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Migration of Hilsa Shad in the Indo-Pacific Region – A Review

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A B S T R A C T

Hilsa,*Tenualosa ilisha* (Hamilton), by habitat is a marine environment species but they migrate to estuarine and fresh waters for spawning purposes. Peak upstream migration of Hilsa in the Rivers mostly starts with the onset of South-West monsoon. Tagging experiments have shown that a Hilsa may cover as much as 70.8 km in one day. Hilsa fishery exists with two distinguished peaks in monsoon and winter in Hooghly-Bhagirathi linkage of Ganga River system. In Bangladesh waters, during the peak breeding season the adult fish run in shoals to the estuaries and the rivers and migrate upstream as much as 1200 km (usual run 50-100 km) for spawning. In Indus, the migration takes place up to the Gulam Mohamed Barrage, which is 161 km from the Sea. In the River Irrawady, Hilsa are known to ascend into upper Burma to Mndalay, a distance of about 724 km from the Sea. Sbour (Hilsa) ascend Shatt Al-Arab River to about 150-200 km north of the city of Amara on the Tigris River. During last few decades the fishery has depleted in the Riverine environment of many countries due to rapid siltation and other degraded ecological conditions including wanton destruction of Jatka (Juveniles). It is, therefore, necessary to formulate and implement a good management plan especially conservation strategies for sustenance of this highly prized fishery across the world.

Introduction

Hilsa shad, *Tenualosa ilisha* (Hamilton) also known as Indian shad, migrates to freshwater environment of the River systems for breeding and thereafter, nourishment of the young ones. The breeding success of species depends on synchronous effect of eco-environmental and biological conditions (Bhaumik and Sharma, 2011c). Hilsa moves on the surface in the foreshore region whereas in the River they move in deeper zones near the bottom. Generally the peak upstream migration of Hilsa in the Rivers takes place during the South-West monsoon. The fish normally inhabits the lower region

of the estuaries and the foreshore areas of the sea. Hilsa prefers to reside in this region due to the presence of sub-surface oxygen, relatively low salinity, strong tidal action, high turbidity, heavy siltation and rich growth of plankton (Pillay and Rosa, 1963). Most of the stocks of Hilsa are anadromous, breeding much above tidal limits (Naidu, 1939). Some stocks have also been reported to remain permanently in the freshwater stretch of Rivers (Hora, 1938, Hora & Nair, 1940) and some spawn in tidal areas. There is no doubt that Hilsa is very salinity tolerant and inhabits freshwater, estuarine and coastal waters in the Bay of Bengal. Migration of Hilsa has been studied by a large number of scientists across the globe and huge numbers of literature have been published on the subject. The explanations of most of the investigators on migratory behaviour of Hilsa are based almost entirely on its capture during commercial exploitation. The paper deals with review of such studies with a view to throwing some light on migration of Hilsa in the waters of Indo-Pacific region.

Migration Behaviour

It is well known that Hilsa ascends the Rivers for spawning (Hora, 1938; Pillay, 1958; De, 1986, Bhaumik *et al.*, 2011b and Bhaumik & Sharma, 2012b) and the spent fish as well as their progeny migrate down the River towards lower estuaries and coastal areas (Pillay, 1958).

Hilsa by habitat is a marine environment species but they migrate in estuarine and fresh waters for spawning purposes, gradually adjusting their osmoregulatory processes through kidney and gills from saline water to freshwater. In sea to minimize the loss of water, kidneys of Hilsa contain less and non-functional glomeruli and the tubules. As the fish moves to fresh water environment and maintain salt balance between body and environment, the kidney starts proper functioning and unwanted salt is extruded. Chloride cells located in gills also help in salt extrusion.

Hilsa are reported to be largely anadromous; adults migrate into freshwater from the sea for spawning; the young upon hatching rear in the River channels and estuaries before descending to the sea for further feeding and growth. Thus, there are three phases for potential exploitation: during the breeding migration, the freshwater rearing stage, and the marine phase (Raja 1984). He further believed that there are three ecotypes: i) fluvial anadromous stocks which move between coastal waters and the lower reaches of Rivers of Rivers and breed in the area above the level of tidal influence; ii) fluvial resident stocks that live and breed only in the middle and upper reaches of Rivers, and iii) purely marine stocks. Apart from the said three types, it has been reported that Hilsa recently has adapted its life cycle to freshwater environment and establishment a self-generating stock in the confined waters of Ukai (Vallabh Sagar Reservoir) in Gujarat, India (Bhaumik *et al*., 2013 a & b).

It has been observed (Bhaumik and Sharma, 2012) that partial cessation of feeding in female migratory Hilsa (*Tenualosa ilisha*) occurs during the spawning period and upstream migration. At that time, stomachs are observed to be mostly empty, as they possess very little space for gut due to the voluminous growth of maturing ovary during this period. They opined, at this point of time, physiological studies seem very important as they play immense role during movement from marine environment to fresh water zones (via estuarine waters). During this period, they perform long journeys without or partial feeding where

the energy comes mainly from stored foods (liver and muscle glycogen). The chloride ions (Cl^-) play important role in osmoregulation by gills and ability to thrive in changed salinity circumstances (from marine 32 ppt salinity to almost 0.01 ppt in complete fresh waters).

The bioenergetic needs for long-distance swimming journeys towards spawning grounds are met not only from reserve carbohydrate sources (liver and muscle glycogen) but from sources other than the tissue reserves of glycogen. Here, the role of lipid is very important. It has been observed that during anadromous migration for spawning purposes, not only the liver and muscle glycogen lipid levels are steadily declined; muscle total lipids (triglycerides) also record persistent diminution in levels for either sex. The decline in level of lipid in muscle and withdrawal of the same is more pronounced in case of female Hilsa than the male, indicating that females withdraw and utilize more lipids than the males, from the muscle tissue lipids. At this juncture, gonads do mature in females and gonadal recrudescence could account for difference in lipid contents between the sexes. The ovaries mature and mobilize (by transfer from muscles) more fats (lipids) during the process of vitellogenesis, than was needed for testicular maturation in males. The number of ova produced by a female (with sufficient gonad, lipid contents and possibilities of formation lipoprotein membrane of ova) varies with size. By accelerating the gonad lipid reserves and lipoprotein membrane formation, the processes of spawning could be accelerated and here plays the active physiological changes in body. Thus, the physiology, bioenergetics under no feeding circumstances (cessation) and mobilization of proper lipids from muscle to gonad plays pivotal role in anadromous migrations *vis-à-vis* spawning events.

The migration behabiour of Hilsa, through tagging experiments, probably were studied first by Pillay *et al*., (1962) in the Ganga. Their findings, although not conclusive, indicated that Hilsa marked in the lower Ganges descended to estuarine areas through the main Padma River that lies in Bangladesh. Hilsa is said to be a fast swimmer (Southwell and Prashad, 1918). Tagging experiments have shown that a Hilsa may cover as much as 70.8 km in one day (Pillay *et al.*, 1963) whereas De (2001) reported to cover 300 km in 3 days/ 5-6 km per hour. Day (1873) described the anadromous nature of Hilsa in the Gangetic Rivers and stated that the fish spends their part of its llife in the sea, not far from the shallow coastal belt. According to the author in the Hooghly River, the Hilsa continue to ascend throughout the South-West monsoon to nearly end of the year (Day, 1889). Prashad (1919) doubted whether Hilsa is really anadromous as the fish is found in the Rivers almost throughout the year. Raj (1932) has reported that shoals of Hilsa visit the Palk-Bay annually from November to May, when a regular sea fishery takes place. Naidu (1939) in his report of the fisheries of Bengal cited Hora (1938) observed that Hilsa is a permanent resident of the Rivers, mostly estuaries, and rarely goes out into the sea**.** He agreed to view of Prashad (1919) that Hilsa is not to be considered as a true anadromous species. Based on the observations made in the Madras Fisheries Department, Raj (1937) stated that Hilsa spends the first year of its life in the lower reaches of Rivers and goes to the sea in the third year. This has not been observed in Bengal waters (Jones & Menon, 1951) with reference to the migrations of Hilsa in the Gangetic River. He reported that Hilsa migrates as far as Patna and Banaras**,** more than 400 miles from the sea, and further stated that HiIsa ascends the Ganges from June to September. Based on the

information that adults are seldom, if ever, caught during the rest of the year, it was presumed that they *go* far out into the sea, which according to him is the natural habitat of the fish. He stated that shoals of small-sized Hilsa of 9" to 10" size begin to make their appearance in October-November every year, in the foreshore of the Bay even down to Cox's Bazar, Bangladesh and the mouths of Rivers including Hooghly, India, evidently to feed on the rich plankton population recorded there at that time. After a short period of stay in the lower reaches, these small-sized Hilsa are said to migrate higher up in shoals in about January-February. He also stated that the small-sized Hilsa may be coming up the River even up to August and they usually swim dose to the surface while the medium and bigger ones swim slightly lower down towards mid-River. The general migration of adult Hilsa takes place from about May or June and they disappear by the second week of October, when presumably they return to the sea**.** Very seldom any spent fish were caught and he could not determine whether this was due to the annihilation of the migrants by extensive fishing or because the spent fish in their return migration swim along the bottom. In view of these observations, he considered that there is not sufficient evidence to say that the Hilsa is not anadromous. He inferred that after the eggs are hatched the fry go down the streams to the sea and remain there till they again appear on the foreshore in about October. Probably same of the medium-sized ones go back to the sea to ascend again the following year In about May and later as big-sized ones. From the measurements of fish examined by him he found the size of the majority group in March-April to be are 10.5"to 11.05", which had evidently grown to 12.0 " to 13.0 " in July and August. The majority size of the medium-sized fish was 15.5" to 18.0" of the big ones**.** Hora and Nair (1940) studied the Jatka (juvenile) caught in East Bengal (Bangladesh) Rivers and stated that they are 2 to 5 months old Hilsa which migrate from estuaries into freshwater for feeding purposes. Prashad**,** Hora and Nair (1940) expressed that the fish migrates into the sea during the first year of its life where it moves along the foreshore and does not go far out into the sea. Hora (1940) pointed out that among the mature Hilsa that swarm into the Rivers during the flood season for spawning purposes, there are a number of young individuals also and that these travel far up before they become sexually mature. He stated that spawning takes place in the tidal waters and in the middle reaches of the large Rivers and inferred that the floods and sexual maturity induce the fish in the sea to undertake the upward migration. Based on the investigation conducted at Chandipur on the Balasore coast of Orissa**,** he concluded that Hilsa in all stages of growth are found in the sea all along the foreshore area and the fish caught in November are less than one year old and that the fish feeds and continues to grow in the sea except during November and Februar**y** and possibly also during May-June. It was inferred that after leaving the Rivers they do not go far into the sea, but move about in shoals in the estuaries and foreshore. Hora (1938) observed that Hilsa is a permanent resident of the Rivers mostly estuaries and rarely goes out into the sea. Raj (1937) stated that Hilsa spend the first year of the life in the lower reaches of the Rivers and goes to the sea in the third year.

In the Mahanadi, Godavari, Krishna, Cauveri estuaries (India) and the lndus (Pakistan) the extent of migration of the species has been greatly affected by the construction of anicuts or dams. In the Mahanadi, the fish have been observed to migrate up to the Naraj anicut which is about 6o miles from the River mouth. In the

Godavari, Kishna and Cauveri the extent of migration is up to the lowermost anicuts which are located at distances of 60, 60 and 35 miles respectively from the River mouths. The migration of Hilsa in the Narbada i**s** restricted to about 100 miles and this is suspected to be due to the high velocity of the current in the upper reaches.

Presently, the migration of the fish is adversely affected in the Rivers due to construction of dams, weirs, anicuts and barrages (Jhingran and Natarajan,1966; Panikkar, 1954), Ghosh, 1987, Kowtal, 1994, Bhaumik *et al.*,2011c and this fish is unable to reach its natural breeding grounds. The construction of Farakka barrage has impacted on Hilsa migration and hence its abundance in further upstream (Chandra *et al.*, 1987, Jhingran and Gupta, 1987, Mukhopadhayay, 1994, Chandra, 1994). The Ukai and Kakrapara dam in Gujarat similarly affected migration of Hilsa in the Tapti River (Dubey 1994, Bhaumik *et al.*, 2013 a, c & e).

Hilsa spends most of its life in the inshore areas of the sea and undertakes extensive migrations ascending the estuaries and Rivers for breeding purpose (Reuben *et al.*, 1992). The life cycles of most marine and estuarine species involve complex migrations between spawning and nursery grounds. Older Hilsa spawn for the second and the third time in the higher reaches, while younger Hilsa making their first spawning migration are more susceptible to changes in salinity and spawn in the lower portions of the River (Azad *et al*., 1999; Rahman, 2005).

Mitra and Devasundaram (1954) expressed that Hilsa is permanent resident in Chilka lake and prefers less saline water. It is well known that Hilsa ascends the Rivers for spawning (Hamilton, 1822: Day, 1873 &1878: Naidu, 1938; Howard, 1938; Jones and Menon, 1951; Hora, 1938; Pillay, 1958; De, 1986; Chandra, 1962; Bhanot,1973; De and Saigal,1989; Bhaumik and Sharma,2012 a & b) and the spent fish as well as their progeny migrate down the River towards lower estuaries and coastal areas (Pillay, 1958). Most of the stocks of Hilsa are anadromous, breeding much above tidal limits (Naidu, 1939). Some stocks have also been reported to remain permanently in the freshwater stretch of Rivers (Hora, 1938, Hora and Nair, 1940) and some spawn in tidal areas.

There is no doubt that Hilsa is wide salinity tolerant and inhabits in freshwater, estuarine and coastal waters in the Bay of Bengal. The upstream migration has been found to be associated with the state of sexual maturity as well as volume of fresh water discharge from the River or estuary during monsoon onwards (Bhaumik, 2012b). However, other minor factors namely rainfall, Current velocity and temperature, low salinity (Mitra and Devasamudram, 1954), turbidity, flood pulse, chlorophyll content and plankton (Bhaumik, 2012b) cannot be ignored.

The peak upstream migration of Hilsa in most of the Rivers of the Indo-Pacific region generally commensurate with South-West monsoon i.e., July and August and continues up to October or November (Kulkarni, 1951; Jones and Menon, 1951; Pillay and Rosa, 1963). While in the Hooghly estuary, the period of migration is found to be prolonged and extended up to winter (De, 1986; De and Saigal, 1989; De *et al*., 1994) whereas Bhaumik *et al*, 2011a and Bhaumik & Sharma (2012b) observed the migration up to February.

Hamilton (1822) recorded the presence of Hilsa near Kanpur and Agra. Day (1873) found Hilsa to ascend as high as Delhi. The

long range migration of the fish has also been reported from other principal River systems of the country *viz*., Brahmaputra (Pillay and Ghosh, 1958; Pillay and Rosa, 1963), Mahanadi (Pillay and Rosa, 1963), Godavari (Chacko ,1952), Krishna (Chacko, 1952), Cauvery (Chacko, 1952), Narmada (Kulkarni, 1954) and Chilika lake (Jones and Sujansingani, 1951). Pillay and Rosa (1963) reported that during peak breeding season, the adult Hilsa run in shoals to the estuaries and Rivers and may migrate upstream as much as 1287 km for spawning. They also reported that it migrates in the Purna River less than 8 km, in Hooghly and Bhagirathi River about 300 km but it is restricted to 56-97 km in Godavari, Krishna and Cauvery. While in the River Brahmaputra, the peak migratory season of the species is observed from May to July due to early monsoon (Rao and Pathak, 1972). It has often been observed that during years of great abundance of Hilsa the usual limits of upstream migration may be extended. Such instances have been recorded in the Brahmaputra River where Hilsa catches were made even in areas above Tezpur during 1955 (Pillay and Ghosh 1958) and in the small tributaries of the Ganges, through which the fish ascended into Lake Mahasratal during 1954 (Banerji 1955). A largest (so far recorded) female Hilsa (*Teualosa ilisha*) of 614 mm in length and 4250 g in weight has been observed to be migrated in the Tapti estuary ascending about 80 km near Surat in Gujarat. (Bhaumik *et al*., 2012 c)

Southwell and Prashad (1918) have stated that the effect of weirs in the Gangetic Rivers is disastrous for the Hilsa fisheries. But their effect in Bengal and neighbouring States differ from that in Madras State, in that in the former States. HiIsa are found only very exceptionally beyond the anicuts even though the water level of the two sides of the weirs may be the same. Hora (1940) expressed the opinion that there is no need for opening any hatcheries to compensate the effect of the weirs. The extent of migration of the fish in the various River systems in India differs greatly. In the Ganga River the fish is believed to migrate as far high as Agra and Delhi. Jenkins (1938) and Naidu (1939) indicated the possibility of the Hilsa in the upper reaches constituting separate stocks and the morphometric comparisons of the samples (Pillay, 1952) support this view. In the smaller Rivers on the west coast they migrate only to very short distances from the River mouth. In all the Rivers where such artificial barriers have been erected the fisheries are reported to have beat adversely affected. The migrating fish gather below the obstructions and are caught in large numbers by the fishermen with disastrous effect on the fisheries (Devanesan, 1952). Day (1873) considered it essential to provide fish passes to facilitate the migration of Hilsa to the upper reaches of Rivers in which artificial obstructions have been constructed. He made observations on an experimental fish pass set up in the lower anicut of the Colermn River and found it not suitable for Hilsa. A similar fish pass was constructed in the weir across the Mahanadi at Cuttack but this also proved to be a failure (Southwdl and Prashad, 1918). Later investigators have all expressed the opinion that it will not be feasible to erect suitable fish passes in Indian Rivers. The possibility of setting up hatcheries near these obstructions and artificially propagating the species for resuscitating the Rivers was considered in Madras and Bengal. Besides the obstruction of Rivers by the construction of weirs and anicuts, silting also appears to affect the migration of Hilsa. Chacko and Dixitulu (I 951) have observed that when the water level in the River Godavari was low due to failure of floods and silting during the

season in 1950, the fish migrated along the shore and afforded a lucrative fishery on the Coconada coast.

It is the fact that upstream migration has been observed to be associated mainly with the state of sexual maturity as well as volume of freshwater discharge from the estuary as well as flood pulse during monsoon onwards but the other factors like rainfall, current velocity and temperature, low salinity, turbidity, primary productivity and availability of planktonic food cannot be ignored (Bhaumik & Sharma, 2011c).

The monsoon run-off of huge turbid water above 100 NTU preferably 100 – 140 NTU turbidity is prime requisite for attracting shoals of brood Hilsa to the Hooghly-Bhagirathi system. Depth plays limiting role in movement of the migrating Hilsa and water column of 18 - 20 m has been observed to be ideal for stress free movement of the brood stocks. Of course the Hilsa fishes pass through comparatively lower depth (av. 10 m) in winter months. To be mentioned here that the size of migratory Hilsa in winter is smaller than that of the monsoon period. Temperature of River-estuarine water has been observed to drop by 1.5 °C from average of 31.3 °C (29.5 – 32.6 °C) to 29.8 °C (29.3-30.2 °C) during monsoon migration of the brood fishes. On the other hand, in late winter (February) the ambient temperature rises by 1.8 °C from average of 27.6 °C (26.8 – 28.4 °C) to 28.6 °C (27.0 – 31.8 °C) which might influence upstream migration and breeding of Hilsa.

Among chemical factors, salinity plays determining role in breeding migration of Hilsa into the system. Since the salinity of the Estuarine-River system remains below 0.1 ppt for greater part of the year migration and so the breeding activities of Hilsa never get hindered within the system. In the system, the fishes get alkaline environment (pH 7.7 – 8.3) during their stay and life span. Dissolved oxygen content of the system by and large fluctuates in the range of 5.0 – 7.0 ppm. However, during monsoon the average oxygen increases by 1.22 ppm from 4.63 ppm to 5.85 ppm. Chlorophyll values of the River-estuarine system fluctuated between 0.114µg/l and 0.180µg/l during monsoon period. It has been observed that the values are comparatively more in some stretches where the nursery grounds have been located.

The threshold values of hydrography and physico-chemical parameters conducive for migration of Hilsa in the Hooghly-Bhagirathi River has been depicted in Table 1(Bhaumik and Sharma, 2012b)

The migratory movement of Hilsa into and from the River was studied at CIFRI recently in the Hooghly River at Diamond Harbour and marine zone of the estuary off Frazerganj (Bhaumik *et. al.*, 2011a, b, c; Bhaumik, 2012 a & b), where fishing of Hilsa by the gill net was observed during January to March and June to November. The direction of entangling of the fish i.e. towards River or Sea, and the position of entangling in the net *i.e.* at the top, centre or the bottom of the net were recorded. It was observed that a large number of Hilsa were entangled in the gill net at the top and central portion during high tide especially in the evening hours during their migration process into the River. However, during low tide migrating spent fishes from the River into the sea were invariably gilled at the bottom of the net indicating the habitat of the spent fish. The experimental fishing to follow the movements of Hilsa was conducted during peak periods of migration in monsoon, post monsoon and winter. As compared to the higher catch of Hilsa obtained in the coastal areas and the lower

estuary, the poor catch was recorded in the River which indicates that Hilsa does not move in the River in shoals. This study is in conformity of the study of Reuben *et al*, 1992.

It has been reported that with increase of depth following monsoon run off the Hilsa migration/catch goes up. It was observed that 4.0-4.5 m as favourable depth from the surface for migration of adult Hilsa. Thus, the ideal total depth in the system should be more than that (preferably > 20 m) for favourable migration and spawning of Hilsa (Bhaumik *et al.*, 2011a&c). Mojumder (1939) indicated that Hilsa move in the sea on the surface whereas in the River they move a depth of 14 –18 m, though on a cool or drizzly day they may rise to within 2 m from the surface. The occurrence limit of the fish does not extend to depths not exceeding 10 fathoms [One fathom=1.8288 m / 6ft] (Jenkins, 1911).

Based on the study of extensive samples of fish for length frequency as well as sex ratio and maturity condition of the migrants it was observed that there are two well-marked migration pattern of Hilsa into the Hooghly (Bhaumik, 2015 a & b), one during monsoon (May - October) and the other during the winter (January-February). In the Riverine area the large size groups of fish are abundant between May and October. After October this group declined to a minimum by December. The catch rates for the Hooghly revealed two peaks, one in May another in August. The medium- sized group was available all through the year. From November to March, medium- sized groups showed dominance over the large-sized group. Fishermen during this time also fished with smaller- meshed nets, because of the predominance of smaller to medium sized Hilsa. The catch rate and GSI value were found to be higher during March. The catch rate of this medium sized fish in winter indicates a lesser degree of migration into the River. Two size groups of 285-323 mm and 300-430 mm, former being the most dominant, participate in spring migration. The monsoon run of Hilsa comprises two groups varying between 300-370 mm and 400-500 mm, the later being most dominant occurring very much in the River catches. Smaller size fish of less than 285 mm also enter the River sporadically in very small numbers along with the bigger size groups of spring as well as monsoon runs of Hilsa . The spring spawners that enter the River for spawning in January-March return to the sea during July- August when these are caught in good numbers. The monsoon spawners that enter the River during September-October return to the sea after spawning and these spent fishes are caught in good numbers during January- March. Similarly, the offspring of spring spawners make journey for the sea from the River during November- January, whereas the offspring of monsoon spawners return to the sea from the River during July- September. The return of the broods of spring and monsoon spawners to the sea is not as precise as the River-ward migrations of Hilsa. Full recruitment of juveniles into the marine fishery is observed for 4 to 5 months in a year i.e. between July and January with a peak in October. The minimum size at recruitment into the sea is at 160 mm to 180 mm whereas the juveniles are fully recruited into the fishery at a length of 260 mm to 270 mm approximately at an age of one year. But the maximum exploitation of this stock is effected when they congregate in the near shore areas and lower estuaries at lengths of 300-390 mm at the age of about 2 years approximately. This also coincides with the size at first maturity of Hilsa. It has been observed that migration of Hilsa takes place in large numbers only when water depth, current velocity, volume of discharge

stimulating flood pulse and temperature are favourable for them.

In Bangladesh Rivers, Hilsa ascend in the entire length of the Gangetic Delta System i.e. about 500 km (Pillay and Rosa, 1963). Like American shad, the Hilsa shad is generally termed anadromous, but it is diadromous, as it migrates frequently between fresh water and the sea. The adults migrate upstream to spawn at the start of the south-west monsoon and associated flooding of the rivers. During the peak breeding season the adult fish run in shoals to the estuaries and the rivers and may migrate upstream as much as 1200 km (usual run 50-100 km) for spawning (Pillay and Rosa 1963, De and Datta, 1998a, Dunn, 1982, Mazid ,1994, Rahman 1997, FishBase 2012, Rahman 2006, Rahman *et. al.* 2010). However, all races/stocks of Hilsa do not migrate following the same pattern. There is no evidence of spawning in sea, the fish advance to maturity in the estuarine area and may spawn both in estuaries and rivers. In the northern Indian Ocean there are some purely riverine stocks, anadromous stocks which migrate between the sea and the river (the river-ward migration is for spawning) and purely marine stock (BOBP 1987). In Bangladesh, Hilsa migration from salt water of the sea to the freshwater Rivers is still an interesting research topic to identify the time they spent in each habitat. Through the microchemistry analysis of the otoliths in the Nottingham Geological Survey laboratory, trace elements composition of the otoliths was found to contain Ca, Mg, Zn and Cu. From the scientific interpretation, it was observed that Hilsa from the marine water comes to fresh water and Hilsa from fresh water migrates to the sea (DoF, Bangladesh, 2009).The spawning migration towards the estuaries and Rivers starts from July till October, also from January to February/March. During this migratory period, the catch percentage of Hilsa from the inland Rivers is very high, and 80% of the females are found in the egg-releasing condition to support the spawning status of the fish (Shafi and Quddus, 1981). After breeding, the juveniles of Hilsha / jatka, from 4-15 cm, are abundant from February to May in the foreshore and Riverine waters of Bangladesh's deltaic Rivers, including the Padma and Meghna (Rahman, 1996, Blabber and Mazid, 2001). After growing 1-2 years in the sea, the fish matures and reaches a size of 32-35 cm prior to their spawning migration towards the inland Rivers, and the life-cycle continues. Hilsa rear in the freshwater environment before heading out to sea to feed and increase in size and they return to spawn as mature adults in much the way that Pacific salmon do. During their spawning migration, almost 70% matured and gravid Hilsa are captured in Bangladesh (Rahman, 2005, Rahman *et al*.2010). This increasing fishing pressure on both juveniles and adults along with the loss of spawning grounds and obstruction to migratory routes by anthropogenic activities such as the construction of barrages, dams, fences and the deterioration of habitat by industrial and agricultural pollution (Haldar and Rahman 1998, Rahman 2001 and 2006, Mome 2007) has gradually declined the fishery in the upper reaches of Rivers. Azad *et al*., 1987, while studying migration, reported that it may be the large-size group of Hilsa which shows a peak in April at Cox's Bazar (same happenes to Chittagang around June) moves into the estuarine and riverine areas. In Khenupara and Chandpur, peak catches of large-sized Hilsa group were observed during July and August respectively. As regards winter spawning medium-sized Hilsa group was abundant during July in marine sector which migrated towards the estuarine and riverine areas for spawning.

Table.1 Threshold Values of Physico-Chemical Parameters for Hilsa Migration

Parameters	Migration
Depth	20 m and above
Turbidity (NTU)	100-140
Temperature (°C)	27-30
Salinity (ppt)	<0.1
D.O (ppm)	5.0-6.8
pH	7.70-8.30
Chlorophyll (µg/l)	0.114-0.180

Table.2 Ascending Run of Hilsa During Migration

River/Estuary where Hilsa migrates	Country	Ascending distance (from sea /River mouth)	Investigators
Irrawady	Myanmar	724 km	Kyaw (1953)
Padma/Jamuna/Meghna	Bangladesh	1200 km Usual 50-100 km	Pillay and Rosa 1963, Mazid 1994, Rahman 1997, FishBase 2012, Rahman 2006, Rahman *et. al.* 2010
Indus (up to Gulam Mohamed Barrage)	Pakistan	161 km	Qureshi (1968)
Indus (up to Sukkur Barrage)	Pakistan	800 km	Qureshi (1968)
Indus (up to Multan pre Sukkur Barrage)	Pakistan	1000 km	Aitkin (1907)
Indus (upto Jamshoro)	Pakistan	300 km	Bhuiyan and Talbot, 1968
Satt Al-Arab (up to Amara on the Tigris River). Al-Hammar marsh- North of Basrah city. South of Nasiria city	Iraq	150-200 km 180 km 45 km	Al-Hassan (1999)
Qalaat Salah on Tigris River and to Al-Fahod on Euphrates River North of Basrah	Iraq	150-180 km	Al-Dham (1977)
Hooghly	India	298 km	Hora,1938, Pillay, 1958, De, 1986
Hooghly (Different schools) Up to Diamond Harbour-Godakhali Up to Hooghlyghat- Balagarh Up to Lalbag- Farakka	India	 32-50 km 126 km 215-298 km	Bhaumik and Sharma (2012b)
Mahanadi (up to Naraj anicut)	India	96 km (60 miles)	Pillay and Rosa (1963)
Godavari	India	96 km (60 miles)	Chacko (1952)
Krishna	India	96 km (60 miles)	Chacko (1952)
Cauvery	India	56 km (35 miles)	Chacko (1952)
Purna	India	8 km (5 miles)	Pillay and Rosa (1963)
Brahmaputra (up to Tezpur)	India	306 km	Pillay and Ghosh (1958)
Narbada	India	129 km (80 miles)	Kulkarni (1954)
Ganga (Patna-Banaras) Pre Farakka	India	644 km (400 miles)	Raj (1937)
Ganga (Delhi-Agra) Pre Farakka	India	1287 km	Hamilton (1822), Day (1873)

In the River Indus (Pakistan) Hilsa begin to enter freshwater in January and some years remain in the rivers as late as November. Peak landings take place June, July and August. Although increased steam flow does not appear to the stimulus that attracts Hilsa into the Indus, as reported for other streams, the peak run does occur during peak flows (Islam and Talbot, 1968). In Indus, the migration takes place up to the Gulam Mohamed Barrage, which is 161 km from the Sea and as a result the Jhelum River stock becomes freshwater stock. Qureshi (1968) working on *Tenualosa ilisha* from the Indus River system in Pakistan, stated that before construction of Kotri barrage in 1965 the mature mature males and females of the species could be collected at Sukkur at a distance of 800 km from the sea. Before construction of Lloyd's barrage at Sukkur in 1932 , the species was reported to travel a distance of 1000 km up to Multan (Aitkin, 1907). Due to imperfect design of fish ladders at Kotri barrage, after 1956 the fluvial migration of *Tenualosa ilisha* has been restricted up to Jamshoro, 300 km from the sea. This obstruction has deprived the species of two-third of their previous spawning area (Bhuiyan and Talbot, 1968). Ahmed (1952) has recorded Hilsa migration in the Indus River near Nawabshah where it spawns in the stretch of the River immediately below the Sukkur Barrage.

In the River Irrawady (Myanmar), Hilsa are known to ascend into upper Burma (Myanmar) to Mndalay, a distance of about 724 km from the Sea. Hilsa migrates in large shoals, as far as the Mergui Archipelago on the Burma (Myanmar) coast (Kyaw, 1953). FAO Report (1971) reveals that during winter migration takes place in opposite direction when spent fish and juveniles move to the sea which indicates that there is no winter run in the Burmese rivers. However, Day (1873a) reported that the minor breeding migration in March-April in the upper Irrawady takes place when the rivers are flooded with melting snow.

Coad (1997) reported that in Iran waters *Tenualosa ilisha wa*s found in both deep (18 m) and shallow waters on the spawning migration while young ones were found in the shallow waters on the branches of the main Rivers. Large concentration of adults was found below the dams which blocked the spawning migration. Spawning migration of the species began as early as February with a peak at the end of March and beginning of April. Fry first appeared at the end of June. There was return migration to the Persian Gulf after spawning.

Al-Hassan (1999), reported around the Arabian Gulf, *Tenualosa ilisha* is known as "Sbour," and it is found along the Iranian side of the Gulf and in the Shatt Al-Arab River. In Iraq waters, the various physical and biological data reveal that movements of the Sbours are observed all round the year. Gonad maturation data suggest that Sbour spawn in the upper reaches of Shatt Al-Arab (probably in the marsh area) during May-August and then migrate to the sea during September-November when they are landed in Kuwait. He further reported, Sbour ascend the Shatt Al-Arab River and migrate upstream to spawn in the marsh area just north of Basrah city. Usually in the first days of March, Sbour ascend Shatt Al-Arab River to about 150-200 km north of the city of Amara on the Tigris River. Some investigators have observed Sbour migrate further upstream. At the beginning of the migration, numbers of males are more than the females, but as the breeding season approaches, females outnumbers the males. The study indicated that males and females migrate upstream in separate groups. Bhaumik *et al.* (2011b) also experienced similar observations in Hooghly- Bhagirathi

River system. In 1955, Sbour were seen in the river Tigris at Baghdad. At present, the upstream limit of its distribution appears to be the Al-Hammar marsh, 180 km north of Basrah city and 45 km south of Nasiria city. Al-Dham (1977) reported that *Tenulosa ilisha* reaches up to Qalaat Salah on Tigris River and to Al-Fahod on Euphrates River about 150-180 km North of Basrah. These fishes enter the estuaries and Rivers for spawning in different dates and duration in different regions. In the Shatt Al-Arab it was found from March to September (Hussein *et al*., 1991; Jabir, 1995). Hussain (1997) reported that *Tenulosa ilisha* is known to ascend at the Shatt Al-Arab River at the tip of the Arabian Gulf (Persian Gulf). The start their spawning migration in March and continue until July. Ascending trend of Hilsa run towards migration into the Rivers/estuaries across the Indo-Pacific region has been depicted in Table 2.

Conclusion

During spawning Hilsa migrates from marine environment to fresh water Rivers and after spawning return to the sea. Earlier this species was available and concentrated in all the major Rivers throughout the year. But for the last few decades the fishery has depleted in the Riverine environment of many countries due to rapid siltation and other degraded ecological conditions including wanton destruction of Jatka (Juveniles). This changing trend has been generating serious concern over the future of the Hilsa fishery. It is, therefore, necessary to formulate and implement a good management plan especially conservation strategies for sustenance of this highly prized fishery across the world.

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