Journal of Fisheries
Volume 6 Issue 1 Pages 563–568 April 2018
Peer Reviewed | Open Access | Online First

eISSN 2311-3111
pISSN 2311-729X

Original Article
DOI: 10.17017/jfish.v6i1.2018.254

# Impacts of water regulation on *Tenualosa ilisha* in the Narmada Estuary, Gujarat, India

**Dibakar Bhakta[1] • Wakamban Anand Meetei[1] • Gopinathan Vaisakh[1] • Sanjoy Kumar Das[2] • Ranjan Kumar Manna[3]**

[1] *Regional Research Centre, ICAR-CIFRI, Vadodara 390 022, Gujarat, India.*
[2] *Regional Research Centre, ICAR-CIFRI, Kolkata 700 064, West Bengal, India.*
[3] *ICAR-CIFRI, Barrackpore 700 120, Kolkata, West Bengal, India.*

**Correspondence**
Mr Dibakar Bhakta; Regional Research Centre, ICAR-CIFRI, Vadodara 390 022, Gujarat, India.
dibakarbhakta@gmail.com

**Manuscript history**
Received 29 March 2017 | Revised 29 January 2018 | Accepted 2 February 2018 | Published online 5 February 2018

**Citation**
Bhakta D, Meetei WA, Vaisakh G, Das SK and Manna RK (2018) Impacts of water regulation on *Tenualosa ilisha* in the Narmada Estuary, Gujarat, India. Journal of Fisheries 6(1): 563–568. DOI: 10.17017/jfish.v6i1.2018.254

**Abstract**

Hilsa, *Tenualosa ilisha* is a highly prestigious fish for esteemed delicious taste, high market demand and price. It forms an important fishery of funnel-shaped 72 km long Narmada Estuary. Rapid decline in hilsa catch has been recorded in the Narmada Estuary over last few decades. Hilsa catch was recorded 5180 ton in 2006–07 that reduced to only 419 ton in 2014–15. Pre-impoundment of dam showed that *T. ilisha* contributed to the tune of 977.1 to 3727 ton from 1974–75 to 1982–83 and the highest catch of hilsa was 15319 ton during 1993–94. Sardar Sarovar Dam started functional in the year 1994 which has impacted natural water flow of the river and resulted in a reduction of freshwater availability in the estuary; the development of sand bars at the mouth of the estuary also reduced the tidal ingress into the system; low depth, loss of breeding, nursery and feeding grounds, over fishing may be the most important factors affecting hilsa fishery in Narmada estuary. Catching of juvenile hilsa during winter by 'Golava' net (small meshed bag net) also led to a rapid decline in hilsa catch. To maintain the sustainable yield of hilsa, selective fishing and control of juvenile catch are the prerequisites along with maintaining regular flow from the dam.

**Keywords:** Sardar Sarovar Dam; *Tenualosa ilisha*; fishing season; Narmada estuary

## 1 | INTRODUCTION

The Narmada River is one of the largest rivers in India which originates from Amarkantak under Shahdol District, Madhya Pradesh and culminates into the Arabian Sea through Gulf of Cambay in Gujarat covering distances of 1312 km. Out of 30 major dams planned on river Narmada, Sardar Sarovar Dam is the largest, located in Navagam (21°49′49″N 73°44′50″E) of Gujarat. The construction of this dam started in April 1987 for the purpose of irrigation and generation of hydro electric supply.

Hilsa (*Tenuaslosa ilisha*) is a very popular fish for esteemed delicious taste and preferred by a wide range of consumers (e.g. Galib *et al.* 2013). It inhabits a wide range of habitats and common in coastal shelf, estuaries and freshwater rivers of the Indo-Pacific region extends from Iran and Iraq in the Persian Gulf to the west coast of India in the Arabian Sea, and the Bay of Bengal in marine distribution. This species has also been recorded from the coastal waters of Sri Lanka (Preston 2004). Hilsa is capable of withstanding a wide range of salinity and travel great distances upstream as far as 1287 km (Amin *et al.*

2004) which feeds and grows mainly in the sea, but migrates to freshwater for spawning (Haroon 1998). The hilsa is an anadromous fish which enters into the freshwater stretch of rivers from inshore areas of sea for breeding (De and Saigal 1989). According to Nasir (2014), this species migrates from the Bay of Bengal to the inland freshwater rivers of Myanmar, Bangladesh and east coast of India like Hooghly-Bhagirathi estuary to spawn. Pillay (1958) observed two distinct spawning seasons in the River Hooghly, one starting in the monsoon season and extending up to November, and the other one during winter from January to February.

Migration is a natural phenomenon for fishes for spawning and obstruction in spawning routes can affect the recruitment process (Lucas and Baras 2001). Construction of dams and other water regulatory structures have a major impact on fish migration and their population (Galib *et al.* 2016, 2018). According to World Commission on Dams Report 2000, substantial losses to downstream fishery production have occurred as a result of dam construction around the world. Construction of dam has both positive and negative impacts (Sugunan 1995). Dam and consequent impoundment bring a sudden transformation of a lotic environment to a lentic one. A number of organisms perish, some migrate to the more hospitable environment, and the more hardy ones adapt themselves to the changed habitat (Sugunan 2000). Wilson (1988) mentioned that dam formation limited the migration of lotic fish fauna to the upstream of the river stretches only. The negative impacts on limnology and fishery in the Beas River due to Beas project are well-documented (Sehgal *et al.* 1986). Construction of Mettur Dam in the Cauvery River collapsed the hilsa and *Puntius* fishery (Sugunan 1995). Tehri Dam in Bhagirathi River; Sardar Sarovar, Narmada Sagar, Omkareshwar, Maheshwar, Tawa, Bargi dams etc. in Narmada River has already impacted mahseer migration (Nath and Shrivastava 1999). Farkaka Barrage at the river Ganga highly affected the migration of carps and hilsa (Sinha *et al.* 1996). The declining trend of hilsa fishery in the inland waters, particularly from the river Padma in Bangladesh has also been reported (Haldar and Amin 2005). Both habitats and fish species can badly be affected by water regulatory structures (e.g. Mohsin *et al.* 2009; Samad *et al.* 2010; Galib 2015).

Various studies have described declining fish biodiversity in the Narmada River (e.g. Rao *et al.* 1991; Tuli and Pande 1992; Singh 1993; Arya *et al.* 2001). The breeding grounds of some species like *Ompok bimaculatus*, *Labeo fimbriatus*, *Labeo calbasu*, *Puntius* spp., mahseer and major carps of Narmada Estuary have disappeared due to dam construction (Arya *et al.* 2001). However, limited works have been carried out on fish and fisheries of estuarine region of the Narmada River, primarily conducted in the middle and upper stretch of the river. The present study was carried out aimed at describing the status of hilsa fishery and associated issues in relation to the construction of Sardar Sarovar Dam.

## 2 | METHODOLOGY

### 2.1 | Study area

Narmada estuarine region is located at geographical coordinates of 21°40′05.19″N and 72°34′26.90″E. Narmada Estuary is primarily a freshwater estuary under the tidal effect which mainly influences the salinity regimes. The funnel-shaped 72 km long estuarine zone occupies an area of 6346 km$^2$. The entire estuarine system is estimated to be about 14250 ha. Four sampling stations were selected for the present investigation (2014–15): Bharuch, Bhadbhut, Mehgam and Ambetha (10–20 km distance between two landing sites) covering 72 km with the true estuarine area (Figure 1).


**FIGURE 1** Study areas in Narmada Estuary

### 2.2 | Sampling and identification of the species

Monthly sampling was carried out to observe the catches of hilsa at four local landing sites (Bharuch, Bhadbhut, Mehgam and Ambetha) of Narmada Estuary. To study physicochemical characters of water surface water was collected from four sampling sites on monthly basis during morning hours for a period of one year (2014–2015). The water quality parameters such as temperatures, pH, salinity, conductivity, dissolved oxygen (DO) and transparency were estimated following standard methods (APHA 2005).

### 2.3 | Statistical analysis

Mean values of water quality parameters with their respective standard deviations (± SD) were calculated using standard statistical methods in Microsoft Excel.

## 3 | RESULTS AND DISCUSSIONS

### 3.1 | Water quality parameters

The physicochemical parameters of water were found to be moderately productive for fish growth (Table 1). The daily mean water temperature was ranged from 28.22 ± 4.37 to 30.40 ± 1.34 °C, pH value was found within the range of 7.9 ± 0.24 to 8.32 ± 0.26, DO was moderately in the higher side and found within ranged from 6.14 ± 0.28 to 7.09 ± 0.56 mg $L^{-1}$. Transparency level was quite low and varied from 3.75 ± 3.33 to 20.86 ± 16.99 cm, the salinity of the estuary varied between 0.40 ± 0.15 and 23.64 ± 8.62 ppt and total alkalinity ranged from 110.5 ± 10.30 to 124.0 ± 8.12 mg $L^{-1}$.

**TABLE 1** Physicochemical parameters of water (Mean ± SD [range]) in Narmada Estuary

| ***Parameters*** | ***Sampling station*** | | | |
|---|---|---|---|---|
| | ***Bharuch*** | ***Bhadbhut*** | ***Mehgam*** | ***Ambetha*** |
| Water temperature (°C) | 30.01 ± 3.32 (24–32.5) | 28.22 ± 4.37 (23.6–31) | 28.64 ± 2.82 (23.5–30.5) | 30.4 ± 1.34 (26 – 32) |
| pH | 8.32 ± 0.26 (7.83–8.58) | 8.05 ± 0.23 (7.79–8.44) | 8.07 ± 0.22 (7.7–8.28) | 7.9 ± 0.24 (7.6–8.28) |
| DO (mg $L^{-1}$) | 7.09 ± 0.56 (6.4–8) | 7.05 ± 0.48 (6.38-7.61) | 6.69 ± 0.68 (5.84–7.5) | 6.14 ± 0.28 (5.68–6.4) |
| Transparency (cm) | 20.86 ± 16.99 (5–60) | 17.5 ± 3.12 (5–35) | 10.17 ± 8.56 (3–30) | 3.75 ± 3.33 (1.5–15) |
| Salinity (ppt) | 0.4 ± 0.15 (0.13–0.57) | 3.67 ± 3.29 (0.14–9.25) | 8.52 ± 6.66 (0.31–17.6) | 23.64 ± 8.62 (11–32.5) |
| Total alkalinity (mg $L^{-1}$) | 110.5 ± 10.3 (98–122) | 119.14 ± 9.12 (107–132) | 124 ± 8.12 (115–136) | 123.88 ± 22.77 (86.4–144) |

Nath (2001) studied water and soil characteristics of Narmada Estuary before commissioning of Sardar Sarovar Dam (1989–1991) and he reported different water quality parameters as follows water temperature (17.5–31 °C), pH (7.4–8.7), DO (5.6–10.8 mg $L^{-1}$), transparency (3–140 cm), salinity (44.04 – 3189 mg $L^{-1}$) and alkalinity (78–190 mg $L^{-1}$). In comparison with present study with Nath (2001), water temperature and salinity were found higher with similar pH but lower DO, total alkalinity and transparency. Similar water quality is also reported in the Atrai River (Chaki *et al.* 2014).

### 3.2 | Hilsa production trend

The yearly production trend of hilsa in Narmada Estuary revealed a massive decline in hilsa catch over a decade (Figure 2). During the year 2014-2015 only 419 ton catch of hilsa was recorded. Two commercial fishing season of hilsa were observed in Narmada Estuary: first one is from June–October and another one from January–March and more than 90% of hilsa catch was observed during monsoon months (June–September). A variety of fishing methods are being used for different fish species (Galib *et al.* 2009; Parvez *et al.* 2017). The commercial catch of hilsa in the Narmada Estuary was done by mono filaments gill net of 50–130 mm mesh size (Figure 3). Catching of juvenile hilsa using bag net, cast net and stake net were also observed. As hilsa is a migratory species and always remains in shoal wide ranges of catch per unit effort (CPUE) was observed during the study period (1–150 kg $boat^{-1}$ $day^{-1}$). The group wise catch composition of fish and shellfish in the Narmada Estuary in 2014–15 showed that hilsa contributed 20% of the total catch (Figure 4). It was observed that before construction of dam carps, catfish and prawns (Anon 1983) dominated the catch whereas mullets and mudskippers dominated the catch after the construction of dam (Figure 5).

Constructing of the Sardar Sarovar Dam resulted in a reduction of freshwater flow from upstream and uncertain water flow badly affected the migration of hilsa in lower stretches of Narmada estuarine region. Data pertaining to pre-impoundment of dam showed that *T. ilisha* contributed to the tune of 977.1 and 3727 ton during the year 1974–75 and 1982–83 respectively. The highest catch of hilsa was recorded 15319 ton in 1993–94. After construction of dam steady decline in hilsa catch was observed (from 3448 ton [2004-05] to 419 ton [2014-15]). The total estuarine production also reduced drastically from 4463 ton (2000–01) to 1618 ton (2014–15) during this period.

Before construction of the dam (1958–66) carp fishery was dominated (60.4%) in the middle stretches of the river which replaced by catfishes (43.3%) after the construction of the dam. Decline in carp fishery (from 60.4% [before dam construction] to 31.29% [after dam construction]) in the Narmada in the context of the construction of the dam on the river and its tributaries has already been stated by Nath *et al.* (1999).

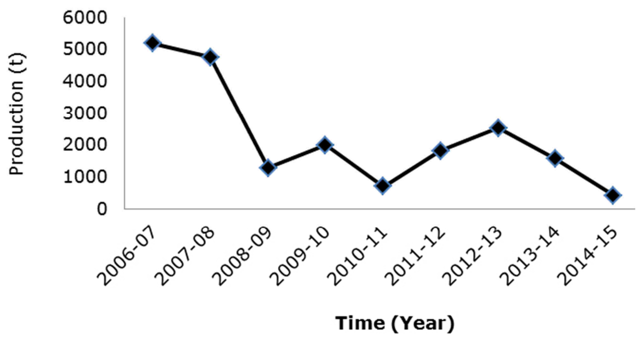


**FIGURE 2** Production trend of hilsa in Narmada Estuary (source: Department of Fishery, Bharuch district, Gujarat)

**FIGURE 3** Fishermen with mono filament gill nets for hilsa catching the Narmada Estuary

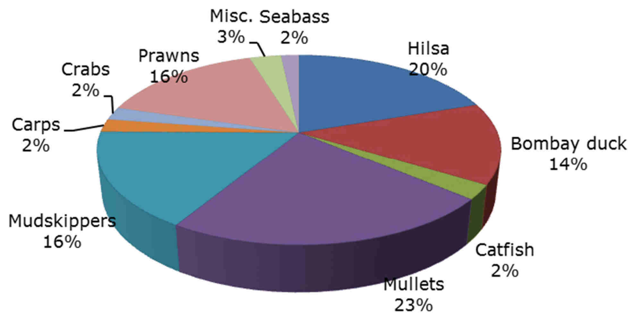


**FIGURE 4** Group wise catch composition of fish and shellfish in Narmada Estuary in 2014–15.

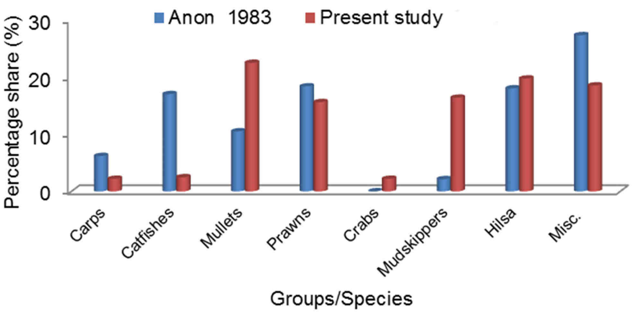


**FIGURE 5** Comparative fish catch (before vs. after) in the downstream of Sardar Sarovar Dam in Narmada Estuary

The fishery like carangids, mullets and the penaied shrimps were drastically declined from the Nile Delta basin due to the construction of dams (Pandian 1980). Agostinho *et al.* (2008) mentioned that in Paraná River of Brazil overall fish diversity declined in the areas influenced by dams. A decreasing trend in *T. ilisha* catch has been reported at Indus River at Sindh of Pakistan and a major factor affecting the fishery was a low flow of freshwater to the sea which directly affects the natural migration of the species (Panhwar and Liu 2013). Various anthropogenic activities, climate change, increased siltation and rising of the river basins disturbed, displaced or even destroyed the migratory routes as well as spawning grounds of hilsa (Miah 2015). During the last two decades in Bangladesh hilsa production from inland waters declined by about 20% whereas, marine water yield increased by about 3 times (Miah 2015).

### 3.3 | Fishing season

Hilsa is a migratory species and the time and duration of availability of hilsa in certain regions also depend upon its migration. Two distinct fishing seasons observed at Narmada estuary, *viz.*, June – October and January – March, though the bulk of the harvest comes from monsoon season (July – September).

Pillay and Rosa (1963) found a year-round fishing activity with two peak periods, monsoon and winter, in the river Ganga and Chilika Lake. Mitra and Ghosh (1979) reported winter season (November – December) has brought richer fishery than monsoon in the Hooghly-Matlah estuarine system. In the river Jamuna Ghosh (1967) described winter season (November – February) as peak hilsa fishing season. In Bangladesh Shafi *et al.* (1978) described that in the Padma River hilsa fishery exists throughout the year with two peaks in October and January.

### 3.4 | Factors affecting hilsa fishery

Several researchers (e.g. Hora and Nair 1940; Mitra and Ghosh 1979; Raja 1985) have reported that variability of the monsoon causes considerable fluctuations in the catches of hilsa. Ecological factors like rainfall, flow rates and water turbidity, sediment and nutrition load, the extent of flooding, levels of primary production and availability of planktonic food, and fishing pressures especially on juveniles determines the hilsa fishery (Dunn 1982). Ghosh (1967) observed that due to more share of juveniles in the catch the hilsa fishery in Jamuna River has been declined. Other than annual fluctuations of hilsa catch five-year cycle of hilsa fishery (majority of the hilsa obtain maturity at the end of five years and the stock enter into the river for breeding) also plays a key role (Hora and Nair 1940; Hora 1941; Biswas 1954; Dunn 1982). The migration of hilsa and consequently the abundance of the fish in the estuaries are correlated with the floods in Chilka Lake and Mahanadi River as reported by Sujansingani (1951).

## 4 | CONCLUSION

Dam significantly reduces the flow of water especially during post monsoon, winter and summer seasons. Formation of the sand bars in the mouth of the estuary also restricts migration of fishes to the estuary. Due to the absence of adequate head water discharge into the estuary, deposition of silt has occurred, which reduced the water depth of the estuary and make the estuary dry during low tides. Over fishing and destructive juvenile fishing by small meshed bag nets led to an overexploitation of the stock. The rapid growth of industrialisation in nearby areas also causes pollution through discharging industrial effluents which may be reduced the productivity of the estuarine waters.

The level of hilsa fisheries in Indian rivers has undoubtedly been adversely affected by the construction of dams. The fish that gathers below these obstructions are caught indiscriminately by the fishermen. Brood and young fish near the dam areas need to be protected by proper legislations. Implementing fishing ban over the spawning time, mesh size regulation, halt destructive juvenile fishing, judicial exploitation of fish without hampering natural recruitment, periodic dredging in silted areas, stopping of intensive seed collection, installing fish passes or ladders, adequate discharge of fresh water flow from dam during breeding and larval growing periods are some of the possible management measures to control and regenerate the hilsa fishery. Further studies on fishery and biology of the stocks in context of environmental changes in the Narmada Estuary are also recommended.

## ACKNOWLEDGEMENTS

Authors are grateful to the Director, ICAR-CIFRI, Barrackpore for his keen interest, encouragement and valuable suggestions. Thanks are also due to Shri RK Sah and Shri JK Solanki for their supports and to Fisheries officials of Department of Fisheries, Bharuch district for sharing the valuable information with us. Thanks are also due to the reviewers for their valuable comments.

## REFERENCES

Amin SMN, Rahman MA, Haldar GC, Mazid MA, Milton DA and Blaber SMJ (2004) Stock assessment and management of *Tenualosa ilisha* in Bangladesh. Asian Fisheries Science 17: 51–59.

Anon (1983) The Sardar Sarovar (Narmada) project-studies on ecology and environment. Department of Botany, The MS University of Baroda, Gujarat, India.

APHA (2005) Standard method for the examination of water and waste water, 20th Edition. American Public Health Association, Washington DC. 541 pp.

Arya SC, Rao KS and Shrivastava S (2001) Biodiversity and fishery potential of Narmada basin western zone (M. P., India) with special reference to fish conservation. Environment and Agriculture: Agriculture and Pollution in South Asia. pp. 108–112.

Biswas JC (1954) Trends in hilsa prices in Calcutta markets. Journal of the Asiatic Society of Bangladesh, Science 20(1): 29–32.

Chaki N, Jahan S, Fahad MFH, Galib SM and Mohsin ABM (2014) Environment and fish fauna of the Atrai River: global and local conservation perspective. Journal of Fisheries 2(3): 163–172. doi: 10.17017/jfish.v2i3.2014.46

De DK and Saigal BN (1989) Spawning of hilsa, *Tenualosa ilisha* (Hamilton), in the Hooghly Estuary. Journal of the Inland Fisheries Society of India 21: 46–48.

Dunn IC (1982) The hilsa fishery of Bangladesh, 1982: an investigation of its present status with an evaluation of current data. Fl: DP/BGD/81/034. Field document 2, FAO, Rome. p. 71.

Galib SM (2015) Fish fauna of the Brahmaputra River, Bangladesh: richness, threats and conservation needs. Journal of Fisheries 3(3): 285–292. doi: 10.17017/jfish.v3i3.2015.120

Galib SM, Lucas MC, Chaki N, Fahad FH and Mohsin ABM (2018) Is current floodplain management a cause for concern for fish and bird conservation in Bangladesh's largest wetland? Aquatic Conservation: Marine and Freshwater Ecosystems. doi: 10.1002/aqc.2865

Galib SM, Naser SMA, Mohsin ABM, Chaki N and Fahad MFH (2013) Choice of fishes for consumption by the rural people of Bangladesh. Trends in Fisheries Research 2(1): 20–23.

Galib SM, Rashid MA, Chaki N, Mohsin ABM and Joadder MAR (2016) Seasonal variation and community structure of fishes in the Mahananda River with special reference to conservation issues. Journal of Fisheries 4(1): 325–334. doi: 10.17017/jfish.v4i1.2016.139

Galib SM, Samad MA, Kamal MM, Haque MA and Hasan MM (2009) A study on fishing gears and methods in the Chalan Beel of north-west Bangladesh. Journal of Environmental Science & Natural Resources 2(2): 213–218.

Ghosh AN (1967) Observations on the hilsa fishery of the river Jamuna during the years 1955-62 at Allahabad. Journal of the Zoological Society of India 17(1 & 2): 135–149.

Haldar GC and Amin SMN (2005) Population dynamics of male and female hilsa, *Tenualosa ilisha* of Bangladesh. Pakistan Journal of Biological Sciences 8(2): 307–313.

Hora S (1941) Life history and wanderings of hilsa in Bengal waters. Journal of the Asiatic Society of Bangladesh, Science 6(2): 93–112.

Hora S and Nair KK (1940) Further observations on the bionomics and fishery of the Indian shad, *Hilsa ilisha* (Hamilton), in Bengal waters. Records of the Indian Museum 42(1): 35–40.

Lucas MC and Baras E (2001) Migration of freshwater fishes. Oxford, Blackwell Science, UK.

Miah MS (2015) Climatic and anthropogenic factors changing spawning pattern and production zone of hilsa fishery in the Bay of Bengal. Weather and Climate Extremes 7: 109–115.

Mitra PN and Ghosh KK (1979) Seasonal pattern in the fish landings from the Hooghly-Matlah estuarine system. Journal of the Inland Fisheries Society of India 11(1): 49–55.

Mohsin ABM, Hasan MM and Galib SM (2009) Fish diversity of community based fisheries managed oxbow lake (Bookbhara Baor) in Jessore, Bangladesh. Journal of Science Foundation 7(1): 121–125.

Naser NM (2014) Conserving trans-boundary migratory hilsa (*Tenualosa ilisha*) fish: a review of Bangladesh experience. In: Sinha RK and Benazir A (Eds) Rivers for life. Proceedings of the International Symposium on River Biodiversity: Ganges-Brahmaputra River System, Ecosystems for life, a Bangladesh India Initiative, IUCN, International Union for Conservation of Nature. pp. 215–221.

Naskar M, Chandra G and Sahu SK (2015) Hilsa fisheries on the west coast of India. In: Edwin L, Nikita G, Ramesan MP, Samanta S and Sahu SK (eds) Hilsa Fisheries and Conservation, Society of Fish technologists (India), Cochin. pp. 45–52.

Nath D (2001) Water and soil characteristics of the Narmada estuary before commissioning of Sardar Sarovar dam. Journal of the Inland Fisheries Society of India 33(2): 37–41.

Nath D and Shrivastava NP (1999) Decline in carp fishery in Narmada in the context of construction of dam on the river and its tributaries. Journal of the Inland Fisheries Society of India 31(2): 25–27.

Pandian TJ (1980) Impact of dam-building on marine life. Helgolinder Meeresunters 33: 415–421.

Panhwar SK and Liu Q (2013) Population statistics of the migratory hilsa shad, *Tenualosa ilisha*, in Sindh, Pakistan. Journal of Applied Ichthyology 29: 1091–1096.

Parvez MT, Mohsin ABM, Chaki N and Galib SM (2017) Risking lives for living: a study on underwater fishing in the Padma River, Bangladesh. Journal of Fisheries 5(3): 525–530. doi: 10.17017/jfish.v5i3.2017.308

Pathak V and Tyagi RK (2010) Riverine Ecology and fisheries vis-a-vis hydrodynamic alterations. CIFRI Bulletin No. 161. 35 pp.

Pillay SR and H Rosa Jr (1963) Synopsis of biological data on hilsa, *Hilsa ilisha* (Hamil- ton) 1882. FAO Fish Biology Synopsis 25: 16–38.

Pillay TVR (1958) Biology of the hilsa, *Hilsa ilisha* (Ham.) of the river Hooghly. Indian Journal of Fisheries 5(2): 201–257.

Preston GL (2004) Review of the status of shared/common marine living resource stocks and of stock assessment capability in the BOBLME region. Sustainable management of the Bay of Bengal Large Marine Ecosystem (BOBLME). GCP/RAS/179/WBG. 94 pp.

Raja BTA (1985) A review of the biology and fisheries of *Hilsa ilisha* in the upper Bay of Bengal. Marine fisheries resource management in the Bay of Bengal, Colombo, Sri Lanka. 56 pp.

Rao KS, Chatterjee SN and Singh AK (1991) Studies on preimpoundment fishery potential of Narmada basin (Western Region) in the context of Indira Sagar, Maheshwar, Omkareshwar and Sardar Sarovar Reservoirs. Journal of the Inland Fisheries Society of India 23(1): 34–41.

Samad MA, Asaduzzaman M, Galib SM, Kamal MM and Haque MR (2010) Availability and consumer preference of Small Indigenous Species (SIS) of the River Padma at Rajshahi, Bangladesh. International Journal of BioResearch 1(5): 27–31.

Sehgal KL (1986) Impact of construction and completion of Beas project on limnology and fisheries of river Beas. Department of Environment, Government of India and Central Inland Fisheries Research Institute Barrackpore, West Bengal.

Shafi M, Quddus MMA and Islam N (1978) Maturation and spawning of *Hilsa iisha* (Hamilton-Buchanan) of the river Meghna. Dacca University Studies 26(2): 63–71.

Shrivastava NP, Jha BC, Nath D and Karmakar HC (2009) Krishna Estuary - ecology and fisheries, CIFRI Bulletin No. 158. 47 pp.

Singh SN (1993) Studies on fish conservation in Narmada Sagar, Sardar Sarovar and its downstream. Central Inland Capture Fisheries Research Institute (Indian Council of Agriculture Research) Barrackpore 743 101, West Bengal, India. A Desk review submitted to Narmada control Authority Indore M.P., India. p. 83.

Sinha M, Mukhopadhyay MK, Mita PM, Bagghi MM and Karamkar HC (1996) Impact of Farakka Barrage on the hydrology and fishery of Hooghly Estuary. Estuaries 19(3): 710–722.

Sugunan VV (1995) Reservoir fisheries in India. FAO Fisheries Technical Paper No. 345. Food and Agriculture Organization of the United Nations Rome. 423 pp.

Sugunan VV (2000) Ecology and fishery management of reservoirs in India. Hydrobiologia 430: 121–147.

Sujansingani KH (1957) Growth of the Indian shad, Hilsa ilisha (Hamilton) in the tidal stretch of the Hooghly. Indian Journal of Fisheries 4(2): 315–335.

Tuli RP and Pande (1992) Fish and fishery resource of Indira Sagar reservoir. (Report submitted to Narmada Control Authority, Indore, M.P., India. 120 pp.

Wilson EO (1988) The current state of biological diversity. In Wilson EO (ed) Biodiversity. National Academy Press, Washington DC, USA.

**CONTRIBUTION OF THE AUTHORS**

**DB** primary data collection and MS writing; **WAM** & **GV** data collection and analysis; **SKD** & **RKM** MS editing and formatting.

***Dibakar Bhakta*** https://orcid.org/0000-0002-3871-3028