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Himalayan Salamander (*Tylototriton himalayanus*): Ecology, Conservation Challenges and Future Prospects for a Relict Amphibian of the Eastern Himalaya.

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ABSTRACT

The Himalayan Salamander (*Tylototriton himalayanus*) is one of the most remarkable amphibians of the Eastern Himalaya and among the only salamander species reported from India. This review-style paper synthesizes available knowledge on its taxonomy, morphology, ecology, reproductive biology, distribution, conservation status and threats. The species is evolutionarily distinct, ecologically sensitiveand strongly associated with mountain wetlands. Current evidence indicates that habitat loss, wetland degradation, climate variability, invasive species, pollutionand infrastructure expansion are contributing to population declines. The paper examines the ecological role of the species as a bio-indicator and explores conservation opportunities through habitat restoration, community participation and transboundary cooperation. The Himalayan Salamander is not only a rare amphibian but also a symbol of the ecological integrity of Eastern Himalayan wetlands.

KEYWORDS

Himalayan Salamander, Eastern Himalaya, Tylototriton himalayanus, conservation, Amphibian, Darjeeling, Habitat, Sukhia Pokhri, Ecosystem, Microhabitat

INTRODUCTION

The Eastern Himalaya is recognized globally as a biodiversity hotspot supporting exceptional levels of endemism. Within this landscape, amphibians occupy an important ecological role and frequently serve as indicators of environmental health. The Himalayan Salamander is among the most unique vertebrates of this region. Its lineage extends deep into evolutionary historyand its survival depends on fragile mountain wetland ecosystems that are increasingly threatened by human activity. The species has attracted scientific interest because of its rarity, specialized habitat requirementsand importance for understanding amphibian evolution in South Asia.

The Himalayan Salamander is currently categorized as Vulnerable on the IUCN Red List, reflecting ongoing population declines across its range. The WWF educational material and recent field studies indicate a decreasing population trend associated with habitat destruction, pollution, climate change, road mortality, invasive species and wetland degradation. In India, the species receives the highest degree of legal protection under Schedule I of the Wildlife (Protection) Act, 1972. Despite these protections, many breeding wetlands remain outside protected areas and continue to face anthropogenic pressures. Conservation of this species therefore requires both legal protection and active management of landscapes where human activities and salamander habitats coexist.

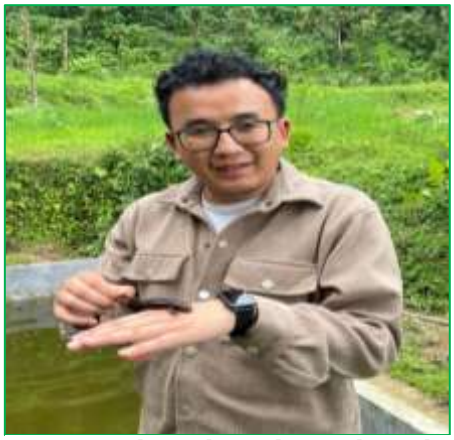

Figure 1. Author with Himalayan Salamander at study site-Pulungdung, Sukhia Pokhri, Darjeeling

The taxonomic identity of the Himalayan Salamander remained uncertain for many years, with populations from the Eastern Himalaya traditionally classified as *Tylototriton verrucosus* (Anders, Christiane C., et al. 1871). However, detailed morphological and molecular studies conducted by Khatiwada et al. (2015) demonstrated that Himalayan populations constituted a distinct evolutionary lineage. Based on differences in body morphology, cranial characteristics, glandular structures, coloration

and genetic divergence, these populations were formally described as a new species, *Tylototriton himalayanus*, in 2015. The species epithet “himalayanus” reflects its close association with the Himalayan region, particularly the Eastern Himalayas of Nepal, India and Bhutan. This taxonomic revision significantly enhanced scientific understanding of amphibian diversity in the region and highlighted the need for targeted conservation strategies for this geographically restricted and evolutionarily distinct amphibian. Morphological studies describe the species as possessing a broad head, blunt snout, granular skin, glandular wartsand a compressed tail. These features distinguish it from related taxa and reflect adaptation to wet montane environments. Scientific interest has also focused on regenerative capabilities and toxin-producing glands, both of which contribute to survival and defense. Although often overshadowed by larger charismatic species, the Himalayan Salamander represents a critical component of mountain biodiversity. The species occurs across parts of India, Nepal and Bhutan and is closely associated with seasonal wetlands, marshes, ponds and forest-edge aquatic habitats. Research conducted over recent decades has revealed important aspects of its ecology and conservation biology, yet major knowledge gaps remain. This manuscript reviews available literature and discusses future directions for conservation and research.

DISTRIBUTION AND HABITAT ECOLOGY

The Himalayan Salamander is distributed across parts of Nepal, India and Bhutan. In India, confirmed records are concentrated in Darjeeling and adjacent Himalayan landscapes, although additional populations have been reported from northeastern states. Habitat studies reveal a close association with cool, moist environments characterized by seasonal wetlands, forest pools, seasonal ponds, tea garden wetlands and marshy depressions.

Unlike many amphibians restricted to pristine forests, the species demonstrates an ability to survive in human-modified landscapes when suitable breeding habitats remain intact. This characteristic has important conservation implications because many populations occur outside protected areas. Tea estates, agricultural wetlands and community-managed ponds frequently support breeding populations. The species depends on a combination of aquatic and terrestrial habitats. Adults spend significant portions of the year beneath leaf

litter, roots, rocks and moist soil, while reproduction occurs in aquatic environments. Consequently, conservation strategies must address habitat connectivity and landscape-level ecological processes.

MORPHOLOGY AND ADAPTATIONS

Adult Himalayan Salamanders generally attain lengths between 15 and 17 centimeters. The body is elongated and robust, with strong limbs adapted for movement through wet substrates. Distinct cranial ridges, glandular structures and a compressed tail contribute to its characteristic appearance. One of the most remarkable adaptations is the presence of toxin-producing glands. These glands secrete defensive substances that discourage predation. The species also possesses regenerative capabilities, allowing damaged limbs and tail portions to regrow. Such traits have attracted scientific attention because they provide insight into developmental and regenerative biology. Coloration typically ranges from dark to light brown dorsally and cream-colored ventrally. This pattern provides camouflage within forest floors and wetland vegetation. Seasonal behavior further enhances survival, as individuals remain concealed during unfavorable environmental conditions and emerge during the monsoon breeding season.

REPRODUCTIVE BIOLOGY AND LIFE HISTORY

Reproduction is closely linked to seasonal rainfall. Adults emerge from underground refuges with the onset of monsoon conditions and migrate toward breeding wetlands. Courtship involves a prolonged underwater ritual often described as a synchronized dance. Following courtship, eggs are attached individually to submerged vegetation.

The species exhibits strong philopatry, meaning adults frequently return to the same breeding sites where they hatched. This behavior increases vulnerability because destruction of a single breeding site may eliminate an entire local population. Larvae develop in aquatic habitats and depend on stable water conditions for survival. Growth rates vary according to environmental conditions, food availability and water quality. Individuals may live for more than a decade and require several years to reach

sexual maturity. Such life-history traits mean populations recover slowly following disturbance.

The observation of Himalayan Salamander larvae during the month of February at the natural marshy habitat of Pulungdung Bhutia Gaon, under Sukhia Pokhri Development Block, Darjeeling, is ecologically significant and may indicate unique local breeding and developmental conditions. The presence of larvae during the late winter period suggests that the breeding season at this site may either extend longer than generally documented or that larval development is prolonged due to the prevailing microclimatic conditions. The marshy habitat, characterized by perennial moisture, stable water availability, dense vegetation cover and relatively low disturbance, may provide suitable conditions that allow larvae to survive and develop over an extended period.

Figure 2 Salamander Larva (salamander nymphs) found in the month of February 2026 at microhabitat

Another possible explanation is that the cooler temperatures at higher elevations slow down the metabolic rate and developmental processes of the larvae, resulting in delayed metamorphosis. Such delayed development has been reported in several amphibian species inhabiting montane ecosystems, where low temperatures and reduced food availability can prolong the larval stage. The finding may also indicate the existence of a locally adapted population exhibiting variation in breeding phenology compared to populations from other regions. Furthermore, the continuous availability of water in the marshland could reduce selective pressure for rapid metamorphosis, enabling larvae to remain aquatic for longer durations.

From a conservation perspective, the detection of larvae in February highlights the importance of maintaining year-round protection of breeding habitats rather than focusing solely on the traditionally recognized breeding season. It also underscores the ecological value of the privately managed breeding site under The Habitats Trust

conservation project, demonstrating that such habitats serve as critical refugia for the successful reproduction and recruitment of the Himalayan Salamander. Continued monitoring of larval abundance, developmental stages, water quality parameters and seasonal habitat conditions will be essential to better understand the species' breeding ecology and to assess whether this late-season larval occurrence represents a regular ecological phenomenon, a response to local environmental conditions or an indicator of broader climatic influences on amphibian life cycles.

ECOLOGICAL SIGNIFICANCE

The Himalayan Salamander serves as a valuable bioindicator of wetland health. Amphibians are highly sensitive to environmental change and salamander populations often reflect broader ecosystem conditions. Healthy populations generally indicate clean water, intact vegetation and stable ecological processes. The species also contributes to food-web dynamics by consuming insects, worms, mollusks and other invertebrates. Through predation, salamanders influence nutrient cycling and ecological balance. At the same time, they provide prey for larger organisms, linking different trophic levels within mountain ecosystems. Because of its sensitivity to habitat degradation the species has become a flagship organism for wetland conservation in parts of the Eastern Himalaya.

THREAT ASSESSMENT

Habitat loss remains the most significant threat to the Himalayan Salamander. Wetlands are increasingly drained, filled, fragmented or modified for agriculture, tourism, infrastructure and urban development. Such changes reduce breeding opportunities and disrupt migration pathways. Agricultural intensification introduces pesticides, herbicides and fertilizers into aquatic systems. Amphibians are particularly vulnerable to chemical contamination because of their permeable skin and aquatic larval stages. Pollution therefore represents a major challenge across several parts of the species’ range.

As part of the ongoing monitoring activities under The Habitats Trust-supported Himalayan Salamander Conservation Project, a significant conservation concern was identified at the Nakhapani roadside natural pond, one of the primary breeding

microhabitats of the Himalayan Salamander. Field observations revealed that the site's easy accessibility has resulted in frequent visitation by tourists and local visitors, leading to the accumulation of plastic waste, food packaging materials and other litter within and around the breeding habitat. Such anthropogenic disturbances not only degrade habitat quality but may also adversely affect water quality, an essential factor for successful breeding, egg development and larval survival. Furthermore, increased human presence and associated noise disturbances during the breeding season may interfere with the species' natural behaviour, potentially affecting breeding success and habitat utilization.

In addition to tourism-related pressures, tea garden operations surrounding the breeding site may be contributing to the gradual decline of the local salamander population. Routine plantation management practices, including vegetation clearance, soil disturbance, alteration of natural drainage patterns and the potential use of agrochemicals, can adversely affect the hydrological and ecological integrity of adjacent wetland habitats. These activities may reduce soil moisture, alter water quality and fragment suitable microhabitats required for breeding, foraging and shelter. Long-term monitoring data from the site indicate a declining trend in salamander observations, suggesting that the cumulative impacts of human disturbance and landscape-level habitat modification may be negatively influencing population persistence. These findings emphasize the urgent need for habitat protection measures, visitor awareness programmes and collaborative conservation efforts involving local communities, tea garden management authorities, and other stakeholders to secure the long-term survival of this threatened amphibian species.

Climate change introduces additional uncertainty. Altered rainfall patterns may disrupt breeding cycles, dry seasonal wetlands prematurely or increase flooding events that destroy eggs and larvae. Invasive fish species further threaten populations by preying upon eggs and juvenile salamanders. Road construction, tourism infrastructure and human disturbance contribute to habitat fragmentation and mortality. Collectively, these pressures create cumulative impacts that may exceed the resilience of local populations.

Although habitat degradation remains the principal threat to *Tylototriton himalayanus*, localized anthropogenic pressures have also been reported. Community-based conservation surveys from parts of the Eastern Himalaya suggest that individuals are

occasionally killed due to misconceptions, fear, or traditional beliefs. Some reports have further indicated limited use of salamanders in folk medicinal practices and cultural rituals, although systematic scientific evidence documenting such utilization remains scarce. Further ethnobiological research is needed to evaluate the extent to which traditional beliefs and human exploitation influence local population dynamics of this species.

During field investigations and community consultations conducted at Majhidhura, a small hamlet near Sukhia Pokhri Bazaar under the Jorebunglow–Sukhia Pokhri Development Block, local residents identified several emerging threats to the persistence of the Himalayan Salamander population. Of particular concern is the increasing disturbance caused by wild boars (*Sus scrofa*), locally known as "Banel," within the salamander's microhabitats at the Pine View area, popularly known as Mini Pahalgam, Sukhia Pokhri. According to local observations, wild boars intensively forage within the moist forest floor during the salamander's hibernation period, excavating numerous pits and overturning soil layers. Such disturbances can directly disrupt subterranean refugia that provide critical overwintering conditions for Himalayan Salamanders. The excavation of moist soil and leaf-litter layers may expose hibernating individuals to adverse environmental conditions, increase mortality through physical injury or desiccation, and alter the thermal and moisture regimes essential for successful overwinter survival.

The findings further suggest that the gradual reduction of natural buffer zones between wildlife habitats and human settlements has intensified ecological pressures on these fragile montane ecosystems. Habitat fragmentation and changes in land use may be forcing wild boars to expand their foraging activities into sensitive salamander habitats, thereby increasing the frequency and magnitude of disturbance events. Such interactions can have cascading ecological consequences, particularly for a species that relies on stable microclimatic conditions and specific underground shelters for hibernation and breeding.

Additionally, the rapid growth of tourism activities at Pine View (Mini Pahalgam) poses a significant anthropogenic threat to the species. Unregulated visitor movement, trampling of vegetation, soil compaction, litter accumulation, noise disturbance and the

development of tourism-related infrastructure can degrade the integrity of critical microhabitats. These impacts may reduce habitat suitability by altering soil moisture, disrupting breeding and hibernation sites, and fragmenting movement corridors. Given the restricted distribution and specialized habitat requirements of the Himalayan Salamander, the combined effects of wildlife-induced disturbance and increasing tourism pressure may substantially affect population viability if appropriate conservation interventions are not implemented.

During field visits and regular monitoring of breeding habitats at Pulungdung, Nakhapani and other known Himalayan Salamander sites under Jorebunglow-SukhiaPokhri Development block of District Darjeeling, an important ecological observation was recorded regarding predation pressure on the larval stages of the species. The Blue Whistling Thrush (*Myophonus caeruleus*)**,** locally known as *Kalchura*, was repeatedly observed foraging around shallow breeding ponds and consuming aquatic organisms, including suspected Himalayan Salamander larvae. This observation suggests that avian predation may represent an under-recognized factor influencing larval survival and recruitment in local salamander populations. While natural predation is an integral component of ecosystem functioning, its impact can become significant when breeding habitats are limited in size, shallow in depth or otherwise degraded, making larvae more exposed and vulnerable to predators.

The shallow nature of many breeding ponds, particularly during periods of reduced water availability, appears to facilitate easy access for Blue Whistling Thrushes to forage on salamander larvae. Such predation pressure may substantially reduce larval survival rates before metamorphosis, thereby affecting population recruitment and long-term population stability. This finding is particularly noteworthy because conservation efforts for the Himalayan Salamander have traditionally focused on habitat loss, tourism pressure, pollution and climate-related threats, while the role of natural predators has received relatively little attention. The repeated occurrence of this behaviour across multiple breeding sites indicates that avian predation may be a locally important ecological factor influencing breeding success. Therefore, further systematic studies are required to quantify predation rates, assess their impact on larval survival, and determine whether habitat enhancement measures, such as maintaining proper protection

sheds/fencing of breeding pools and increasing aquatic vegetation cover, could provide refugia that improve larval survival and contribute to the conservation of Himalayan Salamander populations in the Darjeeling Himalaya.

Another important observation documented by the author during field visits and monitoring activities is the inadvertent mishandling of Himalayan Salamanders by local residents and visitors due to limited awareness regarding the species' ecological requirements and conservation significance. In several instances, individuals were observed capturing, handling and even relocating salamanders from one location to another with the intention of protecting them or out of curiosity. Although often well-intentioned, such actions can pose serious threats to the species. Amphibians possess highly specialized, moist and permeable skin that plays a critical role in respiration, osmoregulation and overall physiological functioning. Direct handling by humans can damage the protective mucous layer, increase stress, facilitate the transfer of pathogens, contaminants or chemicals from human skin and potentially compromise the animal's health and survival.

Furthermore, the translocation of salamanders from their natural microhabitats may disrupt their normal behaviour, breeding activities and habitat fidelity. Himalayan Salamanders are known to be closely associated with specific environmental conditions, including soil moisture, temperature, shelter availability and breeding-site characteristics. Moving individuals between habitats, even over short distances, may expose them to unsuitable environmental conditions, increase predation risk and interfere with local population dynamics. Such unregulated handling and relocation may also contribute to the spread of diseases and pathogens between populations, posing additional conservation concerns. These observations highlight a critical need for targeted awareness and community outreach programmes to educate local residents, tourists and stakeholders about the ecological sensitivity of the species and the importance of adopting a strict "observe, do not disturb" approach when encountering Himalayan Salamanders in the wild. Enhancing public understanding of appropriate wildlife interaction practices will be essential for minimizing human-induced disturbances and ensuring the long-term conservation of this rare Himalayan amphibian.

These observations highlight the urgent need for long-term ecological monitoring, habitat protection measures, visitor management strategies and community-based conservation initiatives to safeguard the remaining microhabitats of the Himalayan Salamander in the Darjeeling Himalaya. The establishment of protective buffer zones, regulation of tourism activities in ecologically sensitive areas and further research on species habitat interactions will be essential for ensuring the long-term survival of this globally significant amphibian species.

CONSERVATION EFFORTS AND FUTURE DIRECTIONS

The conservation of the Himalayan Salamander (*Tylototriton himalayanus*) in the Darjeeling Himalaya requires an integrated, science-based and community-oriented approach that addresses both ecological and anthropogenic threats identified through field investigations. The present study highlights that the species is facing multiple pressures, including habitat degradation, tourism-induced disturbances, predation on larval stages, hibernation site disruption, agricultural activities surrounding breeding habitats, pollution and direct human interference resulting from inadequate awareness. Considering the species' restricted distribution, specialized habitat requirements and low reproductive potential, even minor disturbances can have significant consequences for local population persistence. Therefore, the conservation strategy must prioritize the protection and restoration of critical breeding, foraging and hibernation habitats across its known distribution range.

One of the foremost conservation priorities should be the legal and ecological protection of identified breeding sites, particularly Jorepokhri, Nakhapani, Pulungdung, Pine View (Mini Pahalgam)-Majhidhura and other microhabitats supporting breeding populations. Establishing community-managed conservation zones and habitat protection protocols would help minimize habitat degradation and prevent further loss of wetlands and marshy ecosystems. Habitat restoration measures, including the maintenance of natural hydrological regimes, removal of invasive vegetation, prevention of wetland drainage and restoration of degraded breeding ponds, should be undertaken to enhance habitat suitability. The creation of vegetative buffer zones around breeding habitats would further reduce the impacts of human activities and agricultural runoff.

Tourism management is another critical conservation requirement. Several breeding and hibernation sites have become popular tourist destinations, resulting in litter accumulation, noise pollution, trampling of vegetation and disturbance of sensitive habitats. Regulated ecotourism practices should be introduced through designated visitor pathways, installation of awareness signage and controlled access during breeding seasons and strict waste management protocols. Community-led ecotourism models can simultaneously promote conservation awareness while generating sustainable livelihoods for local residents. Such approaches would encourage local stewardship and reduce conflicts between conservation objectives and economic interests.

The findings related to hibernation-site disturbance by wild animals indicate the need for further ecological investigations into species interactions within these fragile ecosystems. Habitat management interventions, such as protecting critical hibernation zones through natural barriers and monitoring wildlife movements, may help reduce disturbance levels. Similarly, the observed predation of larvae by the Blue Whistling Thrush suggests the need for additional research to quantify predation rates and evaluate their influence on recruitment success. Habitat enhancement measures, including maintaining breeding pools and increasing aquatic vegetation cover, may provide larval refugia and reduce predation vulnerability without disrupting natural ecological processes.

Public awareness and community participation must form the foundation of long-term conservation efforts. The observation that local people occasionally handle, relocate or unintentionally disturb salamanders highlights a substantial knowledge gap regarding amphibian ecology. Comprehensive awareness campaigns targeting local communities, schools, tourists, tea garden workers and nature guides should be developed to promote responsible behaviour and discourage direct handling of salamanders. Educational materials emphasizing the species' ecological importance, legal status and conservation needs can significantly reduce human-induced disturbances. Community-based monitoring programmes involving local youth and residents may also improve conservation outcomes by fostering a sense of ownership and responsibility toward the species and its habitats.

Future research should focus on understanding the species' breeding biology, larval ecology, hibernation behaviour, population dynamics, habitat preferences and responses to environmental changes. Long-term ecological monitoring is essential to assess population trends, recruitment success and habitat quality. Additionally, climate change impacts on breeding phenology, larval development and habitat availability require urgent investigation, particularly in the Eastern Himalayan region where climatic shifts are expected to alter hydrological patterns significantly. The recent observation of larvae persisting into February further emphasizes the need for detailed studies on local breeding phenology and developmental ecology. Scientific evidence generated through such research will be crucial for developing adaptive management strategies and informing conservation policies at regional and national levels.

Collaboration among government agencies, research institutions, conservation organizations, local communities and private landowners will be essential for ensuring effective conservation outcomes. The Habitats Trust-supported conservation initiatives have already demonstrated the value of community engagement and site-based monitoring. Expanding such collaborative models across the species' distribution range could substantially strengthen conservation efforts and provide a framework for safeguarding one of India's most unique and evolutionarily significant amphibians.

DISCUSSION

The present study provides valuable insights into the conservation status and ecological challenges facing the Himalayan Salamander within the Darjeeling Himalaya. While habitat degradation remains the dominant threat, field observations reveal that a complex combination of natural and anthropogenic factors collectively influences the survival and reproductive success of local populations. The identification of previously underreported threats, including hibernation-site disturbance by wild boars, avian predation on larvae by the Blue Whistling Thrush and human-mediated mishandling of individuals, contributes important new knowledge to the understanding of the species' ecology and conservation requirements.

The observation of Himalayan Salamander larvae during February is particularly noteworthy because it may indicate prolonged larval development, delayed

metamorphosis or variation in breeding phenology associated with local environmental conditions. Such findings suggest that breeding ecology in the Darjeeling Himalaya may differ from patterns documented elsewhere within the species' range. The persistence of larvae during winter months may be linked to stable water availability, low temperatures and unique microclimatic conditions that influence developmental rates. These observations warrant further investigation, as they may have important implications for understanding the species' life-history strategies and resilience to environmental change.

Habitat-specific threats identified at Nakhapani, Pulungdung and Pine View highlight the increasing vulnerability of salamander populations to human activities. Tourism development, agricultural expansion, habitat fragmentation and changing land-use patterns are progressively altering the ecological integrity of critical breeding and hibernation habitats. The decline in habitat quality observed at several sites demonstrates how cumulative disturbances can affect amphibian populations even when direct habitat destruction is absent. Such findings reinforce the importance of adopting landscape-level conservation approaches that consider both habitat protection and the broader socio-ecological context in which these populations exist.

The repeated observation of Blue Whistling Thrush predation on salamander larvae represents an important ecological finding. Although predation is a natural process, its impact may become disproportionately significant in fragmented or degraded habitats where breeding pools are small and larval refugia are limited. This highlights the need to understand how habitat quality influences predator-prey dynamics and recruitment success. Similarly, disturbance caused by wild boars during hibernation periods illustrates how ecological interactions may be altered in landscapes experiencing increasing habitat fragmentation and human encroachment.

Human behaviour emerged as a significant conservation concern throughout the study. The handling, relocation, and disturbance of salamanders by local residents and visitors demonstrate that conservation challenges are not solely ecological but also social in nature. Effective conservation therefore requires not only scientific interventions but also public engagement, environmental education and community participation. Conservation success will depend largely on the ability to foster positive attitudes toward amphibian protection while reducing unintentional human-induced threats.

Overall, the study emphasizes that the Himalayan Salamander should be viewed as an indicator species for the health of montane wetland ecosystems in the Eastern Himalaya. The threats documented during this investigation reflect broader environmental changes occurring across the landscape, including habitat fragmentation, biodiversity loss and increasing human pressures on natural ecosystems. Protecting the species will therefore contribute not only to amphibian conservation but also to the preservation of critical ecosystem functions and biodiversity within the Darjeeling Himalayan region.

CONCLUSION

The Himalayan Salamander (*Tylototriton himalayanus*) represents one of the most ecologically significant and conservation-dependent amphibians of the Eastern Himalaya. The present study, based on extensive field observations and monitoring of breeding and hibernation sites in the Darjeeling Himalaya, reveals that the species faces a wide range of interconnected threats that collectively jeopardize its long-term survival. Habitat degradation, tourism-related disturbances, agricultural activities, pollution, climate-related pressures, hibernation-site disturbance, larval predation and human-mediated mishandling of individuals all contribute to increasing conservation challenges across its known habitats.

The study further highlights several important ecological observations, including the occurrence of larvae during the winter month of February and the role of predation and hibernation disturbances in influencing population dynamics. These findings expand current knowledge of the species' ecology and underscore the need for continued scientific investigation. The observed decline in habitat quality and increasing anthropogenic pressures at key breeding sites indicate that immediate conservation interventions are required to prevent further population declines.

Long-term conservation of the Himalayan Salamander will depend upon the protection and restoration of critical habitats, implementation of community-based conservation initiatives, promotion of responsible tourism practices, and strengthening of environmental awareness among local stakeholders. Equally important is the establishment of comprehensive monitoring programmes capable of generating scientific

data necessary for evidence-based management and policy development. The active involvement of local communities, conservation organizations, researchers and government agencies will be crucial for achieving sustainable conservation outcomes.

Given its restricted distribution, ecological sensitivity and role as a flagship species for Himalayan wetland conservation, the Himalayan Salamander deserves urgent conservation attention. Protecting this species will not only safeguard a unique component of the region's biodiversity but will also contribute to the preservation of fragile montane ecosystems upon which numerous other species depend. The findings of this study provide a strong scientific foundation for future conservation planning and reinforce the importance of collaborative, landscape-scale approaches to ensuring the survival of this remarkable amphibian in the Darjeeling Himalaya.

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