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Cover: Orange Oakleaf *Kallima inachus* with colour pencils and watercolor wash by Elakshi Mahika Molur adapted from a workshop by Lenin Raj.



Threat assessment and conservation challenges for the herpetofaunal diversity of Dampa Tiger Reserve, Mizoram, India

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Abstract: Herpetofauna is an important group of vertebrates with key functions in ecosystem sustenance. Nonetheless, with ever-increasing anthropogenic activities and lack of evidence-based studies, about 80% of the herpetofauna diversity of southern Asian region is threatened. Our study reports 80 herpetofauna species distributed across different habitat types in Dampa Tiger Reserve (DTR), Mizoram. We revise the amphibian list of DTR through the addition of seven species and establish the identity of cryptic species such as *Microhyla ornata* which is actually two distinct species, i.e., *M. mukhlesuri* and *M. mymensinghensis*. Through the questionnaire survey, it was found that 90% of the respondents depended on varied forms of forest resources. Herpetofaunal species account for 30% of the faunal resources with *Varanus bengalensis*, *Ophiophagus hannah*, and *Python bivittatus* being the most consumed reptile species. All chelonians and some amphibians like *Duttaphrynus melanostictus*, *Pterorana khare*, *Hoplobatrachus tigerinus*, *Hoplobatrachus litoralis*, *Hydrophylax leptoglossa*, *Minervarya asmati*, *Polypedates teraiensis*, and *Sylvirana lacrima* were also found to be consumed and used for their presumed medicinal values. In addition to hunting, road-kills, use of chemical pesticides, and habitat alteration were recorded to be the prominent threats in the region. The land use and land cover (LULC) data shows a steady recovery of dense forest and a better forest fire scenario as over 90% of the DTR core region falls in the 'low severity' and 'unburned' category. With continuous alteration in forested areas, the present study will not only provide a fundamental baseline for the conservation of herpetofauna and better management of protected areas but also stimulate future herpetological-based research.

Keywords: Anthropogenic, habitat, land use land cover, northeastern India, resource management, sustainable.

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Author contributions: SG and HTD carried-out all the field surveys and prepared the initial draft manuscript. FF, LB has performed the molecular analysis of cryptic species and ascertains the identity of the collected specimens. Mr. Z has analysis the LULC and other GIS related works. HTL has supervised the entire survey period and approved the final draft upon suggesting the necessary corrections to the initial draft

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INTRODUCTION

Amphibians and reptiles are amongst the most diverse and unique group of vertebrates. They play varied roles in natural systems as predators, prey, seed dispersers, or as commensal species (da Silva & de Britto-Pereira 2006). Several herpetofauna species are known to serve as bio-indicators of environmental health providing ideal models for biological and evolutionary studies (Böhm et al. 2013; Hernández-Ordóñez et al. 2015; Erawan et al. 2021). Although available in different land forms, the herpetofauna are sensitive to habitat modification and face global extinction crises because of habitat loss and climate change (Lesbarrères et al. 2014; Trimble & van Aarde 2014; Musah et al. 2019).

Globally, around 41% of amphibians and 21% of reptiles are categorized as 'threatened' by the IUCN Red List (Cox et al. 2022), due to habitat destruction, hunting, poaching, and pet trade (Böhm et al. 2013; Measey et al. 2019; Hughes et al. 2021; Cox et al. 2022). While large body-sized vertebrates are comparatively well studied, little is being documented about the responses of amphibians and reptiles to such changing landscapes and anthropogenic activities (Fulgence et al. 2021).

Nestled in the eastern Himalayan region, the northeastern states of India are located at the crossroads of two biodiversity hotspots of the world, i.e., the Eastern Himalaya and the Indo-Burma biodiversity hotspot (Saikia & Kharkongor 2017). The forests of Mizoram are mainly tropical forests with high species richness and endemism (Lalrem Sanga 2018). Recent studies from Mizoram have reported several new species to the state that include *Amolops indo burmanensis*, *Limnonectes khasianus*, *Microhyla mukhlesuri*, and *M. mymensinghensis*. New country records like *Raorchestes rezakhani* and *Sylvirana lacrima* were also described from the state (Decemson et al. 2021a). Reptiles like *Cyrtodactylus montanus* (Muansanga et al. 2020), and *Gekko lionotum* (now *Gekko mizoramensis*) are some other records. However, with rising incidences of forest fire, shifting cultivation, change in land use, land cover pattern, local consumption, and ethnomedicinal usage, the herpetofauna diversity of the state is in peril (Pawar et al. 2004; Lalrem Sanga 2018; Gouda et al. 2021). As the pressure on herpetofauna in the region continues to mount, threat assessments and inventory studies are of great importance to document and conserve the rich herpetological diversity of the state. Through this study, we aim to: (a) assess the herpetofaunal diversity in and around Dampa Tiger Reserve (DTR), which has been unrepresented or poorly documented, (b) determine the

conservation status and existing threats, and (c) identify and address the research gaps that seek urgent attention from the stakeholders and concerned authorities.

MATERIALS AND METHODS

Study Site

The study was undertaken in and around Dampa Tiger Reserve located in the Mamit District of Mizoram. DTR is part of both the Himalaya and the Indo-Burma biodiversity hotspot. The reserve also forms the international border with Bangladesh. It stretches over an area of 500 km² of the core area (23.3486–23.7972 N, 92.2688–92.5275 E) and a buffer zone of 488 km² (23.8005–23.3533 N, 92.3175–92.5288 E) (Mandal & Raman 2016) (Figure 1). Vegetation type in the area comprises tropical wet evergreen, semi-evergreen and bamboo forests. The terrain in the reserve is steep and rugged ranges run in an altitudinal range of ~230–1100 m. Several perennial streams and small water bodies flow across the reserve. The habitat types in the peripheral areas of DTR are secondary forests of medium-sized, abandoned jhum fields, and small forest patches mixed with shrubs and bamboo plants at varied elevations. The peripheral areas of DTR consist of 14 villages where the main source of livelihood is agriculture and Non-timber forest products (NTFP's) collected from the reserve (Gouda et al. 2021).

Herpetological Sampling

Sampling was carried out in both the core and buffer areas of DTR between July 2020 and November 2022. Extensive surveys were carried out in different seasons and habitat types using multiple approaches such as trail walks, line transect surveys and road surveys by a group of two–four individual researchers (Prasad et al. 2018). Different gradients of fallow lands and secondary forested areas (community forest) were also surveyed. Surveys were carried out in the early morning (0500–0800 h) and evening (1800–2300h). For the chelonian diversity, surveys were carried out along the water bodies, drainage, and river beds that flow along DTR and the surrounding village areas. Common species were photographed and released back to the wild after examination and measurement, while unidentified species including road kills were collected and preserved in 70% ethanol for future evaluation.

Genetic analysis

Liver and other suitable tissue samples were used for the DNA extraction process through DNeasy

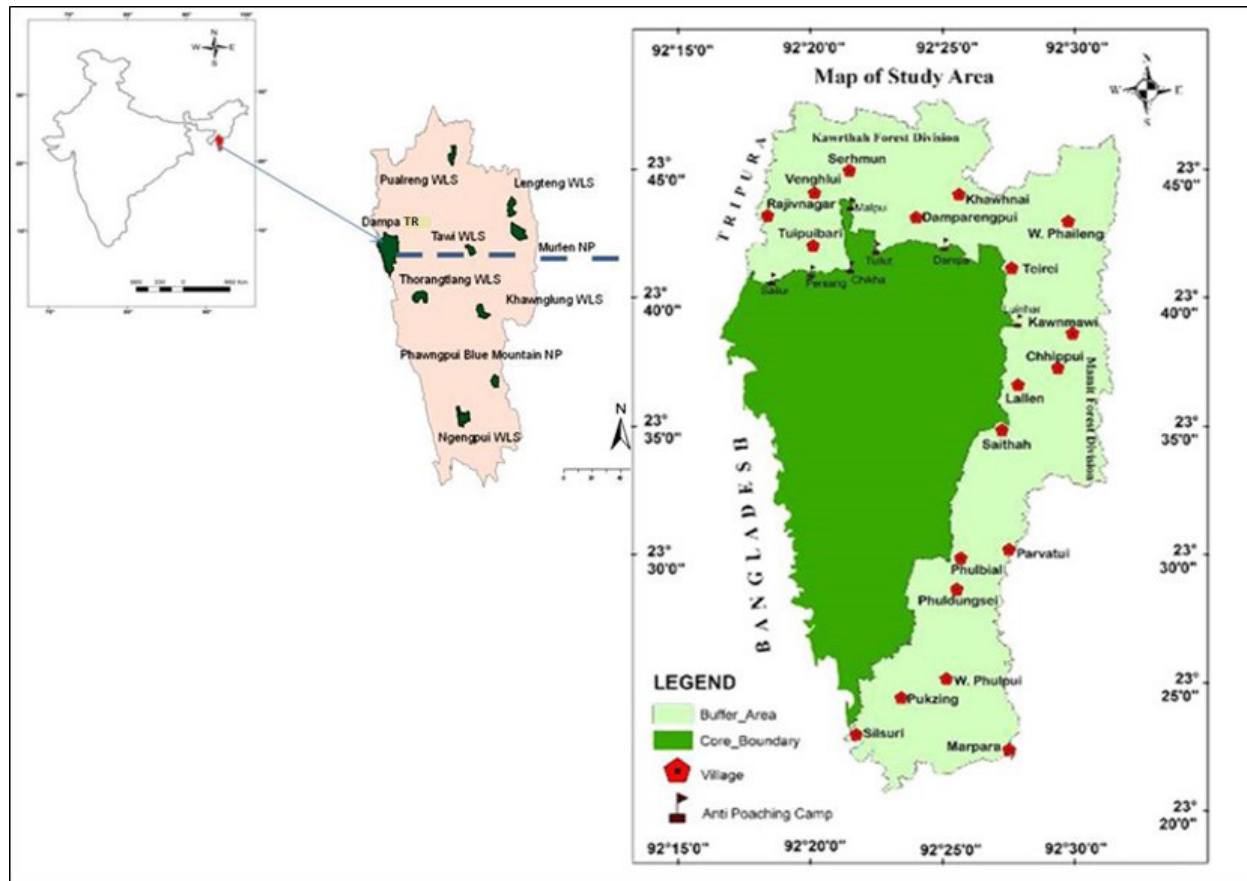


Figure 1. Map representing the study sites.

(Qiagen™) blood and tissue kits. Standard polymerase chain reactions (PCR) were run for amplification using forward primer L02510 and reverse primer H3056. The amplified samples were then sequenced using a sequencer (Agrigenome Labs Pvt. Ltd.) in both directions following Sanger's dideoxy method (Sanger et al. 1977). The obtained chromatograms of 16S rRNA sequences were screened through nucleotide BLAST (<https://blast.ncbi.nlm.nih.gov/>) and ORF finder (<https://www.ncbi.nlm.nih.gov/orffinder/>), the generated sequences were deposited in the GenBank repository and accession numbers were acquired for the same. Voucher specimens for all species were also deposited at the Department Museum of Zoology, Mizoram University (MZMU) for future reference.

THREAT ASSESSMENT

Socio-economic survey

For the assessment of anthropogenic pressure, a semi-structured questionnaire, informal interviews, and interactions with local communities were used to gather information relating to the livelihood options,

agricultural practices, knowledge on herpetofaunal diversity, and usages of the herpetofaunal species (Gouda et al. 2021; Adil et al. 2022). The survey was conducted among all ethnic communities across the fringe villages of DTR, i.e., Mizo, Bru, and Chakma tribes. All discussions and interactions were conducted with the consent of the respondents through the local dialect, which is 'Mizo'.

Land use and land cover (LULC) survey

The presence of humans including settlements, forest cover, forest fire, and agricultural land in fringe villages of DTR was acquired through the Indian Remote Sensing satellite data (LISS-III and Cartosat-I) and digitized using QGIS software for the preparation of LULC maps. LULC classification and NBR mapping were primarily relayed on Landsat 8 data, Level2 products developed and distributed by United States Geological (USGS) Earth Explorer (<https://earthexplorer.usgs.gov/>). Understanding the pattern of LULC change, the study utilized three separate satellite images with different years, months, and dates, like 19 February 2014, 29

January 2018, and 08 January 2023. The study area is covered by path136 and row44. The selection of the data set was influenced by the image quality, especially for those days with limited and low cloud cover. All the selected images had less than 5% cloud cover.

For assessing the forest fire severity, the study utilized multi-date images from Landsat 8 data, firstly, the image representing the pre-fire scenario, acquired on 08 January 2023, and second, the post-fire scenario acquired on 21 March 2022. Specifically, the near-infrared band with 0.845–0.885 μm and short-wave-infrared band with 2.10–2.30 μm forest fire severity were utilized for forest fire severity calculation.

RESULTS

Herpetofaunal diversity of DTR

The study reports 80 herpetofaunal species consisting of ophidians (20 species), saurians (20 species), chelonians (six species) and amphibians (34 species) (Tables 1&2). Among the reptilian fauna, all chelonian species except *Cyclemys gemeli* are categorized as threatened as per the IUCN Red List while among the ophidians, two species—*Python bivittatus* and *Ophiophagus hannah* are ‘Vulnerable’, 15 are in ‘Least Concern’ and three are in ‘Not Assessed’ category. Of the 20 saurian species, *Cyrtodactylus montanus*, is considered ‘Critically Endangered’, *Tropidophorus assamensis* as ‘Vulnerable’, *Varanus bengalensis* as ‘Near Threatened’, and *Sphenomorphus maculatus*, *Gekko mizoramensis* as ‘Not Assessed’, while the remaining 15 species are of ‘Least Concern’ status (Table 1). Among the amphibians, one species—*Bufoides meghalayanus* is categorized as ‘Critically Endangered’, while 16 species are of ‘Least Concern’, four species are ‘Data Deficient’, and 11 are ‘Not Assessed’ (Table 2).

Through this study, we have also updated the amphibian checklist of DTR to 34 species by the addition of seven new species namely *Raorchestes manipurensis* (Departmental Museum of Zoology, Mizoram University MZMU2326–2328 and MZMU2350), *Polypedates braueri* (MZMU2261), *Theloderma baibungense* (MZMU2108), *Kurixalus yangi* (MZMU2273 and MZMU2274), *Ichthyophis multicolor* (MZMU2494A–G), *Bufoides meghalayanus* (MZMU2078 and MZMU2091), and *Ichthyophis benji* (MZMU2809) (Table 3) (Image 1).

The diversity of amphibians was profoundly distributed in small perennial streams, roadside water holes, moist temperate bamboo forests, and secondary forests within the core and also along the

buffer areas. Man-made water bodies like fish ponds in the buffer areas accounted for species such as *Euphlyctis adolfi*, *Fejervarya multistriata*, *Microhyla berdmorei*, and *Sylvirana lacrima* while species like *Amolops indoburmanensis* and *Odorrana chloronota* were more prominent in the cascade flowing of the lotic ecosystem. Agricultural crop fields/ jhum fields were found to be inhabited by species like *Duttaphrynus melanostictus*, *E. adolfi*, *Hydrophylax leptoglossa*, *Hoplobatrachus litoralis*, *Hoplobatrachus tigerinus*, *Kaloula pulchra* and *Minervarya asmati*. Small seasonal drains along roadside were found to harbour species such as *D. melanostictus*, *Ichthyophis multicolor* and *R. manipurensis*. Species like *Rhacophorus bipunctatus*, and *Theloderma baibungense* were more prevalent in the primary forests, while, *Ingerana borealis*, *Limnonectes khasianus*, *Leptobrachium smithi*, *Leptobrachella tamdil* and *Pterorana khare* were found in the slow-flowing streams in the core areas of DTR.

Although we observed saurian and other reptilian species both from primary as well as secondary forests along DTR, activities such as encroachment by humans, increase in number of agricultural crop fields, over-harvesting, and use of chemical pesticides appears to influence the distribution pattern of reptiles in DTR and its peripheral areas. Several species such as *Bungarus fasciatus*, *Bungarus niger*, *Naja kaouthia*, *Ophiophagus hannah*, *Trimeresurus popeiorum*, *Trimeresurus erythrurus*, *Python bivittatus*, *Varanus bengalensis*, *Varanus salvator*, *Cyrtodactylus montanus*, *Calotes irawadi*, *Draco maculatus*, *Ptyctolaemus gularis* and *Tropidophorus assamensis* were frequently encountered in secondary forests, thereby highlighting the role of these mosaic forest patches in the conservation of the herpetofaunal diversity of DTR. All six chelonian species in the study were observed from the streams flowing in the primary forest. However, human activities including illegal hunting and excessive release of pesticides to the water bodies that connect the streams appear to be a challenge for their conservation.

We ascertain the identity of several cryptic species previously misidentified from the region by sequencing mitochondrial genes, 16S ribosomal RNA, and bioinformatics tools. The tissue sample earlier assigned to *Microhyla ornata* was sequenced and the obtained genetic data revealed that it is two distinct species, i.e., *M. mukhlesuri* and *M. mymensinghensis*. Another amphibian species *Xenophrys parva* was established as *X. serchhipii*, which is endemic to the northeastern region of India. *Hoplobatrachus* sp. which was reported as a single species from DTR was sequenced and

Table 1. Chelonian, saurian, and ophidian diversity in and around Dampa Tiger Reserve, Mizoram.

	Common name	Scientific name	Family	Red List status
Chelonia				
1	Assam Leaf Turtle	<i>Cyclemys gemeli</i>	Emydidae	NT
2	Keeled Box Turtle	<i>Cuora mouhotii</i>	Emydidae	EN
3	Asian Giant Tortoise	<i>Manouria emys</i>	Testudinidae	CE
4	Yellow Tortoise	<i>Indotestudo elongata</i>	Testudinidae	CE
5	Black Softshell Turtle	<i>Nilssonina nigricans</i>	Trionychidae	CE
6	Asiatic Softshell Turtle	<i>Amyda ornata jongli</i>	Trionychidae	VU
Sauria				
1	Forest Garden Lizard	<i>Calotes emma</i>	Agamidae	LC
2	Indian Garden Lizard	<i>Calotes irawadi</i>	Agamidae	LC
3	Smooth-scaled Mountain Lizard	<i>Cristidorsa planidorsata</i>	Agamidae	LC
4	Blanford's Flying Lizard	<i>Draco maculatus</i>	Agamidae	LC
5	Green Fan-throated Lizard	<i>Ptyctolaemus gularis</i>	Agamidae	LC
6	Burmese Glass Snake	<i>Dopasia gracilis</i>	Anguidae	LC
7	Jampui Bent-toed Gecko	<i>Cyrtodactylus montanus</i>	Gekkonidae	CE
8	Common House Gecko	<i>Hemidactylus frenatus</i>	Gekkonidae	LC
9	Fox Gecko	<i>Hemidactylus garnotii</i>	Gekkonidae	LC
10	Flat-tailed House Gecko	<i>Hemidactylus platyurus</i>	Gekkonidae	LC
11	Mizoram Parachute Gecko	<i>Gekko mizoramensis</i>	Gekkonidae	NA
12	Tokay Gecko	<i>Gekko gekko</i>	Gekkonidae	LC
13	Khasi Hill Long-tailed Lizard	<i>Takydromus khasiensis</i>	Lacertidae	LC
14	Bronze Grass Skink	<i>Eutropis macularia</i>	Scincidae	LC
15	Common Mabuya	<i>Eutropis multifasciata</i>	Scincidae	LC
16	Indian Forest Skink	<i>Sphenomorphus indicus</i>	Scincidae	LC
17	Spotted Forest Skink	<i>Sphenomorphus maculatus</i>	Scincidae	NA
18	North-eastern Water Skink	<i>Tropidophorus assamensis</i>	Scincidae	VU
19	Bengal Monitor Lizard	<i>Varanus bengalensis</i>	Varanidae	NT
20	Common Water Monitor	<i>Varanus salvator</i>	Varanidae	LC
Ophidia				
1	Yellow Whipsnake	<i>Ahaetulla flavescens</i>	Colubridae	LC
2	Tawny Cat Snake	<i>Boiga ochracea</i>	Colubridae	LC
3	Golden/Indian Flying Snake	<i>Chrysopelea ornata</i>	Colubridae	LC
4	Common/Painted Bronzeback	<i>Dendrelaphis proarchos</i>	Colubridae	LC
5	Asiatic Water Snakes/ Checkered Keelback	<i>Fowlea piscator</i>	Colubridae	LC
6	Common Ringneck	<i>Gongylosoma scriptum</i>	Colubridae	NA
7	Chin Hills Keelback	<i>Hebius venningi</i>	Colubridae	LC
8	Wall's Keelback	<i>Herpetoreas xenura</i>	Colubridae	NA
9	Zaw's Wolf Snake	<i>Lycodon zawi</i>	Colubridae	LC
10	Light-barred Kukri Snake	<i>Oligodon albocinctus</i>	Colubridae	LC
11	Heller's Red-necked Keelback	<i>Rhabdophis helleri</i>	Colubridae	NA
12	Banded Krait	<i>Bungarus fasciatus</i>	Elapidae	LC
13	Greater Black Krait	<i>Bungarus niger</i>	Elapidae	LC
14	Monocled Cobra	<i>Naja kaouthia</i>	Elapidae	LC
15	King Cobra	<i>Ophiophagus hannah</i>	Elapidae	VU
16	Common Slug Snake	<i>Pareas monticola</i>	Pareidae	LC
17	Common Mock Viper	<i>Psammodynastes pulverulentus</i>	Pseudaspidae	LC
18	Burmese Python	<i>Python bivittatus</i>	Pythonidae	VU
19	Pope's Bamboo/ Green Pit Viper	<i>Trimeresurus popeiorum</i>	Viperidae	LC
20	Redtail (Bamboo) Pit Viper	<i>Trimeresurus erythrurus</i>	Viperidae	LC

CE—Critically Endangered | EN—Endangered | LC—Least Concern | NT—Near Threatened | NA—Not Assessed | VU—Vulnerable.

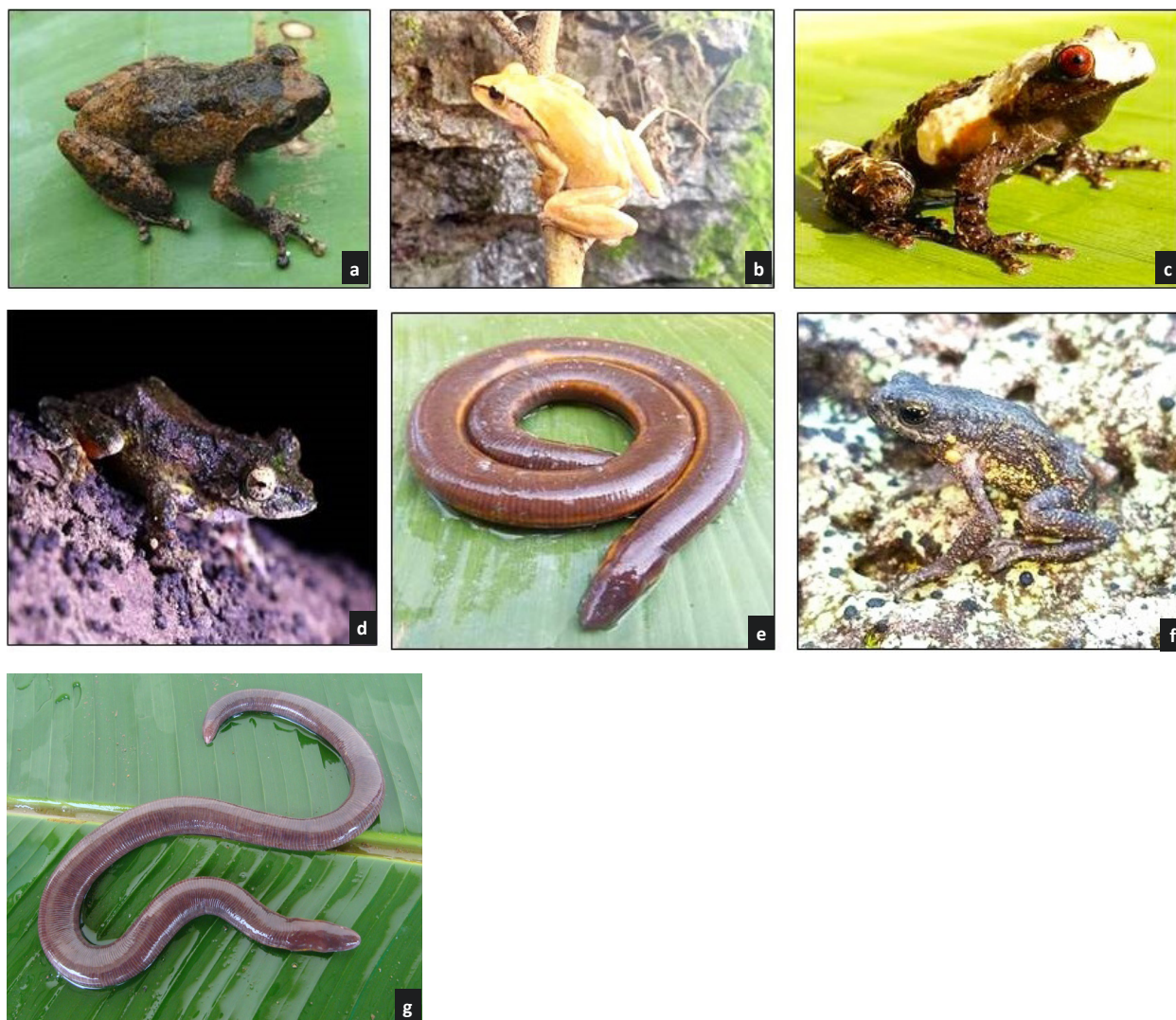


Image 1. Some amphibian species reported through the study: a—*Raorchestes manipurens* | b—*Polypedates braueri* | c—*Theloderma baibungense* | d—*Kurixalus yangi* | e—*Ichthyophis multicolor* | f—*Bufoides meghalayanus* | g—*Ichthyophis benjii*. © HT Lalremsanga.

confirmed to be two separate species, i.e., *H. tigrinus* and *H. litoralis*.

Threats and conservation challenges

The threats for the herpetofaunal diversity were assessed through the socio-economic survey and understanding of the land cover change in and around the DTR region. Some of the major conservation challenges for the herpetofauna of DTR include:

Dependency on forest resources

During the questionnaire survey, it was found that more than 90% of the respondents collected NTFPs and other forms of forest resources such as bamboo shoots, wild berries, different frog, snails, and crab species. from the surrounding forested areas of DTR. About 19% of the

locals interviewed stated that they collect bamboo—*Dendrocalamus longispathus*, *D. asper*, *Melocanna baccifera*, and *Bambusa tulda* for construction, consumption, and fuelwood, while 2% collect timber—*Gmelina arborea* and *Derris robusta*, 24.5% collect fuel wood, and 12.5% collect edible food/medicines. About 39% of the respondents stated to collect all the above forest items, while 3% of the surveyed locals do not collect any form of forest products. Several faunal resources such as fish, tadpoles, crabs and snails are also regularly collected by the locals and sold in the market (Image 2). Large mammals hunted for bushmeat include *Sus scrofa*, *Muntiacus muntjak*, *Rusa unicolor*, *Capricornis sumatraensis*, and *Macaca assamensis*. Encouragement to adopt alternative livelihoods and expand their income sources will be crucial for reducing

the pressure on the biodiversity of DTR and improving the socio-economic status of the tribal communities.

Over-harvesting of herpetofauna

Herpetofaunal species account for 30% of the faunal resources used by locals around DTR. *Varanus bengalensis*, *Ophiophagus hannah*, and *Python bivittatus* were the most consumed reptile species. Several snake species although not consumed, were many a time killed out of fear of snake bite. Among amphibians *Duttaphrynus melanostictus* and *Pterorana khare* were consumed as a delicacy and also used for the treatment of ailments like common cold and cough. Species like *Hoplobatrachus tigerinus*, *H. litoralis*, *Hydrophylax leptoglossa*, *M. asmati*, *P. teraiensis*, *Duttaphrynus* sp., and *S. lacrima* were found to be sold alive or dried at ₹100/ package weighing about 500g in the local market (Pers. obs. of HTL and SG during field visits to the study sites) (Image 3). Tadpoles of *Clinotarsus alticola* and *L. smithi* caught from the streams along the buffer region were also reported to be consumed regularly by locals. Ethnomedicinal or traditional medicines play an important role in the exploitation of herpetofauna species in and around DTR where health facilities are lacking or poor. The questionnaire survey revealed that many locals use reptiles and amphibian's species for treating several health ailments such as skin infections, stomach problems, and burns. The fats of *Python bivittatus* are applied to burns and inflammation, and the glands are sometimes used as a sedative. The fatty oil obtained from *Trimeresurus erythrurus* is used for treating warts. Soup of *D. melanostictus* is administered for common cold and cough. Different species of chelonians including *I. elongata*, *Cyclemys gemeli*, and *Cuora mouhotii* are regularly consumed by the locals and also traded to neighbouring states like Assam and Tripura for their medicinal values (Image 4).

Road kills and lack of awareness

During our survey period, we encountered several species of amphibians and reptiles that were killed on the road that stretches from W. Phaileng to Marpara (84.9 km) and between W. Phaileng to Rajiv Nagar (64 km) (Image 5). Some of the commonly observed roadkill species included *I. multicolor*, *Calotes irawadi*, *Coelognathus radiatus*, *D. melanostictus*, *Pareas monticola*, *M. berdmorei*, *S. lacrima*, *F. multistriata*, and *M. asmati*. (Image 5a-i). Ignorance or lack of awareness of the role of amphibians in biodiversity sustainability, as biological indicators of climate change, pollution, and the benefits of amphibians as pest control agents have led

Table 2. Amphibian diversity of Dampa Tiger Reserve region, Mizoram.

	Common name	Scientific name	Red List status
I	Anurans		
1	Smith's Litter Frog	<i>Leptobrachium smithi</i>	LC
2	Tamdil Leaf-litter Frog	<i>Leptobrachella tamdil</i>	NA
3	Serchhip Horned Frog	<i>Xenophrys serchhipii</i>	DD
4	White-lipped Horned Toad	<i>Xenophrys major</i>	LC
5	Painted Kaloula/ Painted Bullfrog	<i>Kaloula pulchra</i>	LC
6	Pegu Rice Frog	<i>Microhyla berdmorei</i>	LC
7	Mukhlesur's Narrow-mouthed Frog	<i>Microhyla mukhlesuri</i>	NA
8	Mymensingh Narrow-mouthed Frog	<i>Microhyla mymensinghensis</i>	NA
9	Adolf's Speckled / Bangladesh Skittering Frog	<i>Euphylyctis adolfi</i>	LC
10	Indian Bullfrog	<i>Hoplobatrachus tigerinus</i>	LC
11	Bangladesh Coastal Bull Frog	<i>Hoplobatrachus litoralis</i>	LC
12	Khasi Wart Frog	<i>Limnonectes khasianus</i>	LC
13	Indo-Burma Torrent Frog	<i>Amolops indoburmanensis</i>	NA
14	Malay Pointed-snout Frog/ Assam Hill Frog	<i>Clinotarsus alticola</i>	LC
15	Chin WoodFrog	<i>Sylvirana lacrima</i>	NA
16	Copper-cheeked Stinky Frog/ ChloronateHuia Frog	<i>Odorrana chloronota</i>	LC
17	Khare's Gliding Frog	<i>Pterorana khare</i>	LC
18	Cope's Assam Frog	<i>Hydrophylax leptoglossa</i>	LC
19	Terai Tree Frog	<i>Polypedates teraiensis</i>	NA
20	Himalaya Flying Frog	<i>Rhacophorus bipunctatus</i>	LC
21	Leimatak's Bush Frog	<i>Raorchestes manipurensis</i>	NA
22	White-lipped Tree Frog	<i>Polypedates braueri</i>	NA
23	Baibung Small Tree Frog	<i>Theloderma baibungense</i>	LC
24	Yang's Frill-limbed Tree Frog	<i>Kurixalus yangi</i>	NA
25	Paddy Frog	<i>Fejervarya multistriata</i>	DD
26	Bangladeshi Cricket Frog	<i>Minervarya asmati</i>	NA
27	Rotung Oriental Frog	<i>Ingerana borealis</i>	LC
28	Asian Toad	<i>Duttaphrynus melanostictus</i>	LC
29	Khasi Hill Toad/ Mawblang Toad	<i>Bufoides meghalayanus</i>	CR
II	Ichthyophiidae – Caecilians		
1	Manipur Moustached Ichthyophis	<i>Ichthyophis moustakius</i>	DD
2	Colourful Ichthyophis	<i>Ichthyophis multicolor</i>	DD
3	Benji's Caecilian	<i>Ichthyophis benjii</i>	NA

CR—Critically Endangered | DD—Data Deficient | LC—Least Concern | NA—Not Assessed.



Image 2. a—Tadpoles collected by locals | b—Snails collected from the peripheral areas of DTR | c—Shrimps | d—Bamboo shoots | e— Dried fish and frogs sold in the local market. © HT Lalremsanga.

Table 3. New record of amphibian species from Dampa Tiger Reserve, Mizoram.

	Species	Common name	Family	Voucher/ GenBank accession no.	Red List status	Distribution
1	<i>Raorchestes manipurensis</i> (Mathew & Sen 2009)	Leimatak's Bush Frog	Rhacophoridae	MZMU2326, 2327 & 2328 (GBA no. MZ148621, MZ148620 & MZ148619, respectively)	NA	India (Manipur, Mizoram)
2	<i>Polypedates braueri</i> (Vogt, 1911)	White-Lipped Tree Frog	Rhacophoridae	MZMU2261 (GBA no. MH938688.1)	DD	Tropical and Sub tropical China, Taiwan, Vietnam, Thailand, Myanmar and India (Mizoram)
3	<i>Theloderma baibungense</i> (Jiang, Fei & Huang, 2009)	Baibung Small Tree Frog	Rhacophoridae	MZMU2108 (GBA no. OK474164)	DD	Tibet, China, Bangladesh and India (Arunachal Pradesh, Assam, Nagaland)
4	<i>Kurixalus yangi</i> Yu, Rao & Yang, 2018	Yang's Frill-limbed Tree Frog	Rhacophoridae	MZMU2273 & MZMU2274 (GBA no. MT808303.1)	NA	Western Yunnan, China, Northern Myanmar and India (Nagaland, Mizoram)
5	<i>Ichthyophis multicolor</i> Wilkinson, Presswell, Sherratt, Papadopoulou & Gower, 2014	Colourful Ichthyophis	Ichthyophiidae	MZMU1758 (GBA no. MZ098158)	DD	Ayeyarwady region of Myanmar and India (Mizoram)
6	<i>Ichthyophis benjii</i> (Lalremsanga, Purkayastha, Biakzuala, vabeiryureilai, Muansanga and Hmar, 2021)	Benji's Caecilian	Ichthyophidaae	MZMU2809 (GBA No. OR689358)	NA	Mizoram, India
7	<i>Bufoides meghalayanus</i> (Yazdani & Chanda, 1971)	Khasi Hill Toad/ Mawblang Toad	Bufoidea	MZMU2078 & MZMU2091 (GBA no. MW741545 & MW741544)	EN	Meghalaya, Assam, Mizoram (India)

DD—Data Deficient | E—Endangered | LC—Least Concern | NA—Not Assessed.

to their random killing and consumption. Uncontrolled use of chemical pesticides in agricultural crop fields that

ultimately get deposited in the nearby water bodies as a result of water runoff was another factor that led to



Image 3. Different amphibian species skinned, dried and sold at the local market of Dampa Tiger Reserve region, Mizoram. © HT Lalremsanga.

a decline in the local population of certain amphibian species. Hindlimb malformation in Adolf's Speckled Frog *E. adolfi*, Tamenglong Horned Frog *X. numhbumaeng*, Mawphlang Odorous Frog *O. mawphlangensis*, Nagaland Montane Torrent Toad *D. chandai*; anophthalmia in *X. major* are some of the cases reported from the state of Mizoram. From DTR region abnormalities in skinks such as Indian Forest Skink *Sphenomorphus indicus*,

and Spotted Forest Skink *S. maculatus* are also reported (Decemson et al. 2021b; Lalremsanga 2022; Siammawii et al. 2022).

Land use pattern

The forest is a crucial component for the prosperity and sustenance of wildlife in any given area. Data on LULC generated for the years 2014, 2018, and 2022 shows a recovery of densely forested areas in DTR. Nevertheless, substantial alteration in forest cover along the peripheral areas of DTR also cannot be denied (Image 6). Another interesting finding from the LULC is the reduction in areas under 'Jhum cultivation' also known as slash and burnt form of cultivation, thereby resulting in an increased area of open forest. The areas under shifting cultivation recorded during the last five years showed a decrease from 306 km² to 180.49 km² throughout Mizoram. Adaptation of mixed farming over the traditional Jhum cultivation by local farmers around DTR has also helped increase the fallow period between successional Jhum fields allowing the forest vegetation to recover. An increase in plantation areas was also recorded for DTR. Many of the local farmers now grow various forms of cash crops like Betel Nut *Areca catechu*, Cavendish Banana *Musa acuminata*, Plantain *Musa paradisiaca*, Tree Bean/ Stink Bean *Parkia timoriana* apart from their traditionally grown paddy in the crop fields. Such adaptation in agriculture can be attributed to better management practices by the concerned department and the implementation of the New Land Use Policy (NLUP).

Forest fire

Forest fires in the region were categorized based on the frequency of detected forest fires in an area over period of time and the probabilities of occurrence (proneness) shortly as suggested by Kumar et al. (2019). Analysis of satellite imageries of forest fire data shows that more than 90% of DTR's core areas fall under the category of 'low severity' and 'unburned' (Image 7). Some areas namely Tuichar, Charte, and Saithah composed mainly of bamboo forest that were previously cleared for developing grasslands, represent a 'moderate-high severity' zone. The buffer areas close to villages like Rajiv Nagar, Tuipuibari, Damparengpui, and Silsuri pose a greater threat of fire crossover into the core regions and hence require proper monitoring while jhum fields are burnt by the local farmers. Although forest fire prevalence and severity in DTR are relatively low, with the growing incidences of forest fires and increase in temperature (Pers. Obs of HTL and Pramanick et al.



Image 4. Chelonian species from Dampa Tiger Reserve that are locally consumed: a—*Manouria emys* | b—*Nilssononia nigricans* | c—*Indotestudo elongata* | d—*Cuora mouhotii* | e—*Cyclemys gemelli* | f—*Amyda ornata jongli*. © HT Lalremsanga.

2023), timely vigilance by the concerned department and proper awareness among locals will be crucial for the prevention of forest fire in the near future.

DISCUSSION

Herpetofauna is one of the most threatened groups of vertebrates on the planet. The synergistic effect of habitat loss, fragmentation, over-harvesting, pet trade, traditional medicine, and climate change has threatened the global herpetological population with extinction in the next 50 years, especially in southern Asia (Stuart et al. 2008; Rowley et al. 2010; Nori et al. 2015; Hughes 2017; Choquette et al. 2020; Montgomery et al. 2022). Being the largest protected area in the state of Mizoram, the DTR and its surrounding areas hold a rich and diverse group of herpetofauna of the state. Although *Bufoides bhupathyi* was recently described as new species by Naveen et al. (2023) from the similar study area in DTR, we recommend taxonomic reassessment of the *Bufoides* population from this area using a more holistic data with implementing integrated approach (e.g., multilocus phylogeny, natural history, robust morphological

distinctness, etc.) because recognizing cryptic species through a short fragment of 16S rRNA (~413 bp) and few morphological attributes, particularly webbing formulae and shape of parotoid is ambiguous. Thus, we consider *B. bhupathyi* as a subjective junior synonym of *B. meghalayanus* for the time being. Furthermore, the shallow genetic divergence (0-0.6%) across the sequences of *R. manipurensis* from Mizoram (DTR: GBA MZ148617-21; Sailam: GBA MZ148616, MW938629-30; Lunglei: GBA MZ148622) and the type locality in Manipur (GBA MW680944-47), *R. cangyuanensis* from China (Yunnan: GBA MN475866-7), and *R. longchuanensis* from India (West Bengal: GBA MH423740) and Bangladesh (Habigonj: GBA MH699074) suggested that these samples are conspecific and warrant the treatment of *R. cangyuanensis* as a subjective junior synonym of *R. manipurensis* with the subsequent amendment on the taxonomic status of *R. longchuanensis* from India (West Bengal) and Bangladesh into *R. manipurensis*. We report several reptilian species from the reserve such as *R. manipurensis*, *Leptobranchella tamdil*, *R. senapatiensis*, *I. moustakius*, *I. benjii*, *C. montanus*, *G. mizoramensis*, *T. assamensis*, *H. xenura*, and *B. meghalayanus* that are endemic to the northeastern states of India. Other

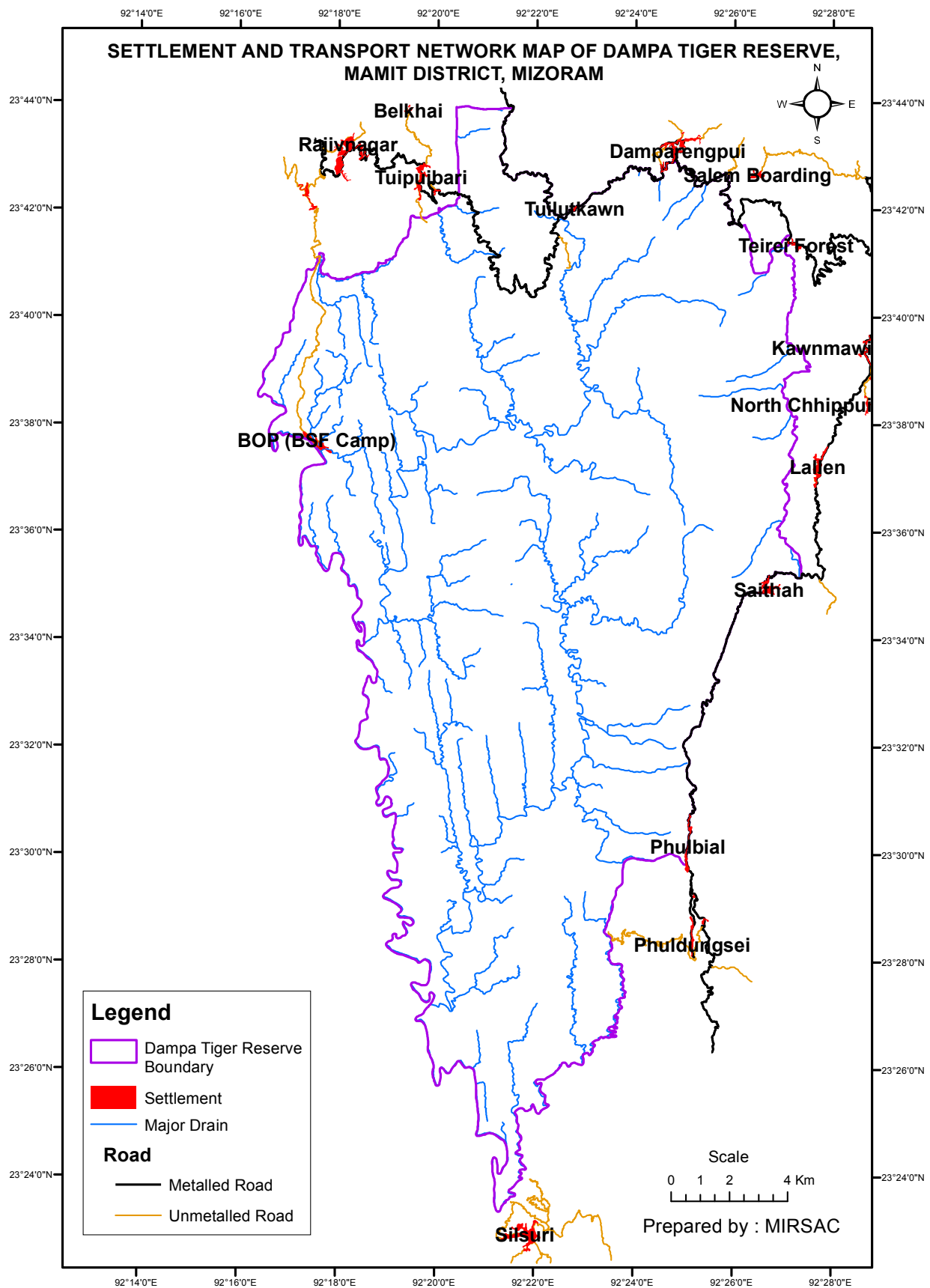


Figure 2. Map representing the road network around Dampa Tiger Reserve.



Image 5. Some road kills recorded from adjacent road to Dampa Tiger Reserve: a—*Coelognathus radiatus* | b—*Pareas monticola* | c—*Boiga ochracea* | d—*Ichthyophis multicolor* | e—*Ovophis monticola* | f&g—*Calotes irawadi* | h—*Sylvirana lacrima* | i—*Duttaphrynus melanostictus*. © Ht. Decemson.

important species reported include *C. montanus*, *T. assamensis*, and *N. nigricans* which are highly cryptic. Several cases of misidentification and misclassification in some of the previous studies from DTR (Pawar et al 2004; Decemson et al. 2021a) such as that of *X. serchhipii* as *X. parva*; *Amolops indoburmanensis* as *A. marmoratus*, *E. adolfi* as *E. cyanophlyctis*, *L. khasianus* as *L. laticeps* are also resolved in the study. However, similar to other tropical forests of southern Asia, DTR too faces the challenge of habitat alteration, increasing human population in the vicinity of villages, hunting, frequent forest fires, monoculture plantation, and high harvesting pressures. A study on the impact of climate change on amphibians by Lalremsanga (2018) showed several distinct changes like altered reproductive activity, phenology, and altitudinal migration from 100–500m to over 824m in Microhylids, and among *Clinotarsus alticola* and *Ingerana borealis* respectively. Biodiversity in protected areas across southern Asia is facing a huge threat mainly due to human population growth (as 25% of the world's population inhabits the region) and the extension of agricultural lands (Ghosh-

Harihar et al. 2019; Chowdhury et al. 2022). Although pet trade and poaching of herpetofauna are yet to be reported from the DTR region, their local consumption and ethno-zoological usage pose a serious threat (Gouda et al. 2021). Mardiasuti et al. (2021) and Montgomery et al. (2022) have also categorized humans as exceptional wildlife consumers pursuing prey species from 34 taxonomic orders of body size ranging from 27 g to 4,400 kg. All of the listed chelonian species in the study are categorized as threatened species and require immediate conservation interventions.

Frequent forest fire is another factor that greatly hampers the herpetofaunal diversity of DTR. As highlighted by Wang et al. (2021), the northeastern region of India alone contributes for about 550,086 ha of the 658,778.4 ha of forested land that is lost every year in India due to various reasons.

A significant proportion of the herpetofaunal diversity in the DTR region is likely to be hidden within morphologically cryptic species groups or genera which are mostly treated as a single species or as many species. Misidentifications between closely resembling species

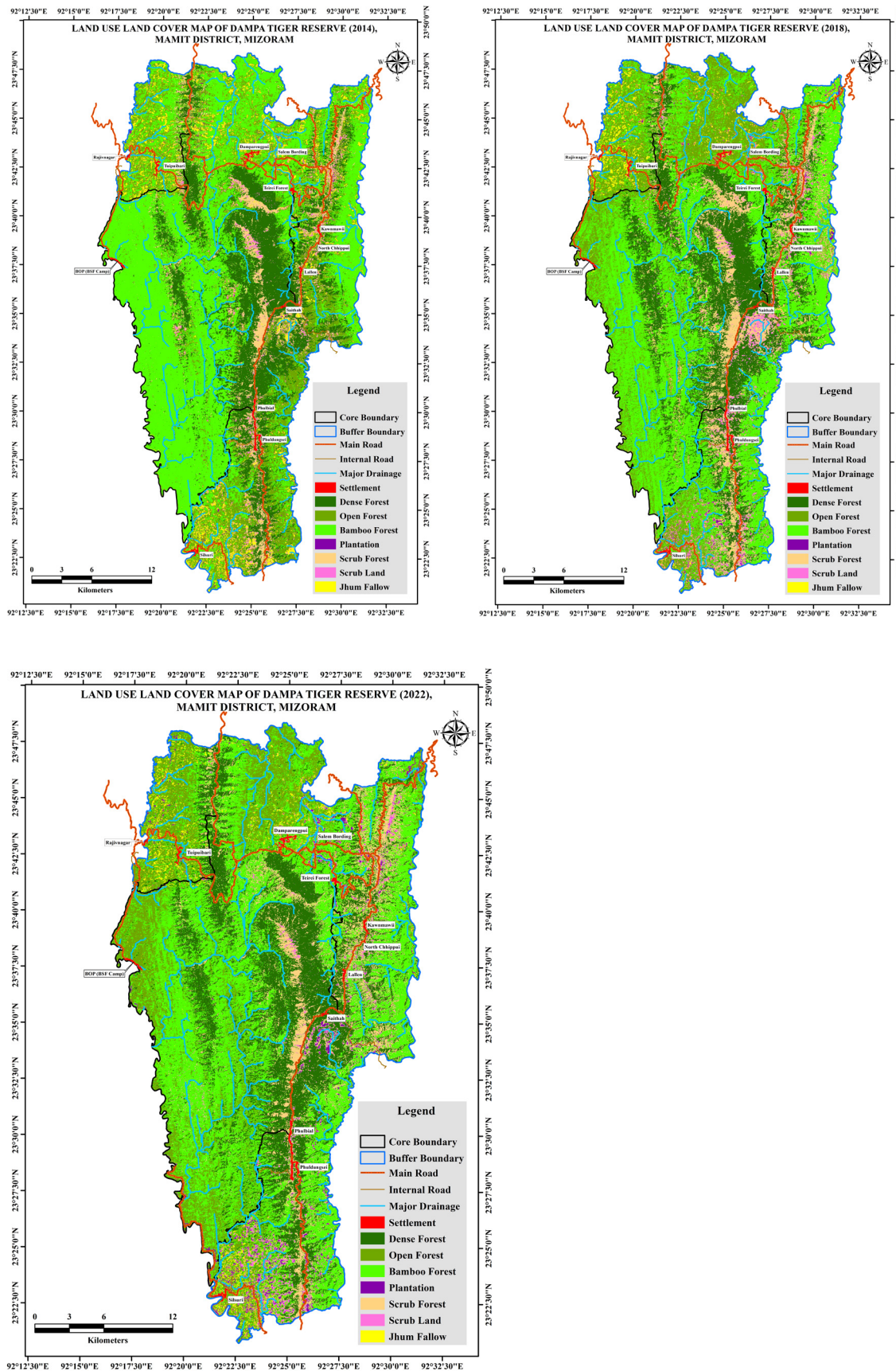


Image 6. Land Use Land Cover pattern in Dampa Tiger Reserve and its surrounding areas from 2014–2022.



Image 7. Forest fire in peripheral areas of Dampa Tiger Reserve. © Sushanto Gouda.

like *Euphlyctis cyanohlyctis* and *E. adolfi*, *Raorchestes manipurensis* and *R. rezakhani*, *Hoplobatrachus tigerinus* and *H. litoralis*, *Microhyla mukhlesuri* and *M. mymensinghensis*, *F. multistriata* and *M. asmati* are quite common in this region and hence require more concerted approaches (Stuart et al. 2006; Kundu et al. 2020; Neves et al. 2020).

While the crucial role of indigenous people and local communities in biodiversity conservation has been greatly valued by organisations such as the United Nations Convention on Biological Diversity, we believe that region-based conservation measures are more likely to have a better impact. As observed in our study, the locals reported the declining trend in amphibian fauna especially the bullfrogs (*Kaloula pulchra*, *Hoplobatrachus litoralis*, and *Hoplobatrachus tigerinus*) which are an important component of their diets. Similar to the findings of Mandal & Raman (2016) and Gouda et al. (2021), the locals during the questionnaire surveys also cited different factors like usage of chemical pesticides, low rainfall, monoculture plantations, habitat alteration and the use of modern machinery as causes for the decline in the population of such species. Since human-dominated landscapes are known for the distribution of over 65% of gap species (Acevedo-Charry & Aide 2019), with the continuous conversion of forested areas into agricultural fields and human habitats in the DTR region, the surrounding areas of DTR can serve as a valuable site for survival and recovery of herpetofauna communities. Considering the paucity of research in the region and cryptic nature of herpetofauna species,

more research initiatives and the knowledge of the local communities are necessary for detailing the diversity and upgradation of the current Red List status. Acknowledging the importance of inventory studies and the role of herpetofauna in a balanced ecosystem will also be necessary for its management and conservation across the eastern Himalayan range and the Indo-Burma biodiversity hotspot. If done regularly, these studies will not only provide a fundamental baseline for the conservation of herpetofauna and better management of protected areas, but also stimulate future herpetological-based research.

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Mizo abstract: Rul, laiking leh uchang te hi nungcha hnungzangruh nei zingah chuan an chenna chhehvel inrellawlna kawngah an pawimawh hle a. Chutih laiin, Asia chhimchhaklam a heng nungcha chi hrang hrang 80% vel chu mihring hnuhma lo pungchho zel leh behchhan nei a zirchianna mumal awm loh avangin dinhmun derthawng an ni tawh a. Dampa Tiger Reserve (DTR)-a heng nungchate leh an chenna hmun chi hrang hrang kan zirchiannaah hian chi hrang 80 chhinchhiah a ni a. Hengte bakah hian chi hrang pasarih dang hmuh belh niin tunhma a uchang chikhat *Microhyla ornata* ang hriat thin chu chi hrang pahni, *M. mukhlesuri* leh *M. mymensingensis* inphumru an lo ni reng zawk tih hmuhchhuah a ni. Zirchianna atan a zawhna siam chhangtu zinga 90% te chu ramngaw hausakna chi hrang hrangah an inghat tih a hriat a. Heng ramsa zing a mihringte ei thin zingah hian 30% chu *Varanus bengalensis*, *Ophiophagus hannah*, leh *Python bivittatus* te an ni. Satel leh sumsi te leh uchang thenkhat, *Duttaphrynus melanostictus*, *Pterorana khare*, *Hoplobatrachus tigerinus*, *Hoplobatrachus litoralis*, *Hydrophylax leptoglossa*, *Minervarya asmati*, *Polypedates teraiensis*, leh *Sylvirana lacrima* te hi ei thin niin tualcher damdawi ang a hman thin an ni baw. Helai hmun a nungchate dinhmun tiderthawng nasa ber zingah hian ei atan a tihlum bakah lirthei chilhlumte, hlotur hman nasat leh an chenna hmun tih chereu nasat vang te a ni. Land use leh land cover (LULC) data atanga a landan chuan helai ramngaw chhehvel 90% hi insiamthar leh chak tak leh kangmei pawhin a tihchhiat loh a ni a. Kan ramngaw te tihdanglam zel an nih lai hian, tun a kan zirna hi heng nungchate leh an chenna ramngaw humhalhna atan chauh niloin, hetiang lam zirbing mi te tan ala tangkai dawn chauh a ni.

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