Ekológia (Bratislava) - Journal of the Institute of Landscape Ecology, Slovak Academy of Sciences Vol. 44, No. 1, p. 46–51, 2025
DOI:10.2478/eko-2025-0006

EXPLOITATION PATTERN OF EDIBLE INDIGENOUS MACROPHYTES IN RURAL WEST BENGAL, INDIA: IMPLICATIONS FOR SUSTAINABLE MANAGEMENT

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Received: 7 September 2024 / **Accepted:** 21 February 2025

Abstract

Rahaman Sk H., Chakraborty A., Saha D., Chakraborty J., Aditya G.: Exploitation pattern of edible indigenous macrophytes in rural west Bengal, India: implications for sustainable management. Ekológia (Bratislava), Vol. 44, No. 1, p. 46–51, 2025.

The market survey of edible indigenous macrophytes (EIM) is a feasible way to follow the abundance, composition, and availability of different macrophyte species and to figure out the exploitation pattern of a natural resource for sustainable management. The present study was carried out to address the exploitation pattern of EIM following certain parameters like species diversity, market availability, and unit price. The survey was conducted between March 2012 and February 2016 at selected vegetable markets in different districts of West Bengal, India. A total of EIMsix EIM species were mostly sold by vendors all over the markets, which were prioritizedto assess the exploitation, sustainable use, and their conservation management. Considering the bundles as a saleable unit for each EIM species, *Marsilea quadrifolia* (mean 851.1 ± 116.6) and *Hygrophila spinosa* (mean 34.89 ± 1.65) contained the highest and lowest number of sticks per bundle. The mean biomass of EIM bundles available in markets was maximum for *Marsilea quadrifolia* (280 ± 40.96 g) and least for *Centella asiatica* (41.41 ± 2.80 g). The mean price (INR) per bundle was maximum in *Marsilea quadrifolia* (7 ± 0.81 INR/bundle), while *Hygrophila spinosa* (3.01 ± 0.14 INR/bundle) was retailed at the least price. The estimated standardized price (selling price/maximum selling price) per gram was highest for *Centella asiatica* (0.10±0.01 INR/g), and the standardized price per stick was maximum in *Hygrophila spinosa* (0.10±0.00 INR/stick). The findings of the study highlight the market price, market availability, and exploitation pattern of edible macrophytes in vegetable markets of rural West Bengal, India, and reflect their significance in food security and livelihood.

Key words: edible macrophytes, market observations, economic value, conservation management.

Introduction

Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. Sustenance of biodiversity, amelioration of water quality, flood abatement, and carbon management are recognized as fundamental ecosystem services provided by wetlands. A considerable variety of fish, molluscs, crustaceans, and macrophytes are harvested from wetlands as food around the world (Silvius et al., 2000; Roos et al., 2003; Heino, Toivonen, 2008). Sustenance of useful harvests and valued functions of wetlands requires the conservation and protection of wetlands (Zedler, Kercher, 2005). As a result, food security and livelihood can be maintained for many communities depending directly or indirectly on wetlands (Fisher et al., 1943; Bostock et al., 2010; Murshed et al., 2010). Lack of sufficient effort to conserve and manage wetland resourcesmay impact food security and the survival of the population dependent on wetlands. Thus, to safeguard ecosystem services derived from wetlands, appropriate planning and management is a prerequisite. Region-specific assessment and monitoring of resource use is, therefore, justified to promote sustainability and human well-being (Costanza et al., 1989, 1997; Schuijt, Brander, 2004).

In South and Southeast Asian countries, a substantial amount of edible indigenous macrophytes (EIMs)is harvested from wetlands for food and livelihood (Gichuki et al., 2001; Ziv et al., 2012). Several species of EIMs are used as dietary supplements, fodder food, and bear medicinal values (Cook, 1996; Gichuki et al., 2001; Jain et al., 2011; Panda, Misra, 2011). The diversity of EIMs in wetlands indicates their potential toward food security (Akpaniteaku et al., 2005; Allison, 2011) and the livelihood of local populations of different countries (Zedler, 2003; Friend, 2007; Maclean et al., 2003; Gichuki et al., 2001; Jain et al., 2011). The nutritional value of wetland macrophytes in terms of cheap sources of protein, vitamins, and minerals is being recognized to a great extent (Mazumder et al., 2008; Jain et al., 2011; Swapna et al., 2011). Empirical studies on the dynamics of demand and supply of wetland living resources indicate a promising role in poverty alleviation apart from food security for the vast majority of the population (E-Jahan et al., 2010). In view of the sustainability of wetland ecosystem services, the present study explores the utilization pattern of EIM species of wetland origin using three selected districts of West Bengal, India as geographic areas. Assessment of the utilization pattern of resources provides key information in understanding the demands and supply of the resource and framing policies for sustainability.

Different species of wetland macrophytes are exploited for horticulture, food, and medicine (Jain et al., 2011; Sarma, Saikia, 2010; Panda, Misra, 2011). However, information on their harvesting and marketing has little been explored, except for a few species (Jain et al., 2004, 2010). Therefore, observation of the exploitation pattern of EIMs will help to design strategies for effective management. Theoretical and empirical studies substantiate that different communities depend on wetland macrophytes to supplement nutritional requirements and livelihood (Mandal, Mukherjee, 2010; Jain et al., 2004, 2007, 2011; Sarma, Saikia, 2010; Panda, Misra, 2011). Still, information on the extent of exploitation is lacking to standardize the strategies for integrating macrophytes in aquaculture practices. In compliance with the goals of preserving wetland ecosystem services and a sustainable economy, documentation of the present exploitation pattern of wetland resources is obligatory. Considering India and West Bengal in particular, sporadic studies document the diversity of macrophytes (Panda et al., 2009; Mandal, Mukherjee, 2010). While the relevance of macrophytes in the subsistence of local communities is justified through these studies, factual evidence in deciphering their role in the economy is yet to be established. Compared to the Indian context, extensive studies in Bangladesh (Thilsted et al., 1997; Roos et al., 2007a,b), Vietnam (Ziv et al., 2012), and African countries (Beck, Nesmith, 2001; Béné et al., 2007, 2010) substantiate that wetland resources can play a crucial role in uplifting human well-being including economy of the geographic region. As an extension of such assessment of wetland resources in preserving ecosystem services and economy, documentation of species-specific exploitation patterns of wetland-derived EIMEIM was emphasized in the present study. The results are expected to highlight the utilization of the wetland macrophyte resources as food and livelihood in rural communities.

Material and methods

The present study on the EIM resources included a survey of selected market places of rural areas of Howrah (22.5604° N, 88.0510° E), Hooghly (22.8963° N, 88.2461° E), and Burdwan (923.2324° N, 87.8615° E) districts of West Bengal, India. In each district, 12 markets were visited, resulting in a total of 36 vegetable markets being surveyed during the study period. The vendors who were directly involved in marketing EIMEIM were interviewed. Rural markets were mostly surveyed as they were situated adjacent to the local wetlands. The selection of the markets was made following a preliminary review of the locations and permanence, such that occasional and weekly marketplaces were excluded from the study.

The economic evaluation of EIM in the selected markets was conducted between March 2012 and February 2016. The market survey was initiated at 7 am to collect market-related information. At least 1–2 h was spent in each market for conversation with vendors and purchase of edible macrophytes. The macrophytes were purchased in terms of minimum units (bundles) sold by the vendors. Prices of edible macrophytes (price per kg) and the trading period were collected by the semi-structured interview method through an on-site survey (Phatlamphu et al.,

Table 1. Summary (range, mean ± SE) of the biomass and price of six EIMspecies sold in the vegetable markets of West Bengal, India.

Macrophyte species	No sticks/EIM bundle	Wet biomass (g)/EIM bundle	Price (INR)/EIM bundle	Price (INR)/g of EIM
Family: Plantaginaceae				
Bacopa monnieri L. Pinnell.	33–176 92.50 ± 7.13	37–300 104.53 ± 12.76	2–10 3.03 ± 0.32	0.01–0.11 0.04±0.00
Family: Apiaceae				
Centella asiatica L. Urb.	16–96 40.08 ± 4.86	10–55 41.42 ± 2.80	2– 6 3.42 ± 0.30	0.04–0.5 0.10±0.02
Family: Asteraceae				
Enhydra fluctuans Lour.	15–188 58.24 ± 4.25	22–250 126.04 ± 6.93	2–5 3.01 ± 0.14	0.01–0.09 0.03±0.00
Family: Acanthaceae				
Hygrophila spinosa T. Ander	7–82 34.89 ± 1.66	18–500 111.49 ± 9.24	2–10 3.16 ± 0.15	0.01–0.17 0.04 ± 0.00
Family: Convolvulaceae				
Ipomoea aquatica Forsskal	17–105 51.55 ± 3.66	38–350 192.82 ±14.71	2–5 3.07 ± 0.22	0.01–0.11 0.02 ± 0.00
Family: Marsileaceae				
Marsilea quadrifolia L.	280–1600 851.10 ± 116.69	150–550 280 ± 40.96	5–10 7.00 ± 0.82	0.01–0.03 0.03 ± 0.00

Note: EIM – edible indigenous macrophyte.

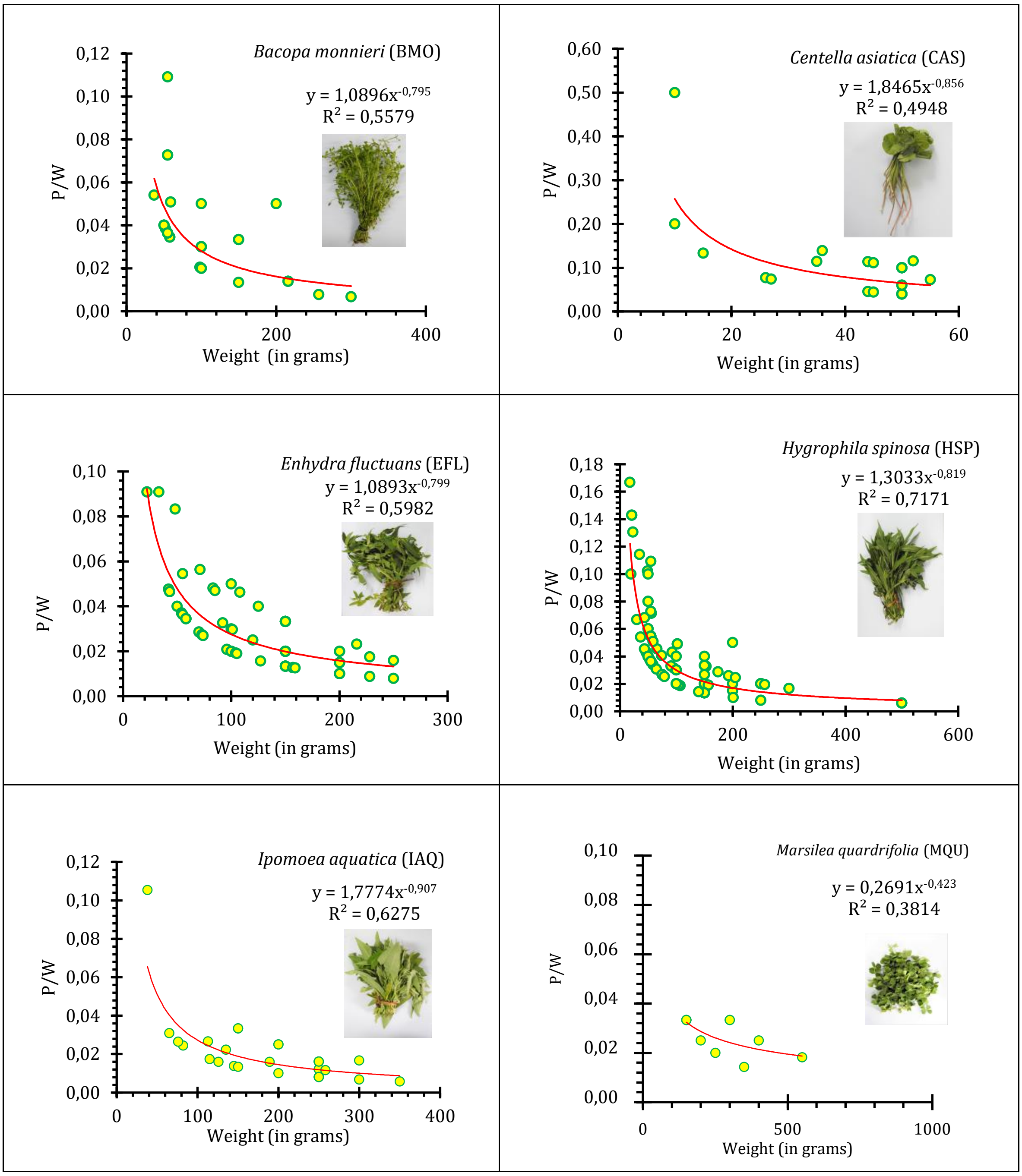

Fig. 1. Relationship between standardised price per gram (P/W) and weight of six macrophytes species.

2023). The collected materials were brought to the laboratory for identification, recording, and analysis. Identification of macrophytes was made following Cook (1996). Local names of the macrophytes were also noted to aid in identification. The survey of the market places was carried out in a gap of at least 10-day intervals during the study period. For each market surveyed, the number of vendors selling macrophytes was recorded. Macrophytes were weighed in individual units consisting of stems and leaves. The length of the leaves of randomly selected plants was measured by using a slide caliper (Insize, Brazil) to the nearest 0.1cm, and the whole unit (stem and leaf) was weighed to the nearest 0.1 g (pan balance, Citizen, India). To comply with the objectives of the study, the data on the vendors selling macrophytes, unit price, and morphologic features of macrophytes were subjected to statistical analyses. Information gathered from the market survey was collated and analyzed using the *XL*STAT software (Addinsoft, 2010). The selection of the statistical tests was made following Krebs (1999) and Zar (1999).

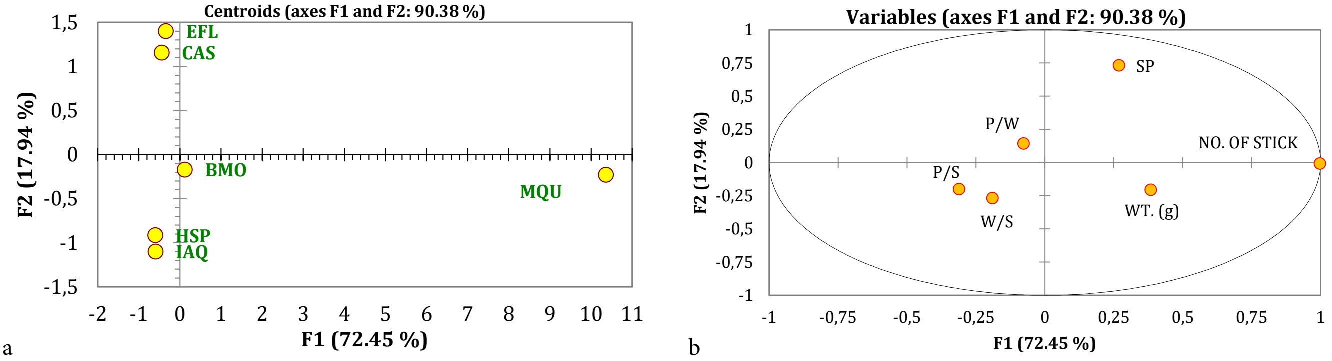

Fig. 2. The results of Discriminant Function Analysis applied to the data of six different macrophytes in 36 vegetable markets of Howrah and PurbaMedinipur districts of West Bengal, India. The two axes correspond to the two extracted factors (F1-x-axis and F2-y-axis). The explanatory variables were the NO. OF STICK (number of sticks of the macrophytes species), WT (weight in grams), SP (standardized price=selling price/maximum selling price), P/W (standardized price per weight), P/S (standardized price per stick in terms of individual plant species), and W/S (weight in gram per standardized price).The Wilk's λ value was 0.049 ($F_{30,970}$ = 36.224, P< 0.0001),justifying the application of the multivariate analysis.The ordination of the response variables (the macrophyte species) is shown in (a), followed by the ordination of the explanatory variables in (b).

Table 2. Results of the discriminant function analysis are presented in tabular form for the different EIMs as the response variables and the price and biomass being the explanatory variables. (a) Eigen values and the canonical correlation functions, (b)variables/factor correlations, (c)Fisher's distance between the response variable pairs (macrophytes), and (d)standardized canonical discriminant function coefficients. Values in bold are significant at *P*< 0.05 level. F1 through F5, the five extracted factors. (*Bacopa monnieri* – BMO, *Centella asiatica* – CAS, *Enhydra fluctuans* – EFL, *Hygrophila spinosa* – HSP, *Ipomoea aquatic* – IAQ, *Marsilea quadrifolia* – MQU). EIM – edible indigenous macrophyte.

a. Eigen values of factors and canonical correlation coefficients.

Measures	F1	F2	F3	F4	F5
Eigenvalue	4.572	1.132	0.405	0.134	0.068
Discrimination (%)	72.448	17.936	6.420	2.124	1.072
Cumulative %	72.448	90.384	96.804	98.928	100.000
Canonical correlations function	0.906	0.729	0.537	0.344	0.252

b. Variables/factors correlations.

	F1	F2	F3	F4	F5
NO OF STICK	0.997	−0.007	−0.046	−0.030	0.050
WT. (g)	0.384	−0.204	−0.658	0.117	0.550
SP	0.269	0.733	0.010	0.358	0.464
P/W	−0.078	0.144	0.877	−0.221	0.379
P/S	−0.311	−0.199	0.441	0.731	0.345
W/S	−0.191	−0.266	−0.218	0.459	0.365

c. Fisher's distance (significant values, *P*< 0.05, are indicated in bold).

	BMO	CAS	EFL	HSP	IAQ
CAS	**11.933**				
EFL	**13.333**	**12.934**			
HSP	**8.995**	**19.864**	**38.552**		
IAQ	**7.302**	**23.139**	**23.309**	**7.412**	
MQU	**129.727**	**139.430**	**167.272**	**177.706**	**148.015**

d. Standardized canonical discriminant function coefficients.

	F1	F2	F3	F4	F5
NO OF STICK	1.080	−0.115	0.244	0.185	−0.215
WT. (g)	−0.274	−0.885	−0.702	−0.523	1.132
SP	0.013	1.313	−0.135	0.296	0.107
P/W	−0.060	−0.090	0.652	−0.698	0.724
P/S	0.009	−0.967	0.186	0.797	0.121
W/S	0.174	0.619	0.384	0.359	−0.278

Results

The survey of 36 vegetable markets in Howrah, Hooghly, and Burdwan districts of West Bengal, India, revealed that EIMs were an abundant component of vegetable trade. As food resources, wetland-derived macrophyte was put up for sale by interested vendors, whose numbers varied in proportions compared to the number of total vendors selling edible plants (Table 1). The number of vendors trading EIM was considerably smaller compared to the total number of vendors in these markets.

In 36 different vegetable markets, six wetland-derived macrophytes were observed in varying proportions of relative selling units, weight, and mean selling price (Table 1). A total of five angiosperms (*Bacopa monnieri*, *Centella asiatica*, *Enhydra fluctuans*, *Hygrophila spinosa*, *Ipomoea aquatica*) and one pteridophyte macrophyte (*Marsilea quadrifolia*) were sold by the vendors all over the rural markets which were prioritized to assess the exploitation, sustainable use, and their conservation management. The relationship between standardized price per weight and weight of macrophytes is shown in Fig. 1. All six EIM species were present throughout the year in each rural market.The relative price (price per unit sold) and biomass are illustrated as biplots in Fig. 2. One-way analysis of variance (ANOVA) results suggest significant differences in unit selling price among the six macrophytes species ($F_{5, 104}$ = 3.3,*P* < 0.01) in the 36 marketplaces surveyed. Significant differences among macrophyte species in terms of biomass are reflected in one-way ANOVA ($F_{5, 104}$ = 6.84,*P*= 0.001).

Using plant stem numbers (unit plant present in a bundle sold), weight, leaf length, price, and vendors as explanatory variables, discriminant function analysis was carried out to explore the differences among the macrophytes species (Fig. 2). Five factors were extracted, of which the first two factors explained >90% discrimination among the different macrophyte species (Table 2). The biplot illustrates the ordination of the macrophytes species in the context of the first two factors F1 (Eigenvalue 4.572) and F2 (Eigenvalue 1.132). Considerable differences among the macrophyte species are reflected through the centroids shown in the biplot (Fig. 2a). The explanatory variables also show similar ordination in the biplots (Fig. 2b). As reflected in the ordination in the two biplots, EIMs show considerable differences as a freshwater edible resource sold in the rural markets.

Discussion

Wetlands are the reservoirs of a wide range of resources that qualify as ecosystem goods. The values of wetland resources remain underestimated and disproportionate to their real estimate (Zedler, Kercher 2005). Suitable valuation of the ecosystem goods is essential to promote sustainability and continue the benefits of ecosystem services (Costanza, 2000; deGroot et al., 2012). From an economic viewpoint, values of ecosystem goods or resources vary with the market characteristics and consumer perception and demand (Braat, deGroot, 2012). Wetland resources are extremely valuable and therefore require monitoring, such that exploitation is made in compliance with the theories of sustainability (Braat, deGroot, 2012). Given the valuation of ecosystem services including wetlands, the present study addressed realized values of edible macrophytes of wetlands that qualify as resources, providing various services to suffice human well-being.

However, a large number of edible macrophytes are commonly associated with wetlands.Six types of EIM were mostly sold by vendors all over the rural markets, reflecting their availability and demand in the rural vegetable markets. Empirical studies showed that a restricted number of indigenous plant species have been traded as economic plants for food consumption, and their supply can be used at the industry level (Botha et al., 2004 a,b; Jain et al., 2007; Rasethe et al., 2019; Liu et al., 2021; Gogoi et al., 2023; Phatlamphu et al., 2023). Apart from supporting nutritional requirements, a larger number of macrophyte species recorded in this study are used as medicinal plants. The existence of vendors and consumers of edible macrophytes reflects that communities of this geographic area depend on EIM for subsistence, food security, and livelihood. The nutritional value of these EIMs is high in contrast to the perceived value of the consumers. This serves as a basis for promoting EIM to meet the nutritional requirements and livelihoods of communities in rural West Bengal, India. Concurrent with the observations, species-specific variations of EIM as food resources are also evident in relative availability and price.The differences in the relative availability of sixEIM species indicate that they vary in terms of their abundance in the wetlands. The relative abundance of a macrophyte species is likely to influence pricing, since the extent of availability of a resource determines demand and price. This hypothesis could not be tested in the present study owing to a low number of samples. However, for a few species like *Marsilea quadrifolia* and *Centella asiatica,* the prices were relatively higher than those of *Enhydra fluctuans*, *Bacopa monnieri,* and *Ipomoea aquatica*. The relative abundance of *Marsilea quadrifolia* and *Bacopa monnieri* was significantly greater than that of other EIM. For a particular macrophyte species, the standardized price was negatively correlated with weight, validating biomass (body weight) as a good indicator of price. On a comparison scale, the mean difference among six hydrophytes in terms of the number of sticks per bundle, standardized price per unit biomass, and standardized price per stick indicates their difference in marketability, abundance, biomass, and selling price. Information related to the market price, abundance, and exploitation pattern of EIM will provide the necessary information about food affordability or, in a border aspect, food security to the local people.

Conclusion

Macrophytes are strong drivers of ecosystem services derived from wetlands. The present study documents the extent of the use of wetland macrophytes as food resources. Owing to the high nutritional and medicinal values and low selling price, EIMshave been consumed by all classes of people irrespective of their economic background. With the rising demand in the open market, selling these EIMs is also crucial for the sustenance of poor communities as it provides an alternative source of income. Monitoring species-specific patterns of harvest of EIM species is thus recommended to ascertain the continuance of wetland ecosystem services.

Acknowledgements

The authors acknowledge the Head, Department of Zoology, University of Calcutta, for the facilities provided including DST-FIST, Government of India.

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