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Hilsa fisheries in India: a socio-economic analysis of fishers in deltaic Ganga region of river Hooghly

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Hilsa (*Tenualosa ilisha*) is a premium table fish in the eastern and some parts of the north-eastern region of India, especially for the Bengali community, contributing uniquely to the societal and economic significance of artisanal fisheries of the country. The major distribution of the fish species in India lies in the Bhagirathi–Hooghly component of the Ganga River system. The aim of the study was to examine if traditional Hilsa fisheries in India are sustainable as the livelihood of artisanal fishers in light of the socio-economic conditions of Hilsa fishers in West Bengal. Structured socio-economic surveys were conducted with 402 fishermen from the upper stretch of river Hooghly to its lower stretch (300 km) in West Bengal during 2020–2021. The average monthly income of the Hilsa fishers in the lower stretch of river Hooghly (Godakhali) (₹25,000–30,000/USD 301–361) was higher than that in the upper stretch at Farakka (₹10,000–15,000/USD 120–180). However, fish species other than Hilsa are generating significantly higher returns for 56% of fishers in the Hooghly district; 40% of Hilsa fishers in South 24 Parganas and Murshidabad (Farakka) districts are engaged in non-fishery activities for livelihood. There are significant differences between Hilsa fishers with other fisheries as secondary occupations and those with non-fishery activities as secondary occupations in terms of socio-economic characteristics. These imply that Hilsa fisheries are profitable as a continued traditional livelihood, but it alone is not sufficient enough to support the livelihood of the artisanal fishers. This indicates the threatened economic sustainability of the Hilsa fisheries sector at present. Considering the high market demand for Hilsa in the eastern and north-eastern regions of India and the market complexities, more significant investments need to be channeled into the Hilsa fisheries of the northern Bay of Bengal region. Such investments encompass a wholesome approach, including more governmental initiatives for conservation and management.

KEYWORDS

socio-economics, Hilsa, fishermen, Hooghly, livelihood

1 Introduction

Hilsa (*Tenualosa ilisha*), also known as Hilsa shad (family Clupeidae), is a premium table fish of India (Dutta et al., 2021). It contributes to the cultural, societal, and economic significance of West Bengal in the eastern region of India and Assam and Tripura in the north-eastern region (Hossain et al., 2020). Salt-fermented Hilsa, locally known as *lonailish,* is a relished delicacy in the north-eastern region (Majumdar et al., 2016). Hilsa is a rich source of omega-3 PUFAs, EPA, DHA, and high-quality proteins (Sahoo et al., 2018). Apart from India, Hilsa is biologically, nutritionally, economically, socially, and culturally significant in Bangladesh, Myanmar, and the Persian Gulf (Rahman et al., 2020; Ahmed et al., 2021). Hilsa is found in rivers, estuaries, and coastal waters. The deltaic habitats of river Ganga spanning the northern Bay of Bengal is a rich source of Hilsa fishery, the life cycle of Hilsa being partially marine (Lauria et al., 2018) and anadromous in nature. In fact, the highest catch of Hilsa in India comes from the deltaic Ganga region in the coastal Bay of Bengal (Suresh et al., 2017). The primary distribution of this fish species in India lies in the Bhagirathi–Hooghly component of the Ganga River system (Bhaumik, 2017; Chacraverti, 2021).

Hilsa fisheries provide a high social impact in the Ganga–Brahmaputra–Meghna basin of the northern part of the Bay of Bengal because of its high abundance, where 250 million people, directly and indirectly, depend on this species. In Bangladesh, the non-consumptive value of Hilsa has been reported to range from USD 167.5 million to USD 355.7 million *per annum*, where poor people place the highest value on Hilsa fishery restoration (Mohammed et al., 2016). It is the source of livelihood for 0.46 million fishers of West Bengal in India. The consumption of Hilsa is culturally significant for the Bengali community in weddings, festivities, and religious ceremonies. There are also indigenous knowledge bases related to Hilsa that if the winds blow from the east, Hilsa will be available in large quantities (Sharma et al., 2019).

The major producers of Hilsa in the world are Bangladesh (76%), Myanmar (15%), and India (4%), contributing 95% of the global Hilsa catches (Hossain et al., 2020). The remaining 5% is shared by Iraq, Iran, Kuwait, Thailand, Myanmar, and Pakistan. If the recently available data for capturing fisheries from FAO in 2021 are taken into account, it is further estimated that the share of Bangladesh to global Hilsa production has increased to 97.01% and that of India has shrunk to 2.41% (FAO, 2023). The global average production of Hilsa was about 5.83 lakh tonnes in 2021, with Bangladesh having the highest production of 5.65 lakh tonnes (FAO, 2023). The annual production of Hilsa in India in 2021 was 0.14 lakh tonnes (FAO, 2023; Supplementary material). It was estimated that Hilsa contributes 14% to the fish catch of river Hooghly and 23% to that of the Narmada estuarine system (Suresh et al., 2017). The northern Bay of Bengal and its associated river systems contribute to 90% of Hilsa catch in the country (CMFRI, 2016). Hilsa accounts for 12.5% of the fish catch (Hossain et al., 2019) in West Bengal in India. A significant chunk of the Hilsa population is also found along the Narmada and Tapti estuaries. Hilsa was also reported as available in Mahanadi estuary (Jhingran and Natarajan, 1969; Suresh et al., 2017), river Brahmaputra (Vass and Moza, 2011; Suresh et al., 2017; Yadav et al., 2022a,b), river Narmada (Suresh et al., 2017; Bhakta et al., 2018), river Tapti (Suresh et al., 2017), Vallabh Sagar (Ukai) reservoir (Suresh et al., 2017), river Godavari (Raj, 1917; Chacko and Krishnamurthy, 1948; Chacko and Ganapati, 1949; Chacko and Krishnamurthy, 1950; Chacko, 1954; Suresh et al., 2017), Chilika lagoon (Suresh et al., 2017), river Cauvery (Jones, 1959; Swayamprakash, 2014), and river Krishna (Jones, 1959). Although Hilsa was a lucrative fishery in all such riverine resources, the construction of dams and barrages resulted in the decline of Hilsa catch in most of the rivers (Supplementary material).

Hilsa fisheries are traditionally open-access in nature. The fisher communities attribute high value to the fish because of its excellent taste and high nutritional value. Hilsa production from inland waters has been reported to be stable during the last two decades, but an increase in marine yields has been observed in the Bay of Bengal regions (Sajina et al., 2020). A decline in the catch of Hilsa has been reported in the Hooghly–Bhagirathi River system for the last two decades (Khatua et al., 2020). The Hilsa fishers of West Bengal undertake Hilsa fishing as their secondary occupation. The production in West Bengal declined from 80,000 t to 20,000 t over 10 years since 2001 (Sahoo et al., 2018). Commercial, environmental deterioration and interest-group threats from anthropogenic impacts such as siltation in the estuary mouth of the Hooghly–Bhagirathi River system obstructing Hilsa migration into the estuarine system, impact of barrages and dams causing the decline of Hilsa in the upper reaches, juvenile fishing, exploitation of brood fish, lack of compliance with mesh size regulation, ineffective fish passes, loss of habitat with increased water abstraction for irrigation and industrialization, pollution, and climate change have resulted in the decline of Hilsa production in India (De et al., 1994, 2001; Bhaumik, 2017; Sahoo et al., 2018). The total landing of Hilsa at Farakka declined gradually from 31.8 to 34.4 tonnes during 1994–1997 to as low as 6.3–6.8 tonnes during 1994–1995 to 2000–2002 (Yadav, 2022).

Hilsa fisheries of West Bengal in India are under the jurisdiction of the State Government of West Bengal (Bandara and Wijewardene, 2023). The management measures that have been followed by the State Government are mesh size regulation in the use of gill nets in the way that only 90–110 mm gill net should be used and that monofilament gill nets below 90 mm mesh size and other nets with mesh size below 40 mm are banned; Hilsa fishing ban period for 10 days in the month of September or October (revolves around 14 September and 24 October depending on lunar cycles) and a general fishing ban on all kinds of fishes in the state from 15 April to 15 June; and mass awareness creation for Hilsa conservation from 2010 onwards. Harvesting, transporting, marketing, and selling Hilsa with less than the body size of 23 cm (through bag net, scoop net, lift net, and small meshed gill nets), especially from February to April every year, is illegal in West Bengal. Fishing of Hilsa is prohibited within 5 sq. km of the Farakka barrage around the year to facilitate brooders spawning in the area. The market value of Hilsa is increasing rapidly due to low availability because of overfishing in West Bengal. The commissioning of the Farakka barrage at Murshidabad in the 1970s caused a drastic decline and consequent depletion of the Hilsa population from the upstream of river Ganga, which was once available in plenty up to Allahabad (now known as Prayagraj).

Comprehensive socio-economic studies of Hilsa fishers in India are lacking, and more socio-economic studies in Hilsa fisheries have been encouraged (Miah, 2015; Supplementary material). Therefore, considering Hilsa as a commercially and culturally important fish but with a significantly declining catch, the socio-economic condition of Hilsa fishermen in river Hooghly of the Ganga River system is deemed essential to analyze the sustainability of Hilsa fisheries. In this

background, a hypothesis was developed to examine if the Hilsa fisheries of river Hooghly in the deltaic Ganga region of India are lucrative enough to sustain the livelihood of Hilsa fishers. The objectives were to (i) analyze the sustainability of Hilsa fisheries toward the livelihood of artisanal fishers in the light of the socio-economic conditions of the fishers in river Hooghly and (ii) examine the impact of Farakka barrage on Hilsa fishers along with conservation and management of Hilsa fisheries in West Bengal. Our study was carried out through structured questionnaires by interviewing the Hilsa fishers of river Hooghly in West Bengal with respect to their socio-economic conditions during 2020–2021.

2 Materials and methods

2.1 Study area

River Ganga (2,525 km) is India's national river and the third largest river in the world. It divides itself into two parts; from Farakka, one part flows to West Bengal as river Hooghly and the other part of Ganga goes to Bangladesh as river Padma. Later, the river Hooghly merges with the Bay of Bengal in the east. Our study was conducted in many villages of the upper stretch of the Hooghly district to its lower stretch (up to almost 300 km) in West Bengal during 2020–2021. The study areas were divided into four major sampling sites in four districts, which are Farakka in Murshidabad, Hooghly, North 24 Parganas, and South 24 Parganas (Figure 1). The geographical location of the study area is 22°23′40.36 N to 24°48′53 N and 87°55′05 E to 88°8′ 5.27 E.

The landing centers in Hooghly district where surveys were undertaken were Triveni, Ranighat, Baidyabati, Baidyabati Sitaram Bagan, Baidyabati Ranighat, Baidyabati Rajbongshi Para, Srirampur Chhatra Gargari Ghat, Banerjee Lane Srirampur Chhatra, and Bichali Ghat Road. Socio-economic surveys were carried out in the landing centers of North 24 Parganas district, namely Amrika Palli, Kalitala, Garulia, Subhash Nagar Kalyanpalli, Bichali Ghat, Deshbandhu Nagar, Ghoshbagan, Sitalatala, Ichapur, Girish Ghat Road, Dakshinpara, Monirampur Daspara, Jhaugachi Chanditala, R. N. T. Path Titagarh, Titagarh Lakshmi Ghat, B. L. Ghat Road Titagarh, Ruiya Barrackpore, and Kutighat Baranagar. The landing centers of Farakka in Murshidabad district where the surveys were carried out are Hossainpur, Khuntipara, Bindugram, Jafarganj, Nayansukh, Raghunathpur, Panchananelpur, Rajnagar, Hatpara Rajmahal, Barman Colony Rajmahal, Masudan Colony Rajmahal, Dahia tola, Nayatola, Durgasthan, Kamaltola, Bartala, Launchghat, and Bijalighat. Finally, in South 24 Parganas, a socio-economic survey was carried out in

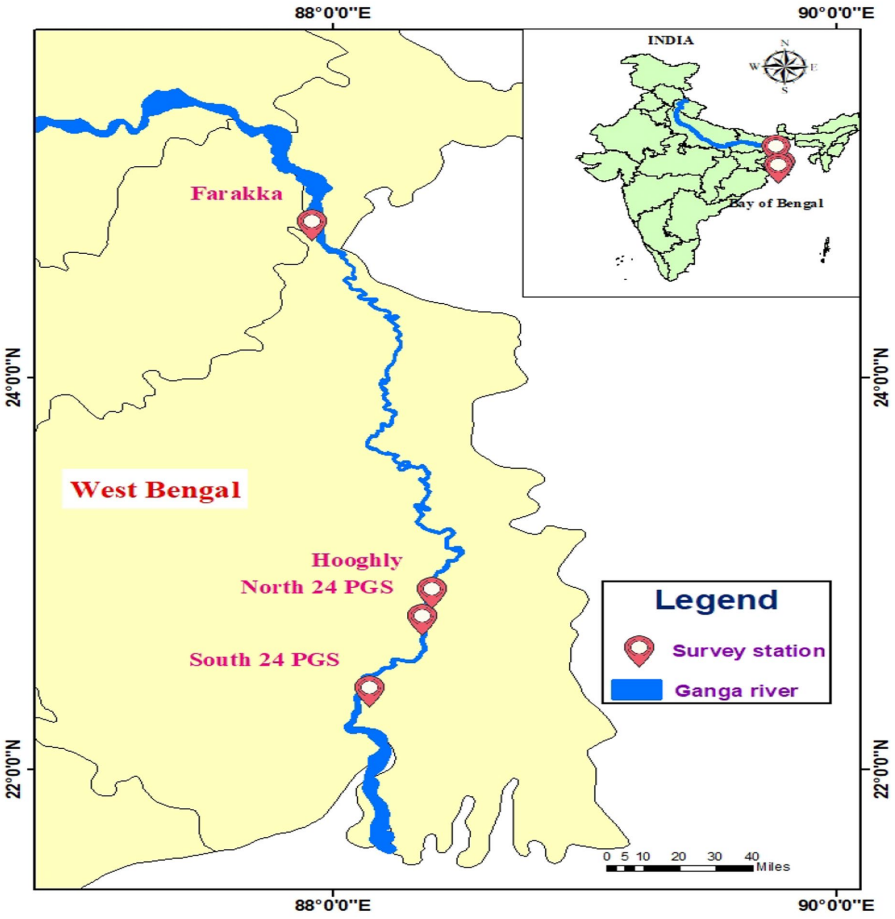

FIGURE 1
Sampling sites of socio-economic survey of Hilsa fishers.

Godakhali. A market survey of Hilsa fisheries was also conducted at the Godakhali fish market in South 24 Parganas district to collect gender-disaggregated data from 24 to 25 February 2022.

2.2 Sampling

A total of 402 fishers were surveyed from December 2020 to November 2021 (Table 1). Stratified random sampling was carried out for the study. Sampling was done in four strata (four districts) longitudinally from the middle stretch to the lower stretch of river Hooghly, namely Murshidabad, North 24 Parganas, South 24 Parganas, and Hooghly, as per designated study sites of the National Mission for Clean Ganga Project of ICAR—CIFRI. In each district, the households of the Hilsa fishers near the important landing centers were selected randomly. The surveys were based on structured questionnaires, which were pre-tested with a few fishermen in study areas. The questionnaires included questions on fishermen's age, educational status, family size, annual income, daily catch of Hilsa fish, number of boats and nets, type of boat and net, etc. Data were analyzed through descriptive statistical analysis using percentages in MS Office 2010 developed by Microsoft Corporation and a non-parametric test (Kruskal–Wallis test) in R-Studio.

In this study, two groups of Hilsa fishers, *viz.* Hilsa fishers who are only dependent on Hilsa fishing for their livelihood and Hilsa fishers who have additional employment, are compared to assess if there exist any differences between them with regard to age, education, family members, number of boats, number of nets owned, and income using the Kruskal–Wallis H test.

3 Results and discussion

3.1 Socio-economic conditions of Hilsa fishers of river Hooghly

3.1.1 Community of Hilsa fishers

The knowledge about communities of Hilsa fishers helps us trace their connection to Hilsa fisheries, whether it was their ancestral occupation or not. The importance of Hilsa fisheries as an integral form of artisanal fishing is well established (Mome and Arnason, 2008; Islam et al., 2016a,b; Porras et al., 2017; Rahman et al., 2020). Hilsa fishers in all the districts except Murshidabad district (Farakka) entirely belonged to the Scheduled Caste (SC) community and were Hindus in religion. The Hilsa fishers in Farakka were from mixed communities such as SC (88%), General (7%), and OBC (5%, who were Muslim in religion). They are traditional fishers who have been engaged in artisanal Hilsa fisheries to earn their livelihood for generations. Similar finding was obtained about Hilsa fisheries in West Bengal, where 93% of the fishers belonged to SC communities (Chacraverti, 2021). However, the traditional fishers are threatened with losing their artisanal heritage of Hilsa fishing with declining catch, where they are being left with alternatives to opt for non-fishery related wage-earning activities to sustain their livelihood.

TABLE 1 Sample size in different sampling stations.

Landing center	Fishers fully dependent on fishing	Fishers partially dependent on fishing
Farakka (Murshidabad)	84	138
North 24 parganas	50	Nil
South 24 parganas (Godakhali)	99	17
Hooghly	14	Nil

3.1.2 Age

In South 24 Parganas district, the dominant age group is 41–60 years. This implies that the fishers of South 24 Parganas, especially in Godakhali, depend considerably on Hilsa fisheries for their livelihood and for supporting their family. The fishers of Hooghly and Murshidabad (Farakka) districts majorly fall in the age group of 21–40 years, where the presence of young fishers is evident. This shows that the young family members of fishers' families still find Hilsa fisheries as a lucrative option for establishing their livelihood. A similar finding was seen in the Meghna River estuary Hilsa fishers of Bangladesh, with 41% of the fishers in the age group of 26–30 years and another 38% of the fishers within the age 40–60 years (Ahmed et al., 2021). Another study reported that the average age of Hilsa fishers in Meghna and Padma Hilsa sanctuaries was 35 years (Mahmud, 2020).

3.1.3 Education

The fishers in the lower stretch of the river Hooghly were comparatively more educated than those in the upper stretch. Most of the Hilsa fishers of Farakka (82%) in the upper stretch of the river Hooghly were illiterate, but in the lower stretch, 65% were educated with at least a primary level of educational attainment. In Murshidabad, only 19% of the fishers fishing in Farakka barrage adjacent area went to school. However, the presence of graduate and post-graduate individuals engaged in fishing was also noticed in Murshidabad and South 24 Parganas districts. Other studies also found that the major educational attainment of Hilsa fishers in West Bengal was only primary school education (Sinha and Katiha, 2001; Chacraverti, 2021). It was observed that more Hilsa fishers with secondary occupations in non-fishery activities were educated up to the secondary level of school education in contrast to Hilsa fishers fishing other fishes for their secondary occupation, who were only primary literate. In Bangladesh, the literacy level of Hilsa fishers was also reported to be 40% (Sinha and Katiha, 2001).

3.1.4 Family size

The highest average family size was observed in Murshidabad district with five family members in each family and the lowest average with three family members was observed in Godakhali in South 24 Parganas district. Another study in Murshidabad district also found that the average family size of Hilsa fishers is more than 4 (Chacraverti, 2021). The average family size in both Hooghly and North 24 Parganas district was 4. A study in Bangladesh stated that the average family size of Hilsa fishers was 6.2 (Sinha and Katiha, 2001).

3.1.5 Occupation

Owing to the dwindling nature of Hilsa fisheries, the fishers in all the study areas depended on avenues other than Hilsa fishing to support their incomes (Supplementary material). Hooghly and North 24 Parganas districts' fishers depended on fisheries for their livelihood,

even during the lean season of Hilsa fishing. They harvested other fish species to supplement their earning from fisheries. However, the fishers of South 24 Parganas and Farakka were more diversified in nature because they depended on non-fishery activities such as mainly working as daily wage laborers and bidi (local cigarette), making for their additional employment. The other minor forms of employment observed were rickshaw drivers, shopkeepers, fruit sellers, tea sellers, nut sellers, and vegetable retailers. However, most of the fishermen had no identity cards, and because of this, they were not getting proper financial support from the government. A study in the Meghna River Estuary of Chandpur, Bangladesh, analyzed that there were significant differences among different groups of Hilsa fishers with varying degrees of dependence on Hilsa fisheries for their livelihood with respect to their age, annual income from fishing, and annual fishing activity days (Ahmed et al., 2021).

3.1.6 Dependence on fisheries

In river Hooghly, no Hilsa fishers depend on only Hilsa fisheries for their livelihood. As Hilsa is mainly available in the monsoon (June to August) and winter (October to December) seasons, Hilsa fishing provides only seasonal employment to the fishers. At other times, they are fishing other fish species and other non-fishery daily wage-earning activities. In the lower stretch, especially in Godakhali at South 24 Parganas district, maximum Hilsa fishers worked as part-time laborers on off-seasons; 17.66% of fishers had fishing other species as their secondary occupation. The highest dependence of Hilsa on other fishes to supplement income from Hilsa fisheries was observed in the Hooghly district (56% of Hilsa fishers). The Hilsa fishers (39.44%) of North 24 Parganas district also had considerable dependence on other fisheries to support their secondary occupation. The significant share of other fishery was contributed by prawns (23.88%), Rohu (10.45%), Giant river catfish (*Aristichthys aor*, 10.45%), and Catla (9.7%) (Figure 2). The other fishes are minor carps such as orangefin labeo (*Labeo calbasu*) and jaya (*Aspidoparia jaya*); catfishes such as snakehead murrel (*Channa striata*), long whiskers catfish (*Mystus gulio*), Giant snakehead (*Channa micropeltes*), rita (*Rita rita*), Climbing perch (*Anabus testudineus*), stinging catfish (*Heteropneustes fossilis*), Gangetic mystus (*Mystus tengra*), freshwater shark (*Wallago attu*), olive barb (*Puntius sarana*), and vacha (*Eutropiichthys vacha*); small indigenous fishes (SIF) such as scribbled goby (*Glossogobius giuris*), chitala (*Chitala chitala*), Ganges river sprat (*Corica soborna*), and bronze featherback (*Notopterus notopterus*); shads (*Gudusia chapra*); and other estuarine fish species such as Gangetic Hairfin Anchovy (*Setipinna phasa*), Asian seabass (*Lates calcarifer*), pama croaker (*Otolithoides pama*), and mango fish (*Polynemus paradesius*) (Supplementary material). A previous study observed that few purely freshwater fishes such as *Rita rita, Wallago attu, Mystus aor, Ailia coilia, Catla catla, Labeo rohita,* and *Labeo bata* and prawn (*Macrobrachium rosenbergii*) were observed for the first time in Hooghly estuary in the post-Farakka barrage period after 1975 (Bhaumik, 2019).

3.1.7 Fishing assets owned

The major types of boats used for Hilsa fisheries are non-motorized dug-out canoes and boats fitted with outboard motor engines. Fishing operations with engine boats dominated in Murshidabad district (93.7%). Hand boats (dug-out canoes) dominated South 24 Parganas and North 24 Parganas districts. Small-scale mechanization was also said to exist in the nearshore waters of the northern Bay of Bengal (CMFRI, 2016) and in the upper stretch through trawlers (Bhaumik and Sharma, 2011). Mechanized boats also operate in the marine zone of the Hooghly–Bhagirathi estuary within 30 km of the estuary mouth during monsoon, which extends up to 60 km in the winter. The majority of the fishers own one boat (Table 2). Eight to eleven fishers join a fishing trip in a boat and share the catch among them (Bhaumik and Sharma, 2011). Sometimes, a fishing trip of a single boat going out for Hilsa fishing also consisted of two to three persons (Chacraverti, 2021).

Gill nets of size 90–120 mm are generally used by the Hilsa fishers. Drag nets and cast nets are used in catching carps and fish other than Hilsa by the fishers who also harvest other fish in addition to Hilsa. At times, particularly during the monsoon season, the Hilsa fishers also use cast nets and drag nets to catch Hilsa when their sizes are big.

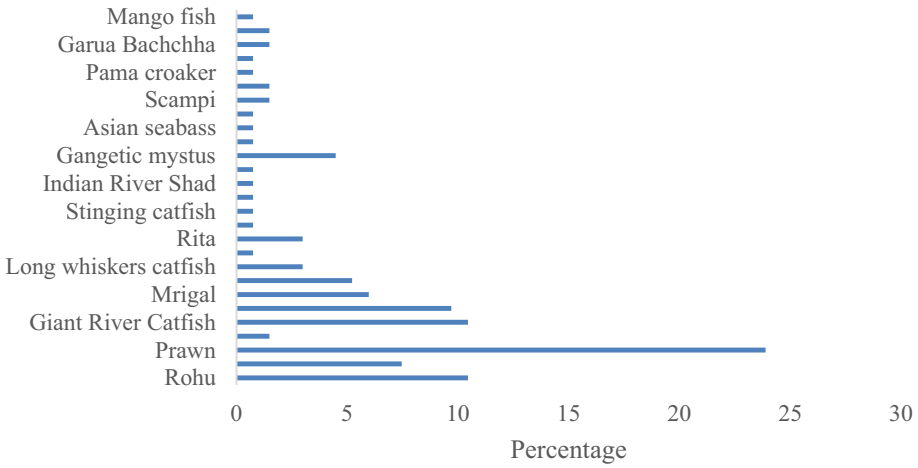

FIGURE 2
Other fishes caught by Hilsa fishers.

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TABLE 2 Hilsa fishing crafts and gears.

Major sampling site	No. of boats owned	Boat possession	No. of nets in possession	Type of Net*	
				Hilsa fishing	Other fisheries
Hooghly district	One boat = 100%	Non-motorized (100%)	No own net = 29% One net = 31% Two nets = 29% Three nets = 8% Four nets = 2%	Gill net possession = 100%	Drag Net = 45.45% Cast Net = 27.27% Mosquito Net = 18.18% Trawl = 9.09%
North 24 Parganas district	One boat = 91% Two boats = 9%	Non-motorized (100%)	No own net = 45% One net = 27% Two nets = 21% Three nets = 5% Five nets = 1%	Gill net possession = 98%	Bag Net = 78.57% Cast Net = 14.29% Set Barrier = 7.14%
Murshidabad district (Farakka)	One boat = 100%	Motorized boat (31%), non-motorized boat (26%), no own boat (42%)	No own net = 38% One net = 62%		
South 24 Parganas district	One boat = 100%	Non-motorized boat (61%), Motorized boat (17%), No own boat (22%)	No own net = 33% One net = 67%		

*Hilsa fishing is carried out by gill net only, and the other types of nets are used by fishers when they harvest fish other than Hilsa.

TABLE 3 Summary statistics of income of two categories of Hilsa fishers: (i) other fisheries as a secondary occupation and (ii) non-fisheries activities as a secondary occupation.

Parameters	Fully dependent on other fisheries for secondary occupation (Average ± SD)	Dependent on non-fisheries activities for secondary occupation (Average ± SD)
Annual income (₹1,000) from only Hilsa fisheries	90.2 ± 27.37	96.99 ± 36.65
Annual income (₹1,000) from other sources	24.30 ± 5.6	14.41 ± 6.18
Total annual income (₹1,000)	114.51 ± 28.79	111.4 ± 38.15

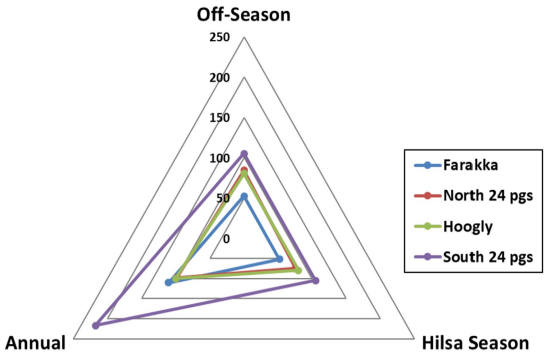

FIGURE 3
Average income (in ₹1,000) of Hilsa Fishers (percentage of fishers).

Catching Hilsa with a gill net was majorly observed at Farakka in Murshidabad. In Godakhali, in the lower stretch of the river Hooghly, male fishermen were 96.7% catching Hilsa and 3.3% were women Hilsa fishers mainly selling Hilsa in the market.

3.1.8 Income

The average monthly income of Hilsa fishers in the lower stretch (Godakhali in South 24 Parganas, North 24 Parganas district, and Hooghly district) was higher than that in the upper stretch (Farakka in Murshidabad district) (Figure 3). In Godakhali, the fisher's average monthly income is ₹25,000–30,000 (USD 301–361), whereas in the upper stretch, the income is approximately ₹10,000–15,000 (USD 120–181) per month. Some studies in the past have reported that the income of individual fishers ranged from ₹5,000–8,000 (USD 60–96) per month (Abdul et al., 2021). The average monthly income of Hilsa fishers from other fisheries was ₹2,205 (USD 27) and that from non-fishery activities as secondary occupation was ₹1,200 (USD 14) (Table 3). A study in Murshidabad district (Chacraverti, 2021) stated that the average monthly income of Hilsa fishers during peak season was ₹9,725 (USD 117) and that in South 24 Parganas was ₹18,135 (USD 218), and the income of Hilsa fishers during lean seasons ranged from ₹5,683–7,383 (USD 68–89).

There is a significant difference between the two categories of fishers with regard to annual income resulting from Hilsa fisheries and secondary occupations, as shown in Table 4. This points to the fact that more significant income from fisheries is essential for the sustainable management of the fisheries resources of the Hooghly River system. More income from fisheries would attract fishers to venture into Hilsa fishing in peak seasons and other fisheries in the lean seasons. Although Hilsa fisheries are popular as a continued traditional livelihood, it alone is not sufficient enough to support the livelihood of the Hilsa fishers. Therefore, investing in sustainable

TABLE 4 Frequency distribution of annual income of two categories of Hilsa fishers: (i) other fisheries as a secondary occupation and (ii) non-fisheries activities as a secondary occupation.

Category	<₹1 Lakh (USD 1205)	₹1–2 Lakhs (USD 1,205–2,409)	>₹2 Lakh (USD 2409)	Total	Chi-square *p*-value
Fully dependent on Other Fisheries for Secondary Occupation	51.25% (82)*	35% (56)	13.75% (22)	100% (160)	0.013 (significant at 5% significance level).
Dependent on Non-Fisheries Activities for Secondary Occupation	60.32% (149)	34% (84)	5.66% (14)	100% (247)	
Total	56.76% (231)	34.39% (140)	8.85% (36)	100% (407)	

*Figures in parentheses denote the number of Hilsa fishers.

TABLE 5 Kruskal–Wallis one-way test between two Hilsa fisher groups.

Parameters	Chi-square	*p*-value
No. of family members	10.7031	0.0011**
No. of boats owned	11.6551	<0.001**
No. of nets owned	43.0845	<0.001**
Annual income (K)	37.5544	<0.001**
Income from Hilsa season	4.4379	0.0351*
Income from secondary occupation	159.933	<0.001**

**Significant at 1% level of significance; *Significant at 5% level of significance.

fisheries management in this area is necessary to facilitate the economic viability of Hilsa fisheries and the sustenance of the traditional livelihood.

3.1.9 Socio-economic characteristic differences between Hilsa fishers fully dependent on fishing and partially dependent on fishing

The major socio-economic variables such as age, education, income, family size, fishing assets, and occupational structure were analyzed to examine if there exist any differences between Hilsa fishers with other fisheries as their secondary occupation and Hilsa fishers with non-fishery activities as their secondary occupation. The results of the Kruskal–Wallis test revealed that there were significant differences with regard to family size, number of boats owned, number of nets owned, annual income and income from secondary occupation at 1% level of significance and income from Hilsa fisheries at 5% level of significance (Table 5). The total annual income of the Hilsa fishers dependent on other fisheries for their secondary occupation was higher than that of the other group. The income earned by Hilsa fishers by harvesting other fish species for their secondary occupation was also significantly higher than that of those with non-fishery activities as their secondary occupation. This testifies to the fact that Hilsa fishers are facing serious challenges in livelihood because of poor and unsustainable catches (Bhaumik and Sharma, 2011). A study at the Meghna River estuary of Chandpur in Bangladesh also revealed that the livelihood and living conditions of Hilsa fishers were affected by low literacy levels, lack of professional skills, and low incomes (Ahmed et al., 2021). More than two-thirds of the Hilsa fishers there did not have alternative occupations during ban periods.

3.1.9.1 Women in Hilsa fisheries

Godakhali fish market is unique in how women retailers dominate the fish business in the retail fish market. Women fishers in the market have been involved in Hilsa fisheries in the form of their traditional occupation. Their significant involvement is in marketing Hilsa fishes around the landing centers, fishing gear fabrication, and pre-sale processing, such as cleaning and packing to assist their husbands. Out of 20 fish retailers involved in fish marketing in the Godakhali fish market, 80% were female retailers selling Hilsa. Among the male fish retailers, 20% were involved in Hilsa catching, transportation, and fishing gear fabrication apart from the fish business. The fishing gear used are gill nets and bag nets. Apart from Hilsa, the fish retailers also sold Gangetic hairpin anchovy (*Setipinna phasa*), Soldier croaker (*Nibea soldado*), and small prawns, as these species were dominant during the period. The main issues in Hilsa fishery that the women Hilsa fishers narrated are over-fishing, river pollution, and competition between commercial and artisanal fisheries. Even though these issues have become over-arching in the sustainability of Hilsa fisheries, the women vow to support their families in earning their livelihood, supporting the local economy, and passing on traditional knowledge through generations. Women associated with Hilsa fisheries in Bangladesh have been reported to be involved in events such as Hilsa breeding festivals and fisherwomen congress. After women's economic empowerment increased, fishers' illegal activities were reduced (Sahoo et al., 2022). Studies in Bangladesh have provided varied narratives about women's participation in Hilsa fisheries. In a socio-economic study conducted with the river Meghna Hilsa fishing community at Chandpur, it was stated that women and men are treated equally in terms of their Hilsa fishing rights, even though the extent of their participation varies. Another study in the Meghna estuary Hilsa fisheries of Chandpur stated that women were not allowed large-scale fishing due to social and security problems (Ahmed et al., 2021).

3.2 Impact of Farakka barrage on Hilsa fisheries in river Ganga

The Farakka barrage commissioned in 1971 posed a significant obstacle to Hilsa migration (Bhaumik and Manna, 2010). The Farakka barrage has had significant and complex impacts on Hilsa fisheries by altering the river's flow and salinity patterns, affecting Hilsa migration and habitat, and increasing fishing pressure, thereby contributing to the decline of Hilsa fisheries in India. Hilsa fishery collapsed in the stretches of river Ganga above the barrage, with the landings at Allahabad, Buxar, and Bhagalpur drastically dropping to negligible levels (Swarup, 1958; Vass and Moza, 2011), up to a decline of 92% (Swarup, 1958). Therefore, Hilsa now only thrives in the downstream areas of the barrage. Consequently, local fishers stopped providing access to fishing in some stretches of the Ganga after the 1970s. The fishing period also extended throughout the year except for the lean fishing season during the monsoon season. In 2001, the annual net returns of a Hilsa fisher were

₹29,869 (USD 360), with an average catch of 1431.7 kg in the Kanpur to Farakka stretch of the Ganga (Bhaumik, 2019). The sale price was ₹24 (USD 0.3) per kg. Before the construction of the Farakka barrage, the average annual landings of Hilsa varied from 114 to 6,573 tonnes, with an average of 1427.6 tonnes (Swarup, 1958).

Hilsa fishery flourished throughout the year in Ganga and its tributaries near Allahabad, with a peak in October and November (Das et al., 2017). However, from 1963 to 1972, the Hilsa catch fluctuated between 7.3 tonnes and 113.4 tonnes, with an average of 33 tonnes (Suresh et al., 2017). Again, after the commissioning of the Farakka barrage in 1975, the average annual landing was 0.96 tonnes (Suresh et al., 2017). The aftermath of such scenarios resulted in Hilsa vanishing from the upstream of Ganga above the Farakka barrage. In the Hooghly estuary, the annual Hilsa landing in the pre-Farakka period (1957–1974) was 1427.6 tonnes, which increased during the post-barrage period to 6,370 tonnes from 1975 to 1999 (Suresh et al., 2017; Bhaumik, 2019). Hydrological changes such as higher freshwater discharge due to water diversion at the Farakka barrage through the river Hooghly might have attracted more Hilsa toward the Hooghly estuary (Swarup, 1958). An important characteristic feature of Hilsa fishery emanated from post-Farakka consequences, which is the winter migratory bag net catches in the lower stretches, resulting in increased catches (Bhaumik, 2019).

It was reported that the production of Hilsa in the Hooghly–Bhagirathi stretches varied from 12,733 to 77,912 tonnes during 2000–2001 to 2010–2011 (Suresh et al., 2017). It has also been reported that there is a spurt in Hilsa production every 10 to 12 years (Suresh et al., 2017). The catch trend of Hilsa off the Hooghly estuary since 2000 indicates a serious decline in the Hooghly River system. In addition, indiscriminate exploitation of Hilsa juveniles through small mesh bags and seine nets was reported during 1991–1998 and 1998–2003. On the other hand, the post-Farakka period has seen an increase in the catch of Hilsa, which peaked in 2004–2005 at 8427 t. The building of the Farakka barrage created a barrier for Hilsa migration upstream, which is why the trend of Hilsa catch at the Hooghly estuary has been rising. The barrage has had a devastating impact on Hilsa breeding due to obstruction in its migration.

India and Bangladesh have also experienced tension due to the Farakka Barrage. Conflicts over water sharing and its effects on Hilsa fisheries have arisen due to the changing river flow, which influenced fisheries in both countries. These issues have had geopolitical and diplomatic ramifications. The socio-economic interviews of our study also revealed some interesting findings in areas upwards of the Farakka barrage. In Jharkhand, young fishers were unable to recognize the Hilsa shown to them in pictures, in contrast to the elderly fishers (above 65 to 70 years) who knew about the identifying characteristics of the fish. Under the umbrella of the National Mission for Clean Ganga (NMCG), an authority under the Ministry of Jal Shakti, Government of India, ICAR-CIFRI, has been making efforts to increase the Hilsa population in the upstream of Farakka barrage since March 2017. From March to June 2017, the Hilsa catch was estimated as 1,315 kg in downstream and 736 kg in the feeder canal. Hilsa catch in the upper stretch and navigational channel was represented by juveniles but negligible in quantity. This finding is unique and indicates the possibilities of breeding and spawning Hilsa in the vicinity of the Farakka barrage. This pointed to the fact that recruitment of Hilsa fishery is dependent on smaller age groups due to the absence of higher age group fishes in and around the Farakka barrage (Das et al., 2017).

4 Conclusion

Hilsa fishers of river Hooghly have been vulnerable to commercial threats (creation of dams and barrages and developmental activities), environmental deterioration threats (deterioration of habitat and pollution), and interest group threats (indiscriminate juvenile catching, overexploitation, non-compliance with regulatory measures, and use of small mesh sized fishing gears), resulting into declining production, uncertain income, and occupational shift. Although Hilsa fish have enormous socio-economic and cultural significance for the Bengali community, the traditional Hilsa fishers no longer depend solely on Hilsa fisheries for livelihood but look forward to other fisheries to secure higher income. The sustainability of the artisanal Hilsa fisheries needs to be looked into to support the livelihood of the fishers. The Farakka barrage commissioned in 1971 altered river Ganga's flow and salinity patterns, affecting Hilsa migration and causing a remarkable decline in Hilsa catch in the upper stretches of Ganga. This has created pressure on the fishery resource, for which recent initiatives have been taken to increase the Hilsa population upstream of the Farakka barrage. The fact that Hilsa was once available in the different river systems of the country and then suffered huge setbacks owing to the construction of dams and barrages needs to be considered in the management and policy decisions for the sustenance and development of Hilsa fisheries. From the study, the occupational shift was observed where traditional Hilsa fishers have shifted to non-fishery activities such as rickshaw driving, shopkeeping, fruit selling, tea shop, nut selling, and vegetable retailing. Since Hilsa fishing is a family business, more involvement of women would be profitable. The management and conservation rules pertaining to Hilsa fisheries policies have to be strictly implemented and monitored through mesh size regulation of gill net, Hilsa fishing ban period (for 10 days in September or October depending on lunar cycles), ban of juvenile catching of Hilsa with body size less than 23 cm, and prohibition of Hilsa fishing within 5 sq. km of the Farakka barrage round the year. Considering the high market demand for Hilsa in the eastern and north-eastern regions of India and the market complexities, more significant investments need to be channeled into the Hilsa fisheries of the northern Bay of Bengal region. Such investments encompass a wholesome approach, including more governmental initiatives for conservation and management. The study provides scope for an enhanced understanding of the factors that would drive the revival of Hilsa fisheries in river Hooghly and supplement the livelihood of fishers in the deltaic Ganga region.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, upon request.

Ethics statement

The experiment conducted in the present study has been passed through the institute's ethical committee, and the committee approved the carry out the experiment sampling of fish and its handling were performed as per the instruction laid by the ethical committee.

Author contributions

HC: Conceptualization, Data curation, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing, Formal analysis. PD: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. AK: Investigation, Writing – review & editing. SN: Investigation, Writing – review & editing. CJ: Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. AS: Conceptualization, Formal analysis, Methodology, Supervision, Writing – review & editing. BD: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1310077/full#supplementary-material

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