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Comparison of Stream Frog Assemblages at Three Elevations in an Evergreen Forest, North-Central Thailand

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Ratchata Phochayavanich, Harold K. Voris, Wichase Khonsue, Somying Thunhikorn, and Kumthorn Thirakhupt (2010) Comparison of stream frog assemblages at three elevations in an evergreen forest, north-central Thailand. *Zoological Studies* **49**(5): 632-639. A study of stream-dwelling frog assemblages was conducted at 800, 950, and 1250 m in elevation on the Nam San Noi stream, Phuluang Wildlife Sanctuary, north-central Thailand. Three transects, each 100 m long which ran along the stream, were designated at each elevation. Visual encounter surveys were conducted within each transect at night from June 2006 to May 2007. The Shannon-Wiener index of species diversity indicated that the diversity was highest at the lowest elevation and lowest at the highest elevation, while Morishita's similarity index indicated that species compositions at 800 and 950 m were very similar to each other, but both of them differed from that at the highest elevation (1250 m). Over all 3 elevations, 4 of the most common species (with abundances exceeding 1%) were least abundant at the highest elevation, while 2 species, *Limnonectes kuhlii* and *Odorrana aureola*, were most abundant at the highest elevation. The abundance of *Lim. gyldenstolpei* fluctuated among the 3 elevations. These results indicated that the frog compositions significantly differed between 2 elevation groups, that is between (a) the group consisting of 800 and 950 m and (b) that at 1250 m, and also that frog diversity tended to be highest at the lowest elevation. http://zoolstud.sinica.edu.tw/Journals/49.5/632.pdf

Key words: Frog diversity, Species composition, Steam transects, Elevational differences.

Terrestrial environments are exposed to both temporal and spatial changes, often rapid, in local environmental gradients. Exploring patterns of species richness and biodiversity across these gradients is a key and central component of understanding the ecology and biogeography of each habitat and geographical domain. For this, elevational gradients in mountainous regions can show particularly large gradient changes in a relatively small area. Documenting the elevational patterns in species richness, and by comparative analysis with other such patterns, identifying the factors that govern them are essential matters for conservation management of any species or habitat in mountainous regions (Pimm and Brown 2004). However, patterns of species richness along elevational gradients considerably vary across the world, while the processes that govern them seem to be equally varied (Rahbek 1995 2005), preventing simple transfer of known data to conceptually similar habitats elsewhere. Nevertheless, the persistence of residential species in a specific area suggests that there are suitable available habitats for those species in that

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area. Thus, data on resident species assemblages in any given habitat can be used to determine the suitability of that habitat for those species by comparison to similar habitats in other locations.

Among terrestrial vertebrates, amphibians are regarded as a major group of animals that are sensitive to environmental change (Hopkins 2007). Amphibians are ectothermic animals that rely on environmental sources for heat gain. As a result, their options for activity are more limited than those of endothermic tetrapods, which maintain an elevated body temperature by means of metabolic heat production. Globally, temperature appears to be the main limiting factor in the diversity and distribution patterns of the herpetofauna (Zug et al. 2001, Huang and Tu 2008). However, on a local scale, there are several other factors that can additionally influence amphibian assemblages. The species richness of amphibians can be influenced by season (amphibian: Allmon 1991, Phochayavanich 2007), precipitation (herpetofauna: Owen 1989, frog: Woinarski et al. 1999), soil texture (herpetofauna: Woinarski et al. 1999), the existence of burned areas (herpetofauna: Giaretta et al. 1999), and litter volumes and moisture levels (frog: Allmon 1991). Moreover, amphibian compositions can be influenced by differences in land use cover (amphibian: Phochayavanich et al. 2008; herpetofauna: Vonesh 2001, Barrett and Guyer 2008). Many environmental factors change along elevation gradients (e.g., plant communities, water pH and temperature, ultraviolet-light exposure levels and canopy cover, relative humidity, litter type and cover, and air temperature). Relative abundances and species compositions of amphibian species that rely on these factors are thus predicted to change along such a gradient. Therefore, the objective of this work was to study and compare the composition of amphibian communities at 3 different elevations on Nam San Noi (NSN) stream in Phuluang Wildlife Sanctuary, Thailand.

MATERIALS AND METHODS

Study area

Phuluang Wildlife Sanctuary is located in Loei Province, Thailand, at 17°3'-17°24'N and 101°16'-101°21'E. The average annual rainfall from 1954 to 2000 was 1229.1 mm, and most of the rain occurs from Apr. to Oct. The sanctuary is covered by a mixture of dry deciduous dipterocarp forest, mixed deciduous forest, dry evergreen forest, montane evergreen forest, coniferous forest, and tropical grassland. This study was conducted on NSN stream which is the main stream within the northern part of the sanctuary (Fig. 1). The stream was divided into 3 sections which were located at 800, 950, and 1250 m in elevation, and all were in the tropical evergreen forest. Intervals between sections were approximately 1.5-2 km. The principal forest types in this sanctuary are tropical dry evergreen forests at 500-900 m and tropical montane evergreen forests at 900-1400 m (Forest Research Center 2002). However, the forest type at 700-900 m can be defined as a sub-community of tropical dry evergreen forest or an ecotonal community composed of both forest types including some oak tree and other plant species similar to the tropical montane evergreen forest. Therefore, the plant communities at the 800 and 950 m sites were more similar to each other than either was to the 1250 m site.

Stream characteristics

The stream width, depth, and rate of water flow were measured at each transect and on each visit. The Kruskal-Wallis test was used to determine differences in stream characteristics among the 3 elevations. The average annual stream characteristics were grouped among transects by a cluster analysis (with Euclidean distance measurements using PC-ORD vers. 4.25 software; McCune and Mefford 1999). Elevations at which stream characteristics were similar were grouped together by the cluster analysis.

Study of frog assemblages

The amphibian species compositions were determined by visual encounter surveys on 100 m transects at 800, 950, and 1250 m on the NSN stream. Nine nights of surveys per month were conducted from June 2006 to May 2007 inclusively on three 100 m stream transects (with intervening distances of 250 m) at each of 3 elevations (800, 950, and 1250 m). The night surveys were conducted by 3 workers for 30 min per transect at 19:00-22:00. Gradients between the three 100 m transects at each of the 3 elevations (800, 950 and 1250 m) were modest in comparison to the overall gradients between the elevations of 800, 950, and 1250 m. The species and numbers of individuals were recorded to calculate the species diversity,

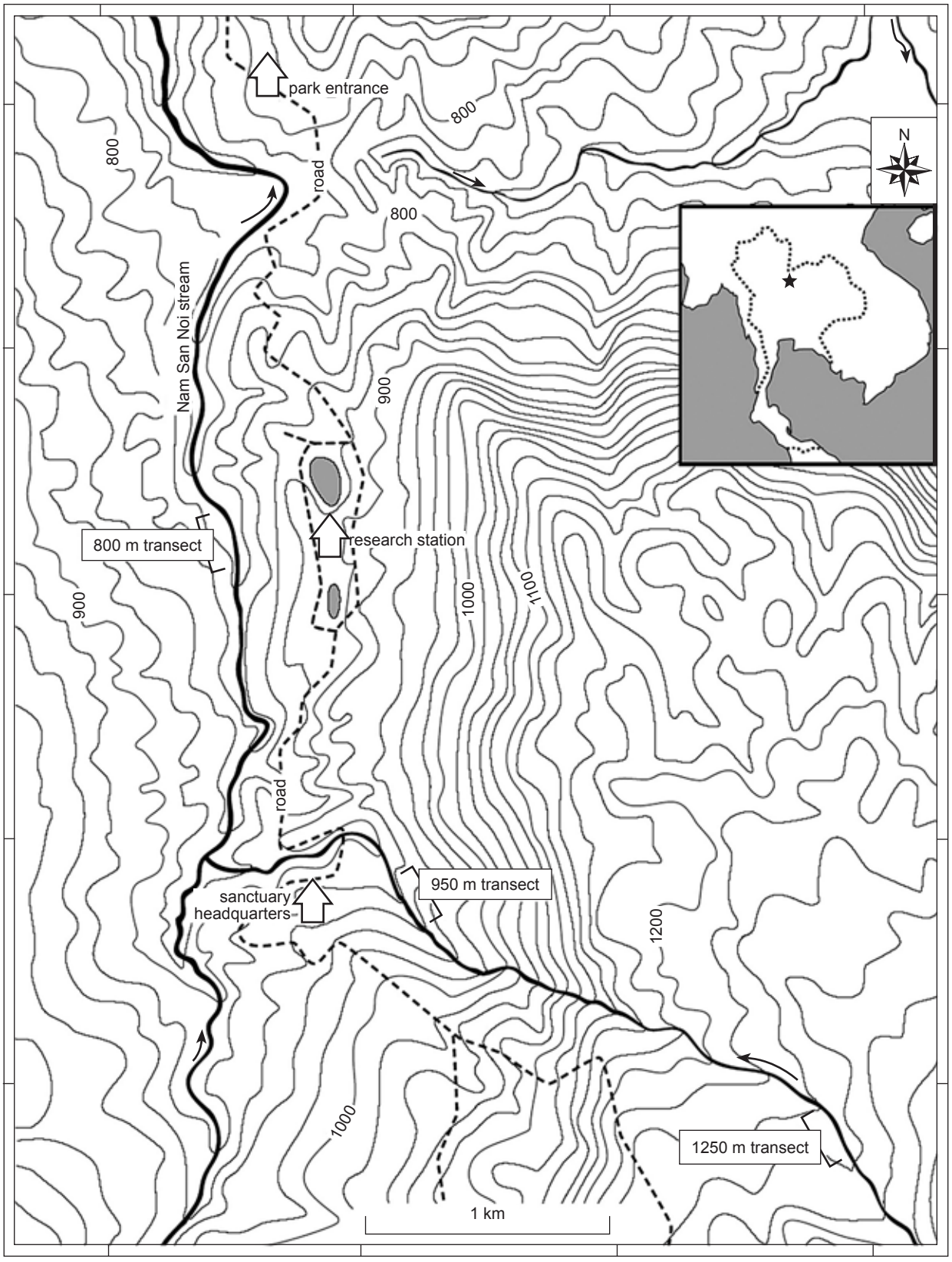


Fig. 1. Map of the study area at the Nam San Noi stream in the Phuluang Wildlife Sanctuary, showing the transect locations at 800 m asl, 950 m asl and 1250 m asl.

species similarity, and species abundance at each elevation. The species diversity was determined by the Shannon-Wiener index of species diversity and similarity was determined by Morishita's similarity index (Krebs 1999).

RESULTS

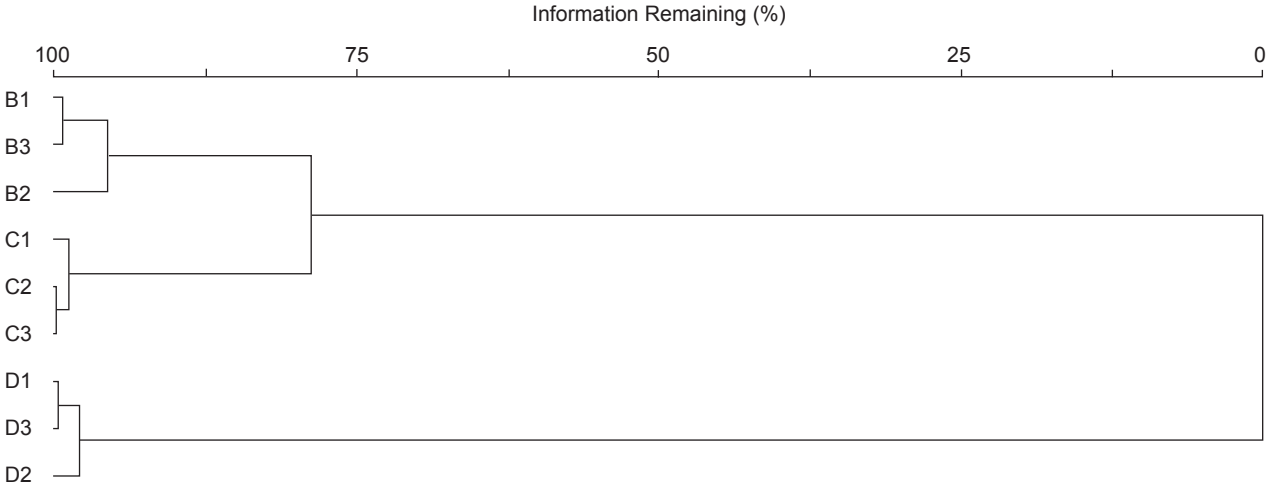
Stream characteristics

The average annual stream width, depth, and rate of water flow significantly differed among the 3 elevations, and all 3 parameters were highest at the lowest elevation (Table 1).

The cluster analysis (with Euclidean distance measurement using PC-ORD vers. 4.25 software) of environmental factors (stream width, depth, and rate of water flow) on the transects at the 3 different elevations on NSN stream indicated that transects were divided into 2 groups, accounting for 75% of the information (Fig. 2). The 1st group was comprised of the stream transects at 800 and 950 m, while the 2nd group was composed of the 3 transects at 1250 m. Thus, stream characteristics of the 800 and 950 m transects were more similar to each other than either was to the stream transects at 1250 m. It is noteworthy that this result was in full agreement with the vegetation similarities between the 2 lower transects compared to the upper one.

Species diversity

In total, 22 species of amphibians were found at NSN stream, Phuluang Wildlife Sanctuary between June 2006 and May 2007. They belong to 2 orders, Caudata and Anura, and 6 families:



B1 - B3 = 1st, 2nd, 3rd stream transects at 800 m asl
C1 - C3 = 1st, 2nd, 3rd stream transects at 950 m asl
D1 -D3 = 1st, 2nd, 3rd stream transects at 1250 m asl

Fig. 2. Similarity of environmental factors among transects at 3 different elevations at the Nam San Noi stream, Phuluang Wildlife Sanctuary, from June 2006 to May 2007, analyzed by cluster analysis with Euclidean distance measurement using PC-ORD version 4.25 software. 1-3 represent the 1st, 2nd, and 3rd stream transects at elevation sites (B) 800, (C) 950 and (D) 1250 m asl, respectively.

Table 1. Stream characteristics (mean ± S.E.) at 3 elevations on Nam San Noi stream from June 2006 to May 2007. Stream width, depth, and flow rate significantly differed among elevations, by the Kruskal-Wallis test, $p \leq 0.05$

Elevation	800 m	950 m	1250 m
Stream width (m)	9.22 ± 0.70	6.45 ± 0.45	2.55 ± 0.30
Stream depth (m)	0.91 ± 0.08	0.39 ± 0.03	0.27 ± 0.03
Rate of stream flow (m/s)	0.81 ± 0.11	0.49 ± 0.06	0.21 ± 0.05

the Dicroglossidae, Megophryidae, Microhylidae, Ranidae, Rhacophoridae, and Salamandridae. *Hylarana nigrovittata* had the highest abundance (44.0%), followed by *Limnonectes kuhlii* (24.4%), *Odorrana chloronota* (15.4%), *Leptolalax pelodytoides* (7.4%), *Limnonectes gyldenstolpei* (3.3%), *Microhyla berdmorei* (1.8%), and *Odorrana aureola* (1.8%) (Fig. 3). The Shannon-Wiener index of species diversity for all observations was a modest 1.61 reflecting a substantial amount of unevenness among the species abundances. Nine species represented > 1% of the total abundance and were considered common species for the purposes of figure 4. The percentage abundance of each of the other 13 other species was < 1%, and these are not shown in figure 4. Figure 4 illustrates that at each elevation, only 1-3 species dominated with 10% or more of the composition.

Species compositions and abundances at different elevations

(a) 800 m: Seventeen species of amphibians were found at this elevation with 7 species having > 1% relative abundances (Table 2). *Hylarana nigrovittata* (Hn) had the highest abundance (50.1%), followed by *O. chloronota* (Oc) (19.6%), *Lep. pelodytoides* (Lp) (12.3%), *Lim. kuhlii* (Lk) (7.9%), *Lim. gyldenstolpei* (Lg) (4.3%), *M. berdmorei* (Mb) (1.9%), and *P. leucomystax* (Pl) (1.2%) (Fig. 4). The percentage abundances for each of the other 10 species were < 1%. The Shannon-Wiener index of species diversity was the highest of the 3 sites, at 1.54.

(b) 950 m: Fifteen species of amphibians were found at this elevation with 7 species with > 1% relative abundance level (Table 2). *Hylarana nigrovittata* had the highest abundance (56.3%), followed by *O. chloronota* (19.0%), *Lim. kuhlii* (10.4%), *Lep. pelodytoides* (7.1%), *M. berdmorei*

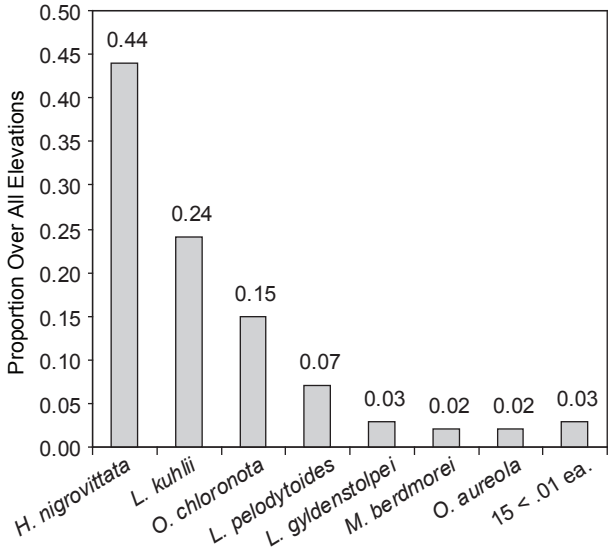


Fig. 3. Proportion of each of the 7 common species at all 3 elevations of Nam San Noi stream, Phuluang Wildlife Sanctuary, from June 2006 to May 2007. The remaining 15 species, whose individual proportions are less than 0.01 each, are shown pooled together on the lower right side. Numbers above each bar show the exact relative proportion.

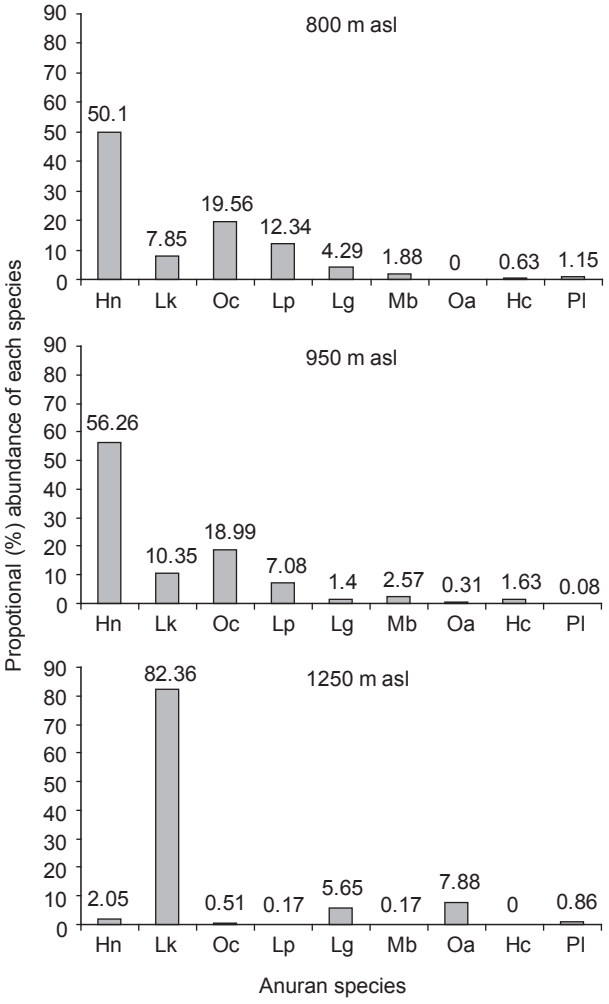


Fig. 4. Percentage abundance of each of the 9 common (in at least one of the 3 elevations) species at each elevation at Nam San Noi stream, Phuluang Wildlife Sanctuary, from June 2006 to May 2007. Species abbreviations are: *Hylarana nigrovittata* (Hn), *Limnonectes kuhlii* (Lk), *Odorrana chloronota* (Oc), *Leptolalax pelodytoides* (Lp), *Limnonectes gyldenstolpei* (Lg), *Microhyla berdmorei* (Mb), *Odorrana aureola* (Oa), *Hylarana cubitalis* (Hc) and *Polypedates leucomystax* (Pl).

(2.6%), *H. cubitalis* (Hc) (1.6%), and *Lim. gyldenstolpei* (1.4%), (Fig. 4). The percentage abundances of the other 8 species were each < 1%. The Shannon-Wiener index of species diversity was 1.38.

(c) 1250 m: Ten species of amphibians were found at this elevation (Table 2). *Limnonectes kuhlii* had the highest abundance (82.36%), followed by *O. aureola* (Oa) (7.88%), *Lim. gyldenstolpei* (5.65%), and *H. nigrovittata* (2.05%) (Fig. 4). The percentage abundances of the remaining 6 species were each < 1%. The Shannon-Wiener index of species diversity (0.71) was the lowest at this elevation.

Combining the data from the 3 elevations, 22 species were found, of which 7 had a total relative abundance of > 1%. Four of the 7 species with a total abundance of > 1% showed their lowest abundance at the highest elevation (1,250 m). *Limnonectes kuhlii* and *O. aureola* were the 2 exceptions, with their maximum abundances being found at the highest elevation. The abundances of *Lim. gyldenstolpei* fluctuated among these elevations, and *Xenophrys major* was only found at 950 m.

Similarities of amphibian species compositions among elevations

Values of Morishita's similarity index between 800 and 950, 950 and 1250, and 800 and 1250 m were 0.99, 0.20, and 0.16, respectively. Thus, the species compositions at 800 and 950 m were very similar to each other, but both of them differed from the species composition at 1250 m.

DISCUSSION

Species diversity and abundance of amphibians at different elevations

Overall, across all 3 surveyed elevations, *H. nigrovittata* had the highest abundance in this stream. However, comparing the relative abundance of each species among the 3

Table 2. Number of observed and the percentage abundance of each of the 22 species of amphibians found on transects at 3 elevations on Nam San Noi stream from June 2006 to May 2007

Family	Species	800 m No. (%)	950 m No. (%)	1250 m No. (%)	Total No. (%)
Salamandridae	*Tylototriton verrucosus*	-	-	1 (0.17)	1 (0.04)
Megophryidae	*Leptobrachium smithi*	6 (0.63)	-	-	6 (0.21)
	Leptolalax pelodytoides	118 (12.34)	91 (7.08)	1 (0.17)	210 (7.43)
	Xenophrys major	-	9 (0.70)	-	9 (0.32)
Dicroglossidae	*Limnonectes gyldenstolpei*	41 (4.29)	18 (1.40)	33 (5.65)	92 (3.26)
	Limnonectes kuhlii	75 (7.85)	133 (10.35)	481 (82.36)	689 (24.39)
	Limnonectes limborgi	-	1 (0.08)	-	1 (0.04)
Ranidae	*Hylarana cubitalis*	6 (0.63)	21 (1.63)	-	27 (0.96)
	Hylarana nigrovittata	479 (50.10)	723 (56.26)	12 (2.05)	1214 (42.97)
	Hylarana taipehensis	1 (0.10)	1 (0.08)	-	2 (0.07)
	Odorrana aureola	-	4 (0.31)	46 (7.88)	50 (1.77)
	Odorrana chloronota	187 (19.56)	244 (18.99)	3 (0.51)	434 (15.36)
Rhacophoridae	*Aquixalus bisacculus*	5 (0.52)	3 (0.23)	-	8 (0.28)
	Chiromantis vittatus	3 (0.31)	-	-	3 (0.11)
	Philautus parvulus	-	2 (0.16)	-	2 (0.07)
	Polypedates leucomystax	11 (1.15)	1 (0.08)	5 (0.86)	17 (0.6)
	Rhacophorus feae	1 (0.10)	-	-	1 (0.04)
Microhylidae	*Kalophrynus interlineatus*	1 (0.10)	-	1 (0.17)	2 (0.07)
	Kaloula pulchra	2 (0.21)	-	-	2 (0.07)
	Microhyla berdmorei	18 (1.88)	33 (2.57)	1 (0.17)	52 (1.84)
	Microhyla fissipes	1 (0.10)	-	-	1 (0.04)
	Micryletta inornata	1 (0.10)	1 (0.08)	-	2 (0.07)
Total number of individuals		956	1285	584	2825
Total number of species		17	15	10	22

elevations, only *H. nigrovittata* had the highest abundances at the low elevations (800 and 950 m), while *Lim. kuhlii* was the most abundant frog at the highest elevation (1250 m). This result is very similar to a previous study in the Lam Ta Kong stream at Khao Yai National Park, Nakhon Ratchasima Province, where *H. nigrovittata* also had the highest overall abundance and was the most abundant frog at low elevations (400-900 m), while *Lim. kuhlii* was the most abundant frog at elevations of > 1000 m (Kongjaroen 2007).

In this study, the species diversity of amphibians was higher at the lower elevations. Parris and McCarthy (1999) reported that the upstream catchment volume was a significant explanatory variable for the species richness of frog assemblages in forest streams in southeastern Queensland, Australia. It was correlated with stream width, stream substrate, permanence of the water, and rates of water flow. Stream-breeding frogs require a stream that is large enough to retain water for a sufficient length of time for their tadpoles to develop to metamorphosis. Thus, large streams usually provide suitable breeding habitats for a greater range of frog species than small streams, because larger streams typically contain water for longer periods of time and allow for a greater diversity of microhabitats and food items to support more niche-differentiated (non-competing) amphibian species. Thus, it can be speculated that the low species diversity at 1250 m observed in this study site was at least in part due to having the lowest stream width, permanence of water, and rates of water flow.

Similarity of amphibian communities among elevations

The similarity index indicates that the species composition of amphibians at the 2 lowest elevations (800 and 950 m) were very similar to each other, but both differed from the composition at the highest elevation (1250 m). Some previous studies (Inger and Voris 1993, Parris and McCarthy 1999) reported that the compositions of frog assemblages on forest streams were correlated with the stream size and gradient. It was observed in this study that the stream width and gradient at 800 and 950 m in elevation were similar, whereas both of them differed from the 1250 m site in these parameters. Thus, these physical factors may at least in part explain why the species compositions at 800 and 950 m were very similar, whereas both of them differed from the composition at 1250 m. However, differences in other biotic and abiotic factors such as the vegetation and microhabitats may also more dramatically differ between the 1250 m site and the 2 lower sites which were more closely related in terms of forest cover type.

Conservation considerations

Generally speaking, in Thailand, high-elevation areas are less disturbed than low-elevation areas which are more likely to be strongly impacted by human activities such as agriculture. The results of this study conducted entirely within a sanctuary indicated that lower sections of the stream (800-950 m) tended to have higher species diversities than the higher sections (1250 m). Thus, these results suggest that there is much to be gained by protecting low-elevation sites from human impacts. In addition, the results demonstrated that several species were restricted to only 1 elevation. This observation suggests that protection of some forest at all elevations will help ensure that all elements of the overall amphibian species diversity will be conserved.

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