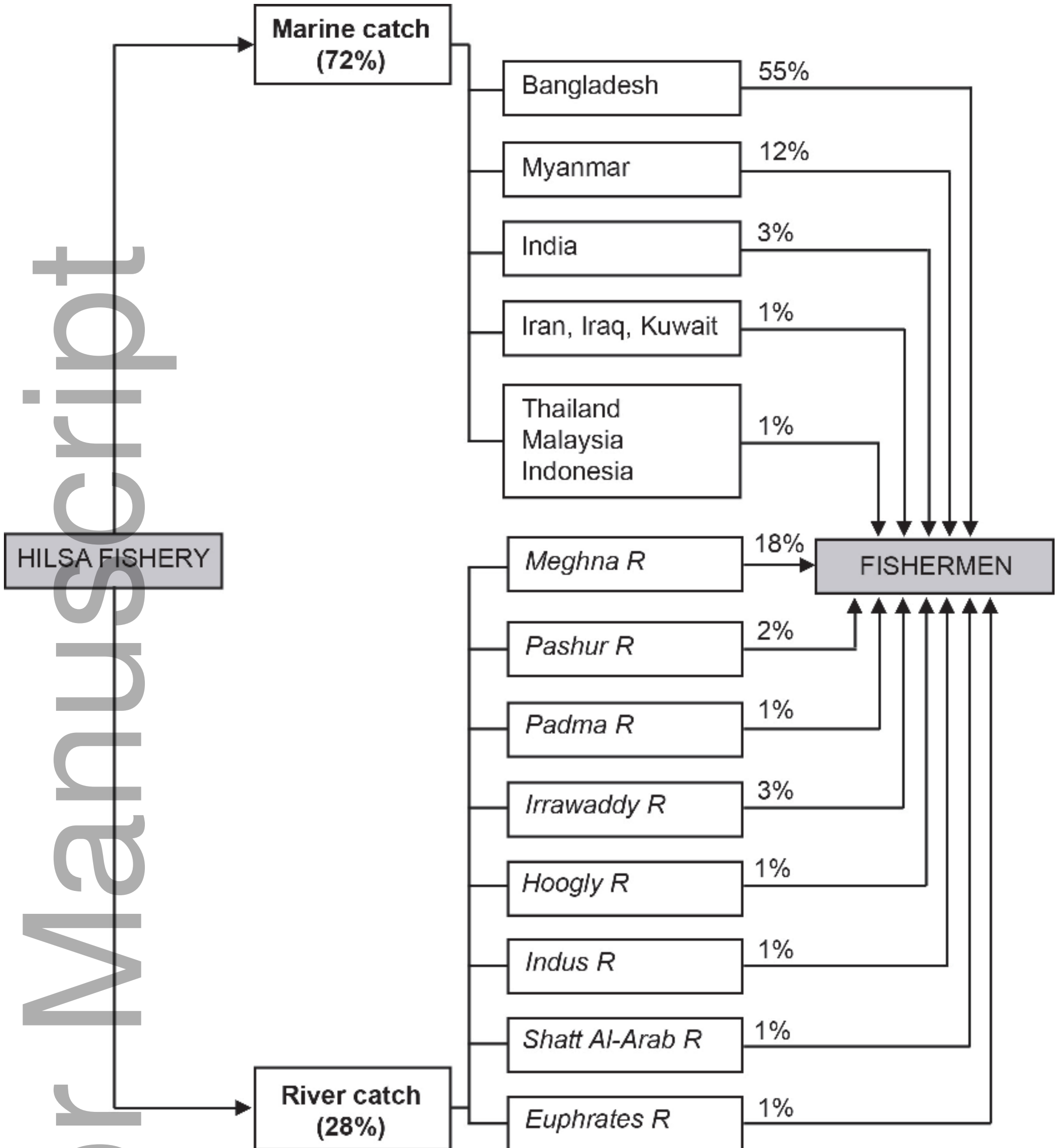

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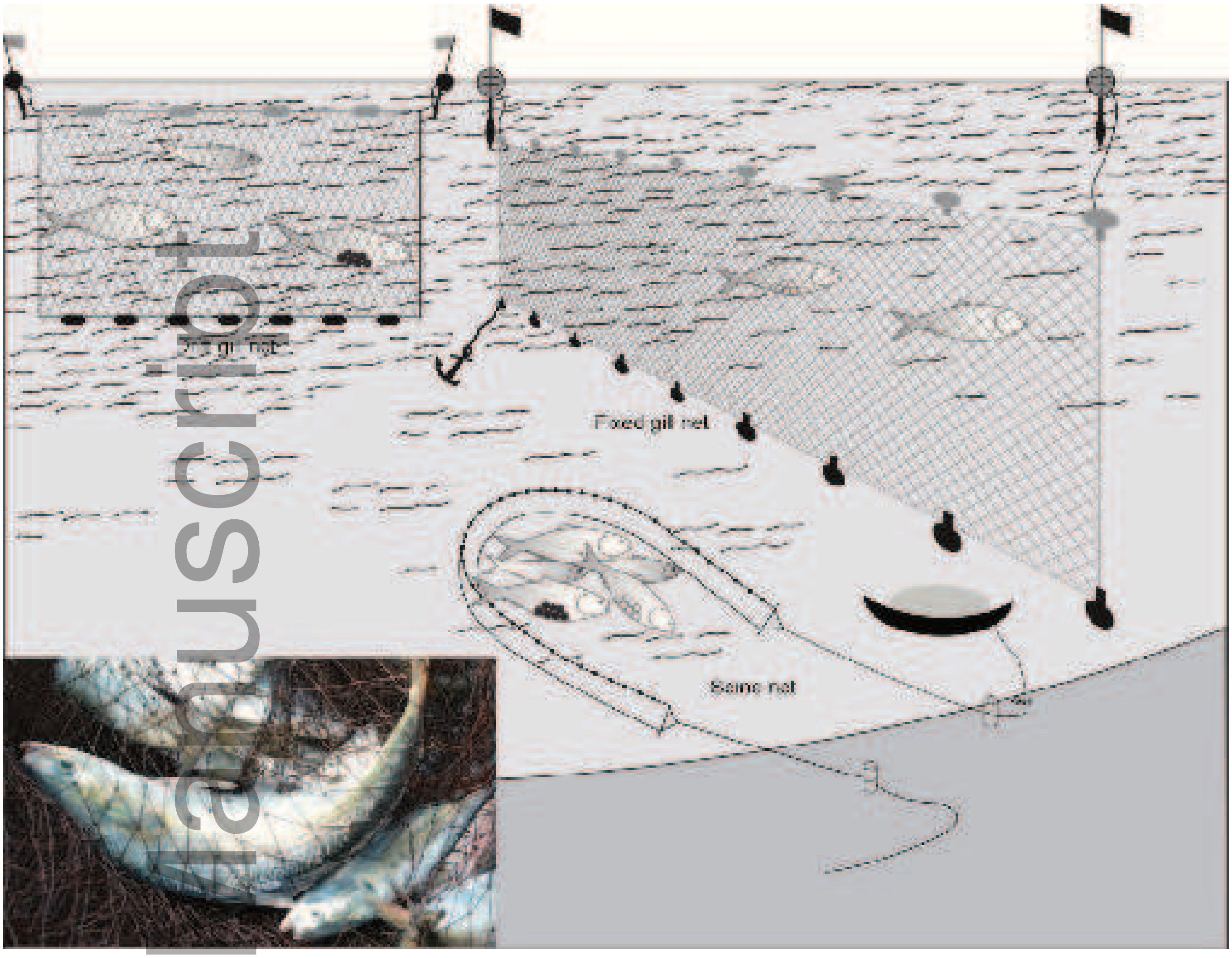

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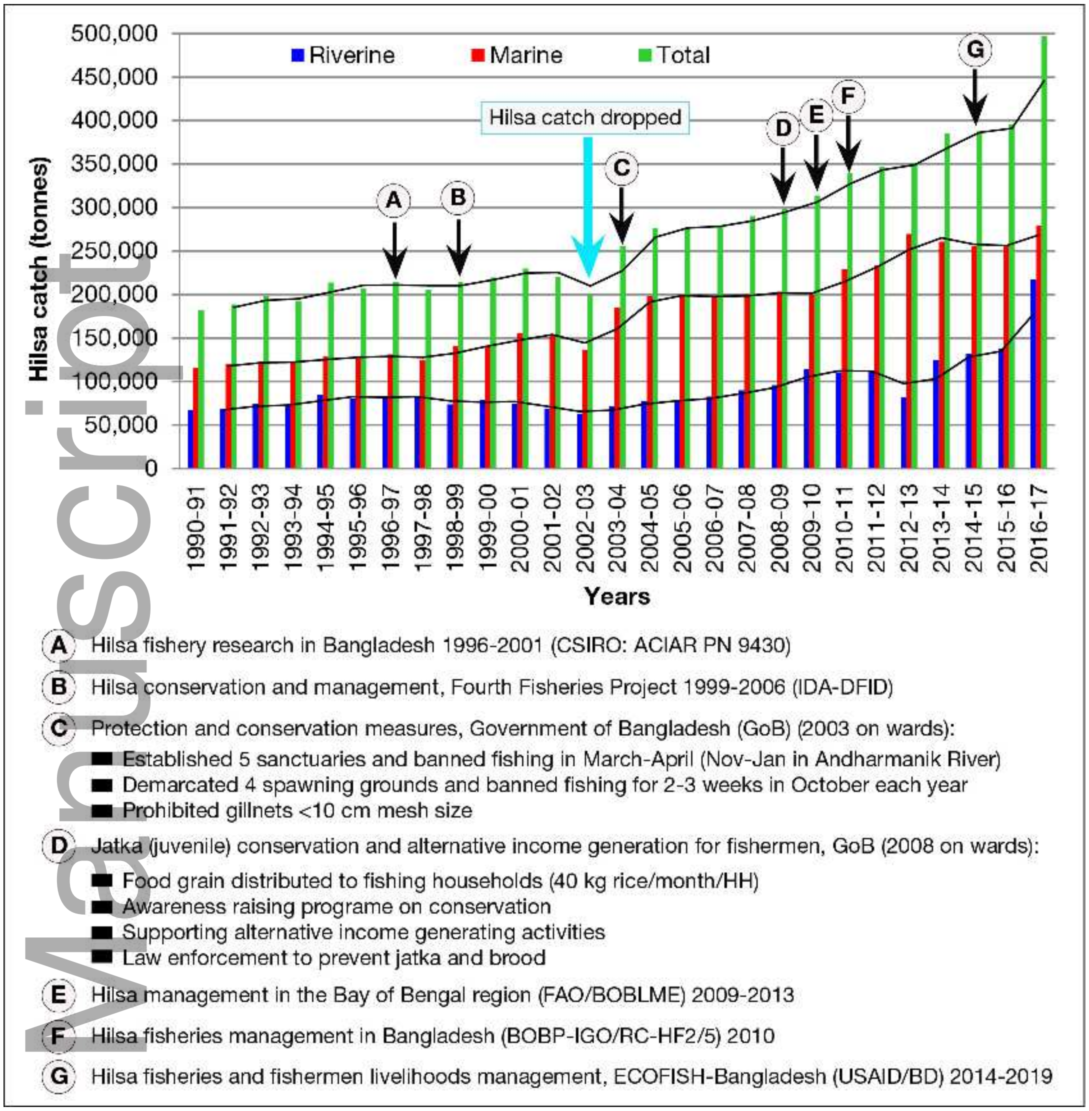

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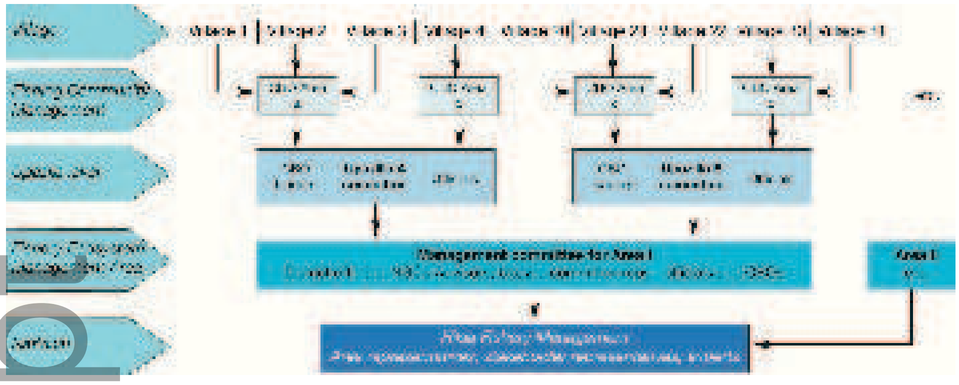

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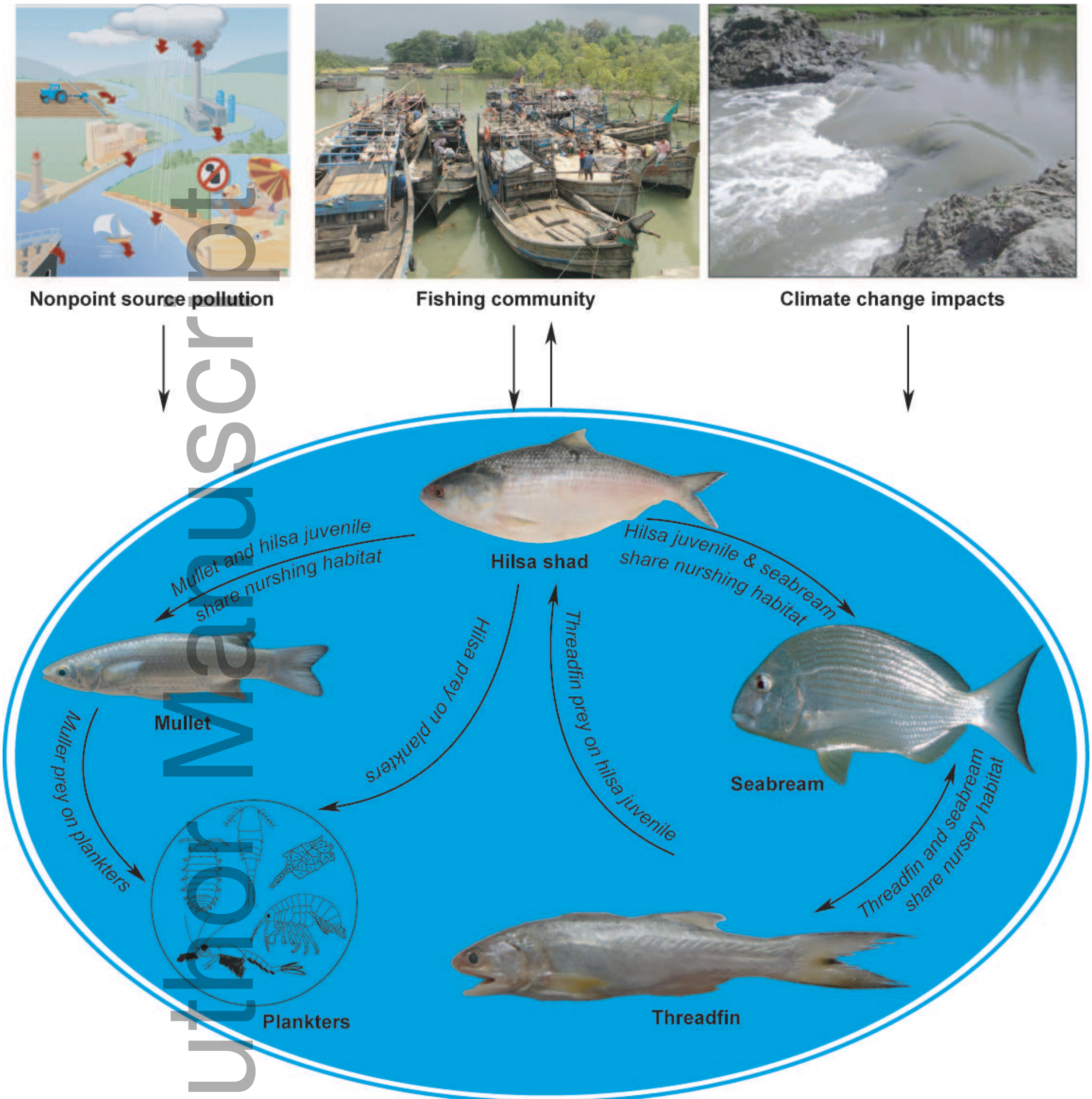

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