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Population size and microhabitat features of the crocodile newt *Tylototriton pasmansi* Bernardes et al., 2020 in northern Vietnam

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Abstract. Pasmans's Crocodile Newt (*Tylototriton pasmansi*) is endemic to tropical broadleaf forests in northern Vietnam. Information regarding its population size, distribution, and habitat characteristics remains extremely limited, and its IUCN Red List status is Data Deficient. This study was conducted in Xuan Son National Park and Phu Canh Nature Reserve, Phu Tho Province, to estimate population sizes and identify relevant habitat features of the species. We found newt habitats based on community interviews and then conducted capture-mark-recapture surveys. The results showed that the population size of these newts was quite small, with only an estimated 70 and 236 individuals at the examined sites in Xuan Son National Park and Phu Canh Nature Reserve, respectively. The microhabitat of *T. pasmansi* primarily comprises small, shallow ponds with minimal water flow and muddy bottoms at elevations of around 1000 m, characterized by a wide pH range. This is the first study estimating the population size of a newt species in Vietnam. As climate change intensifies, habitat monitoring and improvements, such as the establishment of breeding pools, along with education of local residents are needed to prevent local extinctions of this interesting species.

Keywords. Conservation, microhabitat use, Pasmans’s Crocodile Newt, population ecology, Phu Canh Nature Reserve, Xuan Son National Park.

Introduction

Globally, amphibians are facing a severe decline due to climate change, habitat loss, invasive species, diseases, and pollution (e.g., Blaustein and Wake, 1990; Wake, 1991; Blaustein et al., 1994; Green, 1997; Alton and Franklin, 2017; Green et al., 2020). Projected and current climate change are driving nearly half of species declines (Luedtke et al., 2023). Due to their sensitive physiological characteristics, extreme site fidelity, and relatively low movement, amphibians are considered important ecological indicator species, directly reflecting changes in the living environment (Blaustein et al., 1994; Wells, 2007). However, many rare amphibian species in Southeast Asia still lack data on their population status, including 24 species of the 93 endemics in Vietnam (Nesi et al., 2023). This hinders effective assessment and conservation planning making long-term programs necessary (IUCN, 2024).

Pasmans’s Crocodile Newt, *Tylototriton pasmansi* Bernardes et al., 2020 (Fig. 1), is a typical example of the lack of basic biological knowledge. The species was identified and described only in 2020, having previously been considered a Vietnamese population of *T. asperrimus* Unterstein, 1930, which is now considered endemic in China. New collections and reanalysis of museum specimens prompted Bernardes et al. (2020) to divide the *T. asperrimus* complex and describe two new species in northern Vietnam (*T. pasmansi*, *T. sparreboomi*). Pasmans's Crocodile Newt has only been confirmed in a few locations, including Phu Tho, Son La, and Thanh Hoa Provinces, Vietnam (Bernardes et al., 2020). The extent of occurrence for *T. pasmansi* was estimated to be small (ca. 3780 km^2; Pham, 2023),

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Figure 1. An adult *Tylototriton pasmansi* found on July 2025, in Xuan Son National Park, Phu Tho Province, northern Vietnam. Photo by Dung Van Tran.

and while it is currently considered Data Deficient on the IUCN Red List (IUCN SSC Amphibian Specialist Group, 2021), Pham (2023) listed it as Endangered (EN) in the *Vietnam Red List of Threatened Species* by applying IUCN criteria at the regional level. However, population sizes of *T. pasmansi* have not been properly assessed, and it has been shown that this newt species is facing numerous threats, especially from human activities, with the massive loss of habitat driven by forest product extraction and clearcutting forests for agricultural land most concerning (Pham, 2023).

To date, no comprehensive field study has quantified population sizes or examined the ecological correlates of occurrence, thereby limiting the robustness of conservation assessments. To address this gap, we aimed to estimate population sizes of this newt in two protected areas in northern Vietnam and identify the habitat features associated with its distribution. The results provide new data on population parameters and habitat attributes of *T. pasmansi*, which provides critical data to inform an evidence-based management and conservation plan for this species.

Materials and Methods

Study area. Xuan Son National Park (XSNP), Phu Tho Province, Vietnam, has lowland evergreen forest and montane forests and covers an area of 15,048 ha, with its western border adjacent to Son La and Hoa Binh Provinces (Dinh, 2023). The park is located at the southeastern end of the Hoang Lien Mountains at elevations of 200–1386 m (XSNP, 2023). Phu Canh Nature Reserve (PCNR) lies to the south of XSNP and covers 5303 ha, with an elevation range of 300–1349 m. Both study sites are bisected by National Road 433, which provides the only access (Hoa Binh PFPD, 2021). Both parks and their surrounding areas support typical limestone karst and lowland and montane forest ecosystems at the northern tropical-subtropical interface. Vegetation develops on a distinctive karst landscape, forming complex habitats with numerous caves, streams, and vertically stratified forest. These habitats harbour many native species of high conservation value, particularly those that are endemic to northern Vietnam. The presence of rare species, together with the integrity of the ecosystem, makes XSNP and PCNR ideal locations for biodiversity research and the conservation of genetic resources.

Survey methods. Field surveys were conducted in XSNP and PCNR in July and August 2025, the rainy season. Our work included interviews with members of the local community to learn about newts and potential localities, followed by capture-mark-recapture studies (Williams et al., 2002; McCrea and Morgan, 2014) to assess population sizes. The purpose of the interviews was to tap into the indigenous knowledge of local residents, who are usually familiar with the status of wildlife species in their community. This type of knowledge is important when developing conservation policies, whose success invariably relies on buy-in from the communities where they are established (Turvey et al., 2015; Ubale and Badade, 2024). Open-ended questions, focused on population status, distribution, and threats, were asked of forest rangers and local residents, and the information obtained was used to plan our field surveys and threat assessments.

For the newt survey we applied a triple catch-recapture design over three consecutive survey days (Begon, 1979; Pierce et al., 2014). Surveys were conducted in five ponds, including two in XSNP and three in PCNR. On Day 1, individuals were captured, marked, and released at the same location. On Day 2, we again captured newts, and this sample consisted of previously marked individuals and new, unmarked individuals. Unmarked individuals were marked, and all newts were releases. On Day 3 we captured newts for the third time and counted those marked on Day 1, those on Day 2, and unmarked newts. Sex was determined by examining the cloaca, with males having a larger, swollen, and more elongated cloaca, whereas females have a smaller, less swollen cloaca (Langner et al., 2022). Newts were marked using a toe-clipping technique following Donnelly et al. (1994), with each individual assigned a unique combination of two clipped non-adjacent toes which allowed identification across captures. In this process, the hand or foot is cleaned with clean water, sterile surgical scissors are used to remove toe tips, and the site of injury is cleaned with antibiotic solution (Donnelly et al., 1994). This method is particularly suitable for use with crocodile newts since these can regenerate toes in about two weeks and long-term impacts are avoided (Phillott et al., 2007). Data for each capture included GPS coordinates, elevation, time, sex, and habitat characteristics. Individuals were released at the site of capture immediately after data collection.

Habitat characteristics. Habitat characteristics were recorded at five ponds sites, two sites in Ten Mountain (Ponds 1 and 2 in XSNP) and three in the Doi Chong and Tham Luong Mountains (Ponds 3–5 in PCNR; Table 1). The elevation of the sites ranged from 997–1232 m. Microhabitat parameters included pond width and water depth, measured with a tape. The canopy cover was measured using the Canopeo app (Oklahoma State University, USA). Water quality parameters, including temperature (°C) and pH, were measured using the NOYAFA NF-EZ9909 SP multifunction water quality tester.

Data analysis. Field data were structured following the capture-mark-recapture approach (Chao et al., 1992). Each capture history was represented by a binary sequence (0/1), where 1 indicated capture and 0 indicated no capture. The frequency of each capture history was recorded. With three survey days, seven capture histories are possible (001, 010, 011, 100, 110, 111, 101). Data analysis was conducted using the *RMark* package (Laake, 2013) in R v4.5.0 (R Core Team, 2025). *RMark* provides an interface between R and the program MARK (White and Burnham, 1999) and allows the application of population estimation models to capture-recapture data. Population size was estimated under closed population models with the following assumptions: (1) The population size remained constant during the survey (no births, deaths, immigration, or emigration); (2) individuals were identified correctly without recording errors; (3) capture probability could vary by time or among individuals, depending on model structure.

Models constructed in *RMark* included the following parameters: capture probability (p), recapture probability (c); the number of unobserved individuals (f_0). Comparing the values of both capture and recapture probability (p and c) provides important ecological information about newt behaviours in response to research activities.

Table 1. Habitat characteristics of five ponds in Xuan Son National Park (XSNP) and Phu Canh Nature Reserve (PCNR) where *Tylototriton pasmansi* were captured. Elevation, pond width (PW), and pond depth (PD) are given in metres (m). In addition, we provide numbers of individuals (n), canopy cover (in %), water temperature (Temp, in °C), pH, and substrate type.

Location	Pond	Elevation	*n*	PW	PD	Canopy	Temp	pH	Substrate
XSNP	1	1197	4	0.5	0.1	29	22	6.9	Mud
	2	1232	28	2	0.2	28	23	9.2	Mud
PCNR	3	1060	78	6.3	0.3	70	22	7.3	Mud
	4	1011	15	2.5	0.1	96	21	7.1	Mud
	5	997	19	2.6	0.2	97	25	6.2	Mud

We used the following models: (1) The null model (M_0) sets all parameters at ~1 to indicate that all individuals share a constant capture and recapture probability across all survey occasions, such that any variation in the number of captures among sampling days is attributed to sampling stochasticity alone. (2) The time-varying model (M_t) relaxes this assumption by allowing capture and recapture probabilities to vary among survey days, thereby testing whether daily differences in environmental conditions or newt activity influence detectability. With p and c set to be dependent on time, f_0 remains constant at ~1. (3) The behaviour-varying model (M_b) allows the probability of recapture to differ from the probability of initial capture and allows an evaluation of whether individuals exhibit a behavioural response to handling (i.e., becoming "trap-shy" or "trap-happy"), which could alter their subsequent detectability (Otis et al., 1978; Bailey et al., 2004). In this model, p and f_0 are constant at ~1 while c has the behavioural component.

After setup, the models were evaluated using the Maximum Likelihood Estimation algorithm (White and Burnham, 1999). Given our small sample sizes, model comparison was based on the corrected Akaike Information Criterion (AICc; Akaike, 1974), a tool that ranks models based on goodness-of-fit against number of parameters (complexity). Difference from best model (ΔAICc) and probability of being the best model (AICc weight; Burnham and Anderson, 2002) were assessed. An estimated population size (N), a 95% confidence interval (CI), and the number of unobserved individuals (f_0) were calculated from the model with the lowest AICc.

Results

A total of 105 residents were interviewed, including 55 local people from Du, Lang, and Coi hamlets (Xuan Dai Commune), and 50 villagers from Dat 1, Dat 2, Dat 3, Thu Lu, Bao, and Ruoc hamlets (Tan Pheo Commune). The villages are located around XSNP. We also interviewed 80 local people from 11 villages around PCNR in Quy Duc, Tan Pheo, and Tan Nhan commune (Phu Tho Province; Fig. 2).

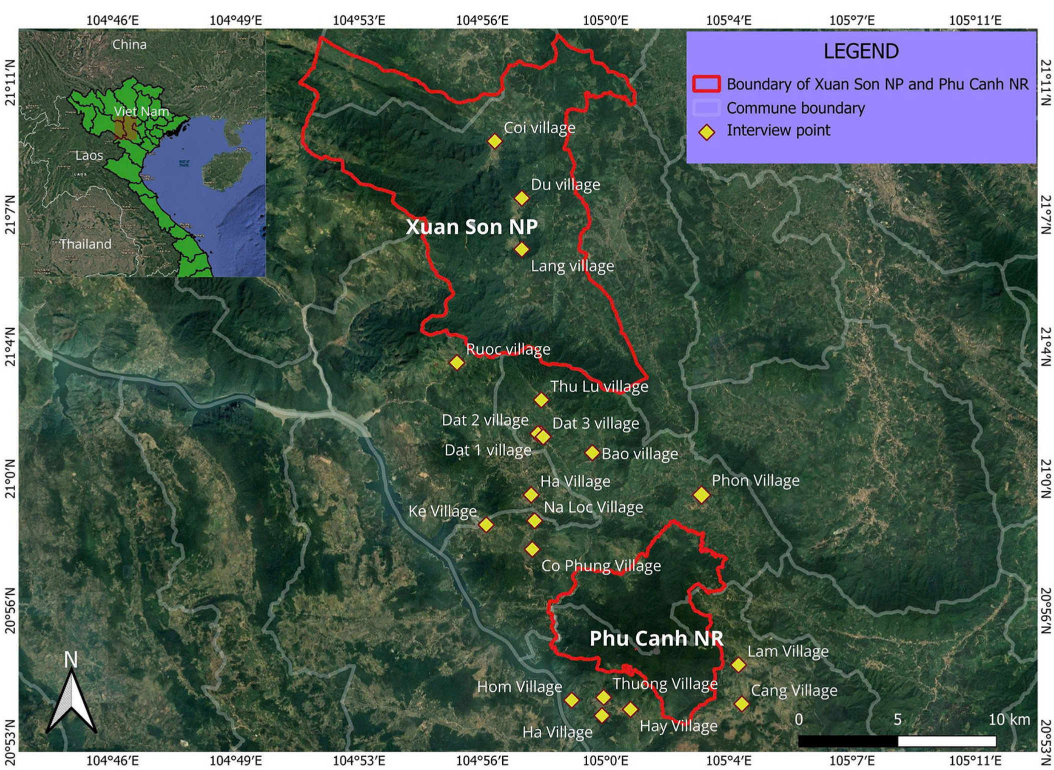

Figure 2. Map of the survey sites in Xuan Son National Park and Phu Canh Nature Reserve, Phu Tho Province, northern Vietnam. Villages where we interviewed community members are indicated by yellow diamonds.

From these interviews, we determined that three locations, including Ten Mountain (XSNP), Doi Chong and Tham Luong mountains (PCNR), are potentially suitable for finding populations of *T. pasmansi*.

During the field surveys in XSNP, we recorded a total of 32 adult *T. pasmansi* (15 ♂, 17 ♀). Most newts were found in Pond 2 (n = 28, 88%) and very few in Pond 1 (n = 4, 12%). We did not record any newt eggs or larvae. In PCNR, we recorded 112 *T. pasmansi* (73 ♂, 39 ♀, 3 subadults), of which most (n = 78, 70%) were found in Pond 3, and substantially fewer were found in Ponds 4 and 5 (n = 15 and n = 19, 13 and 17%, respectively; Table 2). Although no eggs were recorded, many *T. pasmansi* larvae were found in Pond 3.

Newts from XSNP best fit M_b (AICc = −103.7; AICc weight = 0.5). Using this model, the estimated population size of *T. pasmansi* at the XSNP sites was ca. 51 (CI: 48–67), with p = 0.5 and c = 0.2. Because M_t was also competitive (ΔAICc = 0.4), we computed an AICc-weighted, model-averaged estimate across M_b and M_t, yielding an estimated population size of approximately 70 individuals (CI: 34–87; Table 3). *Tylototriton pasmansi* from PCNR best fit M_t (lowest AICc = 808.8) and estimated population size was approximately 236 individuals (CI: 210–276) with p = 0.45 and c = 0.35 and 0.18 for Days 2 and 3, respectively.

In both XSNP and PCNR, *T. pasmansi* was recorded mainly in small, forest ponds at an elevation near 1000 m. This corresponds to montane evergreen tropical forest, characterized by cool climate, high humidity, and limited human disturbance (Fig. 3). The typical species habitat is small, still-water ponds, with widths ranging from 0.5–6 m and shallow depths of 0.1–0.3 m. The sampled ponds had muddy bottoms and were large enough to retain water in the long term. Water temperatures were stable at 21–25°C, which is a range favourable for newt growth and development. The pH value was slightly acidic to slightly alkaline (6–9) which is typical for this type of pond. Vegetation cover surrounding the ponds consisted mainly of trees and shrubs which provided shade, reduced evaporation, and stabilized the microclimate, but the amount of coverage varied greatly (28–97%). Ponds were also sheltered from wind thus maintaining high humidity (Table 1).

Table 2. Number of *Tylototriton pasmansi* individuals recorded during a three-day field survey in five ponds in Xuan Son National Park (XSNP) and Phu Canh Nature Reserve (PCNR) in July and August 2025. The results of the capture-mark-recapture study are provided.

Location	Pond	Day 1	Day 2		Day 3			
			Marked	Unmarked	Marked Day 1	Marked Day 2	Marked Days 1–2	Unmarked
XSNP	1	1	1	1	0	0	0	2
	2	17	5	6	6	3	2	5
PCNR	3	32	14	36	13	19	7	10
	4	13	4	1	2	1	1	1
	5	16	10	2	2	1	1	1

Table 3. Model selection for capture-mark-recapture results for *Tylototriton pasmansi* at Xuan Son National Park (XSNP) and Phu Canh Nature Reserve (PCNR). Models include M_0 (null model, constant parameters), M_t (time-varying model), and M_b (behaviour-varying model), and the values for the corrected Akaike Information Criterion (AICc), best model (ΔAICc), and probability (AICc weight, in %) are provided. The model that best fits each site is shown in bold. The population size estimate includes the 95% confidence interval (CI) and the standard error (SD).

Location	Model	AICc	ΔAICc	AICc weight	*n* (CI)	SE
XSNP	**M_b**	**-103.7**	**0**	**0.5**	**51.3 (47.9–67.4)**	**4**
	M_t	-103.3	0.4	0.4	72.4 (57.8–107.2)	11.7
	M_0	-99	4.7	0.1	76.1 (59.7–113.8)	12.9
PCNR	**M_t**	**-808.8**	**0**	**0.8**	**235.8 (210.2–276.8)**	**16.6**
	M_b	-805.5	3.3	0.2	176.3(171.1–190.5)	4.5
	M_0	-769.7	39.1	0	248.1(219.0–293.6)	18.6

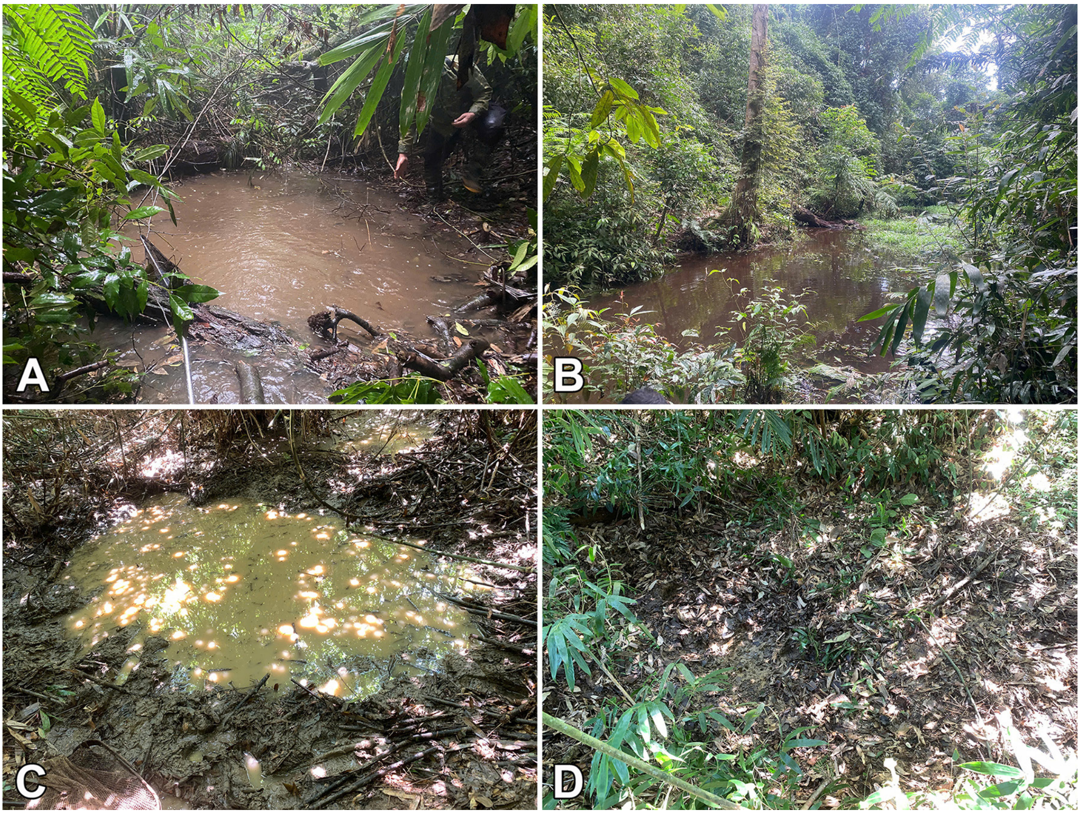

Figure 3. Ponds serving as habitat for *Tylototriton pasmansi* in Xuan Son National Park (XSNP) and Phu Canh Nature Reserve (PCNR), Phu Tho Province, northern Vietnam. (A) Pond 2 in XSNP. (B) Pond 3 in PCNR. (C) Pond 4 in PCNR. (D) A dried-up pond in PCNR without *T. pasmansi*. Photos by Dung Van Tran (A, B) and Phuong Thi Thu Nguyen (C, D).

Discussion

This is the first scientific assessment of *T. pasmansi* population size in Vietnam, providing a crucial foundation for conservation efforts. The discovery that populations of this species are so small raises the alarm about the risk of population decline. Our results not only address the research question at a population level but also provide essential quantitative data to evaluate the species' conservation status under IUCN criteria. Compared with other studies on *Tylototriton* species in Thailand and Laos using similar methods, populations of *T. pasmansi* in XSNP and PCNR are relatively small. In the Maesa-Kogma Biosphere Reserve, Thailand, population estimates for *T. uyenoi* Nishikawa et al., 2013 were 360 individuals in a 16-ha area (Dowwiangkan et al., 2018). Similarly, the population size of *T. podichthys* Phimmachak et al., 2015 in Laos was estimated at 301 individuals during the breeding season within a 5.58-ha site in Xiengkhouang Province (Phimmachak et al., 2015). We surveyed a much larger area in XSNP (15,048 ha) and *T. pasmansi* was present in only a few ponds (estimated population size is 70). In contrast, the much smaller area in PCNR (5303 ha) had the newt estimated population size of 236. This initial survey suggests that *T. pasmansi* has a very small population size and its distribution, even in a healthy-looking environment, may be restricted by the availability of suitable microhabitat. These findings suggest that the current Data Deficient status should be revisited once additional data become available from the species' remaining known range.

Our survey was only conducted for three days during the breeding season, which most likely affected capture probability (more captures because of breeding aggregation). Further surveys are critical and should include sampling at different times of the year to obtain a more comprehensive population estimates to better understand the role of microhabitats in protected areas, especially the availability of suitable waterbodies.

Additionally, in both XSNP and PCNR newt populations appeared to exhibit “trap-shyness”. This behavioural response became apparent when the mean initial capture probability exceeded the recapture probability. Thus, after first handling, individuals likely became wary and were less likely to be caught again (White et al., 2015). This time-linked behaviour can depress recapture rates and, if unmodeled, introduce a bias that artificially lowers abundance estimates.

Because our three-day survey occurred during the breeding season, some newts may already have left the shallow ponds. To estimate population size and to gather more natural history data we suggest conducting 4–5 surveys per year to be able to model both time and behavioural effects on capture probabilities. Lower recapture probabilities may not solely reflect handling-induced trap-shyness but could also result from temporary emigration, as adults of pond-breeding salamandrids typically attend breeding sites for a limited time and may leave shortly after mating or oviposition (Wells, 2007; Bernardes et al., 2017). Within a closed-population framework, such temporary departures cannot be distinguished from behavioural responses and may contribute to the observed difference between capture and recapture probabilities. This dynamic may also help explain the contrasting sex ratios between sites, since males often arrive earlier and remain longer at breeding ponds, whereas females tend to depart soon after oviposition, potentially leading to male-biased ratios depending on survey timing (Bernardes et al., 2017).

In contrast to amphibians that breed in streams or large ponds, *T. pasmansi* breeds in small, shallow, and stagnant pools with a varying degree of canopy cover. While shade can buffer temperature extremes, these shallow pools are typically thermally variable and often oxygen-poor due to both limited mixing and high organic matter. We found the ponds to be slightly acidic to alkaline which may reflect differences in, litter composition, organic matter decomposition, or the influence of limestone geology. These patterns align with earlier work (e.g., Bernardes et al., 2013, 2017) where it was shown that *Tylototriton* species typically rely on small, still, forest waterbodies for reproduction and larval development. In Tay Yen Tu Nature Reserve, Quang Ninh Province, *T. vietnamensis* Böhme et al., 2005 was reported to breed mainly in small, stagnant pools with pH > 4.3 rather than in streams or larger ponds (Bernardes et al., 2013). Likewise, larvae of *T. ziegleri*, Nishikawa et al., 2013, were found developing in small forest pools with thick mud layers and abundant leaf litter. Mud and biomass appear to be important features shaping the developmental conditions for newt larvae in Bac Kan Province, a northeastern mountainous region in Vietnam (Bernardes et al., 2017). *Tylototriton yangi* Hou et al., 2012 in Yunnan Province, southwestern China, were found to breed exclusively in small forest waterbodies in karst landscapes, and the loss of these breeding habitats was identified as a key threat to population persistence (Wang and Yuan, 2018).

The small population size and narrow habitat choice of *T. pasmansi* may increase its risk of local extinction. Climate change is a major potential threat to amphibians because they depend on aquatic habitats for breeding and larval development (Bickford et al., 2010; Luedtke et al., 2023). In XSNP and PCNR, high-elevation ponds are small and scarce, so drying would quickly remove key breeding sites and reduce egg and larval survival. This vulnerability is likely amplified by the restricted population size and high-elevation occurrence of these newts. Conservation should prioritize improving water retention in natural ponds, and the establishment of well-monitored artificial ponds that mimic natural depth and vegetation should be attempted.

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