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Assessment on diversity, distribution and conservation status of Indian freshwater pond mussel *Lamellidens* spp. from upper Brahmaputra basin of Assam

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ABSTRACT

A field survey was conducted in the flood plains of the upper Brahmaputra basin to assess the diversity and distribution of *Lamellidens* spp. Altogether four species of *Lamellidens*, categorized as Least Concerned of IUCN Redlist were recorded from the 17 sampling stations comprising small to large tributaries and wetlands covering a geographical area of approximately 3900 km^2. The recorded *Lamellidens phenchooganjensis* Preston, 1912 corresponds to new reports from the Brahmaputra basin, whereas *Lamellidens jenkinsianus* (Benson, 1862) was found to be unique and endemic to this region. Significant morphometric differences were observed within the *Lamellidens* spp. In terms of richness and species distribution, significant trends of diversity were observed across the northern basin and southern basin of the study area. The outcome of the present work is based on first-hand information on the diversity, distribution and status of *Lamellidens* population of this region and inconsistencies between available data is still a major problem in establishing a database for the planning of species conservation in the region.

Key words: least concerned, endemic, unique, wetlands, conservation, database

INTRODUCTION

Molluscs characterized by the presence of radula and coelom is the second-largest group in the animal kingdom after the insects (Arthropoda). Molluscs are considered an ecosystem engineer (Gutierrez *et al*., 2003) and emerging wealth of the freshwater ecosystem (Elder & Collins, 1991; Maltchik *et al*., 2010) for the pivotal role it plays in the aquatic ecosystem health (Fenchel and Kofoed, 1976; Bertness, 1984; Peterson & Black, 1987; Kay, 1995; Stewart *et al*., 1998; Strayer *et al*., 1999; Vaughan *et al*., 2004; Lydeard *et al*., 2004; Budha *et al*., 2010). Apart from their role in the ecosystem, people across the globe exploit several species of freshwater molluscs as food, can be used in bio-monitoring of pollutants and also in integrated fish farming (Sicuro, 2015).

Freshwater mollusc (Gastropoda and Bivalvia) distributed throughout the freshwater bodies of the globe (Graf & Cummings, 2007; Strong *et al*., 2008; Bogan, 2008; Schiaparelli *et al*., 2014). Most of the information on the status and distribution of Indo-tropical freshwater molluscs is based on the studies in the Eastern Himalayas (Budha *et al*., 2010); Western Ghats (Aravind *et al*., 2011) and Indo-Burma region (Köhler *et al*., 2012). In India studies on diversity, distribution and habitat ecology of freshwater molluscs were at the peak in late 19th and early 20th century. Pioneering work on diversity, distribution and taxonomy of freshwater molluscs were carried out by Preston (1915); Annandale (1918); Prashad (1920, 1928) and more recently reviewed by Subba Rao (1989), Ramakrishna & Dey (2007) and Nesemann (2007). Ironically, no significant studies on the status and distribution of freshwater molluscs have been carried out till date in the Brahmaputra basin of Assam. As a result, studies on the distribution, taxonomy and biology of mollusc population of the region remains obscure and also that of several reported species seem to be doubtful (Budha *et al*. 2010; Kumar & Vyas 2012; Ramesha *et al*., 2013). The Indian pond mussel *Lamellidens* represented by 10 species. *Lamellidens* spp. are one of the most commonly harvested freshwater bivalve species used for human consumption in Nepal and Bangladesh (Aravind, 2010; Budha, 2016).The bivalve especially *Lamellidens* spp. have been found to be one of the popular meat sources among many natives of upper Assam due to its abundance in the natural water bodies and high flesh content compared to other molluscs found in this region. Some ethnic people of North-East India believe that *Lamellidens* spp. has some ethnomedicinal and ornamental value. But our knowledge about *Lamellidens* spp. of this region is fragmentary. These freshwater mussels are more or less widely distributed throughout India. But still the bivalves have not been the subject of intense studies despite the presence of rich diversity of edible and commercial species in India. The literature suggests that no research works on the diversity, distribution,

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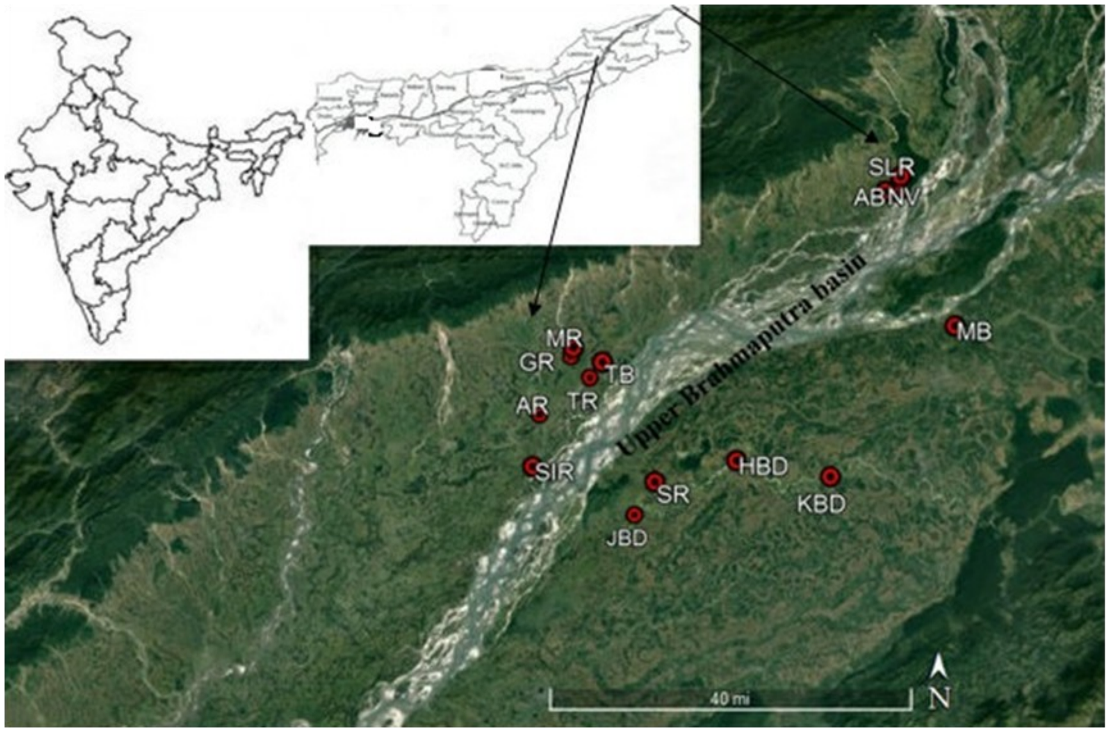

Figure 1. Satellite image of the upper Brahmaputra basin of Assam, India. Red-coloured markings are different sampling stations of the study area.

habitat ecology and potential threats of *Lamellidens* spp. in Assam have so far been carried out. It is expected that if Indo-tropical unionoids are re-examined using modern techniques, the species diversity will be found to be even greater than the present. Keep this view in the mind study is aimed to assess the diversity of *Lamellidens* spp., its distribution pattern across the Brahmaputra basin of Upper Assam and also for identification of important sites for future conservation planning of freshwater bivalves in the Upper Brahmaputra river basin.

MATERIALS AND METHODS

Study area

The present field study was carried in Brahmaputra basin of Upper Assam covering a total geographical area of approximately 3900 km^2 between latitude (27°16'20''–27°47'77'') N and longitude (94°35'30''–95°22'42.16'') E (Table 1; Figure 1). The area was selected because of the large-scale habitat loss during the last few decades due to recurring flood reported having begun after the devastating earthquake of the 1950s and natural as well as man-made anthropogenic activities like the discharge of chemicals from oil field areas and tea gardens. Sample collection was carried out in 10 random sampling points in each sampling station using quadrate method ($1m^2$ size). The large specimens were handpicked and the smaller ones were collected from the bottom substrata by using a metal sieve of mesh size $2mm^2$. Specimens were then washed, sorted into morpho-species and representatives were brought to the laboratory for future reference. Identification of the specimens was done according to Subba Rao (1989); Ramakrishnan and Dey (2007) and with the help of the Zoological Survey of India (ZSI), Kolkata.

Diversity analysis

For each sampling stations abundance (*N*), the number of species or Species richness (*S*), the Shannon- Wiener diversity index (*H*) (in $\log_{10}$), Simpson index (*1-D*), Evenness index ($E^{H/S}$) were calculated to evaluate the state of diversity in the studied area. The program PAST 3 (Paleontological Statistics Version 3.08) was used to calculate diversity indices. Species richness evaluated through individual-based rarefaction (interpolation – extrapolation) using the method proposed by Colwell et. al (2012) using EstimateS programme. ICE, ACE, Chao 1, Chao 2, Jack 1, Jack 2 were performed to evaluate the possibility of finding more (undiscovered) species of *Lamellidens* in the study area. All estimations were calculated using EstimateS (Colwell, 2012) and spadeR software (Chao & Chiu 2016).

Morphometric analysis

The shell measurements were taken, with a precision of 0.1 mm using a digital vernier calliper. Shell length (SL), it was represented by the longest dimension of the shell parallel to the hinge line i.e. the antero-posterior axis of the shell; shell height (SH), maximum distance in dorso-ventral axis; shell width (SW_d), maximum distance in the lateral axis; shell thickness (ST), thickness of the right valve along ventral margin up to the pallial line; adductor muscle scar length (A_mL), the longest distance between anterior adductor muscle scar to posterior adductor muscle scar in the antero-posterior axis of the shell. Shell Weight (SW) i.e. weight of the dry shell (both right and left valve) without tissue were determined by using Kern digital weighing balance with a deviation of ±0.01mg.

Table 1. Name, assigned code and their co-ordinate of the sampling stations

Name	Code	Latitude [N]	Longitude [E]
Maguri beel	MB	27°34′17.73″	95°22′42.16″
Diharng river	DR	27°22′51.68″	95°6′5.42″
Kulagora, Burhi-Dihing River (Tikirabali)	KBD	27°20′0.05″	95°9′11.70″
Hareghat, Burhi-Dihing river	HBD	27°21′24.95″	94°58′59.60″
Sesa river	SR	27°19′32.83″	94°50′20.94″
Janzi,Burhi-Dihing River	JBD	27°16′23.68″	94°48′7.77″
Aamguri River	AR	27°25′55.99″	94°37′58.14″
Laipulia river (Dusutimukh)	LR	27°26′7.57″	94°36′58.14″
Kopahtoli (Bhomura guri)	KR	27°24′55.71″	94°35′30.20″
Sisi River	SIR	27°21′0.75″	94°37′16.33″
Gelua river	GR	27°31′27.36″	94°41′19.88″
Mesu River	MR	27°32′19.81″	94°41′36.40″
Tongani Beel (Tongani majgaon)	TB	27°30′57.02″	94°44′44.30″
Tongani River	TR	27°29′27.23″	94°43′20.85″
Nahor Village (Bahir Jonai)	NV	27°47′9.40″	95°15′17.89″
Sile river (bahir chilai)	SLR	27°48′34.79″	95°16′56.68″
Aagrung beel	AB	27°47′5.76″	95°16′50.85″

RESULTS

Altogether 2135 live specimens belonging to four species of *Lamellidens* spp. were recorded during the survey period (Figure 2). These composed of 832 (38.97% of the total abundance) of *Lamellidens* corrianus (Lea, 1834), 741 (34.70%) specimens of *Lamellidens marginalis* (Lamarck, 1819), 437 (20.46%) of *Lamellidens phenchooganjensis* Preston, 1912 and 125 (5.85%) specimens of *Lamellidens jenkinsianus* (Benson, 1862). Habitat ecology, Population trend, the geographical distribution of *Lamellidens* spp. is listed in Table 2.

As regards the species richness and abundance, sampling stations 'MB' with all four species of *Lamellidens* emerged as the richest sampling stations in the study area, whereas no specimen of *Lamellidens* spp. was recorded in sampling station 'JBD'. The Simpson index (*1-D*) and Shannon diversity index (*H)* does not show any constancy across the sampling stations with values ranges from 0.29 – 0.69 and 0.68–2.13 respectively. Evenness ($E^{H/S}$) index also showed variations across the sampling stations, with values range between 0.76–0.99.

Species richness was evaluated in different sampling stations (northern basin and southern basin) of the

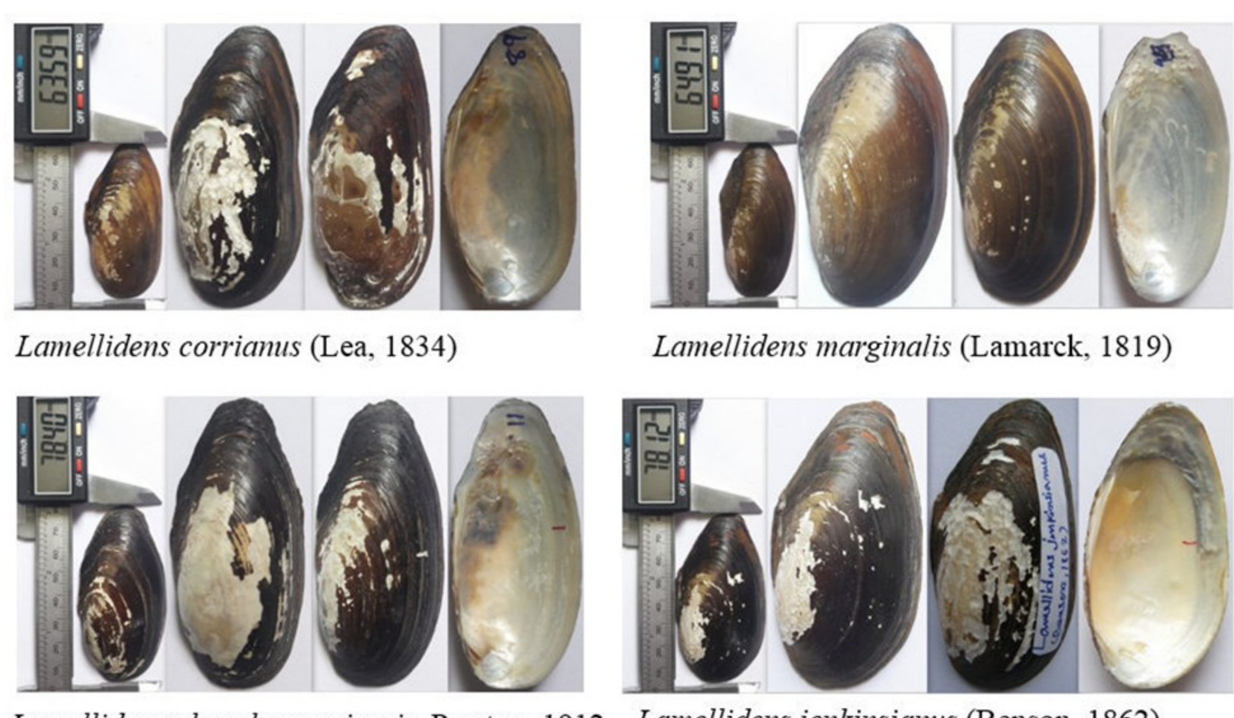

Figure 2. Photographs of recorded *Lamellidens* spp. from the upper Brahmaputra basin of Assam

Table 2. Habitat ecology, population trend, geographic range and possible threats of recorded *Lamellidens* spp.

Species	Habitat & Ecology	Population trend	Geographic range	Possible threats
Lamellidens corrianus	Prefer sand, silt and mud substrate of ox-bow lakes, large lowland rivers, Ponds and beels where the planktonic community is very high	Unknown	Gangetic plains, Brahmaputra basin; Northeastern states; reported from Myanmar also	Not been adequately identified. Overexploitation for human consumption, pollution from agricultural runoff, habitat loss and degradation are considered as possible threats.
Lamellidens marginalis	Mostly prefer lentic water bodies such as ox-bow lakes, ponds and reservoirs; rivers with slow water currents	Unknown	Lower and upper Gangetic plains in India and Bangladesh, Brahmaputra basin Terai region of Nepal; elsewhere Myanmar	Need to be identified. Use of herbicide and pesticide especially in tea gardens, use of chemicals for fishing, overharvesting for food are some inferred threats to this species
Lamellidens phenchooganjensis	It is found under dense macrophytes in stagnant water bodies such as ox-bow lakes and large earthen ponds	Unknown	Lower Brahmaputra River drainage in Bangladesh. In this current study it is reported from ox-box lakes of upper Brahmaputra basin	Yet to be identified
Lamellidens jenkinsianus	River basins where the water current is slow, stagnant water bodies including, ponds, lakes etc.	Unknown	Native to Brahmaputra basin; probably extended to Bihar, Myanmar, Nepal	Agriculture and logging, hydropower development, overexploitation for food are considered as inferred threats to this species

study area by individual-based rarefaction (interpolation--extrapolation) curves is presented in Figure 3. Significant trend of diversity between northern basin and southern basin of the study was observed as both the curves do not overlap at 95% unconditional confidence interval.

Morphometry of shell variables in four *Lamellidens* spp. are listed in table 3. Out of all considered external morphological characters/variables, *L. jenkinsianus* scored highest and vice versa in *L. marginalis.* Significant differences of group variables were observed within the four species, except in shell highest (SH) where no significant difference was observed between *L. corrianus* and *L. marginalis* at 95% confidence interval (Table 3).

DISCUSSION

It has been estimated about 186 species of mollusc that inhabit in freshwater rivers, streams, and lakes in the eastern Himalayan region (Budha *et al*., 2010) which is approximately 6.28–7.1% of the total global estimate of freshwater mollusc (Bogan, 2007; Graf, 2013). In its global distribution range there are only 10 species under the genus *Lamellidens* and we have recorded four of them. As regards the species richness, there is the possibility of encountering more *Lamellidens* spp. as indicated by the individual based rarefaction curve (Figure 3) and different species estimators as number of estimated species is much higher than the observed if the sample

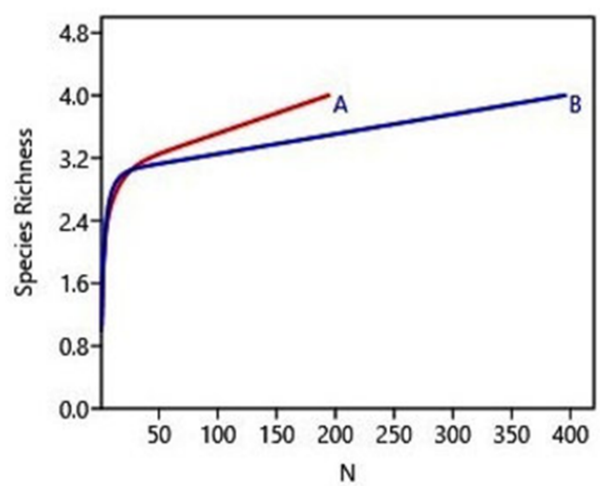

Figure 3. Individual-based rarefaction curve of northern basin (B) and southern basin (A) showing non-overlapping curves at 95% unconditional confidence interval.

Table 3. Morphometric analysis of shell variables in *Lamellidens* spp.

Species	External Morphological Characters					
	SW (mg)	SL (mm)	SH (mm)	SW_d (mm)	ST (mm)	A_mL (mm)
L. Corrianus (*N* = 254)	93.3±0.15[a]	67.62±0.29[a]	33.57±0.13[a]	20.45±0.12[a]	0.67±0.10[a]	39.07±0.23[a]
L. marginalis (*N* = 240)	75.5±0.12[b]	64.40±0.26[b]	33.58±0.15[a]	18.08±0.10[b]	0.52±0.10[b]	37.03±0.16[b]
L. Phenchooganjensis (*N* = 213)	135.6±0.52[c]	75.91±1.01[c]	36.58±0.43[b]	24.27±0.33[c]	0.90±0.02[c]	42.45±0.52[c]
L. Jenkinsianus (*N* = 197)	210.6±0.13[d]	77.41±0.21[d]	37.84±0.23[c]	25.31±0.05[d]	1.73±0.27[d]	44.02±0.35[d]

size is increased (Figure 4). Reports on freshwater mollusc diversity from mainland of India and Indo-Burma region are available (Subba Rao, 1989; Ramakrishna & Dey, 2007; Budha *et al*., 2010; Aravind *et al*., 2010; Köhler *et al*.,.2012; Kumar & Vyas, 2012; Ramesha *et al*., 2013). But research on freshwater mollusc, especially on *Lamellidens* spp. is quite scanty in Brahmaputra basin. The result of the present investigation is significant in the sense that we have recorded *L. phenchooganjensis* which was previously only reported from Phenchooganj (Bangladesh) and Mizoram (Table 2).

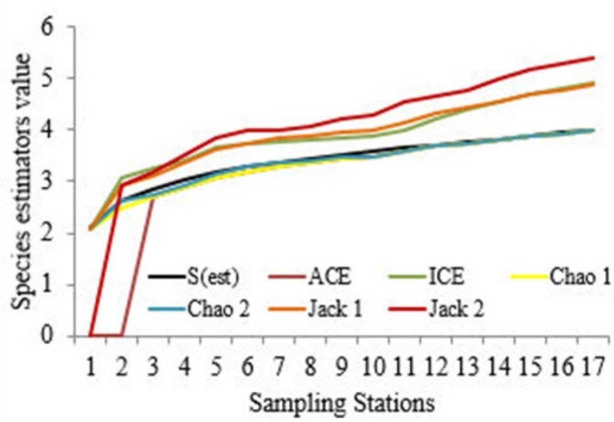

Figure 4. Different species estimators describes the estimated species richness with respect to total observed species richness

Biogeographically, most families of freshwater mollusc from Eastern Himalayan and Indo-Burma hotspot region are cosmopolitan in nature and found all over the globe (Budha *et al*., 2010; Köhler *et al*., 2012). For instance, Unionidae and Cyrenidae have global distribution. However, the scenario is quite different at the species level. The recorded *L. jenkinsisnus* is found to endemic to Brahmaputra basin (Ramakrishnan & Dey, 2007). Few reports on extended distribution are available only with its type locality, e.g. *L. jenkinsianus* sub. *daccaensis*. Further survey and authentication are required for its presence in other Indian states (Budha and Daniel, 2010). It was observed that out of four recorded species, two species viz. *L. phenchooganjensis* and *L. jenkinsianus* are found to be unique i.e. confined to only one or two sampling stations in this present investigation. Confined to a particular sampling station indicating the role of certain abiotic and biotic factors that might influence the habitat specificity for their survival. The presence in only one or two sampling station reflects the change in habitat conditions across the sampling stations indicating habitat heterogeneity in the region (Figure 3) or maybe such species shows a narrow range of habitat adaptability and might have eliminated from other sampling stations of the study area because of other factors related to habitat parameters. Significant trends of diversity in terms of species abundance and distribution of *Lamellidens* spp. has been observed in northern and southern basin of the study area (Figure 3). The most plausible explanations for this dissimilar distribution is due to increasing dissimilarities caused by local driving forces in River Flood Plain Systems (RFS). The floodplain aquatic habitats are isolated from each other and subject to local driving forces during low water periods (Camargo & Esteves, 1995; Thomaz *et al*., 2007; Tockner *et al*., 1999; Lewis Jr. *et al*., 2000). The influence of local driving forces inducing heterogeneity leading to localized physical and chemical characteristics that are basin-specific; induced sediment resuspension, which affects water bodies according to their morphometry and differences in ecological succession. These local forces act with different intensities in the floodplain landscape, thus creating habitats with different characteristics (Thomaz *et al*., 2007). Most of the southern basin areas of the study area are covered by paddy fields, tea gardens and oil field related industries; rivers and tributaries are considerably deep with higher carrying capacity. On contrary, the northern basin of the study area is the worse effected by recurring flood every year. This has affected not only the distribution but also the overall diversity of aquatic faunas due to habitat loss as a result of extensive changes in the wetlands (Furch and Junk, 1985; Hamilton and Lewis, 1990; Bozelli, 1992 and Thomaz *et al*., 2007). In addition to the limnological characteristics, the composition of phytoplankton, zooplankton, fish and macrophytes of rivers and wetlands are more similar in the RFS (Thomaz *et al*., 2007).

About 32.3% of the recorded freshwater molluscs of the Eastern Himalayan region falls under Data Deficient (DD) Category of IUCN Red list (Budha *et al*., 2010). On the other hand, the study conducted in Indo-Burma region assessed 49.76% and 32.55% recorded species under the category of Least Concern (LC) and DD respectively (Köhler *et al*., 2012). Similarly the recorded *Lamellidens* spp. falls under LC category of

IUCN Redlist. These high number of LC and DD is mainly due to unknown species distribution, population trends and potential threats (IUCN, 2010) as there was no available information on such study from this region. However, most of the LC and DD are known only from the late 19th and early 20th century description. So, it may be suggested to emphasize on the review of many taxonomic problems persist in the current literature and to resolve these issues in the light of regional context through further works (Budha *et al*., 2010).

CONCLUSION

There are certain databases for Eastern Himalayas, Indo-Burma and Western Ghats molluscs species. However such databases are not enough to describe all the aspect of species in the recent scenario. Because inconsistencies between available data clearly indicate that the taxonomic situation is still a major problem in establishing a database for the planning of species conservation in the region.

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