Exploitation pattern of small indigenous fish species: observations from fish markets of rural West Bengal, India

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Abstract. An assessment of the small indigenous fish species (SIS) available in the fish markets was made using selected places of West Bengal, India as the geographical area. Information obtained on the species composition, species diversity and unit price was used as parameters to highlight the exploitation pattern of SIS. As a saleable unit, the SIS was sold as an assortment of multiple species following harvest from the local freshwater wetlands. Samples (n = 117) of assorted SIS from the fish markets revealed considerable variations in the composition (species richness ranging between 2 and 11) and diversity (Shannon-Weiner diversity index ranging between 0.69 and 2.27). Among the total of 28 species of SIS, the numerical dominance of *Amblypharyngodon mola*, *Puntius sophore*, *Chanda nama*, *Parambassis ranga* and *Mystus vittatus* were observed in the samples while *Channa striata*, *Badis badis*, *Macrognathus aculeatus* were observed in least numbers in the samples. The relative abundance of fish species was found to decrease with the increase in species richness in the samples complying with a linear regression equation (Relative abundance (y) = 70.06 - 5.182 x Species richness (x); R^2 = 0.553; r = -0.744; P<0.0001). The unit selling price was related to the abundance in the samples as a logistic regression; price (y) = 1 / (1 + exp (-(1.3 - 0.21 x (x) abundance))), indicating variations in the pricing pattern. Application of the multivariate statistics (principal component analysis) explained >67% variation of the data on the price, species richness, relative abundance and absolute abundance of the SIS in the samples. The observation on the SIS in the market was a pioneer effort to document the variations in the species composition and exploitation pattern of a natural resource. The species composition and the exploitation pattern recorded in the present study was primary but essential information on the ecology and economics of the SIS as a food resource enriched with protein, vitamin and minerals. Further studies should be carried out to monitor the harvest and exploitation pattern of SIS from the concerned geographical area.

Key Words: assorted fish species, fish markets, species diversity, ecological economics, principal component analysis.

Introduction. The small indigenous fish species (SIS) are exploited as a part of capture fisheries in India (Sarkar & Lakra 2010; Baishya et al 2016), Bangladesh and other Asian countries. Although the harvest and availability of SIS vary with the seasons and inland water habitats, consistent presence in the fish markets provide evidence as a preferred food resources in the concerned geographical areas. Apart from the significance in food security, SIS is linked with livelihood as well as valued resource in ornamental fish trade (Gupta & Banerjee 2008a, b; Nandi et al 2013). Many species of SIS are considered as cheap source of minerals and vitamins, apart from the protein content, justifying their inclusion in daily diet (Mazumder et al 2008; Roos et al 2003a, b 2007; Belton & Thilsted 2014; Thilsted et al 2016). Monitoring the harvest pattern and economical aspects of SIS is therefore prioritized, evident from the studies in Bangladesh (Fiedler et al 2016; Thilsted et al 2016), Laos (Nurhasan et al 2010), Vietnam (Dey et al 2008) and Cambodia (Vilain et al 2016).

In Indian context, in comparison to the fish species used in traditional aquaculture, fragmentary information is available on the SIS assemblage in natural habitats (Baishya et al 2016), particularly from West Bengal (Aditya et al 2010; Nandi et al 2013). While the role of SIS as biocontrol agent of mosquito is well established in Indian perspective (Chandra et al 2008; Aditya et al 2012), information on the biology and the exploitation pattern is still to be documented. Considering the multifunctional roles of SIS (Nandi et al 2013), particularly in food security, livelihood and biological control (Aditya et al 2012), the information on the exploitation pattern is essential to assess its value as a natural resource. The paucity of information on the species diversity of the SIS may hinder framing the required strategies for sustainable exploitation of these valued natural resources. Thus an assessment of the diversity, exploitation pattern and pricing of the SIS was made from the fish markets of rural West Bengal, India, as a pioneer effort. Data from the fish markets provide essential information on the demand, supply and pricing (Kumar et al 2006; Dey et al 2008; Nunoo et al 2009; Hamerlynck et al 2011; Aktar et al 2013) of the concerned species qualifying as SIS. As a consequence, the resource value of a fish species can be deciphered with emphasis on the exploitation pattern. Thus the results, though primary, would provide the required information on the ecological economics of the SIS at the local scale. A comparison on the pattern of exploitation made in similar geographical areas (Belton and Thilsted 2014; Thilsted et al 2016) can be made so as to infer about the variability of the resource value of SIS.

Material and Method. Selected fish markets of the rural areas of Birbhum (23.646235N, 87.704745E), Burdwan (23.487453N, 87.733108E), Hooghly (23.046164N, 88.317850E) and Howrah (22.523829, 87.901922) districts of West Bengal, India were considered as focal study sites. The vendors selling the small indigenous fish species (SIS) in assortment of multiple species were selected and 200 g of fish samples were purchased at the selling price (in Indian Rupee). Generally, the fishes (SIS) were sold in assorted form of multiple species and thus each sample included multiple fish species in varied proportions. While purchasing the samples, the fish species were pooled at random and collected without bias so as to ensure that all the fish species (richness) are included in the samples in equal proportion (relative abundance) as sold by the vendor. The data on the relative and total abundance in a sample of 200 g of SIS, the species richness, and the unit selling price of the SIS were recorded from multiple vendors from 25 different fish markets during the monsoon periods (July to October) between 2013 and 2015. In all instances, the fish samples were collected from different vendors and in different dates such that the samples qualify as true replicates (Hurlbert 1984). The repeated collections from the fish markets were also made to incorporate the variations in the species composition over time. Following purchase of the fish samples, these were brought to the laboratory and segregated according to species following suitable keys (Jayaram 1981; Talwar & Jhingran 1991; Khanna & Singh 2003) and internet resources (Froese & Pauly 2016). For each SIS sample, the data on the selling price (in INR/kg) the species richness (number of fish species) and relative abundance (numbers of each fish species) was recorded along with the relative biomass of the individuals (unit weight = total abundance/200 g) in the sample of 200 g. In all instances, SIS samples were purchased from fish vendors selling assortment of multiple species as a unit. The data for the fish species were presented as proportion in the assorted sample: n_i/N, where n_i is the abundance of the ith fish species out of the total number of fish (N) in the sample (where total samples = 117). Occurrence of the fish species is presented as number of positive samples with the ith fish species out of the total number of samples (n = 117).

Using the data on the richness and abundance of the fish species, Shannon-Weiner diversity index (H'), maximum diversity value (H_{max}) and evenness (H_{even}) values (Magurran 2004) were estimated for each sample (n = 117). A relation between the relative abundance and the species richness of SIS in the samples was estimated through regression equation (Zar 1999). The proportional abundance and occurrence were used as surrogate to highlight the contribution of each species to the SIS samples. Using a logistic regression (binomial generalized linear model with logit link) the relation between abundance and the diversity (Shannon-Weiner index H') was established for the samples. The logistic regression was of the form: $(y) = 1/(1+ \exp(-(a + b_1x_1)))$, where, y is the dependent variable (species diversity H') and x1 is the explanatory variable (total abundance of assorted SIS). In this regression model, species diversity (relative to Hmax, lnS) of SIS in samples was assumed to follow the binomial distribution (n, p) with n replicates (samples of SIS) for each level of abundance of SIS (explanatory variable). The probability parameter p represents the linear combination of the abundance of SIS in the samples (explanatory variable). Thus the ecological parameter was considered in the form of species composition and the diversity of SIS in the samples while the unit price (initial observation on price per unit kg, in INR) was used to identify the economic value of the SIS as a food resource. In all instances, the relative value of the price was used in the form of standardized price, which was: (Price in INR of a sample/maximum price in INR) x 100, to avoid the unit (currency, INR) in the analysis. Further, owing to the variations in the price and the inflation during the time period of study, the currency of the price was avoided. A logistic regression was applied to relate the total fish abundance in the samples with the unit selling price (standardized price). A multivariate analysis (Principal Component Analysis) (Manly 1994; Legendre & Legendre 1998) was applied (following varimax rotation with Kaiser normalization) using the unit selling price, species richness, unit biomass of a fish, relative abundance and absolute abundance of SIS as input variables to reduce the redundancy of the data and portray the relation of the variables considered in the study. The result of PCA was interpreted in terms of the variations explained by the extracted factors, factor loading of the variables and the correlations among the original variables. All the analyses were carried out in licensed copy of XLSTAT software (Addinsoft 2010).

Results. A total of 28 species of small indigenous fish species (SIS) were encountered with different species composition in the assorted samples sold by the vendors. Among the consistent 22 fish species, *Amblypharyngodon mola*, *Punitus sophore*, *Chanda nama*, *Parambassis ranga* and *Mystus vittatus* were more common than other fish species, revealed from proportional abundance and the occurrence in the samples (Table 1). In only two occasions, *Neotropius atherinoides* (Bloch, 1794) (Siluriformes: Schilbeidae), *Nandus nandus* (Hamilton, 1822) (Perciformes: Nandidae), *Anabas testudineus* (Bloch, 1792) (Perciformes: Anabantidae), the fish species *Xenentodon cancila* (Hamilton, 1822) (Beloniformes: Belonidae), juveniles of *Clarias batrachus* (Linnaeus, 1758) (Siluriformes: Clariidae) and *Heteropneustes fossilis* (Bloch, 1794) (Siluriformes: Heteropneustidae) were observed in the assorted samples. Since these species were present in single or two individuals in a total of five samples, these were restricted from the analysis. Information from the fish vendors indicated that the fish species were harvested from the canals and associated wetlands of the concerned fish markets using the indigenous fishing gears. Apart from the small indigenous fish species, the catches included varied numbers of prawns and snails which were sold separately with different price tags.

In a sample of 200 g, the total abundance (n), ranged between 82 and 359 (mean 215±5.16 individuals), relative abundance (ni), ranged between 13.5 and 90 (mean 34.89±1.3 individuals/species), species richness ranged between 2 and 11 (mean 6.78±0.19) biomass of individual fish (in nearest gm) ranged between 0.44 and 2.44 (mean 1.00±0.03), and fish species diversity (H') ranged between 0.69 and 2.26 (mean 2.10±0.03) for the selling price (INR/ kg) ranging between Rs. 52 and Rs. 130 (Rs. 90.5±1.96). The abundance of the fish individuals (explanatory variable) in the samples was determinant of price (dependent variable) as expressed through a logistic regression: price = 1 / (1 + exp (-(1.3 - 0.21 x abundance))), with the parameters of the model being significant at $P<0.001$ level (intercept = 1.302±0.06; Wald's chi square = 549.027; abundance = -0.214±0.024; Wald's chi square = 82.264). The relative abundance of the SIS was found to be negatively correlated with the species richness in the samples. Thus a decreased relative abundance would mean higher species richness in the samples (Figure 1).

Table 1

The species of small indigenous fish (SIS) observed in the fish markets of West Bengal, India, between 2013 and 2015, along with the relative proportions (mean±SE) and the occurrence in the samples (positive number of samples for the concerned species)

No.	*Specification*	*Proportion in samples*	*Occurrence in samples*
	Family- Cyprinidae		
1	*Puntius sophore* (Hamilton, 1822)	0.16±0.012	0.932
2	*Puntius terio* (Hamilton, 1822)	0.02±0.004	0.274
3	*Pethia ticto* (Hamilton, 1822)	0.03±0.004	0.41
4	*Pethia phutunio* (Hamilton, 1822)	0.02±0.004	0.291
5	*Amblypharyngodon mola* (Hamilton, 1822)	0.33±0.019	0.906
6	*Esomus danrica* (Hamilton, 1822)	0.03±0.005	0.342
7	*Laubuka fasciata* (Silas, 1958)	0.03±0.006	0.333
8	*Laubuka laubuca* (Hamilton, 1822)	0.001±0.001	0.043
	Family- Aplocheilidae		
9	*Aplocheilus panchax* (Hamilton, 1822)	0.03±0.005	0.316
	Family- Ambassidae		
10	*Chanda nama* (Hamilton, 1822)	0.11±0.012	0.564
11	*Parambassis ranga* (Hamilton, 1822)	0.11±0.013	0.59
	Family- Osphronemidae		
12	*Trichogaster fasciata* (Bloch & Schneider, 1801)	0.03±0.005	0.359
13	*Trichogaster lalius* (Hamilton, 1822)	0.01±0.002	0.205
	Family- Bagridae		
14	*Mystus vittatus* (Bloch, 1794)	0.06±0.008	0.521
15	*Mystus tengara* (Hamilton, 1822)	0.01±0.003	0.085
	Family- Mastacembelidae		
16	*Macrognathus pancalus* (Hamilton, 1822)	0.001±0.001	0.085
17	*Macrognathus aculeatus* (Bloch, 1786)	0.002±0.001	0.017
	Family- Gobiidae		
18	*Glossogobius giuris* (Hamilton, 1822)	0.03±0.006	0.419
	Family- Cobitidae		
19	*Lepidocephalichthys guntea* (Hamilton, 1822)	0.003±0.002	0.034
	Family- Badidae		
20	*Badis badis* (Hamilton, 1822)	0.001±0.0001	0.077
	Family- Channidae		
21	*Channa punctata* (Bloch, 1793)	0.002±0.001	0.103
22	*Channa striata* (Bloch, 1793)	0.0002±0.0001	0.023

n - 117 samples. In addition to these species 3 more species were encountered in single numbers in the samples.

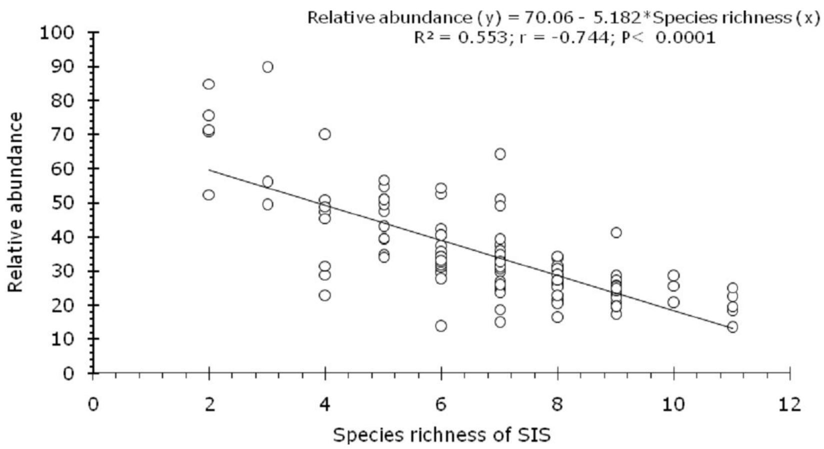

Figure 1. The relationship between the relative abundance and species richness in the samples of assorted SIS observed in the fish markets of West Bengal, India during 2013 and 2015 (n = 117 samples). The coefficient of correlation and the regression equations are shown in the figure.

The Shannon-Weiner species diversity index (H'), evenness value (H_{even}) and the H_{max} values obtained for each sample are shown in Figure 2, arranged in accordance with the higher species richness in the samples of assorted SIS. The H' value was related to the abundance of the fish in the samples as: H' = 1 / (1 + exp (-(-0.93 + 1.16 x abundance))) with one the parameters of the model being significant (intercept = -0.93±0.66; Wald's chi square = 1.973; N.S.; abundance 1.164±0.34; Wald's chi square = 11.718; P<0.001).

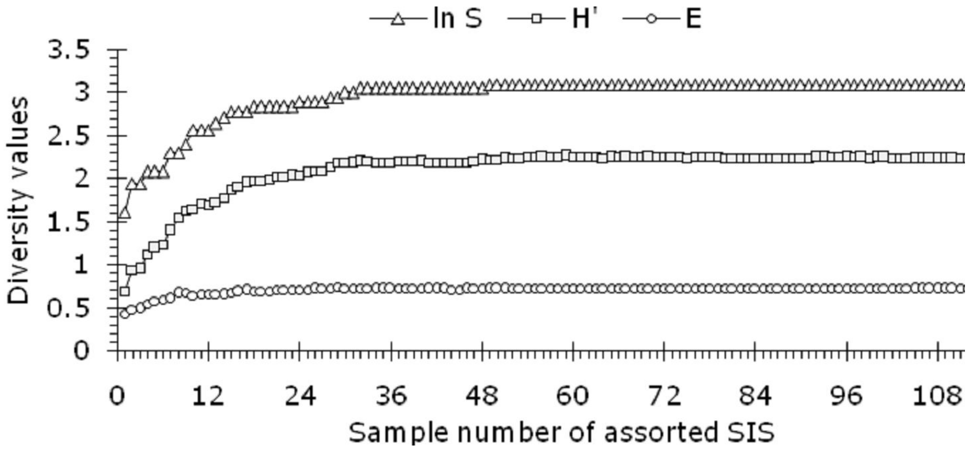

Figure 2. The Shannon-Weiner species diversity indices for the samples of assorted SIS from fish markets of West Bengal, India during 2013 and 2015. lnS - H_{max}, H'- observed value of Shannon-Weiner species diversity index, E- Heven, evenness component of the diversity index (H'/H_{even}) (n = 117 samples).

The mean H' value was however higher with the higher abundance of fish in the samples (Figure 3), indicating that the relative abundance and the richness of the SIS increased with the total abundance.

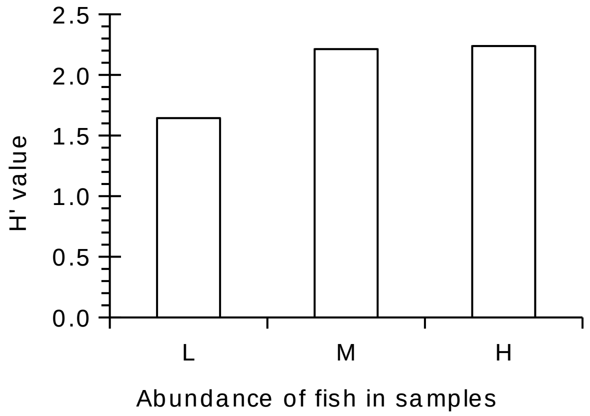

Figure 3. The Shannon-Weiner diversity index (H') against the abundance of fish in the assorted SIS samples from the fish markets of West Bengal, India. L – low abundance; 100-175 individuals/200 g; M- medium abundance; 176–250 individuals/200 g; H- high abundance; 251–325 individuals/200 g; samples below 100 and above 325 were not considered in the analysis. (n = 96 samples) (SE for M and H less than 0.02).

Application of the principal component analysis yielded six factors with the first two factors with the eigen values greater than 1, explaining >67% of variations in the data. The significant value of the Bartlett's sphericity test (Chi square = 437.18; df =15; P<0.0001) justifies the application of the PCA with the communalities of the variables being greater than 0.05 and the anti image correlation being significant for all the variable combinations. The correlation matrix and the factor loading are provided in Table

2, which indicates that the total abundance of SIS in the samples and the relative biomass contributed to factor 1, while the relative abundance and species richness contributed to the factor 2. The selling price and the diversity value contributed to the factor 3.

Table 2

The results of the principal component analysis (PCA) applied on the data on the species richness (SR), total abundance (TA), relative abundance (RA), relative biomass (RB), diversity index (H'), and the selling price (SP) of the fish samples consisting of assortment of multiple SIS observed in the fish markets of West Bengal, India

(a) Correlation matrix					
Variables	*SP*	*SR*	*RA*	*RB*	*H'*
TA	-0.105	0.262	0.309	-0.891	-0.129
SP		-0.070	0.042	0.100	0.421
SR			-0.744	-0.312	0.241
RA				-0.232	-0.326
RB					0.176

(b) Variations explained by the extracted factors			
	F1	*F2*	*F3*
Eigen value	2.174	1.893	1.262
Variability (%)	36.241	31.553	21.034
Cumulative %	36.241	67.794	88.829

(c) Factor loadings			
Variables	*F1*	*F2*	*F3*
TA	*0.894*	0.299	0.235
SP	-0.311	0.020	*0.846*
SR	0.030	*0.957*	-0.161
RA	0.514	*-0.760*	0.323
RB	*-0.886*	-0.347	-0.186
H'	-0.478	0.434	*0.571*

The results appear in sequence as: (a) correlation matrix of the variables; (b) variability explained by the extracted factors (F) with Eigen values greater than 1; and (c) the factor loading of the input variables. Values in bold indicate significance at P<0.001 level.

As shown in Figure 4, the relationship of the variables being aptly portrayed in the biplot obtained following varimax rotation with Kaiser normalization to redefine the relation of the variables and fit against the corresponding axis of the biplot. The results therefore suggests that considerable variations in the diversity of the species constituting the samples of assorted SIS available in the markets with corresponding variations in the price.

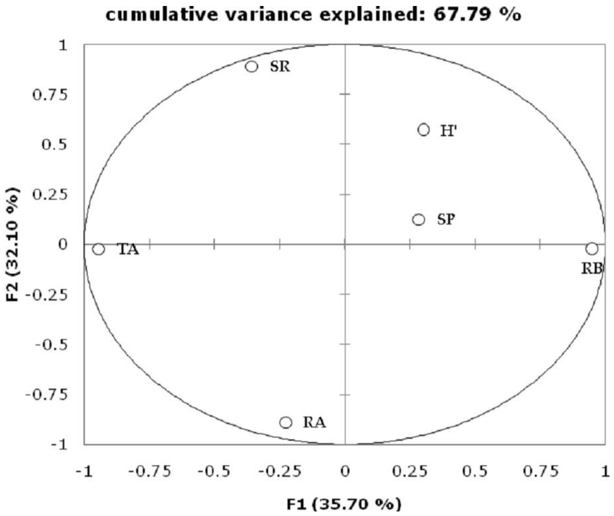

Figure 4. The bi-plot showing the ordination of the input variables used to characterize the fish samples consisting of multiple different SIS observed from the rural fish markets of West Bengal, India. The two axes correspond to the two extracted factors (F1-x axis and F2 – y axis).

Discussion. Fish constitutes a major food resource meeting the demand of the dietary protein requirements and thus forms a key and valuable entity in aquaculture. Traditional aquaculture, particular in Asian countries including India, utilizes limited number of fish species that are mostly favored for the productivity and economic return (Kumar et al 2006; de Silva 2008; Naylor 2016). Intensive aquaculture and breeding of the fish species leads to the loss of the genetic features of these fish species apart from being limited in meeting the market demand (de Silva 2008). Under such context, the small indigenous fish species play a major role in supplementing the dietary protein requirements of many people in Asian countries (Thilsted et al 2016). Many of the species qualifying as small indigenous fish species are common species with wide range of distribution in Indian subcontinent (Hossain et al 2015; Aditya et al 2010; Sarkar & Lakra 2010; Biashya et al 2016; Thilsted et al 2016). Commonly available in the freshwater wetlands of varied types including the rice fields and allied trap ponds (Aditya et al 2010), the SIS are harvested as a part of the capture fisheries using traditional fishing gears. Although incorporation of few species of SIS in polyculture with carps has been promising in yielding the desired productivity level, still, the generalized view of culture of SIS is not promoted. Thus the SIS still continues to be a part of the culture fisheries in the concerned geographical area.

The exploitation of the SIS as a part of the culture fisheries warrants monitoring of the harvest pattern of the constituent fish species so as to frame strategies for sustainable use of the fish species. As observed in the present study, at least 22 fish species are exploited in varied proportion and composition as a food resource. Among the fish species, dominance of *P. sophore*, *A. mola*, *A. nama*, *P. ranga* and *E. danrica* was observed with their presence in almost all the possible combinations of the fish species sold in the markets. Empirical studies suggest that these species are common to abundant in the rice fields (Aditya et al 2010, 2012), beels (lake-like wetland with static water) (Mondal & Kaviraj 2013) and rivers (Baishya et al 2016) in eastern India and are being promoted for their use in rice fish culture (Baruah et al 2000). As a saleable unit the species composition and the size class of the individual species varied considerably even with the dominance of few species. Consistent availability, though in relative low proportion was characteristics of many species like *E. danrica*, *C. fasciata*, *T. lalius* and *G. giuris*, in addition to other dominant species. Perhaps the variations in the relative abundance of the fish species in the concerned habitat is reflected through the differences in the proportional presence and occurrence in the fish samples. Alternatively the differential catchability of the fishing gears might be a reason for the variation in the relative abundance of the fish species in the harvest. A possibility of sampling error may also have lead to the differences, though the consistent presence in the samples defines the total number of fish species harvested from the area. At a regional scale the differences in the species composition of the SIS is observed when the riverine community is compared with the rice field community. Since the study was mostly restricted around the central districts of West Bengal, India, a prospective deviation in the species composition can be expected when compared with the species assemblages in other parts of India (Dahanukar et al 2004) and Bangladesh (Hossain et al 2015). Nonetheless, the present study documents as a pioneer effort the exploitation of the SIS as a food resource in rural west Bengal, India.

Inland water capture fisheries supplement a wide range of fish for the consumers though fish species diversity of the riverine systems are highlighted, leaving the information gap on the small indigenous fish species that are considered of little value in terms of traditional aquaculture. Wetlands including rice fields and associated trap ponds are considered as a major source of the SIS, with considerable work on the availability, marketability, consumption pattern and resource value are recorded from different parts regions of India (Baruah et al 2000; Barman 2007; Aditya et al 2010) and Bangladesh (Kohinoor et al 2005; Mazumdar et al 2008; Kunda et al 2008; Fiedler et al 2016). The nutrient content particularly vitamins and the minerals add to the resource value of the SIS and are being promoted for the consumption by the rural poor (Roos et al 2003a, b; Ross et al 2007a, b; Belton & Thilsted 2014; Thilsted et al 2016). Thus the exploitation of the SIS is a sustainable way to meet the dietary protein, vitamin and the mineral requirements by the people, who may be constrained from the purchase of fish from traditional aquaculture. However, surveillance of the harvest pattern is required to justify the sustainable use of the fish species in proportion to their availability in the natural water bodies (Kolding et al 2016). Preference for one or more species against others may lead to overexploitation and reduce the availability at the local scale, which is a concern in view of the multifunctional role of the SIS. Further studies may also be carried out to identify the differences in the species specific consumption pattern and the preferences among the consumers so as to incorporate the SIS in diversifying aquaculture programmes.

Conclusions. The present commentary portrays the exploitation pattern of SIS, from selected fish markets of rural West Bengal, India. At least 28 fish species including *A. mola*, *P. sophore*, *C. nama*, *P. ranga*, *M. vittatus*, and *E. danrica*, are sold in varied composition and proportions in assortment of multiple species. Species richness of SIS in samples was a negative function of the abundance in a particular sample, while the price was an increasing function of the total abundance and positively correlated with the diversity index. As a primary effort the present document validates the marketability of SIS as a food resource in rural West Bengal, though species specific availability and harvest pattern should be judged further. Considering the significance of the SIS as a cheap source of protein, vitamin and minerals, the harvest pattern should be monitored to ensure sustainable exploitation in the concerned geographical area.

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References

Aditya G., Pal S., Saha G. K., 2010 An assessment of fish species assemblages in rice fields in West Bengal, India: implications for management. Journal of Applied Ichthyology 26:535–539.

Aditya G., Pal S., Saha N., Saha G. K., 2012 Efficacy of indigenous larvivorous fishes against Culex quinquefasciatus in the presence of alternative prey: Implications for biological control. Journal of Vector Borne Diseases 49:217–225.

Aktar N., Islam M. R., Hossain M. B., Rahman M., 2013 Fish species availability and marketing system of fish in different markets of noakhali district in Bangladesh. World Applied Sciences Journal 22(5):616–624.

Baishya R. A., BAsumatary S., Kalita H. K., Talukdar B., Dutta A., Sarma D., 2016 Present status and diversity of small indigenous fish species (SIS) in the upper reaches of river Brahmaputra, in Assam, north-eastern India. Indian Journal of Fisheries 63(1):1–7.

Barman R. P., 2007 A review of the freshwater fish fauna of West Bengal, India with suggestions for conservation of the threatened and endemic species. Records of Zoological Survey of India, occasional paper no. 263:1–48.

Baruah U. K., Bhagowatp A. K., Talikdar R. K., 2000 Prospects of fish farming in ricefields in Assam. Indian Journal of Fisheries 47(2):149–153.

Belton B., Thilsted S. H., 2014 Fisheries in transition: food and nutrition security implications in the global South. Global Food Security 3:59–66.

Chandra G., Bhattacharjee I., Chatterjee S. N., Ghosh A., 2008 Mosquito control by larvivorous fish. Indian Journal of Medical Research 127:13-27.

Dahanukar N., Raut R., Bhat A., 2004 Distribution, endemism and threat status of freshwater fishes in the Western Ghats of India. Journal of Biogeography 31:123–136.

De Silva S. S., 2008 Market chains of non-high value cultured aquatic commodities: case studies from Asia. FAO Fisheries and Aquaculture Circular No. 1032. Rome, FAO. 46 p.

Dey M. M., Yolanda T., Garcia Y. T., Kumar P., Piumsombun S., Haque M. S., Li L., Radam A., Senaratne A., Khiem N. T., Koeshendrajana S., 2008 Demand for fish in Asia: a cross-country analysis. Australian Journal of Agricultural and Resource Economics 52:321–338.

Fiedler J. L., Lividini K., Drummond E., Thilsted S. H., 2016 Strengthening the contribution of aquaculture to food and nutrition security: The potential of a vitamin A- rich, small fish in Bangladesh. Aquaculture 452(2016):291–304.

Froese R., Pauly D., 2016 FishBase. World Wide Web electronic publication. www.fishbase.org, version (10/2016).

Gupta S., Banerjee S., 2008a Ornamental fish trade in West Bengal. Fishing Chimes 28:25–27.

Gupta S., Banerjee S., 2008b Survey on the indigenous ornamental fish species in Kolkata markets. Proceedings of the Zoological Society 61:33–38.

Hamerlynck O., Duvail S., Vandepitte L., Kindinda K., Nyingi D. W., Paul J., Yanda P. Z., Mwakalinga A. B., Mgaya Y. D., Snoeks J., 2011 To connect or not to connect? Floods, fisheries and livelihoods in the lower Rufiji floodplain lakes, Tanzania. Hydrological Sciences Journal 56(8):1436–1451.

Hossain M. A., Abdulla-Al-Asif, Zafar M. A., Hossain M. T., Alam M. S., Islam M. A., 2015 Marketing of fish and fishery products in Dinajpur and livelihoods of the fish retailers. International Journal of Fisheries and Aquatic Studies 3(1):86–92.

Hurlbert S. H., 1984 Pseudoreplication and the design of ecological field experiments. Ecological Monograph 54(2):187–211.

Jayaram K. C., 1981 The freshwater fishes of India, Pakistan, Bangladesh, Burma, and Sri Lanka - a handbook. Zoological Survey of India, Calcutta, 475 pp.

Khanna S. S., Singh H. R., 2003 A text book of fish biology and fisheries. Delhi, Narendra Publishing House, xv+ 524 pp.

Kohinoor A. H. M., Hasan M. A., Thilsted S. H., Wahab M. A., 2005 Culture of small indigenous fish species (SIS) with Indian major carps under semi-intensive culture system. Indian Journal of Fisheries 52(1):23–31.

Kolding J., Jacobsen N. S., Andersen K. H., van Zwieten P. A. M., 2016 Maximizing fisheries yields while maintaining community structure. Canadian Journal of Fisheries and Aquatic Sciences 73:644–655.

Kumar P., Dey M. M., Paraguas F. J., 2006 Fish supply projections by production environments and species types in India. Agricultural Economics Research Review 19:327-351.

Kunda M., Azim M. E., Wahab M. A., Dewan S., Roos N., Thilsted S. H., 2008 Potential of mixed culture of freshwater prawn (*Macrobrachium rosenbergii*) and self recruiting small species mola (*Amblypharyngodon mola*) in rotational rice-fish/ prawn culture systems in Bangladesh. Aquaculture Research 39:506–517.

Legendre P., Legendre L., 1998 Numerical ecology. Second English edition, Elsevier Science BV, Amsterdam ,853 pp.

Magurran A. E., 2004 Measuring biological diversity. Oxford: Blackwell Science, 256 pp.

Manly B. F. J., 1994 Multivariate statistical methods: a primer. 2nd edition, London, Chapman & Hall.

Mazumder M. S. A., Rahman M. M., Ahmed A. T. A., Begum M., Hossain M. A., 2008 Proximate composition of some small indigenous fish species (sis) in Bangladesh. International Journal of Sustainable Crop Production 3(3):18–23.

Mondal D. K., Kaviraj A., 2013 Feeding and reproductive biology of *Amblypharyngodon mola* (Cypriniformes: Cyprinidae) from two floodplain lakes of India. International Journal of Aquatic Biology 1:125–131.

Nandi S., Majumder S., Saikia S.K., 2013 Small freshwater fish species (SFFS) culture: issues from nutrient security, Carp-SFF integration and feeding ecology. Reviews in Fish Biology and Fisheries 23:283–291.

Naylor R. L., 2016 Oil crops, aquaculture, and the rising role of demand: A fresh perspective on food security. Global Food Security 11:17–25.

Nunoo F. K. E., Boateng J. O., Ahulu A. M., Agyekum K. A., Sumaila U. R., 2009 When trash fish is treasure: The case of Ghana in West Africa. Fisheries Research 96:167−172.
Nurhasan M., Maehre H. K., Malde M. K., Stormo S. K., Halwart M., James D., Elvevoll E. O., 2010 Nutritional composition of aquatic species in Laotian rice field ecosystems. Journal of Food Composition and Analysis 23:205–213.
Roos N., Islam M. M., Thilsted S. H., 2003a Small indigenous fish species in Bangladesh: contribution to vitamin A, calcium and iron intakes. Journal of Nutrition 133(11 suppl 2):40215–40265.
Roos N., Islam M. M., Thilsted S. H., 2003b Small fish is an important dietary source of vitamin A and calcium in rural Bangladesh. International Journal of Food Sciences and Nutrition 54(5):329–339.
Roos N., Wahab M. A., Chamnan C., Thilsted S. H., 2007a The role of fish in food based strategies to combat vitamin A and mineral deficiencies in developing countries. Journal of Nutrition 137(4):1106–1109.
Roos N., Waheb M. A., Hossain M. A., Thilsted S. H., 2007b Linking human nutrition and fisheries: incorporating micronutrient dense, small indigenous fish species in carp polyculture production in Bangladesh. Food and Nutrition Bulletin 28(2 suppl):s280–s293.
Sarkar U. K., Lakra W. S., 2010 Life history traits of freshwater fish population and implications on aquatic biodiversity conservation: a review. The Indian Journal of Animal Sciences 80(4) (Suppl.1):85−97.
Talwar P. K., Jhingran A. G., 1991 Inland fishes of India and adjacent countries. Vol. I and II. Oxford and IBH Publishing Co. Pvt. Ltd , New Delhi, India. Vol. I 541p & Vol. II 1158 pp.
Thilsted S. H., Thorne-Lyman A., Webb P., Bogard J. R., Subhasinghe R., Phillips M. J., Allison E. H., 2016 Sustaining healthy diets: the role of capture fisheries and aquaculture for improving nutrition in the post – 2015 era. Food Policy 61:126–131.
Vilain C., Baran E., Gallego G., Samadee S., 2016 Fish and the nutrition of rural Cambodians. Asian Journal of Agriculture and Food Sciences 4(01):26–34.
Zar J. H., 1999 Biostatistical analysis. IV edtion, Pearson Education (Singapore) Pte. Ltd., (Indian Branch), New Delhi, India, 663 pp.
*** Addinsoft SARL, 2010 XLSTAT software, version 9.0. Addinsoft, Paris, France.

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