Article

Economic analysis of *P.monodon* post larvae by-catch in Indian Sundarbans: An impasse between livelihood and conservation

Anjana Ekka [1,†,] 0-2-7752-9928, Arun Pandit [1], Sandhya K.M. [1], Sajina A.M.[1], Suman Kumari [1], D.K. Biswas [1] and B.K.Das [1]

1 ICAR-Central Inland Fisheries Research Institute, India
* Correspondence: aekka@tudelft.nl
† Current address: Water Resources Section, Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands

Abstract: The livelihood of most of the fishers in Indian Sundarbans is dependent on *Penaeus monodon* post larvae fishing. These post larvae collectors are socially backward lacking economic security. The activity of collecting *Penaeus monodon* post larvae for rearing in aquaculture, destroy other aquatic species. Many other juveniles of shellfish and fin fish were destroyed in the process of collection of *Penaeus monodon* post larvae. The removal of juveniles before they reach maturity disturbs the ecological chain by hampering breeding processes and may cause extinction of some fish species in the long run. The present study is an attempt to estimate the economic value of juveniles destroyed in the collection of (*Penaeus monodon*) post larvae. In total 32 species were identified in *P.monodon* the post larval by-catch. The economic loss is assessed based on estimating biomass by taking a length-weight relationship from published literature. Further, the paper illustrates how does a profit enterprise is linked with natural resource exploitation. The paper explores government policy and nature conservation issues for social justice and effective conservation.In conclusion, suggestions are given to reduce the burden of livelihood on natural resources to the extent of exploitation and to strengthen institution and policy-making considering socio-ecological vulnerabilities of the area.

Keywords: Economic analysis; conservation; *P.monodon*; by-catch; livelihood; seed collector, Post larvae collector; coastal aquaculture; Indian Sundarbans

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1. Introduction

The Sundarban Biosphere Reserve is the world's largest mangrove forest and the delta of Ganga–Brahmaputra and Meghna, shared between India (40 percent) and Bangladesh (60 percent).The Sundarban estuary is considered as goldmine of fishes [1]. The unique mangrove vegetation plays an important role in providing ideal nursery and breeding grounds to number of estuarine shell fish and fin fish [1–3].Around 95 percent of the population is directly or indirectly dependent on Sundarban ecosystem for their livelihood and take up occupations like agriculture, aquaculture and fisheries. [4].

Certain livelihood activities become a major threat to ecosystem resilience such as *Penaeus monodon* post larvae collection from the rivers and creeks in the Sundarbans as it affects the ecological balance of the The shrimp farming [1] in Indian Sundarbans started in the 6th five-year plan (1980-1985) to develop

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[1] The shrimp farming refers to the culture of varieties of shrimp like *Penaeus monodon* and *L.Vannamei* but in the paper shrimp is referred to *Penaeus monodon* species

coastal aquaculture with the assistance of the World Bank and other development agencies[5,6]. Due to high market rate in the international market, the culture of shrimp farming more specifically *Penaeus monodon* gained momentum, and the demand of *Penaeus monodon* fry increased many folds as more and more area brought under intensive *Penaeus monodon* culture. The major constraints in shrimp farming were the availability of good quality seeds. Most of the shrimp farmers prefer wild caught fry of shrimps due to low mortality rate. The expanding interest for the *P.monodon* seed by mushrooming fish farm along the shorelines of Sundarbans allured poor coastal fishers into the prawn seed business to earn livelihood [7]. The Hugli-Malta estuarine complex provides a unique and most productive nursery grounds for many shellfish and fin-fish in Indian Sundarbans[8]. Many people are engaged in collecting post larvae of *P.monodon* and it has become a source of livelihood for many households in coastal regions of Indian Sundarbans[8,9].During *Penaeus monodon* post larvae collection, many other juveniles of other shellfish and fin-fish were destroyed [1,8,10].Fishing nets of very small mesh size are used which capture all sizes of fishes including the non-targeted species. The non-targeted species are discarded in high quantity or dried and sold at cheaper price to fish meal industries.The removal of juveniles before they attain maturity could negatively impact fish diversity and have the possibility to destabilize the fisheries potential in the future [11]. From last three decade, many researchers[9,10,12–14] have attempted to document the quantitative assessment and description of non-targeted species found in by-catch but none of the studies gave a glimpse of the economic loss of by-catch in targeted species.

Here, we present a case study of Indian Sundarbans where the shrimp farming has given rise to social and ecological issues impacting the social and ecological integrity of the mangrove ecosystem. Therefore, the objective of the paper is to estimate the quantitative loss of by-catch in monetary terms. Further, the study exemplifies how human activities create environmental problems and creates impasse between livelihood and conservation. The paper is organized into three principal parts. In the first part, we discuss the different aspects of socio-ecological system like institutional policy and government intervention, including demographic distribution contributing to take up vulnerable occupation like prawn seed collection (section 2). The second part focuses on methodology to estimate the biomass of juveniles at first maturity based on length-weight relationship and finally estimating the economic value based on market price (section 3 and 4). The third part discuss about the impasse between livelihood and conservation issues and touches various issues of interconnection among profit enterprise, livelihood and environemental conservation. This paper will therefore provide an socio-economic view point of conservation and government policies which will help to strengthen institution and policy making in future.

2. Fishing and livelihood in Indian Sundarbans

The Sundarbans mangroves are considered a unique ecosystem habitat [15,16].It has been formed by alluvial deposits carried by several rivers in the delta of the Ganga-Brahmaputra and Meghna shared between India and Bangladesh at the mouth of Bay of Bengal [17]. From a geological aspect, the formation of Sundarbans is of recent origin around 12th to 15th century A.D [18,19].The tectonic activity changed the sedimentation process which influences the hydrology of the newly formed deltaic region. The rapid sediment formation leads to the emergence of new landmass, and mangrove vegetation accelerated the progradation of delta[20]. Ecologically, Sundarbans is a rich biodiversity hotspot for flora and fauna. The sole habitat for endangered species like Royal Bengal Tiger and saltwater crocodile [16]. The mangrove swamps also provide ambient breeding grounds and shelter for juvenile fishes and other aquatic organisms [21,22]. The swampy mangrove marshes protect embankments from tidal surges and storms [23]. Land Reclamation for farmlands and human settlements of the Indian part of the Sundarban started in early 1770 [24]. The main movement of the human population in Sundarbans occurred in the 19th century due to migration from adjacent districts of Bengal as well as refugees from East Pakistan (presently known as Bangladesh) [25]. According to

Danda *et al.* 26, human settlements are found in 54 deltaic islands in Indian part of Sundarbans. Before Independence, during the colonial era, around 1500 sq.km of forest were lost due to the clearance of forests for cultivated lands.The fragmentation of landholdings through the generation and harsh climatic conditions in the form of cyclonic events and brackish floodwater makes that area unfit for agricultural cultivation. The majority of population tends to depend on natural resources for their livelihood support. Moreover,fishing plays a vital role in providing livelihood.

After independence, the population of Indian Sundarbans grew from 1.15 million in 1951 to 4.44 million in 2011 [27]. In the year 1973, the Government of India created Sundarban Tiger Reserve, and subsequently the creation of different protected zones prohibited fishing in buffer and core area (Table 1), which is the only source of survival for local inhabitants, which ultimately leads to deprived livelihood. It gave rise to conflict between environmental protection needs and local fishermen [28–30]. Moreover, large and mechanized boats operating in Sundarbans are threatening the livelihood of small scale-fishers[26]. Besides, women and children are hitting local creeks and canals for shrimp seeds and crabs, which make them more vulnerable to adverse conditions. According to Das and Jana [31],prawn seed and crab collectors were worst affected by saltwater crocodile exposing them to life-threatening surroundings.

Table 1. Legal and Institutional overview of Indian Sundarbans

Legal designation	Year	Area (sq.km)	Activities prohibited/regulated
Sundarban Tiger Reserve (STR)	1973	2585	Divided into two parts (Core and buffer). The core area is prohibited from human interference
Sajnakhali Wildlife Sanctuary	1976	362.40	It is a part of the buffer area of the STR. Anthropogenic activities like fishing and hunting are prohibited
Lothian Wildlife Sanctuary	1976	38	It forms a part of the buffer area of the STR. Fishing and hunting activities are prohibited
Haliday Wildlife Sanctuary	1976	6	Forms a part of Sundarban Bio Reserve
Sundarbans National Park	1984	1330	It forms a part of the buffer area of the STR. Fishing and hunting activities are prohibited
Sundarbans Biosphere Reserve	1989	9630	It is divided into 3 parts; Core Area, Buffer Area, and transition Zone
Critical Tiger habitat	2007	1699.62	It is a part of STR where all anthropogenic activities are banned

Source : Compiled from Patel and Rajagopalan [32] and Chacraverti [33]

3. Methodology

The methodology is discussed in the following heads

3.1. Collection of fish samples

The *P.monodon* larvae are generally found in abundant in creeks and estuaries. Also, tidal pools and inundated pits are considered as excellent breeding ground for juveniles of fin fishes[34]. In estuaries, juveniles of shell and fish are found in abundant during full moon and new moon periods ([34,35]. All the estuaries showed a similar trend of the rising graph of abundance both during Full moon and New moon periods. The sampling site is situated in Bakkhali region of Indian Sundarbans in Hatania Doania river(Figure 1). A river of 2 km stretch is taken for the study (N 21 37.182 ′ and E 088 00.000 ′). The fishing area of each zone is divided based on villages. The sampled river stretch covered around 200 fishers.

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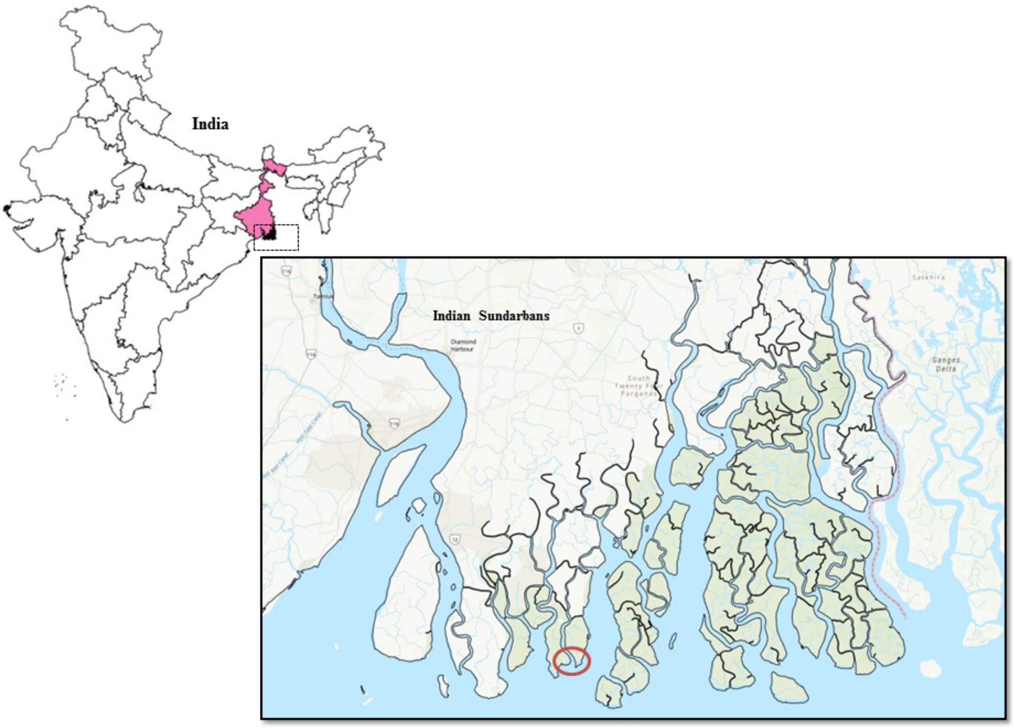

Figure 1. Map of the study area

During this period the *P.monodon* post larvae collection activity is maximum since, the juveniles come on surface due to high tides. Shootings nets were used for collection of samples. The size of the net was diameter 25 m, length 26 m. It is a long funnel shaped net tied at the tail end of the shoot net and set against tidal water to filter seed from the estuarine water (See Figure 2). Before onset of high tide, the boat is taken to midstream and anchored. One or two shoot nets are tied with the boat using big plastic drums floating in the water. At the onset of the tide, the net mouths are kept open and fully extended with the help of bamboo to allow as much as water to flow inside the net. The nets are lifted at an interval of 30-40 minutes, and the whole content is emptied in an aluminum container. The net is lifted and adjusted automatically to the rise in water level. After the segregation is over, the leftover fin fish and shell fishes were dumped or left in due course of time. Samples were collected from 2 nets belonging to commercial *P.monodon* post larvae collectors at the sampling site. When the catch was low, the entire sample is taken, but when the catch was high, a suitable sub sample was analyzed, and the total number was obtained by increasing samples proportionately (figure 3). Samples collected were then segregated according to species or group. Most of the species were identified at field level. Apart from taxonomical identification, some fish species were identified based on their local names. Length and weight of 10 samples of individual species were taken and genera wise aggregate weights of fish were recorded. Unidentified fish species or fish species having some doubt during field level identification were preserved in 5 percent formalin and labelled adequately for laboratory analysis.

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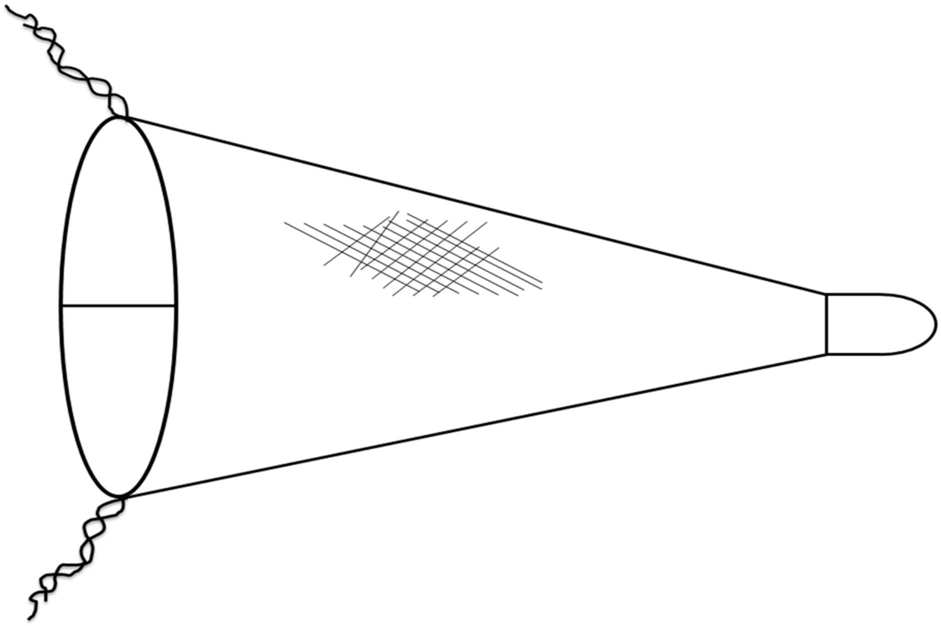

Figure 2. Funnel shaped shooting net used for the collection of *P.monodon* post larvae

3.2. Data collection from P.monodon post larvae collectors

The socio-economic data of *P.monodon* post larvae collectors were collected from the household who are actively involved in the post larvae collection business.It comprises of queries regarding the perception of *P.monodon* post larvae collectors towards *P.monodon* the collection activity including expenses and profit involved in operating boat for post larvae collection. Since, the collection of post larvae is directly linked with shrimp farming business; therefore complete data on marketing channel from post larvae collectors to shrimp farm were also collected to understand the complete marketing link of shrimp business.

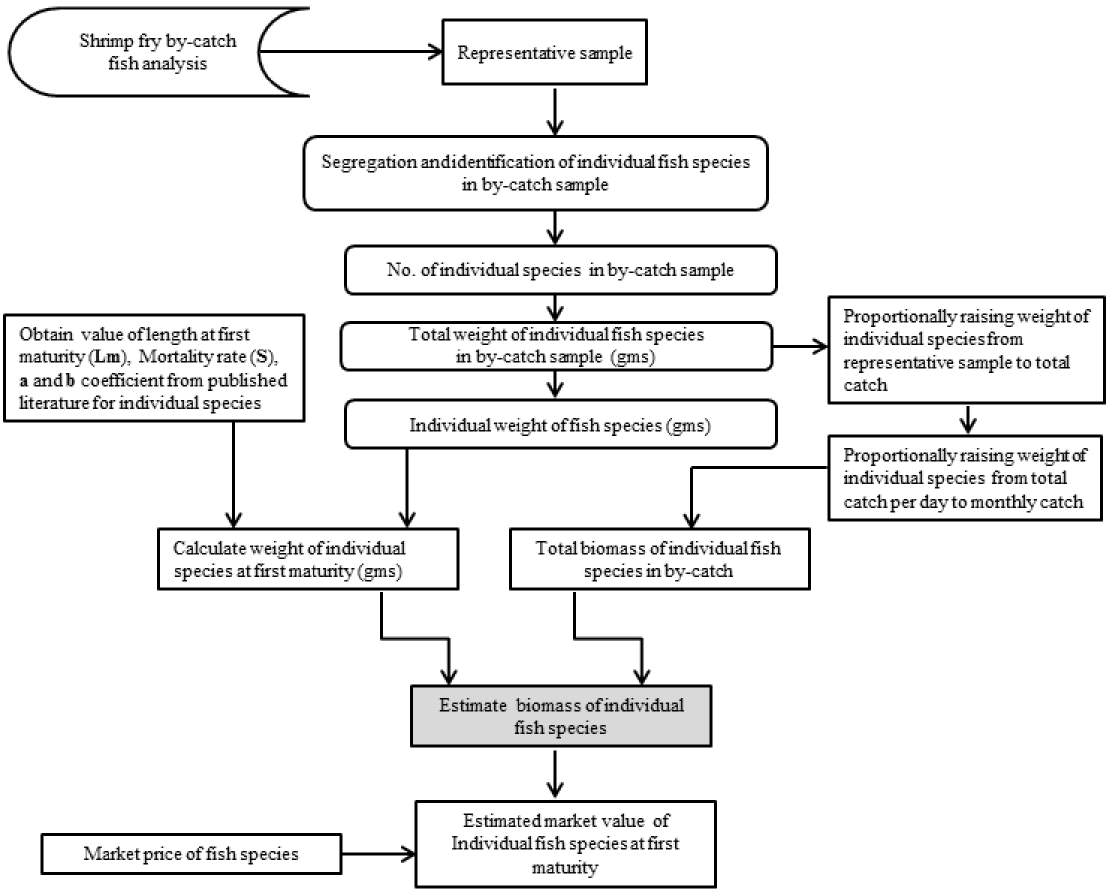

Figure 3. Methodology

131 *3.3. Analytical Techniques*

The methodology for calculating biomass is based on the assumption that if the juveniles are left to grow up to a certain period and were caught later after attaining maturity (known as weight at first maturity) how much it will cost. It is also based on the assumption that biomass of juveniles increase will increase positively with their growth rate and negatively with their mortality rates[36]

$$W = aL^b \tag{1}$$

where, W is the estimated weight (gms) of i^{th} fish species at first maturity, a is constant value and b is length (cm) at maturity of i^{th} species. The average sample () was calculated by FAO, 1984

$$\bar{Y} = \sum_{i=1}^{n} Y_{ij}/n \tag{2}$$

132 where, Y_{ij} is the total catch of i^{th} species, and n is no. of sampling per day

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In certain month, the quantity of catch is much higher, and it is not possible to count and calculate the whole catch. Therefore a representative sample was taken, and the proportion of each species was calculated in the sample. The proportion of each species in total catch was calculated using the following formula:

$$\frac{w_{\mathrm{i}}/ss_{\mathrm{i}}}{ws_{\mathrm{i}}} \times WT_{\mathrm{i}} \tag{3}$$

w_i = individual weight of i^{th} species in representative sample ss_i = no. of i^{th} species in the representative sample ws_i = total weight of representative sample WT_i = total weight of the catch

The quantity of biomass corresponding to juveniles was calculated to juveniles landed by the following formula:

$$Q_{\mathrm{A}} = S \times \frac{W_i}{w_i} \tag{4}$$

Q_A = Estimated quantity of biomass of Juveniles, W_i = weight of *i* species at first maturity (in gms), w_i = weight of juveniles of *i* species (in gms), S= Survival rate of *i* species

The survival rate, S, was estimated by modifyingRicker [37] method as,

$$S = exp^{-M} \tag{5}$$

where M= natural mortality coefficient.

Z, the total mortality coefficient, was replaced by M in the equation as the condition assumed for estimating the economic loss by fishing was the mortality in the population was only due to natural causes, i.e. Z=M.

M for individual species was calculated by [36] based on asymptotic length (L), growth coefficient (K). L and K values were obtained from growth studies in the same habitat area and also from similar ecosystems taken from secondary literature.

4. Results

The results are discussed in the following heads

4.1. Species composition in by-catch

Both taxonomical and field level identification tools were used to identify species.Total 32 species belonging to 24 families have been identified from post larvae by-catch (Table 2). Fish species like *Escualosa thoracata*, *Liza sp*, *Acetes indicus*, *Scylla serrata* are reported every month during whole sampling period. Juveniles of *Tenualosa ilisha*,*Anodontostoma chacunda*, *Setipinna phasa*, *Nandus nandus*, *Coilia dussumieri*, *Photopectoralis bindus*, *Otolithoides pama*, *Periophthalmus sp*, *Glossogobious giuris*, *Pseudapocryptes elongatus* and *Eleotris senegalensis* were found only once during the whole sampling period. Three to four species was recorded from the Clupeidae, Engraulidae, Gobiidae, Penaeidae family. On an average, 11-15 species were recorded every month. In the month of August 22 species were recorded.

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Table 2. Juveniles of fishes identified in the by-catch of *P.monodon* post larvae by-catch

Group	Family	Species	March	April	May	June	July	August	September
Clupeids	Clupeidae	*Tenualosa ilisha*						++	
		Gudusia chapra				++	++	++	++
		Anodontostoma chacunda		++					
		Escualosa thoracata	++	++	++	++	++	++	++
Anchovies	Engraulidae	*Stolephorus commersonii*	++			++	++		
		Coilia dussumieri					++		
		Setipinna phasa		++					
Perch like fishes	Serranidae	*Epinephelus diacanthus*	++						
	Carangidae	*Parastromateus niger*	++	++	++				
	Scatophagidae	*Scatophagus argus*	++	++		++			
	Nandidae	*Nandus nandus*		++					
	Terapontidae	*Terapon jarbua*						++	++
Threadfins	Polynemidae	*Eleutheronema tetradactylum*				++		++	
		Polynemus paradiseus					++	++	++
Pony fishes	Leiognathidae	*Photopectoralis bindus*					++		
Croakers	Sciaenidae	*Otolithoides pama*						++	
Lizardfishes	Synodontidae	*Harpadon nehereus*			++		++	++	++
Mullets	Mugilidae	*Liza sp*	++	++	++	++		++	
Gobids	Gobiidae	*Periophthalmus sp*		++					
		Glossogobious giuris		++					
		Pseudapocryptes elongatus						++	
		Odontamblyopus rubicundus		++	++				
Flatheads	Platycephalidae	*Platycephalus indicus*	++	++		++		++	
	Eleotridae	*Eleotris senegalensis*			++				
Ribbon fishes	Trichiuridae	*Lepturacanthus savala*	++	++	++	++	++	++	
Flatfishes	Cynoglossidae	*Cynoglossus sp*	++						++
Cyprinids	Cobitidae	*Lepidocephalus guntea*						++	++
Catfishes	Bagridae	*Mystus gulio*	++		++	++		++	++
Penaeid prawns	Penaeidae	*Fenneropenaeus indicus*				++		++	
		Metapenaeus monoceros	++		++				
		Metapenaeus brevicornis		++	++	++		++	
		Parapenaeopsis sculptilis					++	++	
Nonpenaeid prawns	Palaemonidae	*Macrobrachium malcolmsonii*	++					++	
		Exopalaemon styliferus		++			++		
	Sergestidae	*Acetes indicus*	++	++	++	++		++	++

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4.2. Biomass loss of fish species

The monthly wise loss of juveniles due to *P.monodon* by-catch is given in figure 4. The maximum loss is recorded in the month of July with 115 kg per day and minimum loss of 2.64 kg is recorded in March. The lean period is observed from the month of October to February. The biomass estimated for the discarded juveniles as by-catch during *P.monodon* post larvae collection is given in Table 3. The estimated biomass is completely based on the juveniles' fish/ discarded fish quantity landed and the mortality rate and weight of fish at first maturity. The highest quantity is estimated for *Acetes* species (25.54 percent) in the total quantity followed by *Esculanta thoracata* (16.73 percent, *Stoloferous commersonii* (12.98 percent) and *Therapon Jharbua* (10.83 percent). The fecundity rate of these fish species are high, therefore the juveniles are found in large quantity in the total catch. The minimum quantity of by-catch is recorded for fish species like *Setipinna phasa*, *Nandus nandus* species.

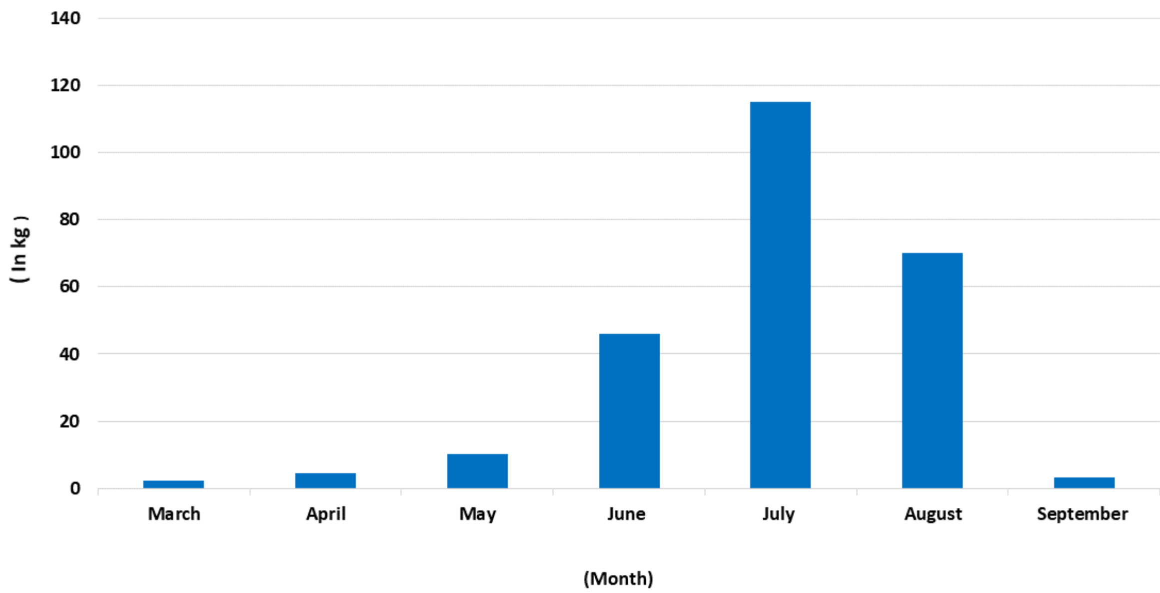

Figure 4. Monthly biomass loss of fish species in by-catch

4.3. Economic analysis of by-catch loss

The economic analysis of *P.monodon* by-catch completely relied on the quantity of by-catch discarded, the composition of fish species in the by-catch, estimated biomass of fish species, and landing price of individual fish species. The economic value of species wise by-catch and estimated value at first maturity is indicated in figure 5. The estimated economic value depends on 2 factors, i.e. Biomass calculated and price of the fish. Minimum landing price is taken to get the exact environmental cost associated with *P.monodon* post larvae collection activity without the addition of other costs of production as used in the analysis. The highest value was recorded for fish species like *Therapon jharbua*,*Liza* sp, *Elutheronema tetradactylum*, *Platycephalus indicus*, *Lepturacanthus savala*. The negative value is estimated for fishes which includes *Acetes sp*, *Cynoglossus sp*, *Lepidocephalus guntea*, *Peripthalamus species*, *Glosogobius girius*, *Nandus nandus*. Since these species have high fecund rate,its juvenile fetches more price in the market compared to market price when sold at first maturity.

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Table 3. Comparison of biomass of by-catch and estimated biomass after attaining maturity

Species	Weight of by-catch (in 1000′kg)	Estimated biomass (in 1000′ kg)	Change in by-catch-adult biomass ratio)
Tenualosa ilisha	16.62	309.49	0.05
Gudusia chapra	389.56	96.09	0.45
Anodontostoma chacunda	1.18	0.00	456.06
Escualosa thoracata	2529.22	465.31	5.44
Stolephorus commersonii	1585.67	1006.39	1.58
Coilia dussumieri	13.78	162.23	0.08
Setipinna phasa	0.67	0.01	-64.76
Epinephelus diacanthus	1.59	0.10	16.18
Parastromateus niger	5.73	0.06	88.98
Scatophagus argus	6.70	0.09	75.78
Nandus nandus	0.44	0.00	12990.44
Terapon jarbua	1065.31	2331.87	0.46
Eleutheronema tetradactylum	108.04	1565.56	0.07
Polynemus paradiseus	1007.63	634.47	1.59
Photopectoralis bindus	248.13	306.64	0.81
Otolithoides pama	24.94	72.13	0.35
Harpadon nehereus	749.29	2725.97	0.27
Liza sp	96.27	709.65	0.14
Periophthalmus sp	0.74	0.00	38539.07
Glossogobious giuris	1.85	0.00	8484.70
Pseudapocryptes elongatus	274.29	1015.32	0.27
Odontamblyopus rubicundus	2.57	0.00	28473.26
Platycephalus indicus	35.87	3213.83	0.01
Eleotris senegalensis	0.87	0.00	872.32
Lepturacanthus savala	1625.60	2542.18	0.64
Cynoglossus sp	678.45	59.33	11.44
Lepidocephalus guntea	52.23	5.32	9.83
Mystus gulio	549.09	219.75	2.50
Fenneropenaeus indicus	107.36	20.34	5.28
Metapenaeus monoceros	1.99	0.00	1502.20
Metapenaeus brevicornis	76.32	5.83	13.10
Acetes indicus	3785.72	23.71	159.65

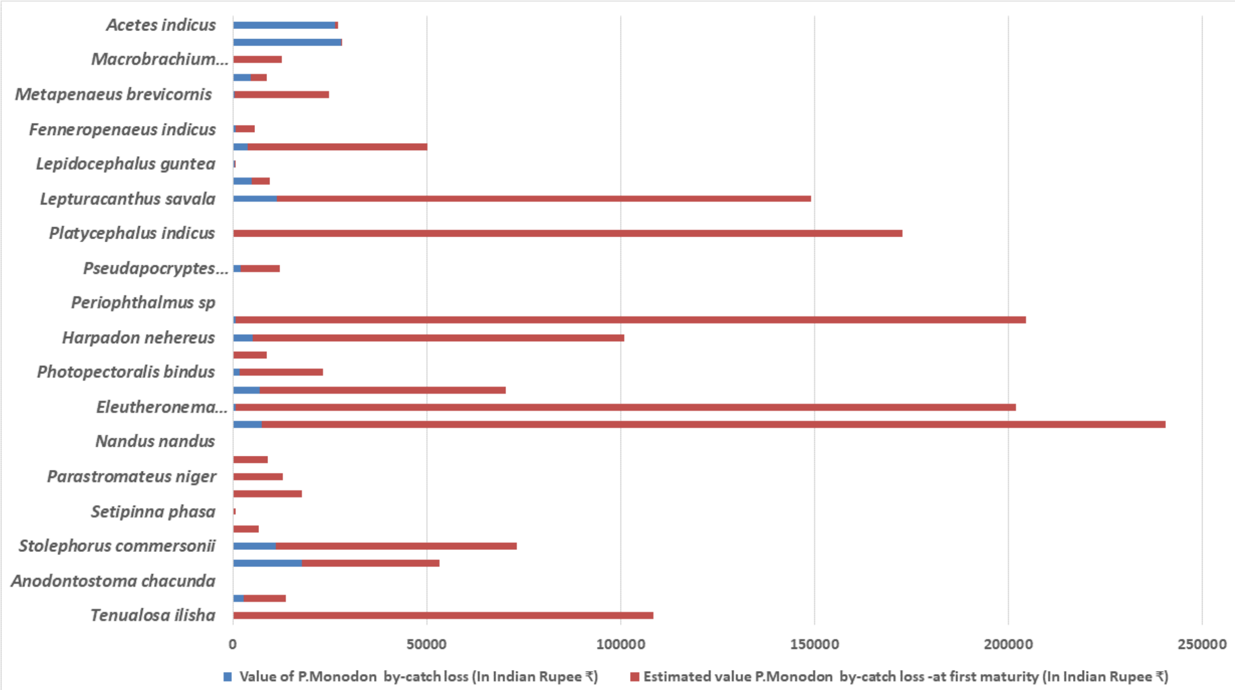

Figure 5. Comparison of economic value of fish species in by-catch and estimated value at first maturity

4.4. Market chain analysis of P.monodon larvae trade

The market chain from *P.monodon* collector to shrimp farmers passes through several intermediaries. Through the primary survey, a total number of 4 intermediaries were identified in the whole marketing channel of shrimp post-larvae trade(Figure 6). The demand for shrimp post larvae is high in shrimp farming, but supply is limited, and therefore a strong network has been developed with shrimp seed collectors and traders. The market intermediates links shed light on a tight business tied up for a very fragile commodity being transported so quickly to the shrimp farms. The fry caught by fishermen is first collected by the middleman in the coastal area. The collected larvae from the coastal regions is then transported by small van to the shrimp farming area at the Kathi centre known as seed collection bank. Then it was transported to the shrimp seed traders located in shrimp farming areas. At this stage, the seed is kept in small nursery ponds and reared to fry or fingerling stage and sold to the shrimp farmers.

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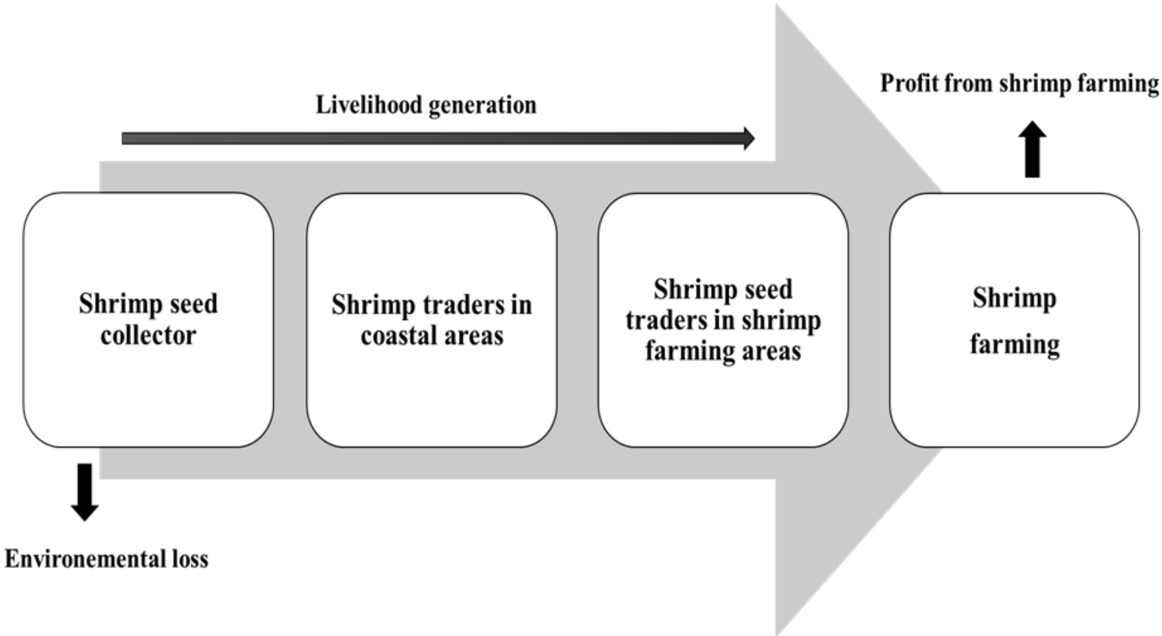

Figure 6. Marketing chain of shrimp post larvae trade

The cost-benefit analysis of market chain trade is estimated based on information collected during the primary survey on each stage of market chain trade. The cost-benefit analysis of fishers involved in fishing is first estimated based on their expenditure on the fixed and variable cost of fishing. The fixed cost variable includes depreciation cost on boat and nets. The variable cost includes daily labour cost, cost of diesel and repair and maintenance cost of craft and gears. The price is taken for the year 2015 and the inflation rate was applied to summate with the year 2019. The benefit-cost ratio at this stage is estimated to be 1.33. The cost-benefit ratio for middleman 1 and middleman 2 is estimated to be around 1.61 and 1.69 respectively. The *P.monodon* larvae collector earns the least as they invest more in fishing infrastructures like gears and boat. which decreases the profit. The investment of other intermediaries is less compared to *P.monodon* larvae collector which resulted in the high benefit-cost ratio. In addition, the economic and social cost of Shrimp farming is calculated based on per hectare profit from shrimp farming (Figure 7) It is assumed that 10,000 *P.monodon* larvae (stocking density) is required for semi-intensive farming per ha. The profit from shrimp farming negatively impact the environment by loss of juveniles. It also creates livelihood opportunities to people in coastal sundarbans thereby providing economic security to some extent. the ecological cost is more compared to the profit from shrimp farming and livelihood generation.

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Table 4. Economic analysis of market chain intermediaries

Market chain intermediaries	Cost price (In Rs)	Revenue earned (in Rs)	Benefit-cost ratio
Seed collector	65495.19	86932.33	1.33
Middleman 1	224856.94	362892.94	1.61
Middleman 2	246418.52	416783.73	1.69
Middle man 3	1348227.53	2657561.56	1.97

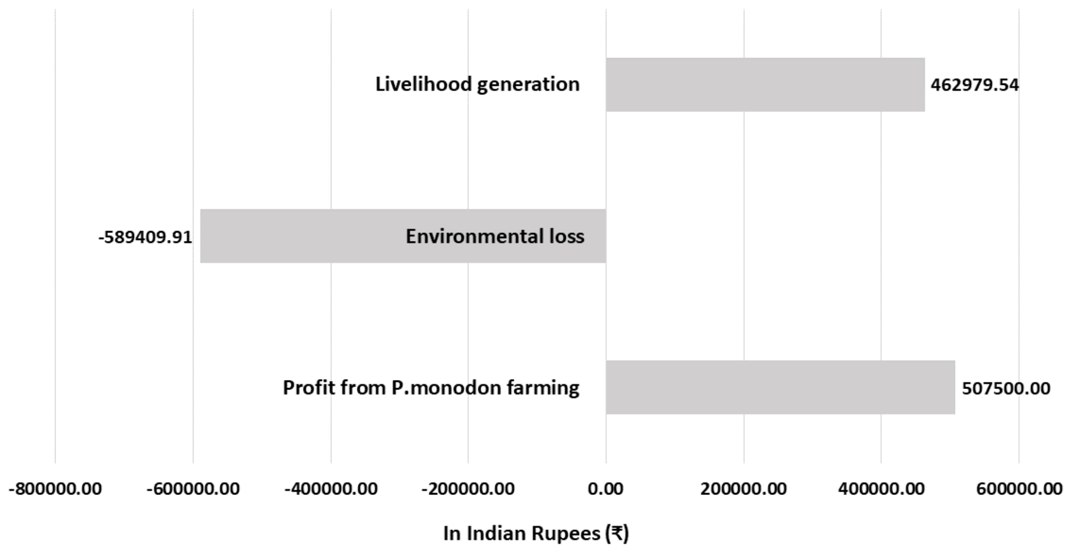

Figure 7. The economic, social and environmental cost of *P.monodon* farming

5. Discussion

Fisheries is a good indicator of the biophysical, ecological, and social integrity of riverine socio-ecological system[38].The paper attempts to explore the complexities of socio-ecological system by addressing the issue of seed collectors and the extent of damage of juveniles in economic terms of other fin fishes during *P.Monodon* larvae collection. The results depicts that price plays an important role in the determination of value of fishes.

The loss of juveniles due to post larvae collection is a matter of concern for sociologist, policymakers as well as environmentalist [39,40] If this activity continues, it has the potential to reduce fisheries in the future. Some low-value species like *Acetes sp.* have a low market price when sold after the first maturity. But the economic value increases when sold in dried form. As the fecundity rate of species like *Acetes sp* and *Liza species* are high which contribute in biggest biomass. Overall the livelihood of people is associated with this larvae collection activity [41]. No doubt, coastal aquaculture contributes significantly to rural employment and livelihood, but this is now hampered by ecological costs and negative social costs [42]. As discussed with fishers during group discussion, it is evident that fisher′ are aware of the ecological loss but having no other option; they are compelled to engage in this tiresome activity.

The result indicates that the monetary loss of juveniles is high compared to the per ha production of shrimp in semi-intensive farm culture and the profit received from it. The ecological cost is often neglected. Simultaneously, the larvae activity is providing livelihood to the fish farmers. In addition, other people in the form of intermediaries are also involved in the post larvae trade. If ecological cost is more then what is the replacement to this activity so that the livelihood of people can be saved.

To answer these questions, we must dig in the past to understand the situation when human evolved and started settling in Sundarbans. The people who came from near districts of West-Bengal as labourer to clear the forest and settled in Indian Part of sundarbans under Jamindars(landlord) became the Meendharas (fishers) after few decades[43]. As bonded labour, these people migrated to Sundarbans, and continued to live under the pressure of harsh climate adjusting with the nature. They fulfil their basic needs by hunting and fishing in the deep forest of Sundarbans. The government's interventions in the form of social and political law prohibited them to reach their livelihood and created a vicious cycle of poverty. This also reveals a series of political and social law that shaped the socio-economic condition of these labours now considered as fisherman. Resource-poor fishers, livelihood diversification is a strategy to cope with the uncertainties and in-adequateness of fisheries as a profession. [38]

6. Conclusions

The study concluded that *P.monodon* definitely helped in securing livelihood of local people in coastal Sundarbans. However, more social and ecological risks are involved. From a social context, the risk of working in critical environment particularly, threat from wild crocodile and skin diseases due to long water exposures during seed collection. From an ecological context, the loss of juveniles can impact the food chain and has the potential to impact fisheries in the long run. There is a conflict between livelihood, economic gain and environmental conservation. The economic gain from shrimp farming is at the cost of ecological damage, livelihood and the risk associated with it. Therefore, some issues need to be further investigated in terms of social justice and effective conservation. The conflict between livelihood and conservation will not be solved unless we provide alternative livelihood to the residents. The government should make provision to explore various livelihood opportunities which would not only provide economic security but also strengthen the social structure of the whole community by following principles of sustainable development. Another important issue is the creation of buffer zones and protected area, the subsequent forest and fishing regulations after creation of protected area hampers the livelihood option of local people.The creation of buffer zones and protected area prohibited the accessibility of fishing which impacted their livelihood. Bhattacharya and Sarkar,2003 suggested for identification of potential breeding grounds for tiger prawns and to make laws prohibiting fishing in those areas which will focus again upon implementation may deprive the local inhabitants of their livelihood. The fisheries resources and socio-economic database of fishers in Indian Sundarbans need to be re-assessed. There should be more coordination between different organization in terms of reaching out to people. Policy guidelines and management action plans should be made available in local language. The fishing community should be involved during decision making process and implementation of conservation project to ensure effective conservation.

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Table A1. Sampling details for *P.Monodon* larvae collection

S.No.	Month	*P.monodon* collected per day/boat	No. of Sample	Average Fishing Hours	No.of fishing days
1	February	550	8	6	14
2	March	1600	8	6	20
3	April	3250	8	6	20
4	May	3750	4	8	25
5	June	2250	4	8	30
6	July	1250	4	8	30
7	August	700	4	8	30

Table A2. Length and weight relationship of species found in by-catch

Species	Lm (cm)	a	b	References	K	References
Acetes indicus	2.3	0.0047	3.108	Froese and Pauly [44]	1.7	Chakraborty *et al.* [45]
Anodontostoma chacunda	16	0.0148	3.06	FAO(1965)Froese and Pauly [44]	0.87	Froese and Pauly [44]
Charybdis rostrata	7	0.14	3.078	Dineshbabu [46]	0.88	Islam *et al.* [47]
Coilia dussumieri	16.25	0.00383	2.801	Mohan Joseph and Jayaprakash [48], Amin and Zafar [49]	0.8	Fernandez and Devaraj [50]
Cynoglossus sp	10.2	0.027	2.42	Manojkumar [51]	0.7	Manojkumar [51]
Eleotris senegalensis	5.7	0.009	3.015	Pezold and Cage [52]	0.36	Hashemi *et al.* [53]
Eleutheronema tetradactylum	28.5	0.016	2.961	Abdul Samad [54]	0.18	Nabi [55]
Escualosa thoracata	8.2	0.0216	2.57	Raje *et al.* [56]	1.4	Nabi [55]
Exopalaemon styliferus	6.3	0.006168	2.95	Leung [57]		Froese and Pauly [44]
Fenneropenaeus indicus	13	0.004758	3.077	Dholakia [58]	2	Mustafa [59]
Glossogobious giuris	10.5	0.006	3.068	Marquez [60]	0.8	Froese and Pauly [44]
Gudusia chapra	8	0.008597	2.8576	Mondal and Kaviraj [61], Vinci *et al.* [62]	0.25	Afroz *et al.* [63]
Harpadon nehereus	21.45	0.00243	3.051	Ghosh *et al.* [64?]	0.519	Balli *et al.* [65]
Lepidocephalus guntea	4.5	0.0029331	3.48	Chakravarty *et al.* [66]	0.7	Sawusdee [67]
Lepturacanthus savala	38	0.000361	3.18	Pakhmode *et al.* [68]	0.75	Ashraful [69]
Lepturacanthus savala	38	0.000361	3.18	Pakhmode *et al.* [68]	0.75	Ashraful [69]
Liza sp	23.79	0.0055	3.1938	Renjini and Bijoy Nandan [70]	0.25	Mitra and Mandal [71]
Macrobrachium malcolmsonii	7.5	0.005	3.33	Venkataswamy *et al.* [72]	0.2184	]Venkataswamy *et al.* [72]
Metapenaeus brevicornis	10	0.01066	2.697	Rajyalakshmi [73]	0.9	http://www.sealifebase.ca/
Metapenaeus monoceros	11.2	0.006	3.084	Abraham *et al.* [74], Dineshbabu [75]	1.5	Dinh *et al.* [76]
Metapenaeus brevicornis	10	0.01066	2.697	Rajyalakshmi [73]	0.9	http://www.sealifebase.ca/
Metapenaeus monoceros	11.2	0.006	3.084	Abraham *et al.* [74], Dineshbabu [75]	1.5	Dinh *et al.* [76]
Mystus gulio	6.2	0.0826038	2.149	Pantulu [77], Begum *et al.* [78]	0.0638	De Graaf [79]
Nandus nandus	5	0.0192	2.95	Hossain *et al.* [80], Parameswaran *et al.* [81]	0.7	Froese and Pauly [44]
Odontamblyopus rubicundus	5.4	0.00933	3.06	Kader *et al.* [82]	0.82	Ullah *et al.* [83]
Otolithoides pama	110.5	0.0123	3.03	Froese and Pauly [44]	0.19	Froese and Pauly [44]
Parapenaeopsis sculptilis	9.3	0.0037	3.26	Fatima [84]	1.25	Mustafa [59]
Parastromateus niger	30	0.0138	2.54	Pati [85]	0.59	Mustafa [59]
Periophthalmus sp	5	0.0164851	2.522	Froese and Pauly [44]	0.51	Rao *et al.* [86]
Photopectoralis bindus	8	0.044	2.52	Abraham *et al.* [74?]Murty (1988)	0.58	Murty [87]
Platycephalus indicus	40	0.005	3.05	Froese and Pauly [44]	0.2313	Jian-Dong [88]
Polynemus paradiseus	16	0.004127	3.1203	Gupta [89]Mitra (2001)	0.48	Froese and Pauly [44]
Pseudapocryptes elongatus	15.4	0.0164	2.81	Froese and Pauly [44]	0.65	Etim *et al.* [90]
Scatophagus argus	14	0.0377	2.922	Shao *et al.* [91], Letourneur *et al.* [92]	0.47	Froese and Pauly [44]
Scylla serrata	12.4	0.00002	3.48	Rezaie-Atagholipour *et al.* [93]	0.28	Dineshbabu [46]
Sepia sp. *(Dorsal mantle length)*	8.6	0.4067	2.5164	Al-Marzouqi *et al.* [94]	0.49	Sukumaran [95]
Setipinna phasa	23	0.002959	3.1985	Jhingran [96] Mitra (2001)	0.24	Alagaraja and Jhingran [97]
Stolephorus commersonii	11	0.004	3.326	Andamari *et al.* [98], Abdurahiman *et al.* [99]	0.96	Froese and Pauly [44]
Tenualosa ilisha	20	0.031	2.8	Pillay [100], Froese and Pauly [44]	0.82	Amin and Zafar [49]
Terapon jarbua	13	0.0154	3.082	Froese and Pauly [44]	0.24	Aydın [101]

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Appendix A Tables

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