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Evaluation of Bycatch Discarded Fishes During Tiger Prawn (*Penaeus monodon*) Seed Collection in Indian Sundarbans: Implication for Sustainable Management

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Abstract: By catch and discards are serious problem of fishing industry driving to the reduction of resources and have negative impact on biodiversity. The diverse biota of the largest delta, mangrove forest Sundarbans are utilized to a large extent as food and livelihood by the stakeholders. Tiger prawn seed collection is a key resource supply of the livelihood for Indian Sundarbans people. In course of the seed collection, assorted samples of non-target juveniles of fish species are destroyed as by-catch due to non -selective fishing gears and push nets. A total of 17 individuals, containing seven orders, ten families, were characterized. The diversity of the fish species ranged between 2.45 and 2.73 with corresponding evenness of 0.93 and 0.98. Among the fish species the dominant species was Stolephorus dubiosus while Pseudapocryptes elongatus had the lowest abundance in the samples revealed through the non-metric multidimensional scaling (NMDS). Station Kantamari, assessed most extreme number of prawn seed assortment during July - September, followed by Gosaba and Golabari. This study underscore the need to embrace suitable bycatch decrease gadgets in shrimp fishery, in addition requirement of fisheries the board guidelines in request to secure the non-target assets.

Keywords: Bycatch; Gadget; Guideline; Prawn seed; Sundarban

1. INTRODUCTION

Commercial fisheries draw attention for seriously affecting the marine ecosystem through the target and non-target species harvesting (Gislason et al., 2000; Raboui et al., 2019). Bottom trawling has been identified as the most destructive fishing method, despite being one of the most effective fishing methods for capturing target species such as shrimps (Cosgrove et al., 2019; Pérez Roda et al., 2019). The estuarine ecosystem is considered as efficient residential for numerous fish, invertebrate species, functioning as spawning grounds and juveniles

growth areas (Elliott and Hemingway, 2002). Estuaries regions are generally recognized to be of high natural and financial worth (de Groot et al., 2012), they are also affected by numerous human activities (Batista et al., 2014; Vasconcelos et al., 2007). By-catch species are represented as the unwanted fish and other species trapped by commercial fishing nets during fishing (FAO, 2011). The bycatch problem is more complicated in India due to existence of multi-species and multi-gear nature of the fisheries (Samanta et al., 2018). In India, shrimp fishery contributed large amounts of bycatch containing various aquatic organisms and juveniles of commercial fishes. Several researchers have attempted to investigate trawl bycatch in India (Boopendranath, 2009; Kumar and Deepthi, 2006; Kurup et al., 2003). The world's largest delta, mangrove forest Sundarbans (21°32' to 22°40' N and 88°85' N to 89°00' E), West Bengal, India has a great value in international and national level for its uniqueness and richness in biodiversity (Gopal and Chauhan, 2006). The diverse biota of the Sundarbans is utilized to a large extent as food and livelihood by the stakeholders. In the deltaic channels of the rivers, the available fish and prawn resources are key to the ecological economics of Sundarbans biosphere reserve. The complex network of mangrove system's provides a valuable habitat for the residence of large spectrum of fishes, shrimp, and crab species, as well as hosting diverse macro algal assemblages (Banerjee et al., 2012; Mitra and Pal, 2002; Kar et al., 2017). Among all the groups of ichthyofaunal resources in Sundarbans mangroves and adjacent areas mainly fin-fishes perform a key role for stabilization of local food chains. This could also develop into a reliable source of daily protein and contribute to local people's socioeconomic advancement (Gopal and Chauhan, 2006). Hence, mangroves contribute to ecological diversity and distribution by providing essential natural environments, breeding grounds, nurseries, and nutrients to a diverse range of estuarine and offshore fish populations (Bhattacharya et al., 2018).

The tiger prawn (*Penaeus monodon.* Crustacea: Decapoda) seeds are collected in the estuary and sold in the near wholesale market as a popular key financial supply for Sundarbans people. The progression of water along the estuaries is thwarted by a large number of nets that are laid along the stretch for catching seeds of tiger prawn (*p. monodon*).The collection of prawn seed and other encountered species is a year-round activity. Seed collection is done by 95% of the local inhabitants with the peak period during April-September. Due to the use of Stationary gear (locally known as "Min Tana Jal") with specific mesh size (<1mm) for tiger prawn seed collection, several others non-target species especially fish juveniles are also caught in nets as bycatch and is discarded on the tidal mudflats. This practice results in a great loss of pelagic biodiversity (Bhattacharya and Sarkar, 2003). These non-targeted species may be economically or ecologically important. Comprehensive data on Species composition and amount of discarded fish species is still lacking. In respect to our knowledge, to date, there is no report available that has quantified the bycatch discarded fishes during netting. The aim of the present investigation is i) to describe the composition of discarded fish species, ii) quantify the different components of bycatch discarded fish species. The findings from this study will provide a preliminary piece of information about the identities of bycatch juvenile fish species. This information can play a pivotal in assisting the proper management and conservation of this ignored fishery resource.

2. MATERIALS AND METHODS

The present study covered species composition, species abundance, catch rate, and quantification of bycatch and discards in the Indian Sundarban shrimp fishery. To address the questions, we were conducted an observer program and collector's questionnaire survey.

2.1. Questionnaire Survey

Interview cum questionnaire survey was conducted to gather information on financial condition, living status, age structure, and educational qualification of the seed collectors. In addition, the information about the number of days in a month and per day exhausted time during shrimp fry collection and total collection day in a year were collected.

2.2. Observer Programme

An observer program was conducted from May through September, 2016 to assess bycatch fish species. Contents after each tow were emptied onto the sorting tray and separated into two kinds of stuffs: shrimp fry (target species) and others than target species(including fishes, arthropods, molluscs). The total weight of shrimp fry and discarded bycatch species were not evaluated as they are very small (juvenile) in size. Standard operational information, for example, the area, date, time, tow term, and essential apparatus design were additionally gathered. Total discarded species were acquired by multiplication of discards per tow with tow numbers in a day. From our samples, the present study focused primarily on fish species due to their economic value in the surrounding local market, West Bengal, India.

2.3. Sample Collection

The bycatch fish species were collected from the prawn seed collectors along the shoreline of ‘Matla’ and 'Bidyadhari' river (Fig. 1) where prawn seeds collection was done. The bycatch species were sampled from three station during the month of March, 2016 and continued up to September, 2016. Samples were collected monthly after the second day of the new moon fortnight at all three stations simultaneously.. The location of the sites was noted through the Global Positioning System (GPS). Collected fish were immediately preserved in the 4% formalin and identified following by standard methods (Talwar, 1991; Mukherjee et al., 2000 ; Jayaram, 1999).

2.4. Data Analysis

Gathering data provided relative-abundance estimates for all by-catch fish species sampled throughout the various spatial and temporal scales of the survey. To determine broad patterns across different locations, non-metric multidimensional scaling (nMDS) was used to ordinate the data (Kruskal and Wish, 1978). To account for the number of species present (species richness), as well as the abundance of each species (evenness), biodiversity indices were measured. Non-metric multidimensional scaling (Manly, 1994) methods are useful for spatially representing the interrelationships among a set of data objects. Non-metric means that configurations are based on the rankings of distances. Therefore, NMDS derives a configuration in which the distances between all pairs of sample points are, as far as possible, in rank order agreement with their compositional dissimilarities (Minchin 1987). The data analyses were carried out using the PAST software (Hammer et al., 2001).

3. RESULTS

3.1. Species identification

From the 25 voucher specimens, the taxonomic analysis based on morphological characters identified 17 species (Table 1), belonging to 7 order (Perciformes, Clupeiformes, Beloniformes, Tetraodontiformes, Siluriformes, Elopiformes, Mugiliformes) and 10 families (Gobiidae, Terapontidae, Engraulidae, Zenarchopteridae, Adriachthyidae, Tetraodontidae, Plotosidae, Megalopidae, Mugilidae).

3.2. Catch rate

Based on questionnaire survey it was found that Seed collection is performed by 95% of the nearby inhabitants. Our observer program results indicated that the monthly catch rates of prawn seeds were maximum recorded during July to September (Fig. 6). Average time spent in three sampling station by prawn seed collectors showing maximum in Kantamari station trailed by Gosaba and Golabari (Fig. 7). Accordingly, the estimated number of seed collectors ranged from a minimum of 40 (in March 2016) to maxima 130 (in August 2016) and 145 (in September 2016) in sampling sites. Normally seed collection was done from the second day after the new moon to the ninth day in a month. Average seed mortality rate (25±8 per 1000 seed) and income (975±180 in INR per 1000 seeds) were estimated based on observer program.

3.3. Discard rate

There were pronounced variations in discard rate, maximum value reported in July - September 2016, followed by constant decreases in the progressive months (Fig. 6). The observer program and field data reveals to get 5000 tiger prawn seed, collectors obliterate approximately 2800 ± 150 juveniles of other prawn species, 400 ± 30 juveniles of fishes, 250 ± 25 crabs.

3.4. Socioeconomic status of prawn seed collectors

The questionnaire survey and our observation program elucidated that about 20% of the prawn seed collectors were youngsters whose ages were between 10 - 14 years, 24% were in the age between 15 - 25 years. In addition, 50% were in the 25 - 50 years age group and the rest of the 6% were maturing adults of over 50 years(Fig. 8) . Maximum youngsters nearly about 80% involved in this labor dropped out of their schools to prepare money for their family. Within the existing 20%, 17% passed the eighth standard and 3% completed secondary in an arduous manner (Fig. 9).

3.5. Shannon-Weiner diversity

As shown in the biplot (Fig. 3) the ordination of the species is satisfactory and dispersed in the quadrants with an equal number of species occupying each quadrant. Depending upon the species richness and abundances, the Shannon-Wiener diversity index ($H^{'}$) (Fig. 4) ranged from 2.45 to 2.73. The corresponding evenness value (H_{even}) was 0.93 and 0.98. Rarefaction is a method used in ecology to estimate species abundance based on sampling data. Rarefaction, which is based on the construction of so-called rarefaction curves, enables the measurement of species richness for a given number of individual samples. Rarefaction curve develop quickly from the start, as the most well-known species are found, however, the level of the bend as just the most extraordinary species stays to be inspected. A rarefaction curve (Mao's Tau) was also constructed based on the available data on abundance and the richness of the fish species. The triangle in the rarefaction curve shows the 100% saturation of the species richness observed by sample 7 (Fig. 5).

4. DISCUSSION

Estuarine ecosystem are diverse and intricately linked to the livelihood of the surrounding community. These diversity include assemblages of fishes, molluscs, crabs for the commercial/economic gain of the local people. Penaeid and nonpenaeid are the main two classified communities of Indian commercial prawns. Tiger prawn *P. monodon*, the most immense In-

dian marine penaeid prawn is a very important paramount commercial species fortifying the export industry of marine prawn fishery in India. The estuarine framework offers phenomenal nursery justification for the majority of the euryhaline finfish and shellfish. A great number of post-larvae, juveniles enter the estuarine system with elevated tides (Raha et al., 2012; Ghosh et al., 2015) and are made accessible with prawn seeds.

Biodiversity is a measure that combines richness and evenness across species. High biodiversity is interpreted as a healthy ecosystem. According to Wilhm and Dorris (1966), diversity index (H) value less than 1 in estuarine waters indicate heavy pollution, values between 1.0 and 3.0 pointed out moderate pollution, and values greater than 3 indicate non-polluted water. In our study, diversity value greater than 2 but less than 3 means the area is moderately polluted. In a homogenous study on the Indian coast, 148 species were recognized as discards and a considerable lot of these were economically significant fishes (Samanta et al., 2018). Another study disclosed that bycatch is characterized by higher species richness, similarly to the other shrimp fisheries from tropical and subtropical marine areas (Stobutzki et al., 2001). From our samples, it was found that eleven species were economically important (mentioned in Tab. 1). Out of eleven species, *Liza macrolepis* (Large-scale Mullets), *Terapon jarbua* (Terapon), *Megalops cyprinoides* (Indo - Pacific Terapon), *Scartelaos histophorus* (Goby), *Pseudapocryptes elongatus* (Pointed tailed Goby), *Plotosus canius* (Gray eel Cat Fish), *Coilia reynaldi* (Anchovy), *Stigmatogobius indicus* (Indian Anchovy) were valuable for commercial fisheries culture fisheries and aquaculture (Patra et al., 2017). The consumption of 100 g mullets fish (*L. macrolepis*) could meet the daily requirements of Ca and P for an adult human being. Mullet could provide 60-75% of dietary value for Se, which is an important micronutrient due to its anti-oxidative properties. The mullets serve as an alternative livelihood source and nutritional security for the coastal population (Dayal et al., 2017). *Stigmatogobius sadanundio, Tetraodon fluviatilis , Pseudapocryptes elongatus and Terapon jarbua* are indigenous ornamental fishes of south Bengal, their specific habitat preferences and ecological requirements may be related to the endemism of these fishes (Banerjee et al., 2012 ; Dubey et al., 2015). Indigenous fish diversity is now a global concern for raising a question about food security. In Bangladesh, 15% of species were reported to have disappeared, 20% are critically endangered and disappearance increasing due to various reasons (Dubey et al., 2015). *S. dubiosus* (Wongratana, 1983), *P.canius* (Varadharanjan et al., 2012), *C. reynaldi* (R. A. Khan, ZSI fish record), *S.histophorus, P.elongatus , L. macrolepis, M.cyprinoides, S.dubiosus, P.canius* are well marketed in several districts of West Bengal (Patra et al., 2017 ; Banerjee et al., 2012) . *P.elongatus* are well known for its commercial value in southeast China, Vietnam, and Taiwan (Bucholtz et al., 2009). In India, these fishes are well marketed in Gujrat and Mumbai fish market (Rathod and Patil, 2009). Furthermore, the Sundarban fisher folk sold these fishes at a very high price for their medicinal importance (Ravi et al., 2015). IUCN status of all collected samples was checked and provided (Tab. 1). The current assessment shows that 24% of young generation within 25 years involve in this profession to earn money. Normally in this age group, students are focused on their carrier but those local student inhabitants took the responsibility of the corresponding family. The unavailability of sufficient money preventing youngsters to continue their education and leading to become earning members of the family. As a result, the possibility of higher ambition and talent are not flourished fully.

Even though the Government of West Bengal precluded the wild seed assortment in Sundarban. In any case, there is no such another scheme to satisfy their day to day essential needs of the local inhabitants. In these conditions, imposition of any laws or regulations won't be effective. For seed assortment, shoot net and drag nets is the most effective and produc-

tive. Yet, 90% of the seed collectors do not use these gears due to the low cost- benefit ratio. Apart from the wreckage of fish juveniles, the practice of towing in the intertidal mudflats often uproots the mangrove seedlings and salt marsh grass (*Porteresia coarctata*), which assist in ecosystem services like control of erosion and beach stabilization. Although, prawn seed collection playing a major role in financial support for impoverished people of Sundarban but consequently this type of non-scientific practice exerting to a larger effect on the ecosystem. Regular loss of commercially important fish species makes an enormous impact on biodiversity as well as the economy in the future. This loss of valuable fish biota would prompt stock diminution that weighed down the food chain structure in a marine ecosystem. It should be noted, however, that the mortality of discarded fishes may have a negative impact on predators by removing them prematurely from the food web. It is also necessary to know of the relative proportion of available biomass of different species that the bycatch from prawn seed collection. In this study, we were focused only on fish species but several others like crabs, molluscs, other prawn species were discarded as bycatch. One report revealed that in order to catch 9586 tiger prawn seeds, collectors destroy approximately 1562862 juveniles of other prawn species, 56000 fishes, 1.9 million crabs (Bhattacharya and Sarkar, 2003). In order to increase the selectivity of shrimp trawls and minimise the effect of trawling on non-target resources and juveniles, various bycatch reduction technologies have been developed in the fishing industry around the world (Boopendranath et al., 2007, 2010; Eayrs, 2007; Larsen et al., 2018; Cosgrove et al., 2019). Bycatch reduction devices is an urgent need today and must be used during trawling (Sabu et al., 2013). Unfortunately, implementation and enforcement of these strategies are still lacking (Pérez Roda et al., 2019). The degree of bycatch mitigation technologies are adopted is highly influenced by the robustness of the fisheries management systems (Samanta et al., 2018). Several scientifically controlled fisheries around the world have mandated and successfully implemented bycatch mitigation technologies (Catchpole et al., 2014) . A strategic fisheries management strategy and enforcement of fisheries regulations are needed to regulate shrimp trawling. Considering the negative impact of this profession it is most needed to develop seed banks and provide alternative livelihoods through ICZM (Integrated Coastal Zone Management) program as a separate section for this mangrove-dominated World Heritage Site.

5. CONCLUSION

This study is the first time attempt to identify the species that are either economically or ecologically important but are destroyed as bycatch during tiger prawn seed collection. Tiger prawn seed hatchery could not see the light of success because it is hard to maintain the dynamic salinity conditions of the estuarine system in an artificial hatchery system. Due to this problem in Indian Sundarbans, the profession of a wild collection of prawn seed has flourished that in turn posing a serious threat to the estuarine biodiversity of the region. Considering the adverse impact of this occupation on economic profile, the health of the fry collectors and fish biodiversity, it is important to provide an alternative livelihood for the fry catchers.

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CONFLICT OF INTEREST

The authors ensure no conflicts of interest in this study.

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TABLE WITH CAPTION

Table 1: List of available bycatch fish species with gene bank accession numbers. Three letter acronyms of species given in bracket after species scientific name. Acronyms were used in figure as stated in this table.

Sl.No	Order	Family	Species Name	Remarks	International Union for Conservation of Nature(IUCN) Status
1	Perciformes	Gobiidae	*Pseudapocryptes elongates* (PEL)	Fisheries : Commercial	Least Concern (LC)
2			*Parapocryptes serperaster* (PSE)	Novel Sequence	Not Evaluated (NE)
3			*Scartelaos histophorus* (SHI)	Fisheries : Commercial	Not Evaluated (NE)
4			*Brachygobius nunus* (BNU)	Novel Sequence	Not Evaluated (NE)
5			*Gobiopterus brachypterus* (GBR)	Ecologically Important	Not Evaluated (NE)
6			*Stigmatogobius sadanundio* (SSA)	Aquarium : Commercial	Not Evaluated (NE)
7		Terapontidae	*Terapon jarbua* (TJA)	Aquaculture : Commercial; Fisheries : Commercial Aquarium : Commercial	Least Concern (LC)
8		Eleotridae	*Butis humeralis* (BHU)	Ecologically Important	Not Evaluated (NE)
9	Clupeiformes	Engraulidae	*Stolephorus dubiosus* (SDU)	Fisheries : Commercial	Not Evaluated (NE)
10			*Coilia reynaldi* (CRE)	Fisheries : Commercial	Not Evaluated (NE)

11	Beloniformes	Zenarchopteri-dae	*Zenarchopterus sp.* (ZEN)	Fisheries : Com-mercial	Species level not identified
12	Beloniformes	Adriachthyidae	*Oryzius dancena* (ODA)	Novel Sequence	Least Concern (LC)
13	Tetraodonti-formes	Tetraodontidae	*Tetraodon fluviatilis* (TFL)	Aquarium : Commercial	Least Concern (LC)
14	Siluriformes	Plotosidae	*Plotosus canius* (PCA)	Fisheries: Com-mercial	Not Evaluated (NE)
15	Elopiformes	Megalopidae	*Megalops cyprinoides* (MCY)	Fisheries : Com-mercial Aquaculture : Commercial Game Fish : Yes	Data Deficient (DD)
16	Mugiliformes	Mugilidae	*Liza macrolepis* (LMA)	Fisheries : Com-mercial Aquaculture : Commercial Game Fish : Yes	Least Concern (LC)

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FIGURE WITH CAPTIONS

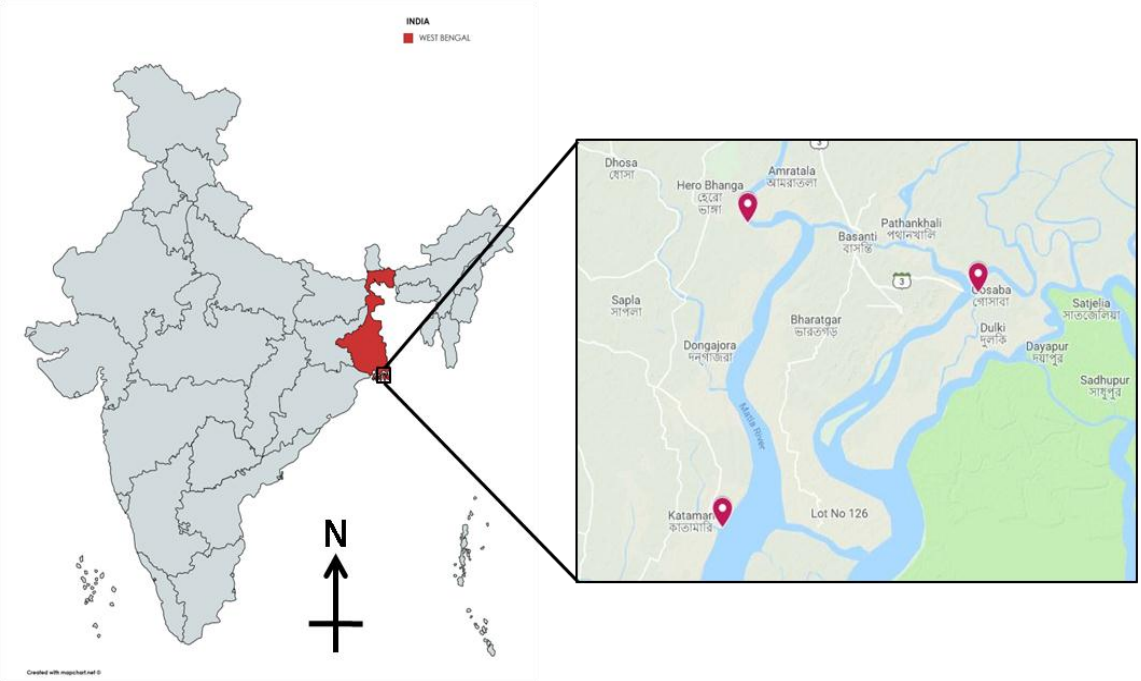

Fig. 1: The map representing the sampling sites in Sundarbans, West Bengal, India and collection spot being marked in red

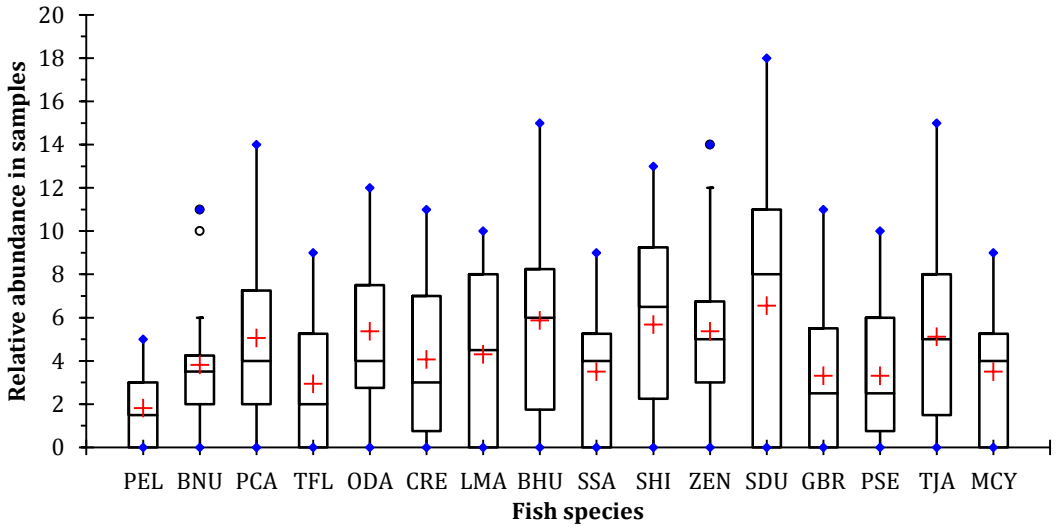

Fig. 2: The relative abundance (mean ± SE) of the discarded fish collected from the different sites of Sundarbans, West Bengal, India in 2016.

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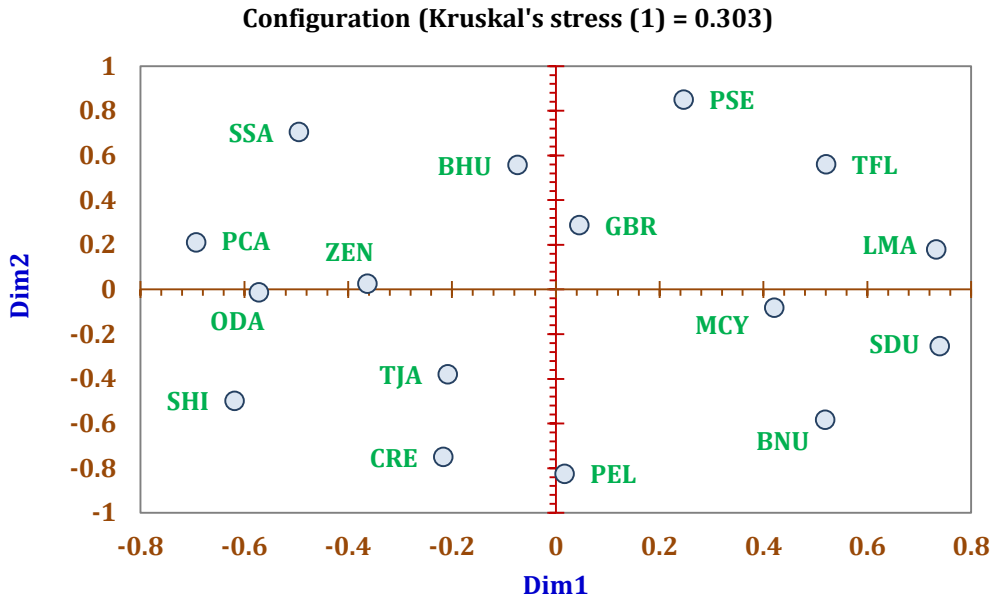

Fig. 3: The variations in the abundances of the bycatch discarded fish species were used as input to deduce the non-metric multidimensional scaling shown in the biplot

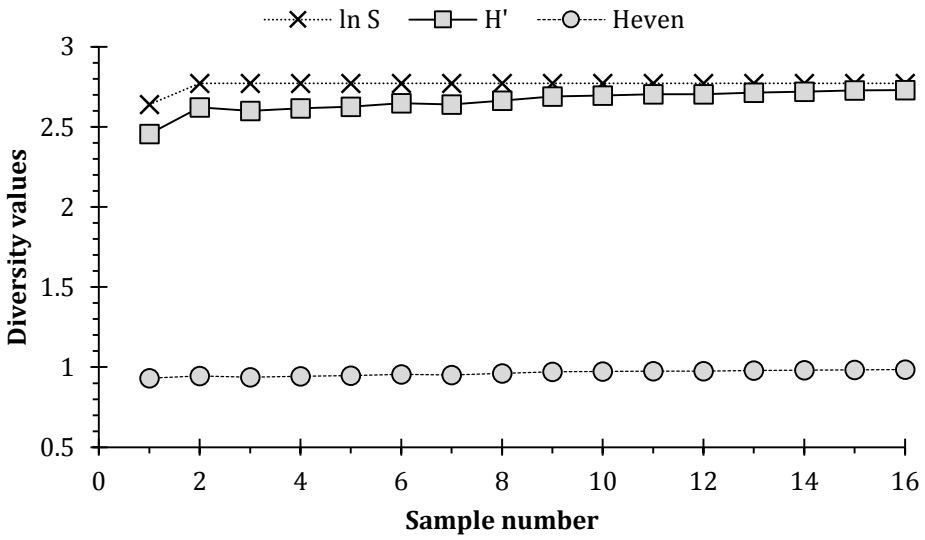

Fig. 4: The results of the diversity analysis (SHE - S-species richness, H- Shannon-Weiner diversity index and E- evenness aspect) of the discarded fish species

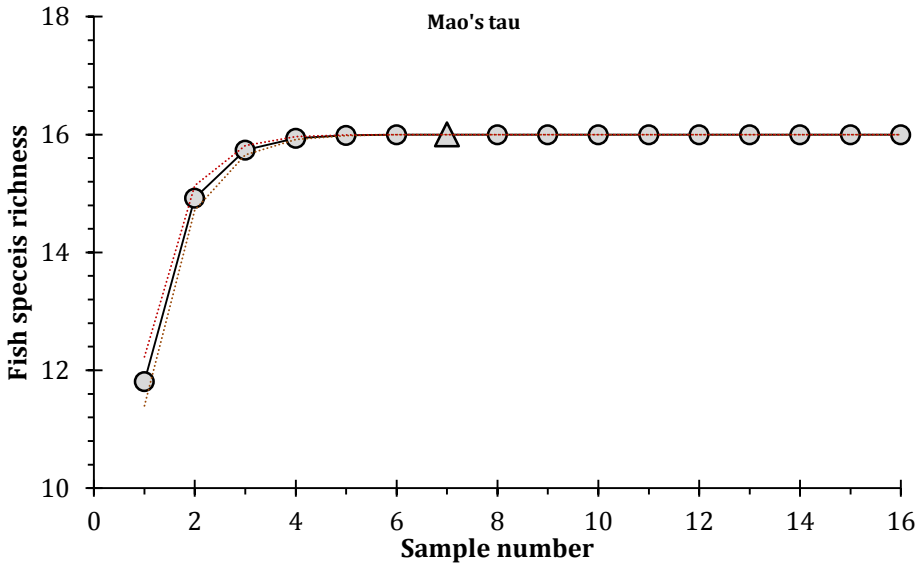

Fig. 5: The rarefaction curve. A rarefaction curve (Mao's Tau) was also constructed based on the available data on abundance and the richness of the fish species in the samples. The triangle in the rarefaction curve shows the 100% saturation of the species richness observed by sample 7

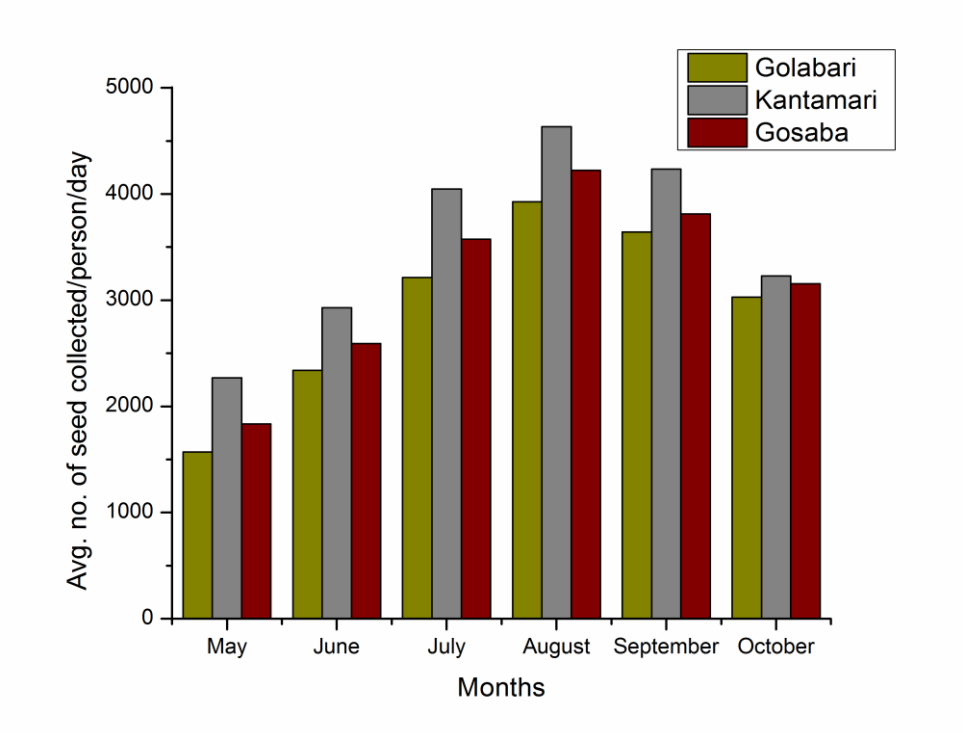

Fig. 6: Monthly variations (May - October) of the average no of seed collection per person per day in 2016

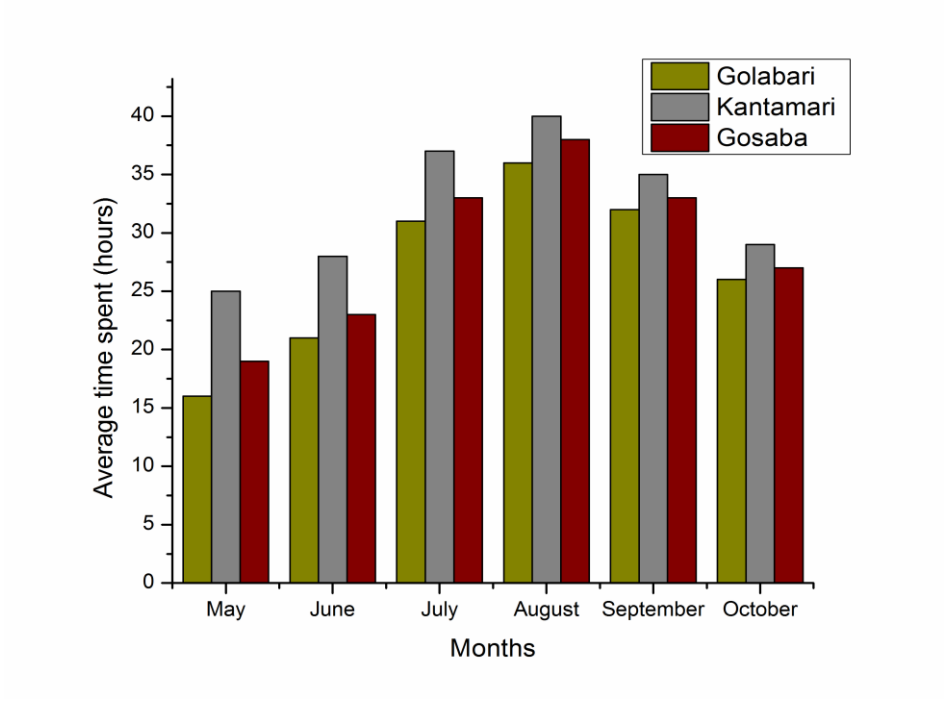

Fig. 7: Monthly variations (May - October) of the average time spent(in hour) at sampling station per person per day in 2016

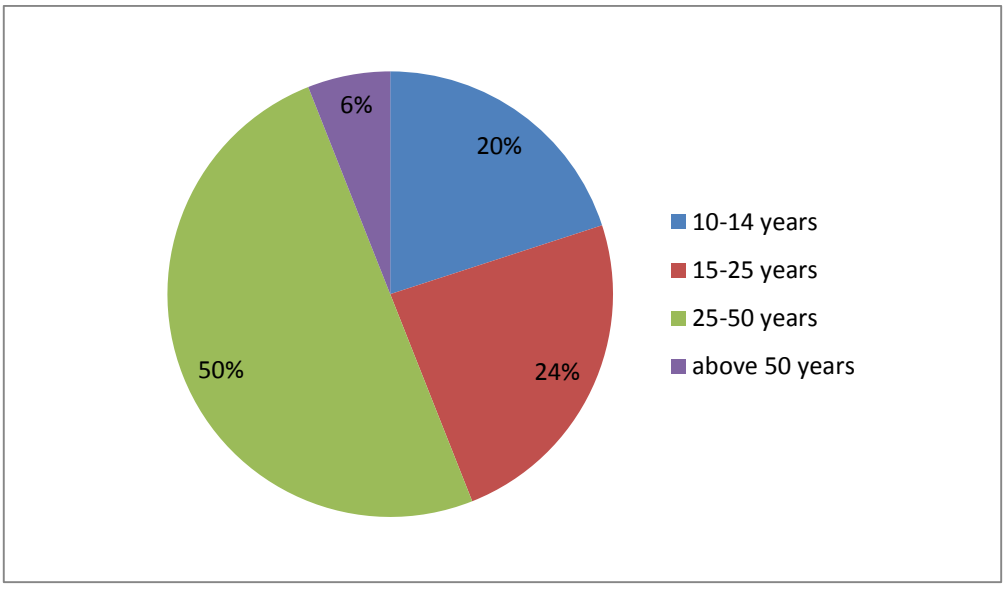

Fig. 8: Age distribution of prawn seed collectors in sampling station after observer and questionnaire survey

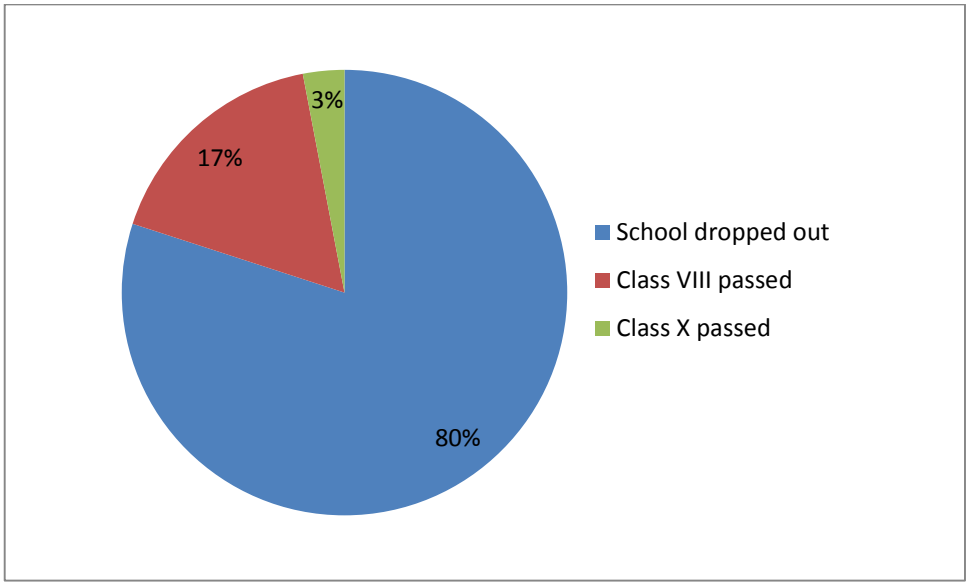

Fig. 9: Educational qualification of prawn seed collectors in sampling station after observer and questionnaire survey