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Snails on the plate: Edible freshwater molluscs of Northeast India

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In many parts of the world, freshwater molluscs are extensively harvested for food and medicine. Northeast India is one such region where freshwater molluscs are consumed by the tribal and economically impoverished communities. These molluscs are in high demand as they are a cheap source of protein and provide food security, livelihoods and medicine. Although there are studies that show the nutritional and mineral value of snails, data on the details of harvest, the number of species consumed, and traditional knowledge associated with them are lacking. This is the first comprehensive study documenting the diversity of freshwater molluscs sold, quantity, location of harvest, associated traditional knowledge and uses among different tribal communities of Northeast India. The information was gathered through market surveys and informal interaction with the vendors selling molluscs. Eighteen species of freshwater molluscs belonging to five families and six genera were recorded from our study. DNA barcode analysis using COI marker for the market collected specimens of *Paludomus* and *Brotia* show six species each from these genera. Most edible freshwater molluscs have incorrect taxonomic status and are Data Deficient or Least Concern. Therefore, it is essential to document for their conservation and management. We also advocate snail farming for their conservation and the nutritional and food security of the tribal communities, which will help in the sustainable use of natural resources.

Keywords: Conservation, Ethnozoology, Gastropods, Livelihoods, Tribes

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Molluscs are soft-bodied invertebrate organisms found in terrestrial, freshwater and marine habitats and are essential components of the ecosystem. Among many uses, the bioresource value of molluscs has gained importance in recent times, which is also beneficial for the socio-economical aspect of the local communities. Traditional knowledge regarding various uses of molluscs, including food and medicine, has also contributed significantly to exploring its potential in scientific research. Historically, molluscs have been consumed as a source of food and have been important in terms of dietary inputs. They also have been serving as a rich nutrient source since the existence of hunter-gatherer societies[1]. The most primitive record of using molluscs as food dates back to the Late Pleistocene and Holocene eras in Benidorm and Malaga of Spain, wherein land snail, *Iberus aloneness* was consumed[2,3]. Thus, molluscs have played a significant role in providing rich and nutritious food to hunter-gatherer societies[4,5]. Even today, the molluscs are considered a delicacy in many European countries[4-6], as well as in the Mediterranean, Asia and Africa[7-10]. For example, snail caviar (snail eggs) is a luxury food item that is highly popular across Europe[10]. Snail farming, also known as heliciculture, is an emerging activity in Europe and Southeast Asian countries for consumption and to obtain snail slime, a component in cosmetics. However, in both underdeveloped and developed parts of the world, wild populations of freshwater molluscs (snails and clams) are extensively harvested and consumed as a cheap source of protein by economically and socially marginalised communities.

India too has a long history of consuming snails in the coastal and inland tribal communities. Freshwater snails belonging to the genus *Pila* are known to be consumed for food as well as for medicinal purposes in various parts of India, but more frequently in Northeast (NE) Indian states[11-13]. Freshwater

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gastropods are in great demand as they are easy to access and collect and comprise some economic importance to the tribal community that sells them. Other studies from the Indian subcontinent have reported that snails are a rich source of calcium and substantial amounts of phosphorus, iron and zinc, especially in species like *Pila globosa*, *Filopaludina bengalensis*, *Melanoides tuberculata* and *Lamellidens marginalis*[9]. Thus, these molluscs are a cheap source of protein for impoverished and marginal tribal communities in India.

Despite their importance as food and medicine, at present, there is no comprehensive list of species harvested and the traditional utilisation of each of these species. Some of the molluscan species command a lucrative overseas market for some of the tribal communities as well. Thus, this study aims to document the diversity of freshwater mollusc harvested, b) the quantity and place of collection of molluscs, c) gender bias among vendors, and d) traditional knowledge associated with the uses of freshwater molluscs in local communities.

Methodology

Study region

The NE India, comprising the eight states viz., Arunachal Pradesh, Assam, Meghalaya, Manipur, Tripura, Mizoram, Nagaland and Sikkim, can be physiographically categorised into the Eastern Himalayas, Northeast hills (Patkai-Naga hills and Lushai hills) and the Brahmaputra and Barak valley. These states cover a total area of 2,69,326 km^2 [14]. The major rivers flowing through these states include Brahmaputra and Barak. The climate of the Northeast region is a humid subtropical monsoon climate with hot and humid summers, severe monsoons and mild winters. The region receives heavy rainfall for about five months during the southwest monsoon (June to October), which gets extended for two more months because of the northeast monsoon season (October to November). The vegetation includes alluvial grasslands and subtropical broadleaf forests amongst the foothills to temperate broadleaf forests in the mid-hills, mixed conifer and conifer forests in the higher hills and alpine meadows and wetland areas[14].

Survey

To document traditional knowledge of the mollusc bioresources, we surveyed local markets in NE India and also the adjoining state of West Bengal. The surveys were undertaken from July 2018 to February 2021. We carried out structured interviews and informal interactions with the vendors selling molluscs in markets and the local people in these states. We collected information about local names, uses, harvest and price, and collection habitats or sites of edible freshwater molluscs. Overall, 23 local markets were surveyed (Fig. 1 and 2; Table 1)

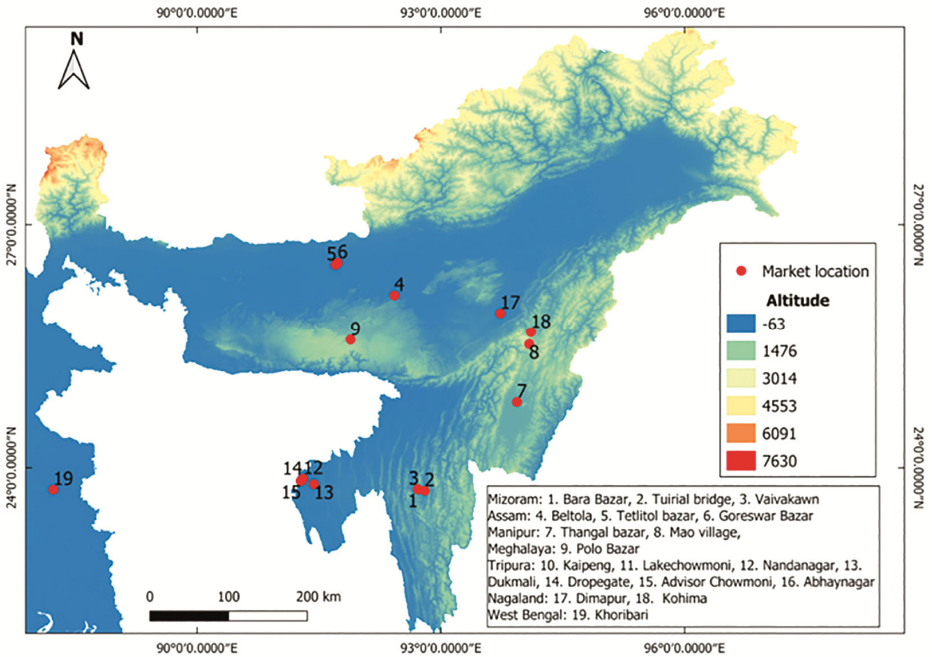

Fig. 1 — Map showing Northeast region of India with market sampling locations. The digital elevation map is obtained from EROS, USA

Table 1 — Details of markets samples, species and cost per unit of freshwater molluscs sold in Northeast India

Sr. No.	State	Market	Latitude	Longitude	No of species	Species	Cost per Mug or kg (in INR)
1	Mizoram	Bara Bazar	23.732 °N	92.717 °E	4	*Paludomus* sp.2, *Paludomus* sp.4, *Brotia insolita, Brotia* sp.1	20 – 60 per mug
2	Mizoram	Tuirial bridge	23.718 °N	92.800 °E	5	*Paludomus* sp.1, *Paludomus* sp.2, *Paludomus* sp.4, *Paludomus* sp.6, *Brotia assamensis*	20 – 60 per mug
3	Mizoram	Vaivakawn	23.738 °N	92.712 °E	None	None	20 – 60 per mug
4	Assam	Beltola	26.13 °N	92.426 °E	1	*Filopaludina bengalensis*	30 – 100 per mug
5	Assam	Tetlitol bazar	26.508 °N	91. 699 °E	None	None	30 – 80 per mug
6	Assam	Goreswar Bazar	26.533 °N	91.730 °E	None	None	30 – 100 per mug
7	Assam	Khanapara	26.121 °N	91.821 °E	3	*Filopaludina bengalensis, Pila olea, Lamellidens marginalis*	
8	Manipur	Thangal bazar	24.811 °N	93.936 °E	3	*Filopaludina bengalensis, Angulyagra microchaetephora, Cipangopaludina lecythis*	50 – 120 per mug
9	Manipur	Mao village	25.524 °N	94.087 °E	2	*Filopaludina bengalensis, Brotia* sp.3	35 – 40 per mug
10	Meghalaya	Polo bazar	25.579 °N	91.888 °E	6	*Filopaludina bengalensis, Viviparidae, Brotia costula, Brotia* sp.1, *Parreysia* sp.1, *Paludomus* sp.3., *Paludomus* sp.5	40 – 100 per kg
11	Meghalaya	Garobadha	25.586 °N	90.023 °E	1	*Brotia costula*	60 per kg
12	Tripura	Kaipeng market	23.838 °N	91.274 °E	2	*Filopaludina bengalensis, Angulyagra microchaetephora*	80 – 150 per kg
13	Tripura	Lakechowmoni market	23.842 °N	91.282 °E	4	*Filopaludina bengalensis, Viviparidae, Brotia* sp.2, *Lamellidens marginalis*	80 – 150 per kg
14	Tripura	Nandanagar market	23.867 °N	91.305 °E	1	*Filopaludina bengalensis*	80 – 150 per kg
15	Tripura	Dukmali market	23.799 °N	91.437 °E	2	*Filopaludina bengalensis, Angulyagra microchaetephora*	80 – 150 per kg
16	Tripura	Drop gate market	23.859 °N	91.294 °E	None	None	
17	Tripura	Advisor Chowmoni	23.838 °N	91.277 °E	None	None	
18	Tripura	Abhaynagar bazar	23.844 °N	91.286 °E	None	None	
19	Nagaland	Dimapur market	25.909 °N	93.729 °E	1	*Filopaludina bengalensis, Brotia* species unknown	50 – 100 per kg
20	Nagaland	Kohima market	25.674 °N	94.108 °E	1	*Cipangopaludina lecythis*	50 – 100 per kg
21	Nagaland	Bamboo market	25.659 °N	94.105 °E	1	*Pila olea, Cipangopaludina lecythis, Filopaludina bengalensis*	40 per mug
22	Nagaland	Supermarket	25.906 °N	93.739 °E	2	*Cipangopaludina lecythis*	40 per mug
23	West Bengal	Khoribari	23.732 °N	88.229 °E	3	*Brotia costula, Pila globosa, Filopaludina bengalensis*	40 – 100 per kg

and 30 individuals (20 women and ten men) were interviewed from various states of Northeast India. All nomenclatures follow www.molluscabase.org.

Results

Diversity of the edible molluscs in the markets

23 markets in Assam, Meghalaya, Mizoram, Manipur, Nagaland, Tripura and West Bengal were

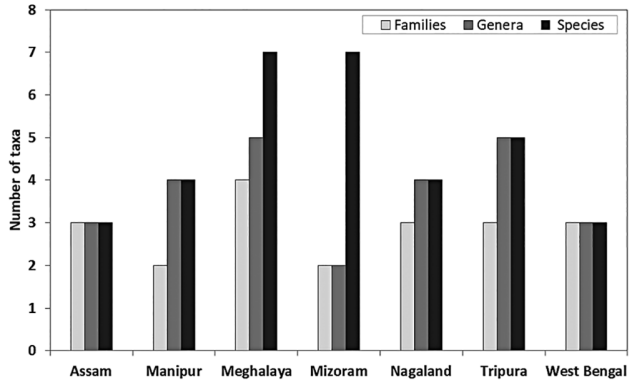

Fig. 2 — Number of families, genera and species of edible freshwater molluscs collected from different states of NE India during present study

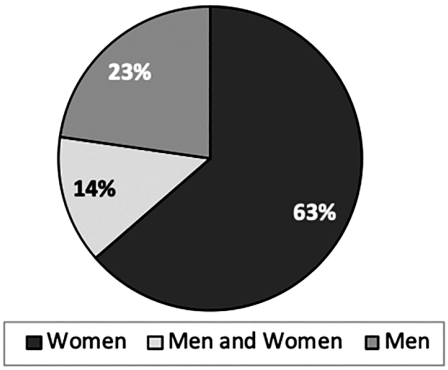

Fig. 3 — Representing the percentage of males and females selling freshwater molluscs in the markets of northeast India

surveyed (Fig. 3). Except for the five markets rest of the places, freshwater molluscs were sold in large quantities. Among all the surveyed states, the highest number of molluscs being sold in the markets was from Mizoram (seven species) followed by Meghalaya (six species) (Fig. 3). Our result also showed that local communities use only freshwater molluscs, and none of the markets surveyed and interviews indicated the use of terrestrial snails. The survey yielded 18 species of freshwater molluscs (16 gastropods and two bivalves) belonging to five families and eight genera (Fig. 4; Table 2). These include *Pila olea*, *Pila globosa*, (Ampullaridae), *Filopaludina bengalensis*, *Angulyagra microchetophora*, *Cipangopaludina lecythis* (Viviparidae), six species of *Paludomus* (Paludomidae), six species of *Brotia* (Pachychilidae), *Lamellidens marginalis* and *Parreysia* sp. (Unionidae) (Table 1). DNA barcode analyses revealed that six species from *Paludomus* and *Brotia* were mixed and sold as the same species.

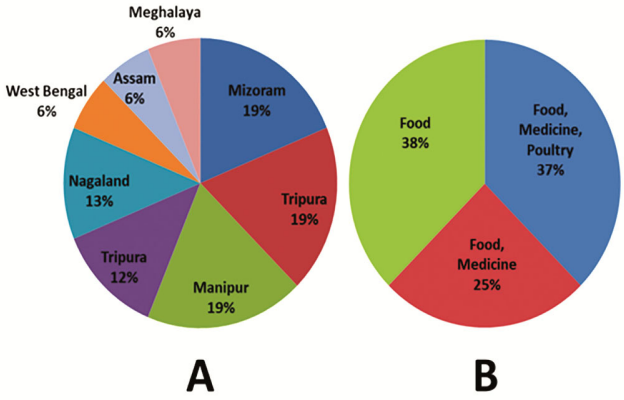

Fig. 4 — State wise percentage of freshwater molluscs being for food, medicine and poultry. B) Percentage of states using freshwater molluscs as food, medicine and poultry, individually and combined together

None of the species sold in the market comes under the Threatened category of the IUCN (International Union for Conservation of Nature) Red List, but all under either the Least Concern (LC) or Data Deficient (DD) categories.

Collection, marketing and cost

Freshwater molluscs are collected live by hand-picking from marshes, lakes, ponds, rivers and streams and also from man-made habitats such as paddy fields. The yield is reported to be the highest from April to August, around 30 – 40 kg. Snails are sold not only in the main markets but also in the roadside markets and small village markets during monsoon and post-monsoon seasons. Snails are either already packed in one-kilogram packets or sold loose according to the weight of one mug (~500 g). The price all over NE Indian states was relatively same for specific species and but varied according to the season. The price for *Brotia* spp., *I. dissimilis, F. bengalensis, P. olea*, *M. tuberculata*, *Paludomus* spp., varies from 20 to 50 INR during monsoon and can go up to 100 INR per mug during off-season (post-monsoon and summer; Table 1). In some cases, only snail meat is sold for INR 100. In Manipur, during the 'Cheiraoba' festival in March and April, the price for bivalves ranges from around INR 100 to 150 for one kilogram. On the contrary, in the markets of Agartala (Tripura), the price range for *F. bengalensis* varied from INR 80 to 100 per kg and for *Lamellidens* sp., the price was INR 40 per kg, which remained quite similar throughout the year.

Table 2 — List of freshwater molluscs sold in the market of NE India, red list status, disease carriers and uses

Family	Species name	IUCN Red List	Carrier for disease	Uses
Ampullariidae	*Pila olea*	DD	No	Food, medicine, poultry
	Pila globosa	LC	No	Food, medicine, poultry
Viviparidae	*Filopaludina bengalensis*	LC	Yes	Food, medicine, poultry
	Angyulyagra oxychaetaphora	LC	May be	Food, medicine
	Cipangopaludina lecythis	LC	May be	Food, medicine
Pachychilidae	*Brotia costula*	LC	No	Food, medicine
	Brotia assamensis	NE	No	Food, medicine
	Brotia insolita	NE	No	Food, medicine
	Brotia sp.1	NA	No	Food, medicine
	Brotia sp.2	NA	No	Food, medicine
Paludomidae	*Paludomus* sp.1	NA	No	Food, medicine
	Paludomus sp.2	NA	No	Food, medicine
	Paludomus sp.3	NA	No	Food, medicine
	Paludomus sp.4	NA	No	Food, medicine
	Paludomus sp.5	NA	No	Food, medicine
	Paludomus sp.6	NA	No	Food, medicine
Unionidae	*Parreysia* sp.1	NA	No	Food, medicine
	Lamellidens marginalis	LC	No	Food, medicine

Preference and consumption

In Mizoram and Meghalaya, communities prefer *Brotia* spp., and *Paludomus* spp. over other species due to availability. In other states, *F. bengalensis*, *A. oxychetophora*, *C. lecythis* and *I. dissimilis* are consumed predominantly. In contrast, bivalves are consumed rarely due to their rarity and difficulty in collection compared to gastropods.

Medicinal importance

Various states exhibited differential patterns of the medicinal importance of snails. Details of the medicinal uses of different freshwater molluscs from this study as well as from the previous studies, are given in Table 3 and summarised in Figure 5.

Gender and ethnic groups

In most cases, men refrained from these activities. Our study reports that almost 63% of the vendors selling edible molluscs in most parts of NE India were women (Fig. 6), 23% were only men, and the remaining 14% were men and women. During our field visit, the respondents from the following major ethnic communities have been confirmed regarding their consumption of freshwater molluscs, such as Tripuri, Debbarma, and Kaipeng (Tripura); Mizo (Mizoram); Metei (Manipur); Ao Naga, Rongami, Mao, Angami, and Lotha (Nagaland); Garo and Khasi (Meghalaya), Bodo and Sarania (Assam). Our study was limited to only the above-mentioned ethnic groups; however, there is a scope for exploring the large ethnicity of this region and their dependence on this natural resource in terms of food and ethnozoological perspectives.

Fig. 5 — A) Different species of freshwater molluscs sold in the markets of North-east India

Discussion

Information on malacophagy (feeding on molluscs) among the various ethnic groups is seldom documented

Table 3 — Uses of freshwater molluscs from different parts of NE India compiled from published literature

Region	Species	Uses	References
Kosi River Basin of North-Bihar	*Bellamya* sp., *Filopaludina bengalensis* (*Lamarck, 1822*), *Pila* sp., *Lamellidens* sp., *Parreysia* sp.	Medicinal (Asthma, arthritis, joint pain, rheumatism, conjunctivitis, rickets, cardiac ailments, blood pressure, giddiness and dehydration, nervousness, night blindness, anaemia)	Prabhakar and Roy 2009
Assam	*Filopaludina bengalensis* (*Lamarck,* 1822), *Brotia costula* (Rafinesque, 1833), *Pila globosa* (Swainson, 1822), *Pila theobaldi, Pila virens* (Lamarck, 1822), *Pila scutata* (Mousson, 1848)	Food	Borkakati et al. 2009
Assam plains	*Filopaludina bengalensis* (Lamarck, 1822), *Brotia costula* (Rafinesque, 1833), *Pila globosa* (Swainson, 1822), *Pila theobaldi, Pila virens* (Lamarck, 1822), *Lamellidens corrianus* (Lea, 1834)	Food	Goswami et al. 1999
Arunachal Pradesh (Adi tribe)	*Parreysia sikkimensis* (Lea, 1859), *Paludomus crassa* (Busch, 1842)	Given to weak person, diabetic patient and used in fertility enhancement	Chinlampianga et al. 2013
Mizoram (Local tribes)	*Lymnaea* sp.	Used to treat measles, liver ailment and jaundice. Swellings and sprain. Also for rearing birds increase egg production	Chinlampianga et al. 2013
Nagaland	*Pila globosa* (Swainson, 1822)	Flesh is eaten after cooking as a relief measure in asthma, tuberculosis, stomach disorders and eye related problems	Jamir and Lal 2005
Upper Brahmaputra valley, Assam	*Pila globosa* (Swainson, 1822)	To treat asthma and tuberculosis, stomach disorder	Bhuyan 2016
Dhemaji district, Assam	*Pila globosa* (Swainson, 1822)	Soup is prepared from flesh is believed to cure asthma, arthritis, joint swelling, rheumatism and quick healing of wounds. Snail immersed water used to cure conjunctivitis	Chutia and Pegu, 2017
Dhemaji district, Assam	*Lamellidens* sp. and *Parreysia* sp., *Filopaludina bengalensis* (Lamarck, 1822)	Used to cure rheumatism, cardiac diseases, controlling blood pressure and asthma.	Chutia and Pegu, 2017
Khowai district, Tripura	*Pila globosa* (Swainson, 1822)	*Pila* water is used to treat conjunctivitis, flesh of the animal is used to treat rickets	Das, 2015
	Pila sp.	Flesh used for bone diseases, injuries, gastritis, tongue blister and shells are used to treat skin burn	Kakati and Duolo 2002
Surrounding areas of Giboon WLS, Assam	*Pila* sp.	Whole body is consumed for better eyesight and soft watery portion (slime?) is applied externally to treat pain.	Borah and Prasad 2017
Ima valley, Manipur	*Pila globosa* (Swainson, 1822), *Pila* species, *Anodonta anatina* (Linnaeus, 1758)	Food	Devi et al. 2010
Dima Hasao, Assam	*Lymnaea* sp.	Cooked and eaten as a cure of jaundice	Betlu 2013
Northeast India	*Filopaludina bengalensis* (*Lamarck, 1822*), *Idiopoma dissimilis* (Muller, 1774), *Angulyagra oxytropis* (Benson, 1836), *Cipangopaludina lecythis* (Benson, 1836), *Pila theobaldi, Brotia costula* (Rafinesque, 1833), *Paludomus blanfordiana* (Nevill, 1877), *Paludomus crassa* (Busch, 1842), *Paludomus pustulosa*	Food	Tripathy and Mukhopadhayay 2015

(*Contd*.)

Table 3 — Uses of freshwater molluscs from different parts of NE India compiled from published literature (*Contd*.)

Region	Species	Uses	References
	Filopaludina bengalensis (*Lamarck, 1822*), *Lamellidens corrianus* (Lea, 1834), *Lamellidens generosus* (Gould, 1847), *Lamellidens marginalis* (Lamarck, 1819), *Lamellidens phenchooganjensis* (Preston, 1912), *Leoparreysia burmana* (Blanford, 1869), *Parreysia favidens* (Benson, 1862), *Parreysia sikkimensis* (Lea, 1859), *Parreysia caerulea, Parreysia occata, Trapezidens exolescens* (Gould, 1843)	Food	Tripathy and Mukhopadhayay 2015
Golapara, Assam	*Filopaludina bengalensis* (*Lamarck, 1822*), *Bellamya bengalensis f. typica, Bellamya bengalensis f. balteata, Idiopoma dissimilis* (Muller, 1774), *Brotia costula* (Rafinesque, 1833), *Pila globosa* (Swainson, 1822), *Pila theobaldi, Pila virens* (Lamarck, 1822), *Pila scutata* (Mousson, 1848)	Snail meat is used treating whooping cough, ulcer, asthma, arteriosclerosis, constipation, haemorrhoids, poor eyesight, kidney related diseases, small pox, preparation of contortions for reduction of labour pain and blood loss in pregnant women during delivery. It is used to overcome deficiency of calcium, phosphorus, iron and copper. Also used to cure small pox, anaemia, high blood pressure and other fat related ailments	Rabha 2014

Fig. 6 — Image showing freshwater mollusc in the market (upper panel), different species of molluscs sold in the market and curry made of *Filopaludina bengalensis* (last image) in Manipur. Legend: Top row, different species of freshwater molluscs sold by the communities in markets of NE India; Middle row: different species of freshwater molluscs (left) and meat isolated from the shell (right); Bottom row: *Pila olea* (left) and curry prepared out of *Filopaudina bengalensis* (right)

across NE India except for a handful of localised studies though not exhaustive, that have listed the mollusc as food in this region[11-13,15]. This study is the first comprehensive documentation of the diversity and ethnic uses of edible freshwater molluscs in NE India. Tripathy and Mukhopadhayay[16] compiled 21 species from published sources. However, there are issues with the taxonomy of the species and the distribution ranges. For example, *P. virens* and *P. globosa* have been reported, but a recent study shows that these two species are not found in NE India[17]. The present compilation is also probably the highest number from Asia. For example, only six edible freshwater mollusc species are known to contribute to the livelihoods of local communities from Sarawak, Malaysia[18]. All the species are collected from the wild population and are widely distributed and locally abundant. *Filopaludina bengalensis* and *P. globosa* are commonly consumed in Bengal[19], whereas in NE India, apart from *F. bengalensis* and *P. olea*, others are also consumed. However, the rate of consumption varied with the availability of the species and its abundance. Viviparidae, Pachychilidae and Paludomidae are the three families with the highest species consumed in NE India. Viviparid snails are very popular in Vietnam and other countries[18]. In West Bengal, apart from the above commonly collected species from NE, *Indoplanorbis exustus, Racesina luteola* and *Radix rufescens* were also used as food and medicine[19], which are seldom used by communities in NE India.

This may be because of low abundance and smaller size.

Traditional foods, consisting of wild plants and animals and their products, have been used sustainably and for economic benefits by the local and tribal communities in different parts of India since ancient times[11]. They also play an important part in nutritional security for impoverished communities in developing countries[20,21]. Molluscs are widely used in the day-to-day diet of the tribal and economically backward communities in Southeast Asia and NE India. It serves as a good and cheap source of protein compared to the other options[22]. The snails are boiled in water and cooked with spices and vegetables. In the case of *Brotia* spp., they break the snails from the middle and suck or remove the entire animal through the shell aperture. *Pila olea* is usually consumed by boiling, and then the entire animal is fried. In some cases, it was also recorded that people prepare a traditional curry of snails (*F. bengalensis*) with black gram.

In NE India and parts of West Bengal, freshwater molluscs are also used as medicines[11,15,16,19,23-25]. The communities across NE Indian states believe consuming snails enhances or helps maintain good eyesight and normal functioning of kidneys and reduces joint pain. The flesh and shells are also given to poultry as a calcium supplement to enhance egg production. In Nagaland, snails are part of their staple diet as consuming snails is beneficial for eyes and muscles and should be eaten after being medically operated. They are also consumed after surgical procedures to ensure speedy recuperation; however, these claims need scientific validation. Species such as *L. marginalis, F. bengalensis* and *P. olea* are used extensively as a cure for common illnesses such as vomiting, anaemia, eye-related diseases, jaundice, giddiness, etc.[12,19]. *Lamellidens marginalis* is used to treat menstrual disturbances in women[19]. The use of these molluscs as food, medicine, household utensils, totem materials, ritual goods, ornament and decorative materials, playing tools and trade materials is very much in practice by the people belonging to different families irrespective of caste and creed, residing in West Bengal, India[19]. *Filopaludina bengalensis* is widely used in Indian traditional medicine to treat conjunctivitis, visional dilemma, joint pains, enlarged spleen, gastritis, jaundice, asthma, and healing wounds[24,25]. In our study as well, we have recorded the use of this species as a cure for common eye-related ailments. There are several studies regarding these freshwater molluscs in India showing their nutrient content[9] and the potential to be considered as mini livestock[26-30]. Studies have shown that the snail has protein content ranging from 6 to

Table 4 — Nutritive value (per dry mass in percentage) of different species of edible freshwater molluscs from NE India and Bangladesh

Sl No	Species	Protein	Fat	Carbohydrates	References
1	*Filopaludina bengalensis* (Lamarck, 1822)	8.79-17.20	1.67-4.83	5.034-13.12	Khaluala et al. 2014
2	*Filopaludina bengalensis* (Lamarck, 1822)	8.97	0.984	4.31	Baby et al. 2010
3	*Pila globosa* (Swainson, 1822)	8.27	0.73	2.9	Baby et al. 2010
4	*Melanoides tuberculata* (Muller, 1774)	12.36	1.79	7.57	Baby et al. 2010
5	*Lamellidens marginalis* (Lamarck, 1819)	6.46	0.51	4.94	Baby et al. 2010
6	*Gyraulus convexiusculus* (Hutton 1849)	12.93	0.97	5.79	Baby et al. 2010
7	*Lamellidens marginalis* (Lamarck, 1819)	4.24-11.27			Sable and Vedpathak 2017
8	*Brotia costula* (Rafinesque, 1833)	44.42	2.9	21.89	Chutia et al. 2020
9	*Filopaludina bengalensis* (Lamarck, 1822)	35.67	2.53	22.54	Chutia et al. 2020
10	*Pila globosa* (Swainson, 1822)	33.31	3.12	12.11	Chutia et al. 2020
11	*Pila ampullacea* (Linnaeus, 1758)	45.059	0.253		Ghosh et al. 2016
12	*Lymnaea stagnalis* (Linnaeus, 1758)	41.707	4.48		Ghosh et al. 2016
13	*Pila globosa* (Swainson, 1822)	57.048	5		Ghosh et al. 2016
14	*Melanoides tuberculata* (Muller, 1774)	48.65	7.059		Ghosh et al .2016
15	*Lamellidens marginalis* (Lamarck, 1819)	45.844	3.596		Ghosh et al. 2016
16	*Brotia costula* (Rafinesque, 1833)	12.91±2.52		9.12±2.81	Debnath et al. 2016
17	*Filopaludina bengalensis* (Lamarck, 1822)	13.14±1.82		11.97±6.96	Debnath et al. 2017
18	*Idiopoma dissimilis* (Muller, 1774)	11.18±2.17		11.46±6.42	Debnath et al. 2018
19	*Pila globosa* (Swainson, 1822)	15.59±1.14		5.62±5.83	Debnath et al. 2019
20	*Lamellidens corrianus* (Lea, 1834)	71.21%	5.43		Suryanarayanan and Alexander 1972

20% of the total wet weight[9,26] (Table 4). This high protein content is equal to or higher than traditionally used meat sources such as chicken and is rich in calcium and phosphorus[9].

Apart from human consumption, *P. olea* and *F. bengalensis* are harvested commercially as fish feed for shrimp farms in certain areas of Bangladesh[9]. In many parts of NE India, *Pila* spp. is used for other than human consumption, such as poultry feed. According to local communities in Manipur, Assam and Tripura, feeding poultry with *Pila* and *Filopaludina* would increase egg production. Thus, there might be a great potential for the use of freshwater snails in enhancing egg production. The shells of these molluscs are used by the communities as measuring pots, collyrium preparation pots, and jeweller's chemical containers. The shell of *L. marginalis* also used to cut the umbilical cord of the new-born baby in the village area[19]. However, not all the medicinal uses mentioned above have been proven scientifically and need scientific validation.

Ethnic groups

The percentages of mollusc-eating families are higher in scheduled castes and scheduled tribes than for general castes in West Bengal[19], Assam, Bangladesh[9] and as reported in this study. In NE India, most of the communities are scheduled tribes. Hence there are no such patterns observed in our study. In West Bengal, the rate of consumption varied with species and castes and the location of the villages and households[19]. Our study did show similar patterns in terms of preferred species and not caste. This could be due to no or little importance given to caste-related issues.

Snail farming for livelihoods and nutritional security in NE India

The government should formulate a formal policy to encourage 'Heliciculture' programs that will help in the conservation of the wild population and provide employment opportunities for the poor and tribal people. This will reduce the rampant collection of molluscs from the wild population. Other alternatives, such as the rearing of molluscs in their backyard ponds or along with the rice paddy during the monsoon season, should be encouraged. Species belonging to Ampullariidae and Viviparidae are hardy, and they can be easily reared in artificial ponds in the backyards, as their reproduction rate is quite high.

Molluscs are one of the major groups being reared in aquaculture in Southeast Asia, especially marine or brackish water species[28]. Countries like Mexico, Thailand, Philippines and Taiwan[26-28], where freshwater snails are consumed on a regular basis, have developed methods for the successful rearing of these snails. It is important to find a way to sustainable harvest and secure the nutritional and food security of the poor communities in developing countries such as India. This can be achieved by encouraging and emphasising the use of traditional and indigenous foods, which are already easily accessed by the local communities[29]. In the case of regions like NE India, where already such rich traditional knowledge exists and people are largely dependent on natural resources, snail farming has great potential.

Given the current food and nutritional insecurity, it is high time to start looking at the possibilities of farming edible snails and treating them as mini livestock. Several studies show that the protein content in snails is higher than that found in poultry[30]. Also, looking at the present global climate change issues due to farming and consumption of beef, pork, and chicken, edible freshwater snails can act as an excellent substitute. Snail farming can also be a mode of income generation for the indigenous people by earning a substantial amount of money by selling freshwater molluscs in local markets[28]. Snail cuisines can be made "boutique cuisine" to increase the tourism potential of NE India[29]. Studies elsewhere have shown that snails are easy to rear with low maintenance at the commercial level with high yields on minimal input[10,26]. However, species such as *Paludomus* and *Brotia* are difficult to rear as they require flowing and clean water. Further research needs to be done to develop an efficient method to rear these highly valued species. At the same time, the local communities need to be educated about the sustainable harvest of their animal wealth[19] and also made aware of the zoonotic diseases caused by these snails if not cooked in the right manner. Combining the use of traditional knowledge in snail farming and methods of snail rearing will not only provide the locals with substantial protein resources but also avoid the overexploitation of these freshwater molluscs directly from the wild[15].

Conclusion

Overharvesting, pollution, change in land use, water abstraction, and dam construction are the major threat to the freshwater water habitats of the Northeast

region[31,32]. Many freshwater molluscs are used for food and medicine as well as in the lime and pearl industries in Bihar, Orissa, Jharkhand, West Bengal, and NE states[15,16,23,29]. Most freshwater molluscs consumed either have incorrect taxonomic status or are assigned as DD or LC. It is important to document, study and develop effective conservation strategies to conserve freshwater biodiversity and their habitats, considering the threats, extinctions and underlying causes[32]. Hence documentation and systematic analysis should be given utmost importance to understand the association between richness and distributional patterns, the impacts of habitat fragmentation, and the role of indigenous tribal communities and their traditional knowledge, which is vital for determining biodiversity-management strategies. Freshwater molluscs are being harvested and extracted directly from the wild populations in large quantities from Northeast India. It is important that data on population trends, habitat requirements, ecological importance, and the consequences of any species loss needs to be documented and shared with the local communities, managers and policymakers to protect and conserve the species before it goes extinct. Large-scale harvest or production of molluscs for human consumption has several issues that have to be considered, including the practicality of collecting from the wild and the possibility of overharvesting, economic mass-rearing techniques, preservation and storage of the products and marketing.

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Conflict of Interest

The authors declare no conflict of interest.

Authors' Contributions

AJ, NKD conducted fieldwork, analysed the data and wrote the manuscript. MS helped in analysis and manuscript writing, NAA got funding, conceptualised the idea, supervised manuscript writing and finalised and approved the manuscript.

References

1 Burgos A, Younger A C & Wolverton S, Human mollusk interactions in a changing world, *J Ethnobiol,* 39 (2) (2019) 175-181.

2 De Pablo J F L, Badal E, García C F, Martínez-Ortí A & Serra A S, Land snails as a diet diversification proxy during the Early Upper Palaeolithic in Europe, *PloS One*, 9 (8) (2014) e104898.

3 Serrano F, Guerra-Merchán A, Lozano-Francisco C & Vera-Peláez J L, Multivariate analysis of remains of molluscan foods consumed by latest Pleistocene and Holocene humans in Nerja Cave, Málaga, Spain. *Quat*, 48 (2) (1997) 215-227.

4 Jerardino A, Faulkner P & Flores C, Current methodological issues in archaeo-malacological studies, *Quat Int*, 427 (2017) 1-4.

5 Waselkov G A, Shellfish Gathering and Shell Midden Archaeology, In: Advances in Archaeological Method and Theory, edited by M B Schiffer, (Academic Press, New York), 1987 p. 93-210.

6 Cobbinah J R, Vink A & Onwuka B, Snail Farming: Production, processing and marketing. Agrodok 47, (Agromisa Foundation, Wageningen, the Netherlands), 2008, p. 1-9.

7 Yildirim M Z, Edible Snails (Terrestrial) of Turkey, *Turk J Zool*, 28 (2004) 329-335.

8 Evans J G, The exploitation of molluscs. In: *The Domestication and Exploitation of Plants and Animals*, edited by P J Ucko, & G W Dimbleby (Routledge, New York), 2008 p. 6.

9 Baby R L, Hasan I, Kabir K A & Naser M N, Nutrient analysis of some commercially important molluscs of Bangladesh, *J Sci Res*, 2 (2) (2010) 390-396.

10 Ivan C, Vesna K H, Borche M, Elena J, Katerina B, *et al*., A survey of snail farming technology (*Helix aspersa maxima*) in Pelagonia region, R Macedonia, (2017) p. 130-133

11 Borkakati R N, Gogoi R & Borah B K, Snail: from present perspective to the history of Assam, *Asian Agri-History*, 1 (3) (2009) 227-234.

12 Betlu A L S, Indigenous knowledge of zootherapeutic use among the Biate tribe of Dima Hasao District, Assam, Northeastern India, *J Ethnobiol Ethnomed*, 9 (1) (2013) 1-16.

13 Chinlampianga M, Singh R K & Shukla A C, Ethnozoological diversity of Northeast India: Empirical learning with traditional knowledge holders of Mizoram and Arunachal Pradesh, *Indian J Tradit Know*, 12 (1) (2013) 18-30.

14 Chakravarty S, Suresh C P, Puri A & Shukla G, North-east India, the geographical gateway of India's phytodiversity, *Indian For*, 138 (8) (2102) 702-709.

15 Jamir N S & Lal P, Ethnozoological practices among Naga tribes, *Indian J Tradit Know,* 4 (1) (2005) 100-104.

16 Tripathy B & Mukhopadhayay A, Freshwater molluscs of India: an insight of into their diversity, distribution and conservation, In: *Aquatic Ecosystem: Biodiversity, Ecology and Conservation,* edited by M Rawat, S Dookia & C Sivaperuman, (Springer, New Delhi), 2015 p. 163-195.

17 Sil M, Aravind NA & Karanth P, 2020, Into-India or out-of-India? Historical biogeography of freshwater gastropod genus Pila, *Biol J Linn Soc*, 129 (2020) 752-764.
18 Köhler F, Seddon M, Bogan A E, Tu D V, Sri-Aroon P, *et al*., 2012, The status and distribution of freshwater molluscs of the Indo-Burma region. In: *The Status and Distribution of Freshwater Biodiversity in Indo-Burma,* edited by D J Allen, K G Smith & W R T Darwall, (IUCN, Cambridge, UK, Gland, Switzerland), 2012 p. 66-88.
19 Chattopadhyay D K, Freshwater molluscs in the economy and tradition of Bengal India, Ph.D. Thesis submitted to University of Calcutta (1992).
20 Costa-Neto E M, Animal based medicines: biological prospection and the sustainable use of zoo therapeutic resources, *An Acad Bras Ciênc*, 77 (2005) 33-43.
21 Sangma R H C, Pal R & Singh D R, Edible Insects of Northeast India, In: *Bioprospecting of indigenous bioresources of North-East India,* edited by J Purkayastha, (Springer, Singapore), 2016 p. 253-267.
22 Karna R R & Shrestha J, Molluscs as a cheap source of animal protein in Sarlahi district, *NJST,* 7 (2006) 45-48.
23 Kakati L N & Doulo V, Indigenous knowledge system of zootherapeutic use by Chakhesang tribe of Nagaland, India, *J Hum Ecol*, 13 (6) (2002) 419-423.
24 Prabhakar A K & Roy S P, Ethno-medicinal uses of some shell fishes by people of Kosi river basin of North-Bihar, India, *Stud Ethno-Med*, 3 (1) (2009) 1-4.
25 Bhattacharya S, Chakraborty M, Bose M, Mukherjee D, Roychoudhury A, *et al*., Indian freshwater edible snail *Bellamya bengalensis* lipid extract prevents T cell mediated hypersensitivity and inhibits LPS induced macrophage activation, *J Ethnopharmacol*, 157 (2014) 320-329.
26 Ghosh S, Jung C & Meyer-Rochow V B, Snail farming: an Indian perspective of a potential tool for food security, *Annals Aquac Res*, 3 (3) (2016) 1-6.
27 Flores-Garza R, Lores-Rodríguez P, Torreblanca-Ramírez C, Galeana-Rebolledo L, Valdés-González A, *et al*., Commercially important marine mollusks for human consumption in Acapulco, México, *Nat Resour*, 3 (2012) 11.
28 FAO, The State of World Fisheries and Aquaculture 2018, Meeting the sustainable development goals (FAO, Rome), 2018.
29 Ghosh-Jerath S, Singh A, Kamboj P, Goldberg G & Magsumbol M S, Traditional knowledge and nutritive value of indigenous foods in the Oraon tribal community of Jharkhand: an exploratory cross-sectional study, *Ecol Food Nutr*, 54 (5) (2015) 493-519.
30 Diarra S S, Utilisation of snail meal as a protein supplement in poultry diets, *World's Poultry Sci J*, 71 (3) (2015) 547-554.
31 Vishwanath W, Diversity and conservation status of freshwater fishes of the major rivers of Northeast India, *Aquat Ecosyst Health Manag*, 20 (1-2) (2017) 86-101.
32 Budha P B, Aravind N A & Daniel B A, The status and distribution of freshwater molluscs of the Eastern Himalaya, In: The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya, Complied by D J Allen, S, Molur S & B A Daniel (IUCN, Cambridge, UK and Gland, Switzerland and Zoo Outreach Organization, Coimbatore, India), 2010 p. 42-53.