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Growth overfishing of hilsa shad in Hooghly-Bhagirathi river system, India: Assessment and management implications

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ABSTRACT

Juvenile fishing of the migratory hilsa shad *Tenualosa ilisha* (Hamilton, 1822), is rampant in the coastal waters of northern Bay of Bengal and associated Hooghly-Bhagirathi river system. The average annual economic loss due to this was estimated at ₹497.84 million (around US$ 7.8 million) necessitating urgent need for managing it to maximise benefits from the fishery as it forms a major fishery resource in the region. Factors leading to juvenile fishing and the possible solutions to control the resultant biological and economic loss are discussed.

Keywords: Economic deficit; Growth overfishing; Hilsa; Hooghly-Bhagirathi River; *Tenualosa ilisha*

Introduction

Overfishing persists in many of the world's fisheries and thus is the most obstinate fisheries management issue globally. World fisheries have rarely been 'sustainable' due to serial depletions induced by overfishing, long masked by improved technology, geographic expansion and exploitation of fish species lower in the food web (Pauly *et al*., 2002). Among the two forms of overfishing, growth overfishing is a substantial problem (Hsieh *et al*., 2006; Beamish *et al*., 2006; Ottersen, 2008) as it leads to depletion of young part of the stock before attaining full biological and economic potential. Diekert *et al.* (2010) asserted that growth overfishing squanders large parts of the potential rents in fisheries as the value of an individual fish grows significantly with age in most of commercial fisheries. The works on economic loss through juvenile fishing (Najmudeen and Sathiadhas, 2008; Mohamed *et al*., 2009; Kamei *et al*., 2013; Sugumar *et al*., 2015, 2016) indicated that impacts of growth overfishing are severe in tropical fisheries and the management measures to tackle this issue are difficult to implement due to the greater probabilities of incidental harvesting of non-targeted species and size groups associated with multi-gear, multi-species characteristics of the fisheries coupled with the local socio-economic and political scenarios. The annual economic loss through juvenile fishing by motorised and mechanised marine fishing fleet of entire Indian coastline was estimated at US$ 19,445 million (Najmudeen and Sathiadhas, 2008) which provides insight to severity of the issue in tropical fisheries. Not many efforts have been taken to assess the extent of growth overfishing in tropical inland waters, the management efforts for which always suffer with data-poor situations owing to its inherent diffuse and small-scale nature.

The shads all over the world (more than 30 species belonging to subfamily Alosinae under family Clupeidae dispersed across six continents) face anthropogenic pressures such as overharvesting, pollution and habitat loss in both freshwater and marine environments as most of them migrate between both environments (Limburg and Waldman, 2003). Hilsa, *Tenualosa ilisha* (Hamilton, 1822), an anadromous migratory shad, contributes to commercial catches in a number of countries bordering Bay of Bengal, Indian Ocean, Persian gulf and Arabian Sea with Bangladesh, India and Myanmar being the important hilsa fishing nations (Ahmed *et al*., 2008). It forms a rich fishery in the coastal waters of northern Bay of Bengal and associated river systems; the river Hooghly-Bhagirathi passing through West Bengal, an eastern State in India. Hilsa fishery is by far the largest single species fishery in the Hooghly-Bhagirathi river system and has long been important to the economic and socio-cultural heritage of the people of the entire Gangetic plains (Suresh *et al*., 2017). The fishery is a source of occupation and livelihood for the riparian fisher communities, characterised by open access fishing with crowding of effort in the estuarine and tidal freshwater stretches, chiefly due to lack of alternative sources of subsistence. This scenario synergised by lack of understanding, lack of appropriate policies and poor enforcement of existing management

measures, leads to overexploitation of resources, in the form of both recruitment and growth overfishing. In case of hilsa fishery, the indiscriminate exploitation of juveniles has been identified as one prominent reason where declining hilsa catch has been discussed (Amin *et al*., 2000; BOBLME, 2010; Bhaumik and Sharma, 2011, 2012; Bala *et al*., 2014). Though there are a number of reports on the juvenile fishing of hilsa in Indian waters (BOBLME, 2010; Bhaumik and Sharma, 2012; Bhaumik, 2015; Prajith *et al*., 2017), no effort has so far been taken to estimate the economic loss.

Comparison of the recent catch statistics of hilsa (Suresh *et al*., 2017) with the earlier reports (Hora and Nair, 1940; Pillay, 1957; De, 1986, 1998, 2001; Mitra *et al*., 1987, 2001) indicated that the once abundant commercial fishery of the fish in Hooghly-Bhagirathi river system is in a waning stage. The existing situation of the hilsa fishery suggests that proper assessment is necessary for finding a way to make it sustainable while maximising economic benefits. In case of fishes like hilsa which grow significantly faster in a short time span and fetch higher price, the economic and biological damage from harvesting fish before they have grown to marketable size could still be very high. Efforts were thus made to estimate level of overfishing and mean annual economic deficit incurred by catching juveniles along the Hooghly-Bhagirathi river system. Factors leading to juvenile fishing and the possible and practicable solutions to curb the biological and economic loss due to the same are then discussed.

Materials and methods

Study area

The river Ganga, after flowing over 2000 km from its origin in Himalayas, bifurcates into eastern and western courses (at Farakka), the western course being the Hooghly-Bhagirathi river system, which encompasses the Hooghly Estuary, which is the first deltaic off-shoot of the river, through which it drains to the Bay of Bengal. The Hooghly-Bhagirathi river channel forms an important migratory path for the anadromous hilsa from Bay of Bengal waters to upstream of Ganga. The river system consists of upper Bhagirathi stretch, middle tidal freshwater stretch of Hooghly and lower Hooghly Estuary. The river stretch from Farakka (upper most site of Bhagirathi) to Digha and Frazerganj (two lower most points where river drains to Bay of Bengal) were studied with sixteen sampling stations spread over a distance of 550 km (Fig. 1).

Quantification of juvenile catch

A catch monitoring programme on hilsa was being carried out in the Hooghly-Bhagirathi river system and

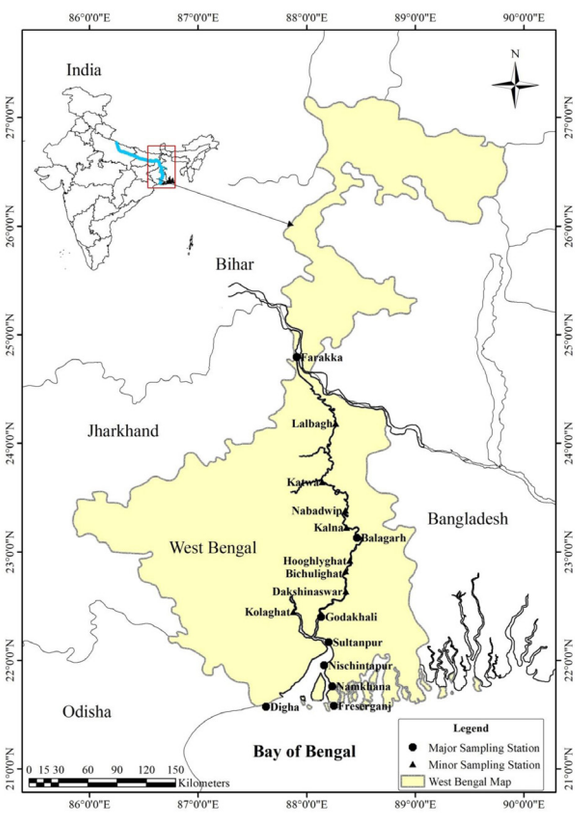


Fig. 1. The study area and sampling stations

associated coastal waters of northern Bay of Bengal using a stratified multistage random sampling method. Along with catch data, length frequency data of the species were also collected on a monthly basis from 16 landing centres from Farakka to Digha (Fig. 1) for four consecutive years from April 2013 to March 2017. The length frequency data was tabulated in length classes with 50 mm interval. Hilsa of first three length classes *viz.* 1-50 mm, 51-100 mm and 101-150 mm, were considered as juveniles as there was no gonad development in fishes below 150 mm. There were conflicting reports on the size at first maturity of the species from the same river system (Jones and Menon, 1951; De, 1980, 1986) and the lowest size at first maturity was reported by Pillay (1958), which was 160-170 mm for males and 190-200 mm for females and hence it could safely assume that fishes below 150 mm were juveniles. The information on gears that captured hilsa was also collected simultaneously.

From the length frequency data (of sample) and monthly catch estimates, corresponding monthly length frequency data for the entire catch were worked out for all stations, following the procedure of Alagaraja (1984). Weight corresponding to the mid-length of each length class was taken as the average weight of the length

class that was obtained using length-weight relationship estimated for the species. Thus, the total weight of each length class was estimated by multiplying the average weight estimated for that length class with the respective frequency. The total juvenile catch was obtained by summing up the total weight of juveniles obtained for all centres.

Modelling and analysis

Assumptions

The minimum size of hilsa caught by gillnet (the most dominant gear used for fishing hilsa) was taken as 300 mm using the legal mesh size of 90 mm (Gazette notification of Govt. of West Bengal, 2013) which was decided from the length-girth relationship of hilsa as well as through experimental fishing. Hilsa grows to a minimum of 270 mm in the first year (Pillay, 1958). Hence, if the juveniles are left uncaught, the survivors (after applying the normal rate of natural mortality) are likely to grow enough to be caught by gears with legally allowed dimension (90 mm mesh) by next year.

Estimation of harvestable biomass

Since the study targeted only hilsa and all biological parameters of the species were well known, the methodology followed for estimation of potential adult biomass were simpler and straight in comparison to the earlier works on economic assessment of juvenile catch in Indian waters; most of which targeted marine multi-species juvenile catch (Najmudeen and Sathiadhas, 2008; Kamei *et al*., 2013). Using exponential decay model (eq.1), the expected survivors were estimated from the number of juveniles caught and natural mortality [obtained through empirical formula by Pauly (1980)]. The fishing mortality was assumed to be zero *i.e.* situation of no juvenile fishing. The harvestable biomass or potential catch from the survivors those would grow for one more year if they were left uncaught were estimated using length-weight relationship for the species.

$$S=N_0 \times \exp(-M) \quad \ldots (1)$$

where, S = No. of survivors; N_0= No. of fishes in the original population and M= Natural mortality coefficient

The values of growth and other parameters used in Pauly's equation were L_∞ (cm) = 64.8, K = 0.46 (year^{-1}) and average habitat temperature=28.2ºC (Sandhya *et al*., 2016).

Estimation of economic deficit

The bio-economic model given in Najmudeen and Sathiadhas (2008) for estimating economic loss by juvenile fishing in entire marine fisheries of Indian coastline was followed in the study. The information on landing centre price of each length class was collected during sampling time and as the dataset comprised repeated values due to the less fluctuating price of juveniles, modal value of the price distribution was applied in the model to fetch the gross revenue. The gross revenue from juvenile fishing was obtained from the estimated landing weight and modal value of price of the juvenile catch. Potential revenue *i.e.* the revenue from the catch of larger hilsa if the juveniles were spared to grow for one year in the river/marine system was also estimated using the estimated number of survivors and corresponding body weight (Najmudeen and Sathiadhas 2008; Kamei *et al*., 2013). The annual economic loss due to growth overfishing was calculated by subtracting the gross revenue of juvenile fish landings from the estimate of potential revenue.

Results

Juvenile catch

The length-weight relationship of hilsa calculated through linear regression of weight on length was obtained as $W=0.000006229\times L^{3.096728}$, where W is weight in g and L is length in mm. Using the weight corresponding to mid-value of length class and estimated average annual juvenile catch, the average annual catch of hilsa juveniles for the four year period (2013 to 2017) was estimated at 30 t, with an average total landing value of ₹0.32 million (Table 1).

In the juvenile catch, weight-wise maximum contribution was by 51-100 mm length class, followed by 101-150 mm class, whereas by number it was by the 1-50 mm class (Table 1). The highest share of juvenile catch was in January, followed by April-May (Fig. 2a). Zone- wise break up of juvenile catch showed that maximum growth overfishing of the species occurred in freshwater zone (88%), followed by estuarine zone (Fig. 2b), which was an expected trend considering the anadromous migratory

Table 1. Estimation of revenue from juvenile catch of hilsa

Length class (mm)	Average annual juvenile catch (Nos.)	Weight corresponding to mid-value of length class (g)	Average annual juvenile catch (kg)	Landing centre price (₹ kg^{-1})	Total landing value of juveniles (₹)
1-50	15540889	0.13	2020	80	161625.25
51-100	3709458	3.99	14801	100	1480073.9
101-150	683478	19.4	13259	120	1591136.7
Total	19933826	-	30080.5	-	3232836.0

and breeding pattern of the species. The widely accepted migratory pattern of hilsa is by Pillay (1964) and Dutt (1966), where the species breeds in freshwater and returns to sea for maturation. The juvenile catch from offshore marine zone was almost nil as only adolescent and adult hilsa enters sea for growth and attaining sexual maturity, though a small quantity of juveniles were caught in the coastal waters along the sea mouth. The fishing gear-wise contribution to hilsa juvenile catch indicated that bag net was the major gear that landed hilsa juveniles (80%) (Fig. 2c).

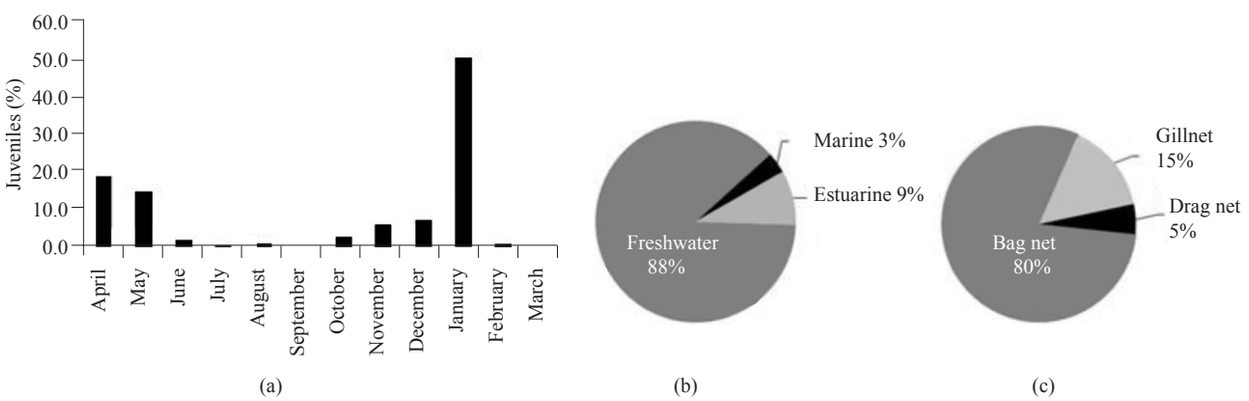
Economic deficit due to juvenile fishing

Hilsa is a highly preferred fish in West Bengal, which fetches high price owing to its taste as well as cultural importance. The price of juvenile hilsa in general was much less compared to the price of adults and was often sold as trash fish. The modal landing centre price (mode of the price values throughout the study period) of hilsa juveniles was ₹80 for 1-50 mm size group, ₹100 for 51-100 mm and ₹120 for 101-150 mm size groups. Based on the four year juvenile catch estimates, the average annual gross revenue from hilsa juveniles were calculated as ₹32.32 million (Table 1). The harvestable biomass or potential catch from the survivors after one year growth was estimated at 2505 t.

As the landing price of adult hilsa fluctuated depending on the demand and supply, the lowest landing price of ₹200 per kg was taken for estimating the landing value of the potential catch, which figured at ₹501.07 million. The average annual economic deficit due to juvenile fishing for the system was calculated at ₹497.84 million (around US$ 7.8 million) (Table 2).

Discussion

Combining biology with economics, *i.e.* estimating the biological loss and expressing the consequence in economic terms, is often an effective approach to highlight the severity of state of affairs and to lay stress on management actions. The present study was such an effort that indicated the economic deficit inflicted due to capture of hilsa juveniles, which is colossal. The study negated the common perception about growth-overfishing as a less detrimental form of overfishing, in comparison to recruitment-overfishing, which directly impedes the future viability of fish stocks (Gulland, 1983). It is evident from the study that allowing the juveniles to grow just one more year without harvesting them would itself boost total production by an additional 2505 t per year and its impact on population would be even greater considering the contribution of those survivors into the recruitment of next generation. Though there are no economic statistics available on the hilsa fishery in Indian waters, it is obvious that growth overfishing has marked impact on the total takings from the fishery. The annual hilsa landings from the Hooghly-Bhagirathi system including the associated coastal waters varied between 12192 t to 48922 t during 2013-2017 (Suresh *et al*., 2017) with an average of 30000 t per year. The estimated economic deficit was



(a) (b) (c)

Fig. 2. Juvenile fishing in Hooghly-Bhagirathi System. (a) Monthly catch trend, (b) Zone-wise catch and (c) Gear-wise catch

Table 2. Estimation of average annual economic deficit due to juvenile fishing

Length class (mm)	Average annual landing of juveniles (Nos.)	No. of survivors after one year	Harvestable biomass (kg)	Total landing value of potential catch (₹)	Average annual deficit due to juvenile fishing (₹)
1-50	15540889	6510880	1953264	390652784	(501078433)-(3232836)= 497845597
51-100	3709458	1554083	466225	93245000	
101-150	683478	286344	85903	17180650	
Total	19933826	8351307	2505392	501078433	

the minimum loss as the landing price of ₹200 taken in calculation is lowest and the deficit in reality would be of a higher magnitude.

The annual pattern of juvenile catch very well reflected the breeding pattern of the species. There are two dominant breeding seasons reported for hilsa, *i. e.* during south-west monsoon (July-October) and towards end of winter (February-March) (Hora and Nair, 1940; Pillay, 1958; Bhaumik and Sharma, 2012). As the juveniles remain in the rivers/estuaries till they probably reach a length of 150-160 mm which is believed to be attained in about five months time (Bala *et al*., 2014), the major peak observed in January might be contributed by the monsoon bred hilsa and the minor peak in April-May by the winter bred hilsa. Several authors had commented on the destructive nature of bag nets by catching juveniles of all fishes (Hoq, 2007; Rashed-Un-Nabi and Ullah, 2012) including that of hilsa (Bhaumik and Sharma, 2012; Prajith *et al*., 2017) which was reaffirmed in the present study with 80% juveniles caught by bag nets. Prajith *et al.* (2017) based on their study in River Narmada (Gujarat) suggested that bag nets may be phased out based on some incentive scheme to sustain and improve the hilsa fishery in India.

Management interventions to control growth overfishing

In India, fisheries are a state subject and hence legislations related to fisheries management are enacted by elected State Governments. Legislated seasonal fishing closures and size at capture guidelines already exist for West Bengal for conservation of hilsa (The West Bengal Inland Fisheries Act, 1984; The West Bengal Marine Fishing Regulation Act, 1993; West Bengal Inland Fisheries (Amendment) Act, 1997; Notification No. 719 in The Kolkata Gazette Extraordinary-Restrictions regulating catching of hilsa in Rivers, dated 9th April, 2013), which have defined minimum legal mesh size (MLS) of fishing nets for hilsa and minimum size of hilsa to be caught. The MLS, being the most popular fisheries management tool to protect juvenile fish by controlling the sizes of fish caught, was defined as 90 mm for gillnets, the major gear targeting hilsa. The capture of hilsa of below 230 mm size had been prohibited during February to April every year in estuarine area and bay mouth through the gazette notification of 2013. Seasonal fishing ban in total or in critical sites is another efficient management measure that finds scope in case of hilsa and hence the gazette notification of 2013 also banned all kind of fishing during June-August and October-December in the three identified hilsa sanctuaries of Hooghly-Bhagirathi river system. Despite these enactments in place, the huge scale of growth overfishing seen in the present study points towards poor enforcement of the legislated management measures. Strict implementation of legal mesh sizes in fishing nets would particularly help in preventing growth overfishing and not allowing recruitment overfishing to happen by restricting its capture during the breeding period through implementing fishing bans.

As hilsa is a fish in high demand in the region and its fishery involves huge population of fisher folks belonging to poor economic background, strict implementation of management measures can affect fishers' livelihood. Hence the fishery at present is more or less in the global pattern of convenience overfishing, which was defined by Froese (2004) as deliberate overfishing allowed by official bodies who find it more convenient to risk eventual collapse of fish stocks than to risk social and political conflicts. Increased efforts on enforcement of legislated management measures and introduction of management programmes with PES (payment for ecosystem services) options could contribute to effective management of hilsa fishery in Indian waters. Bangladesh has initiated PES for hilsa fishery management where direct economic incentives are being used for conservation, both to optimise total production and ensure fishers' livelihoods (Mohammed, 2013).

The detailed analyses of juvenile catch divulged many aspects of the fishery, where there could be management interventions, namely:

- *Ban on destructive fishing gears*: Banning bag net fishing totally or seasonally (post-breeding seasons) in Hooghly-Bhagirathi system can significantly reduce growth overfishing of hilsa.
- *Enforcing minimum legal mesh size (MLS)*: Though MLS was defined throughout the state of West Bengal through the gazette notification (2013), enforcement of the monitoring and surveillance system has to be strict.
- *Seasonal fishing ban*: Enforcement of hilsa sanctuaries can contribute to sustainable hilsa fishery and areas critical for hilsa to be revised time to time based on scientific studies.
- *Payment for ecosystem services (PES)*: As hilsa is linked to livelihoods of millions of fisher folk, management approaches like PES may be undertaken in which cash payments or other compensation are offered to refrain fishers from catching juveniles.
- *Awareness campaigns*: A key step in curbing growth overfishing of hilsa is through raising awareness among the key stake holders of the fishery *i.e.* fisher folks about the consequences of their actions, which would apparently improve compliance of management measures.

- *Thrust on alternate production strategies*: Focus to be given on developing alternate production strategies such as captive breeding, domestication and aquaculture techniques for the species, which will eventually lead to more supply.
- *Uniform management strategies in the region*: Hilsa being a trans-boundary species and as it is assumed as a common stock in Bay of Bengal shared by India, Bangladesh and Myanmar, there is need to unify management strategies in the region for effective conservation of the species.

Growth overfishing of hilsa resulted in substantial economic loss, hence pragmatic approaches are essential to maximise the benefits the fishery can generate. The surveillance and enforcement of fishery management measures are often expensive, which leads developing nations like India with poor enforcement of the measures. The present study indicated that it would be cost effective and worth the efforts to enforce strict management measures in the case of hilsa fishery. Hence, necessary changes in the enactments and thrust towards their enforcement must be ensured, so that the valuable hilsa resources can be managed sustainably.

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