Indian Journal of Ecology (2025) 52(3): 511-519
DOI: https://doi.org/10.55362/IJE/2025/4529

Manuscript Number: 4529
NAAS Rating: 5.38

Faunal Diversity of Tembao Lake Complex- High-Altitude Wetland In North Sikkim, Eastern Himalaya

Bhoj Kumar Acharya, Iswar Kumar Chettri, Bishal Thakuri, Roshan Tamang, Thangsuanlian Naulak[1], Aita Hang Subba Limboo, Basundhara Chettri and Sailendra Dewan[1*]

Ecology, Biodiversity and Conservation Biology Laboratory, Department of Zoology, School of Life Sciences, Sikkim University, Gangtok-737102, India
[1]Ashoka Trust for Research in Ecology & the Environment (ATREE), Regional Office Eastern Himalaya-Northeast India, Gangtok -737 102, India
**E-mail: sailendra.dewan@atree.org*

Abstract: High-altitude wetlands in the Himalaya are critical biodiversity rich ecosystems, supporting unique alpine flora and fauna while providing essential ecosystem services to downstream communities. However, due to their remote locations and extreme environmental conditions, these ecosystems remain understudied. This study presents a comprehensive faunal assessment of the Tembao Wetland Complex (TWC) in Sikkim, India, located at an elevation of 5,200 m asl. The study recorded five butterfly species, indicating the presence of diverse insect life adapted to high-altitude conditions. Observation of *Scutiger boulengeri* (Boulenger's Lazy Toad), reaffirmed the significance of TWC as a key breeding ground for high-altitude amphibians. Avian sampling revealed 16 bird species, with evidence of breeding activity in many, underscoring the wetland's role as a crucial avian habitat. Additionally, direct and indirect observations of five mammalian species highlight the area's importance for sustaining wildlife populations in these extreme conditions. Given its ecological significance, we advocate for the designation of TWC as a Ramsar and Heritage Site to ensure the long-term conservation of its biodiversity and to recognize the broader importance of high-altitude wetlands in the Himalayan landscape.

Keywords: Amphibians, Birds, Butterflies, High Altitude Lakes (HALs), Mammals, Wetland ecosystems

Lakes are the major wetland types in the high-elevation region in the Himalaya and those located above 3000 m elevation are generally considered as High-Altitude Lakes (HALs). As per the national wetland inventory and assessment report of the Space Application Centre, Government of India, 4703 HALs occur in the Indian Himalaya, and cover a total area of 126249 hectares. Among the total lakes, few are very large (> 500 ha) or large lakes (100-500 ha), whereas the majority are small (10-25 ha) and very small (<10 ha) of which maximum numbers are of <2.25 ha (Panigrahy et al., 2011). HALs play a significant role in the well-being of the people as well as wetland-dependent biodiversity. In general, these HALs have three important roles- (a) serve as an important habitat for various kinds of organisms, especially birds, amphibians, and insects; (b) due to their aesthetic beauty and pristine nature, these lakes are ecotourism sites of global importance, thus contributing to cultural ecosystem services; and (c) they also form a reservoir for small streams which originates either from nearby glaciers or from the lake itself.

Sikkim state of Indian Union located in the Eastern Himalaya is bestowed with spectacular natural landscapes such as snow-clad mountain peaks (including Mt. Kanchendzonga, 3rd highest mountain peak in the world), high altitude alpine meadows and cold deserts and several wetlands (Acharya and Sharma 2013). Local communities of Sikkim consider all kinds of water bodies as holy places and worship them considering guardian deities of the mountains (Sharma et al., 2012). Lakes form the major components of wetland types. Among all the lakes in the state, 534 lakes have been mapped as HALs which cover an area of 3325 hectares. Sikkim does not have any very large lakes and the majority of the lakes are very small or <2.25 ha in size (Panigrahy et al., 2011).

A few lakes such as Gurudongmar, Tsomgo, Khecheopalri, and TshoLhamo are well known to the people as they are accessible through roads and have become a tourist hub. Scientific studies have been conducted in and around some of these lakes (Subba et al., 2015, Chettri and Acharya 2020). However, information on the geology, environment, and biodiversity of many other lakes, especially those fed by nearby glaciers, is very limited. This is mainly because these lakes are located in high-altitude areas with extremely harsh environmental conditions and are not accessible by road, and also forms a part of sensitive geopolitical boundaries. The shrinkage of glacial areas in high-altitude Himalayan lakes and the expansion of glacial lakes due to climate change pose major threats (Ives et al., 2010). These changes significantly alter the hydrogeological cycle throughout the catchment area, negatively impacting ecosystems and their services, and increasing the risk of Glacial Lake Outburst Flood (GLOF) events (Milner et al., 2017). Despite their significance as high-priority biodiversity sites and the threats they face, such lake complexes lack proper scientific assessment and policies for their management. An instance of policy gaps is the serious outcomes of the 2023 outburst of high altitude Lhonak Lake in the Sikkim Himalaya. This event occurred as per the predictions and alerts provided by earlier studies (Sattar et al., 2021). Consequences of habitat destruction and biodiversity loss throughout the catchment areas due to this devastating event are entirely unknown due to the unavailability of data before the incident. Therefore, it is essential to establish a fundamental understanding of the biodiversity and function of the ecosystem within the HALs. This information is crucial for developing effective management plans.

The wetland ecosystem offers a variety of essential services that sustain life on Earth and enhance human well-being (Maitry et al., 2023). The Tembao Wetland Complex (TWC), located in the high-altitude alpine region of Mangan district, northern Sikkim, comprising Tembao Lake, glacial-fed Tembao Chu, and smaller high-altitude lakes, remains scientifically unexplored (ENVIS 2007). Despite its ecological and geological significance, TWC faces threats such as catchment degradation, wetland shrinkage, and traditional grazing, necessitating urgent conservation efforts. The Sikkim government aims to integrate TWC with nearby wetlands for better management and potential inclusion in the National Wetland Conservation Programme, but baseline biodiversity data is essential for conservation planning and Ramsar designation. To address these data gaps, we conducted a rapid biodiversity assessment of TWC's faunal components in August 2022, focusing on butterflies, amphibians, birds, and mammals. These taxa serve as indicators of habitat quality and climate change, representing key species of the high-altitude alpine ecosystem.

MATERIAL AND METHODS

Study area: The Tembao Wetland Complex (27^{O} 54' 51'' to 27^{O} 54' 37'' and 88^{O} 43' 37'' to 88^{O} 47' 24'' E) is situated at the northern frontiers of Lachung-Yumthang valley in Mangan district of Sikkim, India (Fig. 1, 2). The elevation of the entire complex ranges between 4400 to 5200 meters above sea level (m asl), and has an area of approximately 15 hectares. The complex is fed by a river originating from the glacial Tembao Lake at around 5200 m asl elevation. The average annual temperature of the area remains close to sub-zero and the average precipitation is below 500 mm. The vegetation type is representative of the alpine tundra far above the tree line where grasses and herbs are more dominant. The TWC is a unique high-altitude ecosystem near the tri-junction of India, China, and Bhutan, home to specialized plant species such as *Meconopsis*, *Saussurea*, *Rheum nobile*, and others, thriving in extreme climatic conditions (Acharya and Sharma 2012). While largely free from tourism and development pressures, the region experiences seasonal cattle grazing, whose impact on biodiversity remains debated. However, climate change poses a major threat, with rising temperatures accelerating glacial retreat, increasing the risk of GLOFs, and causing catchment degradation, highlighting the need for continuous monitoring and transboundary conservation efforts (Kaltenborn et al., 2010; Milner et al., 2017, Veettil and Kamp 2019, Liu and Chen 2023).

Taxon sampling

Butterflies: During the study, transect walks (along existing trails) and opportunistic survey methods was used to assess the species richness and abundance of butterflies in the TWC. In total, four transects, each 1 km in length, were identified and selected, maintaining a minimum distance of 1 km between consecutive transects. Sampling took place from morning to afternoon hours (9:00-14:00 hrs), coinciding with peak butterfly activity during foraging, mating, and patrolling behaviors. Butterflies observed within 5 m distance on either side of the trail/transect were identified, and their species name and abundance were recorded. Comprehensive field guides such as Haribal (1992) and Kehimkar (2016) were used to identify all butterflies recorded during sampling and opportunistic observations. For butterflies posing identification challenges in the field, photographs were taken and identification was performed at a later stage when resources were accessible following field guides (Haribal 1992, Kehimkar 2008, 2016, Smetacek 2016) and online repository (Kunte et al., 2022).

Amphibians: Visual Encounter Survey (VES) method, as outlined by Heyer et al. (1994), was used for sampling amphibians. VES was conducted extensively across all feasible habitats and microhabitats within the TWC, with particular focus on water bodies such as ponds, ditches, and rivers. Visual scanning, along with the careful manipulation of boulders, pebbles, plant leaves, and mud, was employed to uncover amphibians. Sampling occurred between 10:00 hrs and 16:00 hrs over five consecutive days, amounting to a total of 30 man-hours of VES effort. During the VES, species encountered above the surface were recorded without disturbing their microhabitats. Furthermore, following species identification, various parameters including the number of individuals, tadpoles, eggs, encounter time, and precise location (GPS coordinates) were recorded during the study.

Birds: The opportunistic sampling method was used to assess the bird community in the TWC, North Sikkim, following the protocol outlined by Vaz et al. (2020). The sampling consisted of walking through existing trails within the lake complex during both morning (05:00-09:00 hrs) and evening hours (14:00-16:00 hrs), during which we recorded all bird species observed or heard. The bird sampling was conducted over five consecutive days, covering various parts of the TWC to ensure comprehensive coverage without repeating surveyed areas on subsequent days. Birds were observed using binoculars and identified visually. In cases where instant identification was not feasible, photographs were taken whenever possible, and identification was subsequently performed by referencing the Merlin Bird ID app and the field guide (Grimmet et al., 2019).

Mammals: Mammal sampling was conducted utilizing camera traps, a non-invasive technique, in conjunction with direct observation. A total of eight camera traps (Cuddeback C2 Xchange Infrared Trail Game Camera) were strategically positioned in areas exhibiting frequent animal activity, discernible from direct observations and signs such as tracks, pugmarks, hoofs, scat, faeces, and digging signs to maximize chances for photo capture (Sathyakumar et al., 2011). The cameras were configured in wide detection mode

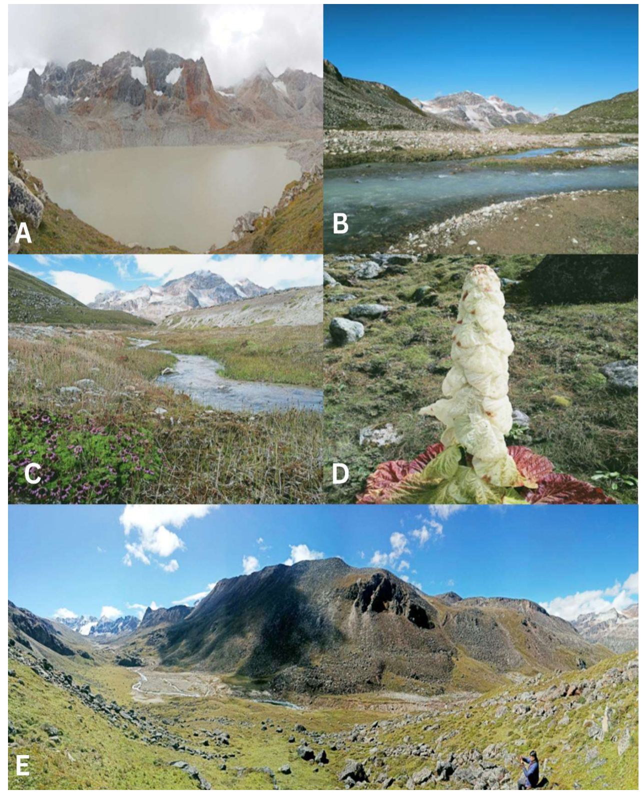

Fig. 2. A: Tembao Lake, B-C: Glacial-fed River and stream flowing through TWC valley, D: *Rheum nobile*, a giant herbaceous plant found in the TWC area, E: Panoramic view of TWC located in northern Sikkim, Eastern Himalaya

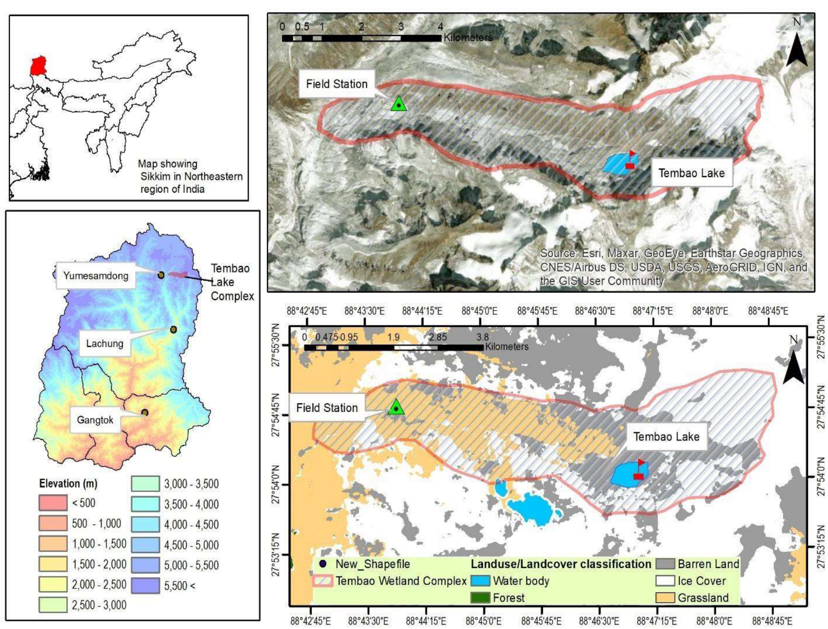

Fig. 1. Location of Tembao Wetland Complex in North Sikkim. The green legend with the black dot in the center indicates the field station and the red rectangular legend with the black dot in the center indicates the field station and the red rectangular legend with the red flag depicts the location of Tembao Lake

to ensure the capture of smaller and fast-moving animals (Meek et al., 2014, Gillespie et al., 2015). A minimal time lapse between camera triggers, set to FAP (as fast as possible), with burst mode capturing three images per encounter, was implemented. The cameras remained deployed in selected locations covering the areas of the TWC for durations ranging from two to four consecutive days, without the use of baits to attract animals. Simultaneously, direct observations were conducted through walk along existing trails and surrounding areas. This involved approximately 40 km (equivalent to approximately 20 man-hours) of on-foot transects along paths, and approximately 12 km (equivalent to approximately 10 man-hours) of exploration around the vicinity. Species encountered during the study period were identified with the help of field guides such as "Mammals of India" by Menon (2014), and through consulting with domain experts.

RESULTS AND DISCUSSION

Butterflies: During the study period, 19 butterfly individuals representing five species, with three species belonging to the family Nymphalidae and one species each from Papilionidae and Pieridae were recorded (Table 1). The most abundant species was the Himalayan Dark Clouded Yellow (*Colias fieldii fieldii*), followed by the Darjeeling Gem Silverspot (*Issoria gemmata gemmata*), Ladakh Tortoiseshell (*Aglais ladakensis*), Himalayan Tortoiseshell (*Aglais caschmirensis aesis*), and the Common Blue Apollo (*Parnassius hardwickii*). The findings represent a significant portion of the expected biodiversity in the Trans-Himalayan Wildlife Corridor (TWC) and likely do not capture the full extent of the alpine butterfly fauna, particularly species with cryptic behaviors or those exhibiting seasonal fluctuations. Rapid assessment surveys, though valuable for providing quick biodiversity insights, have inherent limitations that may have led to under-detection. The survey recorded only 16% of the 31-butterfly species expected at this elevation (>4000 m asl.) (Haribal 1992, Kehimkar 2016), with several missing species from diverse groups such as Apollos (*Parnassius acco, Parnassius acco hunningitoni, Parnassius acdestis, Parnassius hardwickii, Parnassius simo*), Argus (*Paraoeneis palaearcticus sikkimensis, Paraoeneis pumilus bicolor*), Tibetan Blackvein (*Mesapia peloria*), Blues (*Albulina arcaseia, Albulina asiatica*), Nepalese Large Cabbage White (*Pieris brassicae nepalensis*), and Fritillaries (*Issoria issaea, Melitaea arcesia sikkimensis, Melitaea arcesia thibetana*). 32% of the unrecorded species have restricted geographic ranges (<1000 meters), suggesting their strong dependence on specific alpine habitat features or microclimates (Kehimkar 2016). Despite these limitations, the presence of the observed species underscores the resilience and adaptability of butterflies in this high-altitude ecosystem.

Herpetofauna: We recorded single amphibian species, *Scutiger boulengeri*, commonly known as Boulenger's Lazy Toad or Xizang Alpine Toad. A total of nine adults were observed in various ditches and ponds around the Tembao Wetland Complex, along with 336 tadpoles at different developmental stages. As this species requires stable and calm aquatic environments for metamorphosis, the smaller ponds within the complex serve as critical breeding grounds. Such ponds are particularly significant as the main river originating from Tembao Lake flows at high velocity due to the steep terrain. Conservation of these small water bodies is therefore vital for the long-term survival and reproduction of *Scutiger boulengeri*. The species holds the record for the highest-altitude toad, having been documented at 5270 m asl. at Gurudongmar Lake in North Sikkim (Subba et al., 2015). Its detection in Sikkim marked the first-ever record of this species in India, extending its known distribution beyond northwestern Nepal, southeastern Qinghai, eastern and southern Xizang, southern Gansu, and northwestern Sichuan in western China (Ohler et al., 2011). The presence of this high-altitude specialist further highlights the ecological uniqueness of the TWC and underscores the importance of conserving its diverse microhabitats.

Birds*:* A total of 142 individual birds from 16 species across nine families were documented during the study period (Table 1). The families Motacillidae and Muscicapidae exhibited the highest species richness (three species each), while Accipitridae, Columbidae, Passeridae, and Turdidae were represented by only one species each. The Red-billed Chough (*Pyrrhocorax pyrrhocorax*) was the most abundant species (29 individuals), followed by the Alpine Accentor (*Prunella collaris*, 25 individuals) and the White-winged Redstart (*Phoenicurus erythrogastrus*, 22 individuals). In contrast, the Bearded Vulture (*Gypaetus barbatus*), a Near Threatened species on the IUCN Red List, was the least encountered species, with only a single individual recorded. Habitat utilization patterns revealed three primary categories, with rocky area species exhibiting the highest richness (56.25%), followed by wetland-dependent species (25%) and shrubland species (18.75%).

Notably, 87.50% of the species recorded during the study were altitudinal migrants, with only 12.50% being resident species. The breeding elevation ranges of the recorded species, assessed following Grimmett et al., (2019) and the IUCN Red List (2024), spanned from 1800 m to 6200 m asl., with 81.25% of species having breeding ranges within the TWC elevation range (4400–5200 m asl) (Fig. 3). Species such as the White-rumped Snowfinch (*Montifringilla* *taczanowskii*), Grandala (*Grandala coelicolor*), and Alpine Accentor have breeding distributions closely aligned with TWC's elevation range, emphasizing the importance of this wetland as breeding ground for high-altitude avifauna. Although the species recorded represent only 2.79% of the total bird species documented in Sikkim, they account for 9.47% of temperate species recorded in the state (Acharya and Vijayan 2011). Additionally, 43.75% of the birds recorded in TWC are biome-restricted species associated with the Eurasian high montane (alpine and Tibetan) biome, including the Alpine Accentor, Alpine Chough (*Pyrrhocorax graculus*), Common Rosefinch (*Carpodacus erythrinus*), Grandala, Robin Accentor (*Prunella rubeculoides*), Rosy Pipit (*Anthus roseatus*), and Snow Pigeon (*Columba leuconota*) (Ganguli-Lachungpa et al., 2011). The microhabitat around the wetlands supports a diverse range of bird species (Jamakhandi and Kadadevaru 2024). The prevalence of rocky area specialists and altitudinal migrants, along with the significant number of

Table 1. Different faunal species in the Tembao Wetland Complex in North Sikkim, Eastern Himalaya

Family	Species name	Common name	Abundance
Phylum Arthropoda Class Insecta Order Lepidoptera			
Family Papilionidae	*Parnassius hardwickii* (Gray 1831)	Common Blue Apollo	1
Family Nymphalidae	*Issoria gemmata* (Butler, 1881)	Gem Silverpsot	5
	Aglais ladakensis (Moore, 1878)	Ladakh Tortoiseshell	4
	Aglais caschmirensis (Kollar,[1844)	Indian Tortoiseshell	3
Family Pieridae	*Colias fieldii* Ménétriés, 1855	Dark Clouded Yellow	6
Phylum Chordata Class Amphibia			
Family Megophryidae	*Scutiger boulengeri* (Bedriaga 1898)	Boulenger's Lazy Toad	9 adults, 336 tadpoles
Class Aves			
Family Accipitridae	*Gypaetus barbatus* (Linnaeus 1758)	Bearded Vulture	1
Family Corvidae	*Pyrrhocorax graculus* (Linnaeus 1766)	Alpine Chough	3
	Pyrrhocorax pyrrhocorax (Linnaeus 1758)	Red-billed Chough	29
Family Columbidae	*Columba leuconota* (Vigors 1831)	Snow Pigeon	6
Family Prunellidae	*Prunella collaris* (Scopoli 1769).	Alpine Accentor	25
	Prunella rubeculoides (Moore 1854)	Robin Accentor	6
Family Muscicapidae	*Phoenicurus frontalis* (Vigors 1832)	Blue-fronted Redstart	4
	Chaimarrornis leucocephalus (Vigors 1831)	White-capped Water Redstart	5
	Phoenicurus erythrohastrus (Güldenstadt 1775)	White-winged Redstart	22
Family Motacillidae	*Motacilla flava* (Linnaeus 1758)	Yellow Wagtail	2
	Anthus trivialis (Linnaeus 1758)	Tree Pipit	4
	Anthus roseatus (Blyth 1847)	Rosy Pipit	8
Family Turdidae	*Grandala coelicolor* (Hodgson 1843)	Grandala	12
Family Fringillidae	*Leucosticte nemoricola* (Hodgson 1836)	Plain Mountain Finch	7
	Carpodacus erythrinus (Pallas 1770)	Common Rosefinch	4
Family Passeridae	*Montifringilla taczanowskii* (Prjevalsky 1876)	White-rumped Snowfinch	4
Class Mammalia			
Family Bovidae	*Pseudois nayaur* (Hodgson 1833)	Blue Sheep	65
Family Sciuridae	*Marmota himalayana* (Hodgson 1841)	Himalayan Marmot	6
Family Canidae	*Vulpes vulpes* (Linnaeus 1758)	Red Fox	1
Family Mustelidae	*Mustela altaica* (Pallas 1811)	Altai Weasel	3
Family Ochotonidae	*Ochotona macrotis* (Günther 1875)	Large-eared Pika	2

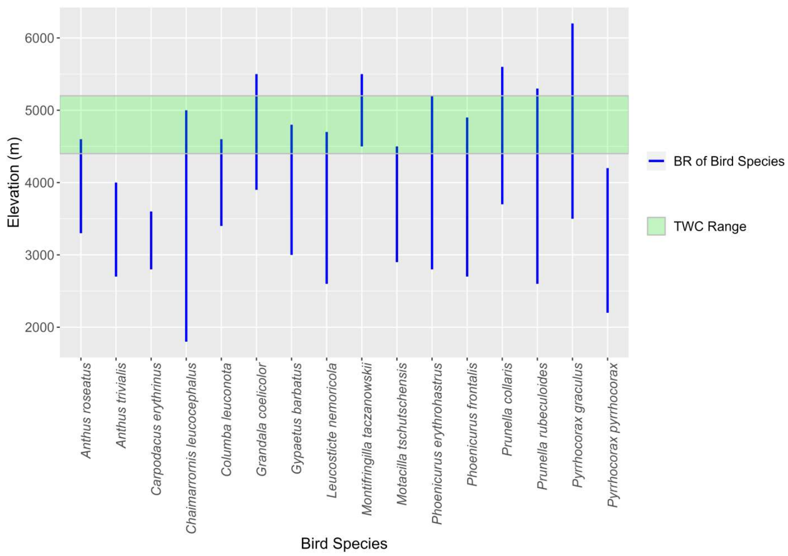

Fig. 3. Elevation BR (breeding range) of bird species relative to TWC (Tembao Wetland Complex) elevation range

species that breed within the TWC, underscores the ecological significance of this wetland complex in supporting specialized high-altitude bird communities.

Mammals: Five mammal species from five families were recorded. Blue Sheep (*Pseudois nayaur*) was the most frequently observed species, with three herds comprising 65 individuals (6, 25, and 34), detected both through direct observation and camera traps (Table 1). Blue Sheep typically inhabit elevations between 2500 and 5500 m asl. (Harris 2014a), and the present study recorded them at over 5000 m asl., making it the highest documented occurrence in the Sikkim Himalaya. This exceeds previous records from the Khangchendzonga Biosphere Reserve (>4000 m asl.; Sathyakumar et al., 2011) and the Tso Lhamo Plateau (>4300 m asl.; Chanchani et al., 2010). The topography of the TWC, characterized by gentle slopes and minimal rock cover, provides a prime habitat for this species. Additionally, Himalayan Marmots (*Marmota himalayana*) were recorded through six direct sightings and one camera trap, with over 15 burrows identified. These burrows were primarily found near sunny slopes and water sources, consistent with previous studies (Aryal et al., 2015, Shrestha 2016, Wang and Hou 2021). Marmots coexist with Yaks, benefiting from grazing activity that promotes the growth of young plants by clearing dead vegetation (Nikol'skii and Ulak 2006), though guarding dogs used by herders may influence their activity (Poudel et al., 2015). Red Fox (*Vulpes vulpes*), typically found up to 4500 m asl. (Hoffmann and Sillero-Zubiri 2021), was recorded at over 5000 m asl., suggesting an upward range extension that warrants an update to its distribution. Similarly, Altai Weasel (*Mustela altaica*), recorded at three locations, is usually found between 80 and 4900 m asl (Abramov 2016). However, the absence of agriculture and regulated grazing under the traditional Dzumsa system (Acharya and Sharma 2012) minimizes the threats faced by this species in the study area, and its presence above 5000 m asl. further suggests a potential range expansion. Lastly, Large-eared Pika (*Ochotona macrotis*) was observed in rocky habitats, which provide ideal conditions due to moraines formed by past glaciations. This species typically inhabits elevations between 2300 and 6400 m asl. (Smith and Lissovsky 2016), and no immediate threats to its population were observed.

The recorded mammal species represent approximately 28% of the potential mammalian diversity in the area based on geographical distribution and literature reviews. The presence of healthy Blue Sheep populations suggests the potential occurrence of apex predators such as the Snow Leopard (*Panthera uncia*; Aryal et al., 2016), emphasizing the ecological significance of the region. Furthermore, based on their known distributional ranges, other mammal species likely to inhabit the Tembao Wetland Complex include Plateau Pika (*Ochotona curzoniae*, 3000–5000 m asl.; Smith and Liu 2019), Royle's Pika (*Ochotona roylei*, 2400–5400 m asl.; Bhattacharya and Dahal 2021), Woolly Hare (*Lepus oiostolus*, 2500–5400 m asl.; Smith and Johnston 2019), Eurasian Lynx (*Lynx lynx*, 0–5500 m asl.; Breitenmoser et al., 2015), Dhole (*Cuon alpinus*, 0–5300 m asl.; Kamler et al., 2015), Tibetan Fox (*Vulpes ferrilata*, 2500–5200 m asl.; Harris 2014b), Brown Bear (*Ursus arctos*, 0–5000 m asl.; McLellan et al., 2017), Siberian Weasel (*Mustela sibirica*, 0–4875 m asl.; Acharya et al., 2016), Kiang (*Equus kiang*, 2700–5400 m asl.; Shah et al., 2015), Alpine Musk Deer (*Moschus chrysogaster*, 2000–5000 m asl.; Harris 2016), Tibetan Gazelle (*Procapra picticaudata*, 3000–5750 m asl.; IUCN SSC Antelope Specialist Group 2016), Himalayan Tahr (*Hemitragus jemlahicus*, 1500–5200 m asl.; Ale et al., 2020), and Argali (*Ovis ammon*, 400–5500 m asl.; Reading et al., 2020). The potential presence of these species further highlights the biodiversity and conservation importance of the Tembao Wetland Complex.

The present findings underscore the ecological significance of the Tembao Wetland Complex (TWC) as a crucial habitat for diverse faunal groups, highlighting their reliance on specific alpine habitat features and microclimates. The absence of several expected species during our survey emphasizes the need for targeted research spanning different seasons, employing long-term monitoring to enhance baseline biodiversity data. Future studies should incorporate comprehensive survey methods, including microhabitat assessments, intensive camera trapping for elusive and nocturnal species, and focused conservation efforts such as protecting smaller ponds and managing habitat alterations. Additionally, addressing climate change impacts through mitigation strategies and fostering community engagement will be essential for safeguarding TWC's unique biodiversity. Implementing these measures will provide a robust framework for conservation, ensuring the ecological integrity of this high-altitude ecosystem for future generations.

CONCLUSIONS

The Tembao Wetland Complex (TWC) is a unique high-altitude glacial-fed ecosystem supporting rare and cold-adapted species, emphasizing its ecological and conservation significance. Despite the study's seasonal limitations, the presence of breeding habitats for rare fauna highlights the wetland's importance for biodiversity retention and conservation. To safeguard this fragile ecosystem, we recommend its designation as a “Ramsar Site” based on Criteria 1, 2, 3, 4, and 9, which would be a milestone for wetland conservation in Sikkim. Additionally, developmental activities, including road construction, should be strictly prohibited, as increased accessibility could disturb the habitat and threaten rare species. If necessary, a walking trail using eco-friendly methods may be constructed for herders and trekkers to minimize environmental impact. Furthermore, considering its ecological and cultural significance, TWC can also be declared a “Heritage Site” under the Indian Biological Diversity Act, 2022, and the Sikkim Biodiversity Rules, 2006, ensuring long-term protection of this fragile alpine ecosystem.

ACKNOWLEDGEMENTS

Study was financially supported by the Forest and Environment Department, Government of Sikkim (Ref. No. 56/E & SC (N) F&ED/GOS dated 26th August 2021) and authors are grateful for the same. Authors thank various Sikkim government officials for their assistance throughout the study.

AUTHOR'S CONTRIBUTION

BKA initiated and conceptualized the study. BKA, IKC, BT, RT, TN, and SD contributed to field data collection, data analyses and writing of the original manuscript draft. All authors contributed to the editing and final draft of the manuscript.

REFERENCES

Abramov AV 2016. *Mustela altaica*. The IUCN Red List of Threatened Species 2016: e.T41653A45213647. Available at: https://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T41653A45213647.en [05 March 2024].

Abramov AV, Duckworth JW, Choudhury A, Chutipong W, Timmins RJ, Ghimirey Y, Chan B and Dinets V 2016. *Mustela sibirica*. The IUCN Red List of Threatened Species 2016: e.T41659A45214744. Available at: https://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T41659A45214744.en [27 May 2024].

Acharya BK and Sharma G 2012. The traditional Dzumsa system and their role in resource management in cultural landscape in North Sikkim, pp 169-80. In: Ramakrishnan PS, Saxena KG, Rao KS and Sharma G (eds). *Cultural Landscapes: The Basis for Linking Biodiversity Conservation with the Sustainable Development*. UNESCO and National Institute of Ecology, New Delhi, India.

Acharya BK and Sharma G 2013. Forests and Biodiversity in Sikkim, pp 42-70. In: Kharel S and Bhutia Z (eds). *Gazetteer of Sikkim*. Home Department, Government of Sikkim, Gangtok, India.

Acharya BK and Vijayan L 2011. The birds of Sikkim: an analysis of elevational distribution, endemism and threats, pp 255-82. In: Arrawatia ML and Tambe S (eds). *Biodiversity of Sikkim: Exploring and Conserving a Global Hotspot*. Department of Information and Public Relations, Government of Sikkim, Gangtok.

Ale SB, Sathyakumar S, Forsyth DM, Lingyun X and Bhatnagar YV 2020. *Hemitragus jemlahicus*. The IUCN Red List of Threatened Species 2020: e.T9919A22152905. Available at: https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T9919A22152905.en [27 May 2024].

Aryal A, Brunton D, Ji W, Rothman J, Coogan SCP, Adhikari B, Su J and Raubenheimer D 2015. Habitat, diet, macronutrient, and fiber balance of Himalayan marmot (*Marmota himalayana*) in the Central Himalaya, Nepal. *Journal of Mammalogy* **96**(2): 308-316.

Aryal A, Shrestha UB, Ji W, Ale SB, Shrestha S, Ingty T, Maraseni T, Cockfield G and Raubenheimer D 2016. Predicting the distributions of predator (snow leopard) and prey (blue sheep) under climate change in the Himalaya. *Ecology and Evolution* **6**(12): 4065-4075.

Bhattacharya S and Dahal N 2021. *Ochotona roylei* (Green Status assessment). The IUCN Red List of Threatened Species 2021: e.T41268A4126820221. Available at: https://www.iucnredlist.org/species/41268/45184591 [27 May 2024].

Breitenmoser U, Breitenmoser-Würsten C, Lanz T, von Arx M, Antonevich A, Bao W and Avgan B 2015. *Lynx* (errata version published in 2017). The IUCN Red List of Threatened Species 2015: e.T12519A121707666. Available at: https://www.iucnredlist.org/species/12519/121707666 [27 May 2024].

Chanchani P, Rawat GS and Goyal SP 2010. Unveiling a wildlife haven: status and distribution of four Trans-Himalayan ungulates in Sikkim, India. *Oryx* **44**(3): 366-375.

Chettri B, Acharya BK 2020. Distribution of amphibians along an elevation gradient in the Eastern Himalaya, India. *Basic and Applied Ecology* **47**: 57-70.

ENVIS 2007. *State of the Environment Report Sikkim.* Forest Environment and Wildlife Management Department, Govt of Sikkim, Gangtok, Sikkim, p 183.

Ganguli-Lachungpa U, Rahmani AR and Islam MZU 2011. Eleven priority areas for conservation: important bird areas of Sikkim, pp 281-300. In: Arrawatia M L and Tambe S (eds). *Biodiversity of Sikkim: Exploring and Conserving a Global Hotspot*. Department of Information and Public Relations, Government of Sikkim, Gangtok.

Gillespie GR, Brennan K, GentlesT, Hill B, LowChoy J, Mahney T, Stevens A and Stokeld D 2015. *A guide for the use of remote cameras for wildlife survey in northern Australia*. Darwin: Charles Darwin University, p 54.

Grimmet R, Inskipp C, Inskipp T, Sherub. 2019. *Birds of Bhutan and the Eastern Himalayas*. Bloomsbury Publishing, London, United Kingdom, p 416.

Haribal M 1992. *The butterflies of Sikkim Himalaya and their natural history*. Sikkim Nature Conservation Foundation, Gangtok, India, p 217.

Harris RB 2014a. *Pseudois nayaur*. The IUCN Red List of Threatened Species 2014: e.T61513537A64313015. Available at: https://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T61513537A64313015.en [27 May 2024].

Harris R 2014b. *Vulpes ferrilata*. The IUCN Red List of Threatened Species 2014: e.T23061A46179412. Available at: https://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T23061A46179412.en [27 May 2024].

Harris R 2016. *Moschus chrysogaster*. The IUCN Red List of Threatened Species 2016: e.T13895A61977139. Available at: https://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T13895A61977139.en [27 May 2024].

Heyer WR, Donnelly MA, McDiarmid RW, Hayek LC and Foster MS 1994. *Measuring and monitoring biological diversity: standard methods for amphibians*. Smithsonian Institution, Washington DC, p 384.

Hoffmann Mand Sillero-Zubiri C 2021. *Vulpes* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2021: e.T23062A193903628. Available at: https://dx.doi.org/10.2305/IUCN.UK.2021-1.RLTS.T23062A193903628.en [27 May 2024].

Hornskov J and Foggin M 2007. Brief notes on the Altai weasel *Mustela altaica* on the Tibetan plateau. *Small Carnivore Conservation* **36**: 48-49

IUCN Red List 2024. Version 2021-3. Available at: https://www.iucnredlist.org/ [28 May 2024].

IUCN SSC Antelope Specialist Group 2016. *Procapra picticaudata* (errata version published in 2017). The IUCN Red List of Threatened Species 2016: e.T18231A115142581. Available at: https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T18231A50192968.en [27 May 2024].

Ives JD, Shrestha, RB and Mool PK 2010. *Formation of glacial lakes in the Hindu Kush-Himalayas and GLOF risk assessment*. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal, p 56.

Jamakhandi H, and Kadadevaru GG 2024. Avifaunal diversity and feeding guild structure in and around Unkal Lake: A semiarid urban wetland in Karnataka, India. *Indian Journal of Ecology*. **51**(2): 453-467

Kaltenborn BP, Nellemann C, Vistnes II 2010. *High mountain glaciers and climate change: challenges to human livelihoods and adaptation.* UNEP, GRID-Arendal, p 52.

Kamler JF, Songsasen N, Jenks K, Srivathsa A, Sheng L, Kunkel K 2015. *Cuonalpinus*. The IUCN Red List of Threatened Species 2015: e.T5953A72477893. Available at: https://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T 5953A72477893.en [27 May 2024].

Kawamichi T 1971. Daily Activities and Social Pattern of two Himalayan Pikas, *Ochotona macrotis*and *O. roylei*, observed at Mt. Everest. *Journal of the Faculty of Science, Hokkaido University, series VI. Zoology* **17**: 587-60.

Kehimkar I 2008. *The Book of Indian Butterflies.* Bombay Natural History Society, Mumbai, India, p 497.

Kehimkar I 2016. *Butterflies of India.* Bombay Natural History Society, Mumbai, India, p 516.

Kunte K, Sondhi Sand Roy P 2022. Butterflies of India. v.3.0.3. Indian Foundation for Butterflies. Available at: https://www.ifoundbutterflies.org [11 March 2024].

Liu H and Chen H 2023. Third Pole needs more than legal protection. *Science* **382**(6676): 1254-1254.

Maitry A, Sharma D, Shah P, Baretha G, and Patil G 2023. Assessment of wetland ecosystem services (RAWES approach) in urban settlement area: A case study of Bilaspur, Chhattisgarh, India. *Indian Journal of Ecology* **50**(4): 954-962.

McLellan BN, Proctor MF, Huber D and Michel S 2017. *Ursusarctos* (amended version of 2017 assessment). The IUCN Red List of Threatened Species 2017: e.T41688A121229971. Available at: https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T41688A121229971.en [27 May 2024].

Meek PD, Ballard G, Claridge A, Kays R, Moseby K, O'Brien T, O'Connell A, Sanderson J, Swann DE, Tobler M and Townsend S 2014. Recommended guiding principles for reporting on camera trapping research. *Biodiversity and Conservation* **23**: 2321-2343.

Menon V 2014. *Indian mammals: a field guide*. Hachette Book Publishing India Pvt. Ltd, p 528.

Milner AM, Khamis K, Battin TJ, Brittain JE, Barrand NE, Füreder L, Cauvy-Frauni S, Gislason GM, Jacobsen D, Hannah DM, Hodson AJ, Hood E, Lencioni V, Olafsson JS, Robinson CT, Tranter M, Brown LE 2017. Glacier shrinkage driving global changes in downstream systems. *Proceedings of the National Academy of Sciences* **114**(37): 9770-9778.

Naulak T and Pradhan S 2020. A checklist of mammals with historical records from Darjeeling-Sikkim Himalaya landscape, India. *Journal of Threatened Taxa* **12**(11): 16434-16459.

Nikolskii AA and Ulak A 2006. Key factors determining the ecological niche of the Himalayan marmot, *Marmota himalayana* Hodgson. 1841. *Russian Journal of Ecology* **37**: 46-52.

Ohler A, Wollenberg KC, Grosjean S, Hendrix R, Vences M, Ziegler T and Dubois A 2011. Sorting out Lalos: description of new species and additional taxonomic data on megophryid frogs from northern Indochina (genus *Leptolalax*,*Megophryidae*,*Anura*). *Zootaxa* **3147**(1): 1-83.

Poudel BS, Spooner PG and Matthews A 2015. Temporal shift in activity patterns of Himalayan marmots in relation to pastoralism. *Behavioral Ecology* **26**(5): 1345-1351.

Reading R, Michel S and Amgalanbaatar S 2020. *Ovisammon*. The IUCN Red List of Threatened Species 2020: e.T15733A22146397. Available at: https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T15733A22146397.en [27 May 2024].

Reshamwala HS, Mahar N, Dirzo R and Habib B 2021. Successful neighbour: Interactions of the generalist carnivore red fox with dogs, wolves and humans for continued survival in dynamic anthropogenic landscapes. *Global Ecology and Conservation* **25**: 1-10.

Panigrahy S, Patel JG and Parihar JS 2011. *National Wetland Atlas:*

High Altitude Lakes on India. Space Applications Centre, ISRO, Ahmedabad, India.

Sathyakumar S, Bashir T, Bhattacharya T and Poudyal K 2011. Assessing mammal distribution and abundance in intricate eastern Himalayan habitats of Khangchendzonga, Sikkim, India. *Mammalia* **75**: 257-268.

Sattar A, Goswami A, Kulkarni AV, Emmer A, Haritashya UK, Allen S, Frey H, Huggel C 2021. Future glacial lake outburst flood (GLOF) hazard of the South Lhonak Lake, Sikkim Himalaya. *Geomorpholog*y **388**: 1077-1083.

Shah N, St Louis A and Qureshi Q 2015. Equus kiang. The IUCN Red List of Threatened Species 2015: e.T7953A45171635. Available at: https://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T7953A45171635.en [27 May 2024].

Sharma G, Rai L and Acharya BK 2012. The socio-cultural and socio-ecological dimensions of Demazong sacred Himalayan landscape in the Eastern Himalayas, pp 151-68. In: Ramakrishnan PS, Saxena KG, Rao KS and Sharma G (eds). *Cultural Landscapes: The Basis for Linking Biodiversity Conservation with the Sustainable Development*. UNESCO and National Institute of Ecology, New Delhi, India.

Shrestha T 2016. *Marmota himalayana* (errata version published in 2017). The IUCN Red List of Threatened Species 2016: e.T12826A115106426. Available at: https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T12826A22258911.en [27 May 2024].

Smetacek P 2016. *A naturalist's guide to the butterflies of India, Pakistan, Nepal, Bhutan, Bangladesh and Sri Lanka*. John Beaufoy Publishing Limited and Prakash Books, Delhi, India, p 176.

Smith AT and Johnston CH 2019. *Lepus oiostolus*. The IUCN Red List of Threatened Species 2019: e.T41283A45188432. Available at: https://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T41283A45188432.en [27 May 2024].

Smith AT and Lissovsky A 2016. *Ochotona macrotis*. The IUCN Red List of Threatened Species 2016: e.T41265A45183918. Available at: https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T41265A45183918.en [27 May 2024].

Smith AT and Liu S 2019. *Ochotona curzoniae* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2019: e.T41258A160699229. Available at: https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T41258A160699229.en [27 May 2024].

Subba B, Ravikanth G and Aravind NA 2015. Scaling new heights: first record of Boulenger's Lazy Toad *Scutiger boulengeri* (Amphibia: Anura: Megophryidae) from high altitude lake in Sikkim Himalaya, India. *Journal of Threatened Taxa* **7**(10): 7655-7663.

Vaz FF, Raso TF, Agius JE, Hunt T, Leishman A, Eden JS and Phalen DN 2020. Opportunistic sampling of wild native and invasive birds reveals a rich diversity of adenoviruses in Australia. *Virus Evolution* **6**(1): 1-13.

Veettil BK and Kamp U 2019. Global disappearance of tropical mountain glaciers: observations, causes, and challenges. *Geosciences* **9**: 196.

Wang SL and Hou FJ 2021. Burrow characteristics and ecological significance of *Marmota himalayana* in the northeastern Qinghai-Tibetan Plateau. *Ecology and Evolution* **11**(13): 9100-9109.

Wilson P 1981. Ecology and habitat utilisation of blue sheep *Pseudois nayaur* in Nepal. *Biological Conservation* **21**(1): 55-74.

Received 12 February, 2025; Accepted 31 May, 2025