ความหลากชนิด และกิจกรรมตามฤดูกาลของสัตว์สะเทินน้ำสะเทินบก ที่ระดับความสูงต่างกัน บริเวณลำน้ำสานน้อย เขตรักษาพันธุ์สัตว์ป่าภูหลวง

นายรัชต โปชยะวณิช

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SPECIES DIVERSITY AND SEASONAL ACTIVITY OF AMPHIBIANS AT
DIFFERENT ELEVATIONS IN NUM SAN NOI STREAM
AT PHULUANG WILDLIFE SANCTUARY

Mr. Ratchata Phochayavanich

A Thesis Submitted in Partial Fulfillment of the Requirements
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By	Mr. Ratchata Phochayavanich
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การศึกษากิจกรรมตามฤดูกาลของสัตว์สะเทินน้ำสะเทินบกที่ระดับความสูงต่างกันบริเวณลำน้ำสานน้อย เขตรักษาพันธุ์สัตว์ป่าภูหลวงได้ดำเนินการตั้งแต่ เดือน พฤษภาคม พ.ศ. 2549 ถึง พฤษภาคม พ.ศ. 2550 ด้วยวิธีการสำรวจแบบพบเห็นตัวโดยตรงในเวลากลางคืน โดยวางเส้นทางสำรวจตามแนวลำธารที่ระดับความสูง 800 950 และ 1250 เมตรจากระดับน้ำทะเลปานกลาง ระดับความสูงละ 3 เส้นทางความยาวเส้นทางละ 100 เมตร ทำการสำรวจในแต่ละเส้นทาง 1 ครั้งต่อเดือน บันทึกชนิด และจำนวนของสัตว์สะเทินน้ำสะเทินบกที่พบในการสำรวจแต่ละครั้ง จากการสำรวจพบสัตว์สะเทินน้ำสะเทินบกทั้งหมด 22 ชนิด ดัชนีความหลากชนิดในฤดูฝนมีค่าสูงกว่าในฤดูแล้งทั้ง 3 ระดับความสูง ดัชนี ความคล้ายคลึงกันของชนิดสัตว์สะเทินน้ำสะเทินบกระหว่างฤดูกาลที่ระดับความสูง 1250 เมตร มีความคล้ายคลึงกันสูง ในขณะที่ที่ระดับความสูง 800 และ 950 เมตร มีความคล้ายคลึงกันค่อนข้างน้อย ความชุกชุมรวมของสัตว์สะเทินน้ำสะเทินบกทุกชนิดและความชุกชุมในแต่ละชนิดของสัตว์สะเทินน้ำสะเทินบกจำนวน 6 ชนิด มีค่าแตกต่างกันอย่างมีนัยสำคัญระหว่างฤดูกาล โดยในฤดูฝนพบความชุกชุมของกบชะง่อนผาภูหลวง และกบชะง่อนผาสูงกว่าในฤดูแล้ง ในขณะที่ฤดูแล้งพบความชุกชุมของปาดลายเลอะอีสาน กบหงอน กบอ่อง และอึ่งแม่หนาว สูงกว่าฤดูฝน รวมถึงความชุกชุมรวมในฤดูแล้งก็มีค่าสูงกว่าในฤดูฝนเช่นกัน มักพบค่าความชุกชุมของชนิดที่พบเป็นจำนวนมากสูงขึ้นควบคู่ไปกับการพบกิจกรรมการสืบพันธุ์ การวิเคราะห์การจัดลำดับ พบว่าความชุกชุมของสัตว์สะเทินน้ำสะเทินบกระหว่างฤดูกาลส่วนใหญ่มีความเชื่อมโยงกับความชื้นสัมพัทธ์ อุณหภูมิน้ำ อุณหภูมิอากาศ อุณหภูมิพื้นผิว และความกว้างของลำธาร

ผลการศึกษาข้อมูลองค์ประกอบของชนิดและความชุกชุมของสัตว์สะเทินน้ำสะเทินบกในลำธารแห่งนี้ พบความแตกต่างขององค์ประกอบของชนิดสัตว์สะเทินน้ำสะเทินบกในแต่ละระดับความสูง และค่าดัชนีความหลากชนิดมีแนวโน้มลดลงเมื่อระดับความสูงเพิ่มขึ้น ดัชนีความคล้ายคลึงของชนิดสัตว์สะเทินน้ำสะเทินบกที่ระดับความสูง 800 และ 950 เมตร มีค่าใกล้เคียงกัน ในขณะที่องค์ประกอบของชนิดสัตว์สะเทินน้ำสะเทินบกที่ระดับความสูงทั้งสองมีค่าแตกต่างจากที่ระดับความสูง 1250 เมตร และสัตว์สะเทินน้ำสะเทินบกที่มีค่าร้อยละความชุกชุมสูงจำนวน 7 ชนิด มีค่าความชุกชุมต่ำที่ระดับความสูง 1250 เมตร ยกเว้น กบห้วยขาปุ่ม และกบชะง่อนผาภูหลวง ที่มีค่าความชุกชุมสูงที่ระดับความสูง 1250 เมตร

เนื่องจากลำน้ำสานน้อยมีส่วนที่ไหลผ่านป่าธรรมชาติ และพื้นที่เกษตรกรรมที่ระดับความสูงใกล้เคียงกันที่ประมาณ 750-800 เมตรจากระดับน้ำทะเลปานกลาง ดังนั้นจึงทำการเปรียบเทียบองค์ประกอบของชนิด ความชุกชุม พื้นที่วางไข่และร้อยละของไข่ที่มีการพัฒนาของแต่ละชนิดระหว่างพื้นที่ดังกล่าว โดยการวางเส้นทางสำรวจในพื้นที่ป่าและพื้นที่เกษตรกรรม พื้นที่ละ 3 เส้นทางสำรวจ เส้นทางละ 100 เมตร สำรวจเส้นทางละ 1 ครั้งต่อเดือน ค่าดัชนีความหลากชนิดระบุว่า ความหลากชนิดของกบบริเวณลำธารที่ไหลผ่านพื้นที่เกษตรกรรมสูงกว่าในป่า ค่าความคล้ายคลึงพบว่า องค์ประกอบของชนิดสัตว์สะเทินน้ำสะเทินบกของเส้นทางสำรวจในพื้นที่เกษตรที่อยู่ติดกับป่ามีความคล้ายคลึงกับในป่ามากที่สุด ในขณะที่อีกสองเส้นทางมีความคล้ายคลึงกับในป่าน้อยกว่า อีกทั้งสัตว์สะเทินน้ำสะเทินบกชนิดที่พบเห็นได้ทั่วไป มีความชุกชุมสูงขึ้นในลำธารที่ไหลผ่านพื้นที่เกษตร ในขณะที่สัตว์สะเทินน้ำสะเทินบกชนิดที่พบได้เฉพาะในป่ามีค่าความชุกชุมต่ำลง นอกจากนี้ระหว่างช่วงเวลาศึกษาไม่พบกลุ่มไข่ของสัตว์สะเทินน้ำสะเทินบกชนิดใดในเส้นทางสำรวจของลำธารในพื้นที่เกษตรกรรม และจากการวิเคราะห์การจัดลำดับ สรุปได้ว่าความชุกชุมของสัตว์สะเทินน้ำสะเทินบกชนิดที่พบเห็นได้ทั่วไปมีความเชื่อมโยงกับการสูงขึ้นของค่าพลังงานแสงอาทิตย์ อุณหภูมิอากาศ และอุณหภูมิน้ำ ขณะที่ความชุกชุมของสัตว์สะเทินน้ำสะเทินบกชนิดที่พบได้เฉพาะในป่ามีความเชื่อมโยงกับการสูงขึ้นของค่า ความชื้นสัมพัทธ์ และค่าความสามารถในการส่องผ่านของแสงในน้ำ จึงสรุปได้ว่าพื้นที่เกษตรบริเวณสองข้างลำธารส่งผลในทางลบต่อความชุกชุมของสัตว์สะเทินน้ำสะเทินบกชนิดที่พบได้เฉพาะในป่า

ภาควิชา ชีววิทยา	ลายมือชื่อนิสิต....รัชด โปชยะวณิช....
สาขาวิชา สัตววิทยา	ลายมือชื่ออาจารย์ที่ปรึกษา....กำธร ธีรคุปต์....
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KEY WORD: AMPHIBIANS, SPECIES DIVERSITY, SEASONAL ACTIVITY, STREAM, DIFFERENT ELEVATIONS

RATCHATA PHOCHAYAVANICH: SPECIES DIVERSITY AND SEASONAL ACTIVITY OF AMPHIBIANS AT DIFFERENT ELEVATIONS IN NUM SAN NOI STREAM AT PHULUANG WILDLIFE SANCTUARY. THESIS ADVISOR: ASSOC. PROF. KUMTHORN THIRAKHUPT, Ph.D., THESIS CO-ADVISOR: HAROLD K. VORIS, Ph.D., 80 pp.

Seasonal activity of amphibians at Nam San Noi stream, Phuluang Wildlife Sanctuary was studied from May 2006 to May 2007. Night visual encounter surveys were conducted on three 100 m stream transects at each of three elevations, 800, 950, and 1250 m. Each stream transect was surveyed once a month. Species and number of amphibians found in each survey were recorded. A total of 22 species was found during the survey period. The species diversity in the wet season was higher than in the dry season at all three elevations. The similarity index indicated that species composition between seasons at 1250 m were similar whereas at 800 and 950 m they differed. The total abundance of all species and abundance of the 6 most common species had significant differences between the wet and dry season. The abundances of *Odorrana aureola* and *Odorrana chloronota* were high during the wet season while the number of *Limnonectes gyldenstolpei, Hylarana nigrovittata, Aquixalus bisacculus,* and *Microhyla berdmorei* and total abundance of all species peaked in the dry season. The highest abundances of the most common species were found to be associated with breeding activity. The Canonical Correspondence Analysis (CCA) indicated that the year-round abundances of most amphibians at difference elevations were associated with stream size, water temperature, and substrate temperature whereas the variations in amphibian abundance between season at each elevation were associated with relative humidity, water temperature, air temperature, substrate temperature, and stream width.

Species composition and abundance of amphibians at Nam San Noi stream in the Phuluang Wildlife Sanctuary were also observed. Shannon-Wiener's diversity index indicated that the lowest elevation (800 m) had the highest diversity whereas the highest elevation (1250 m) had the lowest value. Morishita's similarity index showed that species compositions at 800 and 950 m, were very similar but both were different from the highest elevation, 1250 m. Seven species which had the highest percentage of total abundance had low abundance at the highest elevation with the exception of *Limnonectes kuhlii* and *Odorrana aureola* that were most abundant at the highest elevation. *Xenophrys major* was a species found only at one elevation, 950 m. These results indicated that species diversity of amphibians tended to be higher at the lower elevation.

Num San Noi stream also flows across an agricultural area. Therefore, species composition, abundance, oviposition sites and percentage of developing eggs of each species of amphibians were compared between forest and agricultural stream at similar elevations (750-800 m). Six 100 m stream transects, 3 in the forest and 3 in the agricultural area were surveyed once a month. The Shannon-Wienner's diversity index indicated that the diversity in agricultural stream transects (ASTs) was significantly higher than the FSTs. The Morishita's similarity index indicated that the species composition of the 1st AST (closest to the forest) was the most similar to the FSTs, 0.744 – 0.867, whereas the species composition of the other 2 ASTs (far from the forest edge) were less similar to FSTs, 0.493 – 0.527. In the ASTs, abundances of each of 5 forest species were significantly lower whereas 6 urban species were significantly higher when compared with the FSTs ($p \leq 0.05$). Moreover, during the study period oviposition sites and developing eggs were not found in ASTs. The CCA showed that the abundance of urban species were associated with high solar energy, air temperature, and water temperature whereas the forest species were found associated with high relative humidity and stream water transparency. The results indicated that the agricultural area had a negative effect on the abundance of forest species.

Department Biology	Student's signature Ratchata Phochayavanich
Field of study Zoology	Advisor's signature K. Thirakhupt
Academic year 2007	Co-advisor's signature Harold K. Voris

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The usefulness of this study, I dedicate to Associate Professor Dr. Virayuth Lauhachinda, person who inspired me, and also to the every individual of amphibians in my study transects. Any mistakes, omissions, or errors in this thesis were my responsibility.

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CHAPTER I

INTRODUCTION

The problems of amphibian decline have been reported globally (Barinaga, 1990; Schloegel, *et al.,* 2006; Stuart *et al.,* 2004). Six hypotheses have been proposed to explain about this problem (Collins and Storfer, 2003). One of the six hypotheses is habitat destruction. The natural habitats in Thailand have been destroyed continuously in many places but to date there is no information about the effect to amphibians. Due to the fact that when the natural habitat is destroyed, the amphibians in that area should be affected because amphibians are sensitive to environmental changes. Therefore, the study on species composition and abundance of amphibians in the stream between agricultural and natural area which are connected is urgently needed and the results may help to explain about the effect of habitat change to amphibian population.

Documenting the elevational patterns in species richness and identifying factors that govern them is essential for conservation purposes (Pimm and Brown, 2004). The elevation can affect both biolog ical and physical factors. Therefore, the species composition of amphibian across di fferent elevations is predicted to be different. To identify the factors that govern species composition at different elevations, many studies are needed. This study provides a record of species composition of amphibians at different elevations and may help to explain the effect of elevation on species composition.

The monitoring of amphibian population was conducted to determine their population trends in many part of the world (Bishop and Pettit, 1997; Crouch and Panton, 2000; Nelson and Graves, 2004). However, Thailand has little knowledge about problems of amphibian decline and never had systemic methods to monitor them. Their populations can fluctuate correlated to the changes of environmental factors (Duellman, 1995). This means that the amphibian abundance can change in different seasons. Studies on the patterns of anuran reproduction in tropical and subtropical regions have repeatedly demons trated (Duellman, 1995; Inger, R. F. and Voris, H. K., 1993; Kam and Chen, 2000) and it was found that the reproductive phenology is closely associated with rainfall. Rainfall influences the reproductive phenology of many amphibian species, partic ularly in tropical forests with seasonal precipitation (Donnelly and Guyer, 1994). However, most of these studies concentrated on terrestrial species that br eed in ephemeral bodies of water. Species that breed in streams receive far less attention even though they are commonly found in tropical region (Inger, 1966). Stream breeders may have different reproductive phenology from ephemeral pond breeders. Therefore, seasonal abundance of stream dwelling amphibians should be studied to understand the fluctuation in each period of the year. If the fluctuations in abundance of amphibians along the stream are well understood, then the amphibian monitoring method can be conducted in the suitable survey period in that stream to save time, man, money and other resources.

1.1 Objectives

1. To determine the species composition of amphibians at different elevations on Num San Noi stream, Phuluang Wildlife Sanctuary, Thailand
2. To determine seasonal activities; species present, occurrence period, abundance and breeding duration of amphibians living in different elevations along the Nam San Noi stream, Phuluang Wildlife Sanctuary
3. To determine and compare species composition, oviposition sites and breeding success of frogs at Num San Noi stream flowing through forest and agricultural areas

CHAPTER II

LITERATURE REVIEW

2.1 Study Area

Phuluang Wildlife Sanctuary is located in Loei Province, Thailand at $17^{\circ} 3^{'}$ – $17^{\circ} 24^{'}$N and $101^{\circ} 16^{'}$ – $101^{\circ} 21^{'}$E. The average annual rainfall from 1954 to 2000 was 1229.1 mm. Much of the rain occurs from April to October. The sanctuary is covered by dry deciduous dipterocarp forest, mixed deciduous forest, dry evergreen forest, montane evergreen forest, coniferous forest, and tropical grassland. This study was conducted on Nam San Noi stream which is the main stream of the northern part of the sanctuary (Figure 2.1). The stream was divided into 4 study sites. One site was located in agricultural area about 750 m asl. The other 3 sites located at 800, 950, and 1250 m asl and are in tropical evergreen forest. Forest Research Center, Faculty of Forestry, Kasetsart University (2002) reported that the forest type at 500-900 m tropical dry evergreen forest whereas at 900-1400 m is tropical montane evergreen forest. However, the forest type at 700-900 m can be defined as the sub-community of tropical dry evergreen forest or the ecotonal community located between both forest types because there are some oak tree species and other plant species similar to the tropical montane evergreen forest. Therefore, the sites at 800 and 950 m asl were more similar in plant community to each other than either was to the site at 1250 m asl.

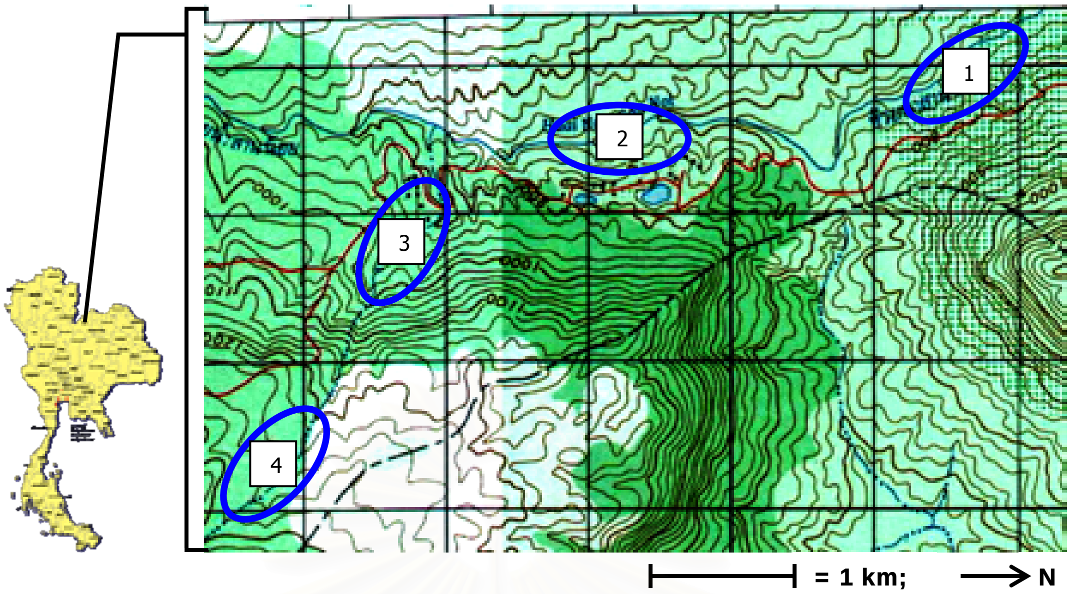


Figure 2.1 Topogaphic map of Num San Noi stream, Phuluang Wildlife Sanctuary; 1 = Agricultural area (750 m), 2 = Forest area at 800 m, 3 = Forest area at 950 m, and 4 = Forest area at 1250 m asl

2.2 Previous Studies on Amphibians at Phuluang Wildlife Sanctuary

Fourteen species of amphibians were reported at the sanctuary by Forest Research Center (2002). The species were *Megophrys* sp., *Bufo melanostictus* (*Duttaphrynus melanostictus*), *Phrynoglosuss martensii* (*Occidozyga martensii*), *Rana kuhlii* (*Limnonectes kuhlii*), *Rana pileatus* (*Limnonectes. gyldenstolpei*), *Rana rugulosus* (*Hoplobatrachus chinensis*), *Rana erythraea* (*Hylarana erythraea*), *Rana nigrovittata* (*Hylarana nigrovittata*), *Polypedates leucomystax, Rhacophorus bimaculatus, Kaloula pulchra, Microhyla berdmorei, Microhyla heymonsi,* and *Microhyla ornata* (*M. fissipes*). To date, there are only a few published data on amphibians at Phuluang Wildlife Sanctuary. Simchareon and Duangchantrasiri (2002) studied the nesting site characteristics of *Limnonectes kuhii* and Stuart *et al.* (2006) described the new species of the genus *Odorrana* from the Sanctuary.

2.3 Seasonal Activities of Amphibians

2.3.1 Seasonality and Amphibian in Thailand

The seasons in subtropical Thailand are commonly divided into two major periods; wet season (6 months) and dry season (6 months). The rainy season usually occurs during the middle of May to the middle of October. The dry season is from November to the middle of May (Royal Institute, 2002).

Anurans are cosmopolitan except for high latitudes (Duellman and Trube, 1994). The greatest diversity of anurans is in the tropics (Heyer *et al*. 1994). Living anurans are classified into 25 families, currently about 333 genera and 3,843 species are recognized (Frost, 1985). In Thailand, 9 families and 169 species are recognized (Frost, 2007).

2.3.2 Seasonal Activities and the Relationship between Amphibian Activities and Environmental Factors

The reproductive cycle in amphibians is subject to hormonal control that responds to environmental variable and produces certain patterns. Adults of most species are widely dispersed in the environment except at specific times of the year when they congregate at aquatic sites to breed. Breeding may be synchronous over one or a few days or spread over a few weeks or months at aquatic sites (Wells, 1977 cited by Heyer *et al*. 1994). Most amphibians have external fertilization and lay eggs in aquatic environments. (Duellman and Trube, 1994; Heyer *et al*. 1994).

Among anurans, two basic reproductive patterns are evident. The first, most tropical and subtropical species are capable of reproduction throughout the year and rainfall seems to be the primary extrinsic factor controlling the timing of reproductive activity. The second, in most temperate species, reproductive activity is cyclic and dependent on a combination of temperature and rainfall. In aseasonal tropical lowlands, both sexes may reproduce throughout the year. This has been demonstrated for several species in tropical Asia and in the upper Amazon Basin in South America (Duellman and Trube, 1994). In the upper Amazon Basin, rainfall occurs throughout the year but is uneven and unpredictable. Four patterns are evident among the 87 species of anurans in one area in Amazonian Ecuador: (1) The breeding occurs continuously every night with the exception of clear, dry nights with intense moonlight. (2) The breeding occurs opportunistically after heavy rains throughout the year. (3) The breeding occurs sporadically after heavy rains. (4) The breeding occurs sporadically during infrequent dry periods (Duellman and Trube, 1994).

In aseasonal rain forest environments, the breeding activity of some anuran species can be episodic. Inger (2003) reported sharp differences among species in activity patterns along a stream in Sarawak, Borneo, over a study period of one year and suggested that to estimate species richness in any tropical region of any size it is essential that the sampling period be designed to cover variation in activity patterns.

Watanabe, Nakanishi, and Izawa (2005) reported that the floor-dwelling frogs on Iriomote Island of the Ryukyu Archipelago in Southern Japan were found throughout the year but the abundance was strongly seasonal and peaked in the hottest month of August. The seasonal pattern of abundance showed considerable variation among species most likely due to their differences in reproductive season, and in physiological characteristics under the influence of varying temperature and rainfall. These patterns are more similar to those of temperate species than those of tropical species.

However, the studies on the activity of some species had different results. For example, the reproductive activity of *Physalaemus gracilis* was not correlated with rainfall or temperature in Espinas stream, Maldonado, Uruguay (Camargo, *et al*., 2005). Moreover, the correlation of activity in both sexes with future changes in temperature suggests that internal mechanisms may have been involved in shaping similar activity patterns during the two consecutive seasons.

In Thailand, few studies on the relationship between environmental factors and amphibians have been conduced. Chuaynkern, 2001 concluded that the species diversity of amphibians correlated with the soil humidity and the total abundance correlated with relative humidity in Pang Sida National Park, Sa Kaeo Province. Some studies concluded that the abundance and species richness of amphibians in the stream were different between wet and dry seasons (Khonsue, 1996 in Chachoengsao Wildlife Research Center; Kongjaroen, 2007 in Khoyai National Park). Therefore, it may be concluded that changes in environmental factors can affect the abundance and activity of amphibians.

2.4 Pattern of Amphibian Community Structure at Different Elevations

Many previous studies (Fauth, Crother, and Slowinski, 1989; Fu *et al*. 2006; Inger and Voris, 1993; Parris and McCarthy, 1999; Hofer, Bersier, and Borcard, 2000) reported on amphibian communities at difference elevations. These studies were conducted in streams, ponds, and on the forest floor.

Inger and Voris (1993) and Parris and McCarthy (1999) reported that the species richness of amphibian at lower elevation was higher than at higher elevation and the composition of frog assemblages on forest streams was correlated with stream size and stream gradient.

Species richness of herpetofauna in the leaf-litter at a Costa Rican locality was positively correlated with leaf-litter depth, and negatively correlated with elevation (Fauth *et al*. 1989).

Fu *et al.* (2006) studied species diversity of endemic and non-endemic frogs along an elevational gradient in the Hengduan Mountains in China reported and that species richness of all frogs, endemics and non-endemics peaked at mid-elevations. A suite of interacting climatic and geometric factors were the best factor to explain the pattern of total species richness along the elevational gradient.

Hofer *et al.* (2000) reported that species assemblages of amphibians and reptiles in Mount Kupe, Cameroon showed a significant relationship with the gradient, which suggested that most species respond to the physical continuum associated with the change in elevation. The effect of gradient explained more variation in the reptiles than in the amphibian because the distributions of most amphibians also depended on aquatic breeding sites which were not available at all elevations. Therefore, it reduced the relative importance of the gradient to amphibian assemblages.

Therefore, it may be concluded that the amphibian communities change in response to difference biological and physical factors at different elevations. In Thailand, there is only one published research report that focuses on amphibian communities along an elevation gradient (Kongjaroen, 2007) and thus, to determine the factor affecting amphibian communities at different elevations, more studies are needed to conclude in this country.

2.5 Amphibian Communities and Habitat Modifications

Effects of habitat modification on amphibians have been studied widely and has included studies in agricultural area, different types of forests, and human-dominated landscapes.

Ficetola and Bernardi (2004) who studied amphibian populations in a human-dominated landscape in Northern Italy reported that the common species, *Rana synklepton esculenta* and *Hyla intermedia*, were able to move through the area using canals and hedgerows, and could maintain metapopulations across the landscape whereas the rare species (newts and toads) were more sensitive to habitat alteration, and they were strongly affected by isolation effects.

Delis, Mushinsky, and McCoy (1996) estimated the species richness and abundances of anurans in west-central Florida wetlands at a residential development and in similar wetlands at a nearby undeveloped park. They found that both richness and abundances of anurans in the residential development were different than those in the undeveloped park.

Urbina-Cardona, Olivares-Pe´rez, and Reynoso, 2006 found the difference in species composition between pasture and both forest edge and interior habitats. A high correlation between distance to forest edge and temperature, understorey density, canopy cover, leaf litter cover, and leaf litter depth was found. There was also a strong relationship between the composition of amphibian and reptile ensembles and the measured environmental variables. The most important variables related to amphibian and reptile ensembles were canopy cover, understorey density, leaf litter cover and temperature.

Peltzer, *et al*. (2007) reported that residues of organochlorine pesticides and nutrients were higher in the agricultural ponds with respect to those from the control pond in Mid-Western Entre Rios Province (Argentina). They suggested that the interactions among washed-off nutrients and pesticides from agriculture and environmental factors accounted for deleterious effects on *S. nasicus* survival, growth and development rate, thereby compromising their health status. These effects can lead, in turn, to an increase in tadpole vulnerability to opportunistic parasites, erythrocytes nuclei aberrations or hemolysis.

de Lima and Gascon (1999) surveyed small mammal and litter-frog communities in the Amazon Basin, Brazil on linear remnants of primary rainforest along watercourses ranging from 140 to 190 m in width, and in adjacent continuous rainforest, to compare their species ri chness, composition, and abundance. No significant differences were found in any aspect of community structure or species abundance. This suggests that linear remnants along watercourses provide suitable habitat for at least some forest vertebrates, a conclusion reinforced by the fact that many frogs and small mammals were found reproducing and moving in the remnants. These results highlight the potential of linear remnants to serve as habitat for small forest vertebrates and suggest th ey could function as corridors for some species to increase landscape connectivity.

Therefore, it may be concluded from these studies that modification of natural habitat can affect amphibian communities. However, few studies have been done in Thailand in particular and thus studies are needed on this topic.

2.6 Oviposition Site Characteristics and Breeding Success

Oviposition site selection is the choice of suitable sites for offspring development. It can strongly affect parental fitness or breeding success because it can directly influence offspring survival. Many characteristics of the local environment can facilitate assessment of nesting site quality (Dillon and Fiano, 2000). Seale (1982) suggested that water temperature strongly affected nesting site selection in *Rana sylvatica.* Additionally, frogs may assess vegetation structure (*R. catesbiana*) (Howard, 1978) and water depth (*Hyla pseudopuma*) (Crump, 1991) of potential nesting sites. The value of a potential nesting site may also depend on biotic factors, including the presence of predators and conspecifics.

In Thailand, the nesting site characteristics of *Limnonectes kuhlii* have been reported by Simchareon and Duangchantrasiri (2002). The common nesting site of this species is in slow flowing water with rocky bottom. The nest is usually found at the middle of the steam or near to the bank. The water depth at nesting site is approximately 11.17 cm but the depth from the water surface to the eggs is approximately 3.04 cm.

CHAPTER III

SPECIES COMPOSITION OF AMPHIBIANS AT DIFFERENT ELEVATIONS ON NUM SAN NOI STREAM AT PHULUANG WILDLIFE SANCTUARY

3.1 Abstract

Species composition and abundance of amphibians at Nam San Noi stream in the Phuluang Wildlife Sanctuary, northeastern Thailand were observed at three elevations; 800, 950, and 1250 m asl by visual encounter surveys from May 2006 to May 2007. Three 100 m stream transects at each elevation were surveyed each month at night. A total of 22 species was found. Shannon-Wiener's diversity index indicated that the lowest elevation had the highest diversity whereas the highest elevation had the lowest diversity. Morishita's similarity index showed that species compositions at 800 and 950 m, were very similar but both of these were different from the highest elevation, 1250 m. The seven species which had high percentages of total abundance overall elevations had low abundance at the highest elevation (1250 m) with the exception of *Limnonectes kuhlii* and *Odorrana aureola* that were abundance at the highest elevation and *Limnonectes gyldenstolpei* abundance fluctuated among these three elevations. *Xenophrys major* was a species found only at one elevation, 950 m. These results indicated that species diversity of amphibians tends to be higher at the lower elevation.

3.2 Introduction

Documenting the elevational patterns in species richness and identifying factors that govern them is essential for conservation purposes (Pimm and Brown, 2004). Different elevations can produce differences in plant and animal communities, temperature, and other physical factors. It is well recognized that amphibians are sensitive to environmental change therefore, the species composition across different elevations is predicted to be different. To my knowledge there is only one study that focused on species communities of amphibians at different elevations in Thailand (Kongjaroen, 2007). To identify the factors that govern species composition at different elevations many studies are needed. This study provides a record of species composition of amphibians at different elevations and may help to explain the effect of elevation on species composition.

3.3 Objective

The objective of this work is to determine the species composition of amphibians at different elevations on Num San Noi stream in Phuluang Wildlife Sanctuary, Thailand.

3.4 Methodology

Species compositions of amphibian were determined by visual encounter surveys at 800, 950, and 1250 m asl. The surveys were conducted in three 100 m-stream transects per elevation of Num San Noi (NSN) stream at night every month from May 2006 to May 2007. The species and number of individuals were recoded to calculate diversity, similarity and abundance at each elevation. Species diversity and similarity were determined by Shannon and Wiener's species diversity index and Morishita's similarity index, respectively (Krebs, 1999). Stream width, stream depth, and stream flow at each transect were record to determine the similarity in the stream condition among stream transect at each elevation by cluster analysis.

3.5 Results

3.5.1 Stream Width, Stream Depth, and Stream Flow at Difference Elevations

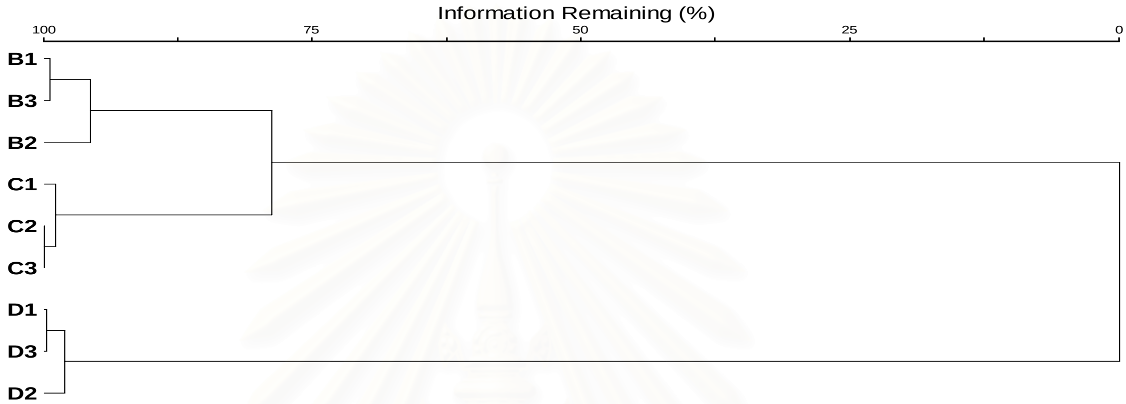
Stream width, stream depth, and rate of stream water flow were significantly different among elevations. Stream width, stream depth, and stream flow at the lower elevations trended to be higher than at highest elevation (Table 3.1).

Table 3.1 Stream conditions among elevations at Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

Stream condition	800 m asl		950 m asl		1250 m asl	
	mean	SE	mean	SE	mean	SE
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

* *Kruskal-Wallis* test, $p \leq 0.05$

The stream conditions were grouped among transects by cluster analysis. The cluster analysis indicated that transects were divided in to 2 two groups at 75% of information remaining (Figure 3.1). The first group included stream transects at of 800 and 950 m. The second group included transects at 1250 m. This means that stream conditions at the 800 and 950 m st ream transects were similar and both of them were different from the stream transects at 1250 m.



B1 - B3 = 1st-3rd stream transects at 800 m asl

C1 - C3 = 1st-3rd stream transects at 950 m asl

D1 - D3 = 1st-3rd stream transects at 1250 m asl

Figure 3.1 Similarity of environmental factors among transects at different elevations analyzed by cluster analysis, Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

3.5.2 Species Diversity

Twenty two species of amphibians were found at Num San Noi stream, Phuluang Wildlife Sanctuary from May 2006 to May 2007 (Appendix A). They belong to two orders; Caudata and Anura and six families; Dicroglossidae, Megophryidae, Microhylidae, Ranidae, Rhacophoridae, and Salamandridae. *Hylarana nigrovittata* had the highest abundance (43.0%), 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%), respectively (Figure 3.2). The Shannon and Wiener's species diversity for all observations was 1.61.The percentage of abundance for ea ch of 15 species was found to be lower than 1% and was not shown individually in Figure 3.1. The amphibian species that represented more than 10% of the total abundance were considered the common species.

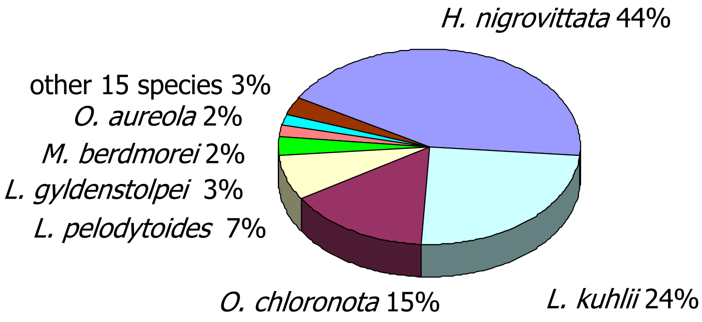


Figure 3.2 Percentage of each species at all elevation of Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

3.5.3 Species Composition and Abundance at Different Elevations

3.5.3.1 800 m asl

Seventeen species of amphibians occurred at this elevation. *Hylarana nigrovittata* had the highest abundance (50.10%), followed by *Odorrana chloronota* (19.56%), *Leptolalax pelodytoides* (12.34%), *Limnonectes kuhlii* (7.85%), *Limnonectes gyldenstolpei* (4.29%), *Microhyla berdmorei* (1.88%), and *Polypedates leucomystax* (1.15%) (Figure 3.3). The percentage abundance for each of 10 other species was lower than 1%. Shannon and Wiener's species diversity was 1.54.

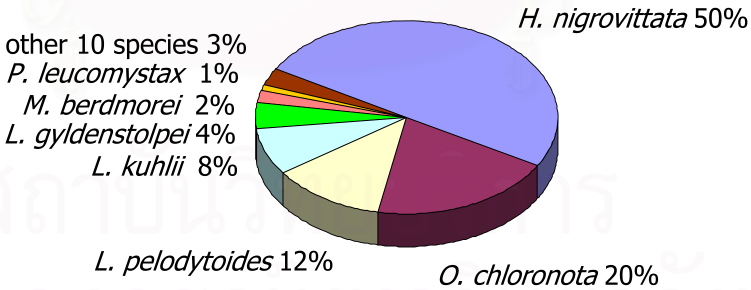


Figure 3.3 Percentage of each species at 800 m of Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

3.5.3.2 950 m asl

Fifteen species of amphibians occurred at this elevation. *Hylarana nigrovittata* had highest abundance (56.26%), followed by *Odorrana chloronota* (18.99%), *Limnonectes kuhlii* (10.35%), *Leptolalax pelodytoides* (7.08%), *Microhyla berdmorei* (2.57%), *Hylarana cubitalis* (1.63%), and *Limnonectes gyldenstolpei* (1.40%), (Figure 3.4). The percentage abundance of each 8 species was found lower than 1%. Shannon and Wiener's species diversity was 1.38.

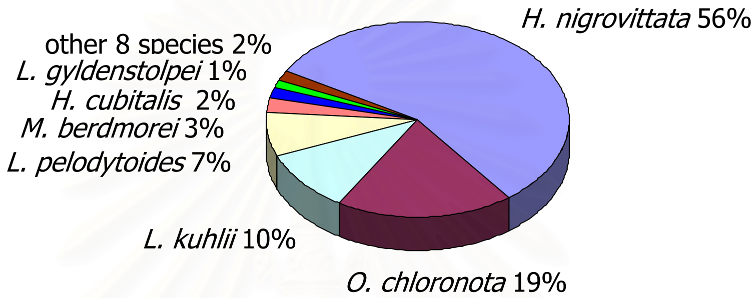


Figure 3.4 Percentage of each species at 950 m of Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

3.5.3.3 1250 m asl

Ten species of amphibians occurred at this elevation. *Limnonectes kuhlii* had highest abundance (82.36%), followed by *Odorrana aureola* (7.88%), *Limnonectes gyldenstolpei* (5.65%), and *Hylarana nigrovittata* (2.05%), respectively (Figure 3.5). The percentage abundance of each 6 species was found lower than 1%. Shannon and Wiener's species diversity was 0.71.

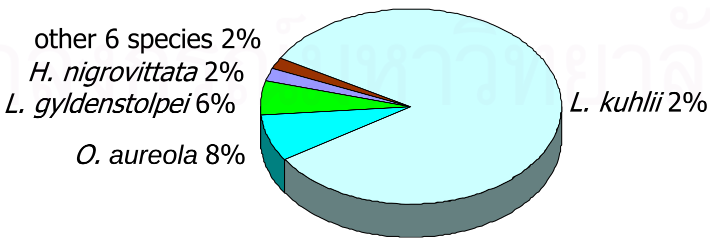


Figure 3.5 Per centage of each s pecies at 1250 m of Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

The seven species which had high percentage of total abundance overall elevations had low abundance at the highest elevation (1250 m) except *Limnonectes kuhlii* and *Odorrana aureola* was found to have the maximum abundance at the highest elevation and *Limnonectes gyldenstolpei* abundance fluctuated among these elevations. *Xenophrys major* was a species found only at 950 m asl.

3.5.4 Similarity of Amphibian Species among Elevations

The Morishita's similarity index between 800 and 950 m, 950 and 1250 m, and 800 and 1250 m were 0.99, 0.19, and 0.16, respectively (Table 3.3). The similarity index indicated that species co mpositions at 800 and 950 m were very similar but both of them were very dissimilar to the index value at 1250 m.

Table 3.2 The Morishita's similarity index of amphibians among elevations at the Num San Noi stream observed from May 2006 to May 2007

Elevation (m asl)	800	950	1250
800	1	-	-
950	0.99	1	-
1250	0.16	0.19	1

3.6 Discussion

3.6.1 Species Diversity and Abundance of Amphibians at Different Elevations

The results indicate that *Hylarana nigrovittata* is the most abundant frog of this stream in overall elevation. However, the abundance of each species compared among elevations indicated that *Hylarana nigrovittata* had high abundance at low elevations (800 and 950 m asl) while *Limnonectes kuhlii* abundance was highest at high elevations (1250 m asl). This result is similar to a previous study by Kongjaroen (2007) who reported that *Hylarana nigrovittata* had the highest abundance in the Lam Ta Kong stream, Khao Yai National Park, Nakhon Ratchasima Province and also found that the abundance of *Hylarana nigrovittata* had high at low elevations (400-900 m asl) while *Limnonectes kuhlii* showed high abundance at high elevations (more than 1000 m asl).

These diversity index indicated that species diversity of amphibian show tend to higher at the lower elevation. Parris an d McCarthy (1999) reported that upstream catchment volume was a significant explanatory variable for the species richness of frog assemblages at forest streams in southeast Queensland, Australia. It is correlated with stream width, stream substrate, permanence of water and rates of water flow. Stream-breeding frogs require a stream that is large enough to hold water for a sufficient length of time for th eir tadpoles to develop to metamorphosis. Therefore, the large streams provide suitable breeding habitat for a greater range of frog species than small streams because they may contain water for longer time. It may be speculated that species diversity at 1250 m asl in this study site was lowest because it had lowest in stream width, permanence of water and rates of water flow.

3.6.2 Similarity of Amphibian Species among Elevations

The similarity index indicated that species compositions at the low elevations (800 and 950 m asl) were very similar but both of them were very dissimilar to the index value at high elevation (1250 m asl). Some previous studies (Inger and Voris, 1993; Parris and McCarthy, 1999) reported that the composition of frog assemblages on forest streams was correlated with stream size and stream gradient. It may be concluded that both 800 and 950 m elevations in this study were similar in stream width and stream gradient whereas both of them differed in stream width and stream gradient from the 1250 m site. Therefore, the species compositions at 800 and 950 m were very similar whereas both of them were very different from the composition at 1250 m.

3.6.3 Conservation Considerations

In Thailand, high elevation areas are less disturbed than lower level than in low elevation areas. The results from this study indicate that the lower stream (800-950 m asl) tend to have higher species diversity than the higher stream (1250 m asl) and some species are restricted to one elevation. Therefore it may be concluded that both high elevation stream and also low elevation stream should be protected to conserve species diversity.

CHAPTER IV

SPECIES DIVERSITY AND SEASONAL ACTIVITY OF AMPHIBIANS AT DIFFERENT ELEVATIONS IN NUM SAN NOI STREAM AT PHULUANG WILDLIFE SANCTUARY

4.1 Abstract

Field work was conducted at Nam San Noi stream, Phuluang Wildlife Sanctuary from May 2006 to May 2007. Night visual encounter surveys were conducted every month on three 100 m stream transects at each of three elevations, 800, 950, and 1250 m. Species and number of amphibians found in each survey were recorded. A total of 22 species was found during the survey period. Species diversity index indicated that the species diversity in the wet season was higher than in the dry season at all three elevations. The similarity index showed that species comparing between seasons at 1250 m were similar whereas at 800 and 950 m were different. The total abundance of all species and abundances of the 6 most common species had significant differences between the wet and dry seasons. The abundances of *Odorrana aureola* and *Odorrana chloronota* were high during the rainy season while the number of *Aquixalus bisacculus, Limnonectes gyldenstolpei, Microhyla berdmorei,* and *Hylarana nigrovittata* and total abundance of all species peaked in the dry season. The high abundance of most common species was found to be associated with breeding activity. The cluster analysis indicated that environmental factors at 800 and 950 m were similar but both of them were different from 1250 m. The Canonical Correspondence Analysis indicated that the abundances of most amphibians around the year among elevations were associated with stream size, water temperature, and substrate temperature whereas the variation in amphibian abundance between seasons in each elevation were associated with relative humidity, water temperature, air temperature, substrate temperature, and stream width.

4.2 Introduction

The problem of amphibian decline has been occurring globally (Barinaga, 1990; Schloegel, *et al.,* 2006; Stuart, *et al.* 2004). An amphibian population are been monitored in many parts of the world to determine their population trends (Bishop and Pettit, 1997; Crouch and Panton, 2000; Nelson and Graves, 2004). However, Thailand has few studies on this problem and never has used systematic methods to monitor them. Amphibian populations can fluctuate due to environmental changes (Duellman, 1995). This means that the amphibian abundance in any location can change in different seasons. Studies on the patterns of anuran reproduction in tropical and subtropical regions have repeatedly demonstrated (Duellman, 1995; Inger and Voris, 1993; Kam and Chen, 2000). The reproductive phenology is closely associated with rainfall and temperature (Duellman and Trueb, 1994). Rainfall influences the reproductive phenology of many amphibian species, particularly in tropical forests with seasonal precipitation (Donnelly and Guyer, 1994). However, most of these studies concentrated on terrestrial species that breed in ephemeral bodies of water. Species that breed in streams receive far less attention even though they are commonly found in tropical region (Inger, 1966) and stream breeders may have different reproductive phenology from ephemeral pond breeders. Therefore, seasonal abundances of stream dwelling amphibians should be studied to understand the fluctuation in each period of the year. If the fluctuations of amphibian species along the stream are well understood, then the amphibian monitoring method can be determined and conducted in the suitable period which will save time, man, money, and other resources.

4.3 Objective

The objective has to determine seasonal activities; species present, occurrence period, abundance and breeding duration of amphibians living in different elevations along the Nam San Noi stream, Phuluang Wildlife Sanctuary

4.4 Methodology

Seasonal activities of amphibians were observed by the visual encounter surveys. The survey was conducted every month at night along three 100 m stream transects at each of three elevations; 800, 950, and 1250 m. Activities of each species; abundance, calling, mating and egg masses found in each survey were recorded. Species diversity and similarity index between seasons were determined by Shannon and Wiener's species diversity index and Morishita's similarity index, respectively (Krebs, 1999). The abundances of each species were compared between wet and dry seasons by *Mann-Whitney U*-test. Data on air temperature and relative humidity on the survey day were gathered from the weather station (Vantage Pro 2

Davis Weather Station) within 24 hrs. Th e maximum and minimum of ground level air temperature and water temperature on the survey day were collected by maximum and minimum mercury thermometer and calculated for mean of each day. Substrate temperature and surface water temperature when encountering amphibians were collected by temp gun (Duratrax model Flashpoint). Water temperature at 5 cm was collected by alcohol thermometer when amphibians were encountered. Air temperature and relative humidity when encountering amphibians were collected by thermo-hygrometer (Thermo-hygro Model WZ-37401-00). Stream width and stream depth on each surveys were measured by meter tape. Stream water flow of each survey was collected by mechanical flowmeter (General oceanics model 2030 series). The total rain fall data during the study period was contributed by the methodological station at Phuluang Wildlife Sanctuary. Air temperature, water temperature, relative humidity, stream size, and total rainfall in each season, and the elevation were analyzed by cluster analysis to determine the similarity of environmental factors between seasons and among elevations. The variations on the abundance of each species along the gradients of physical factors were determined by Canonical Correspondence Analysis (CCA).

4.5 Results

4.5.1 Determination of Environmental Factors among Elevations and between Seasons

The wet and dry season of this study were determined by the total rain fall. The months which had the total rain fall higher than 100 mm were included as the rainy season (Whitmore, 1990) therefore, the rainy season in this study was from April to October and the dry season was from November to March (Figure 4.1)

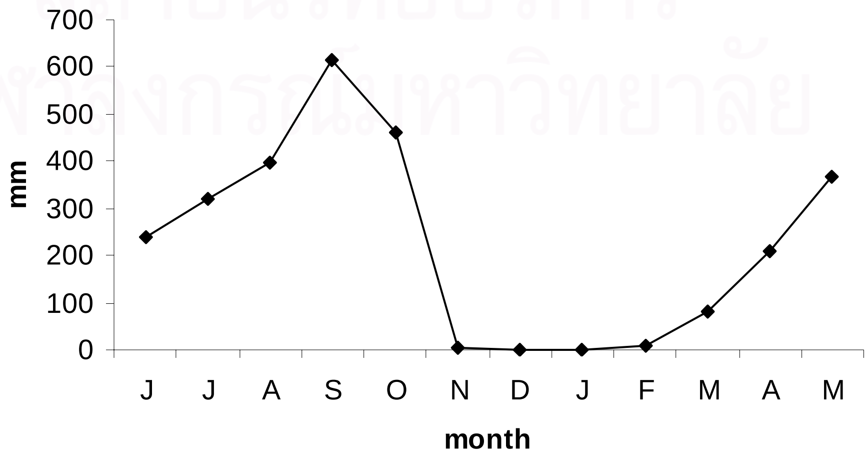


Figure 4.1 Total rain fall from June 2006 to May 2007 at Phuluang Wildlife Sanctuary

4.5.1.1 Comparisons of Environmental Factors at Three Elevations

Air temperature [1], ground level air temperature [1], water temperature [1], substrate temperature [2], surface water temperature[2], 5 cm water temperature [2], stream width, stream depth, and rate of stream water flow were significantly different among elevation whereas other physical factors were not significantly different (Table 4.1).

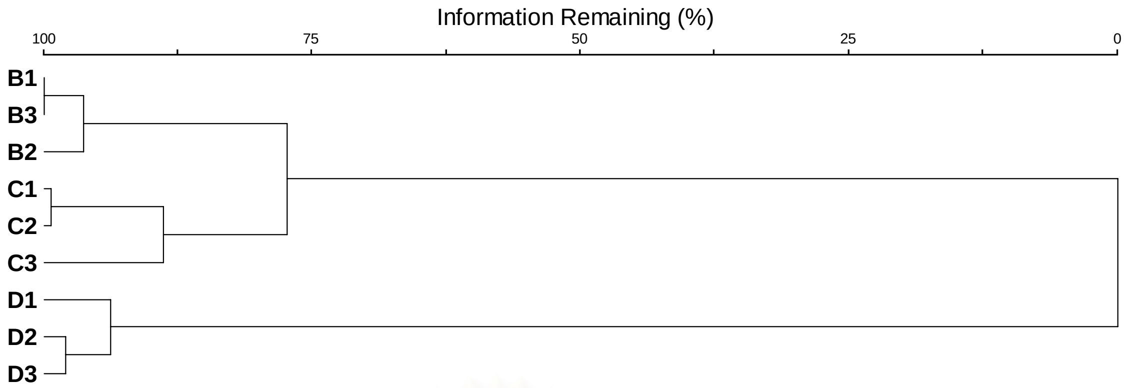
Table 4.1 Environmental factors among elevations at Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

Environmental factors	800 m mean±SE	950 m mean±SE	1250 m mean±SE
air temperature [1] (°c) *	20.99±0.40	21.31±0.44	19.43±0.27
ground level air temperature [1] (°c) *	20.48±0.48	20.81±0.47	19.47±0.33
water temperature [1] (°c) *	19.48±0.39	19.53±0.36	17.54±0.61
relative humidity [1] (%)	85.17±1.60	82.78±1.64	83.51±1.91
surface water temperature [2] (°c) *	21.06±0.29	20.87±0.22	19.97±0.27
5 cm water temperature [2] (°c) *	19.52±0.35	19.39±0.27	18.40±0.35
air temperature [2] (°c)	20.81±0.54	20.53±0.50	19.45±0.45
substrate temperature [2] (°c) *	21.27±0.29	20.74±0.30	18.87±0.32
relative humidity [2] (%)	86.35±1.08	84.88±1.78	82.90±1.69
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 water flow (m/s) *	0.81±0.11	0.49±0.06	0.21±0.05

[1] 24 hrs. data; [2] encountering amphibian data;

* *Kruskal-Wallis* test, $p \leq 0.05$ show significant differences among elevations

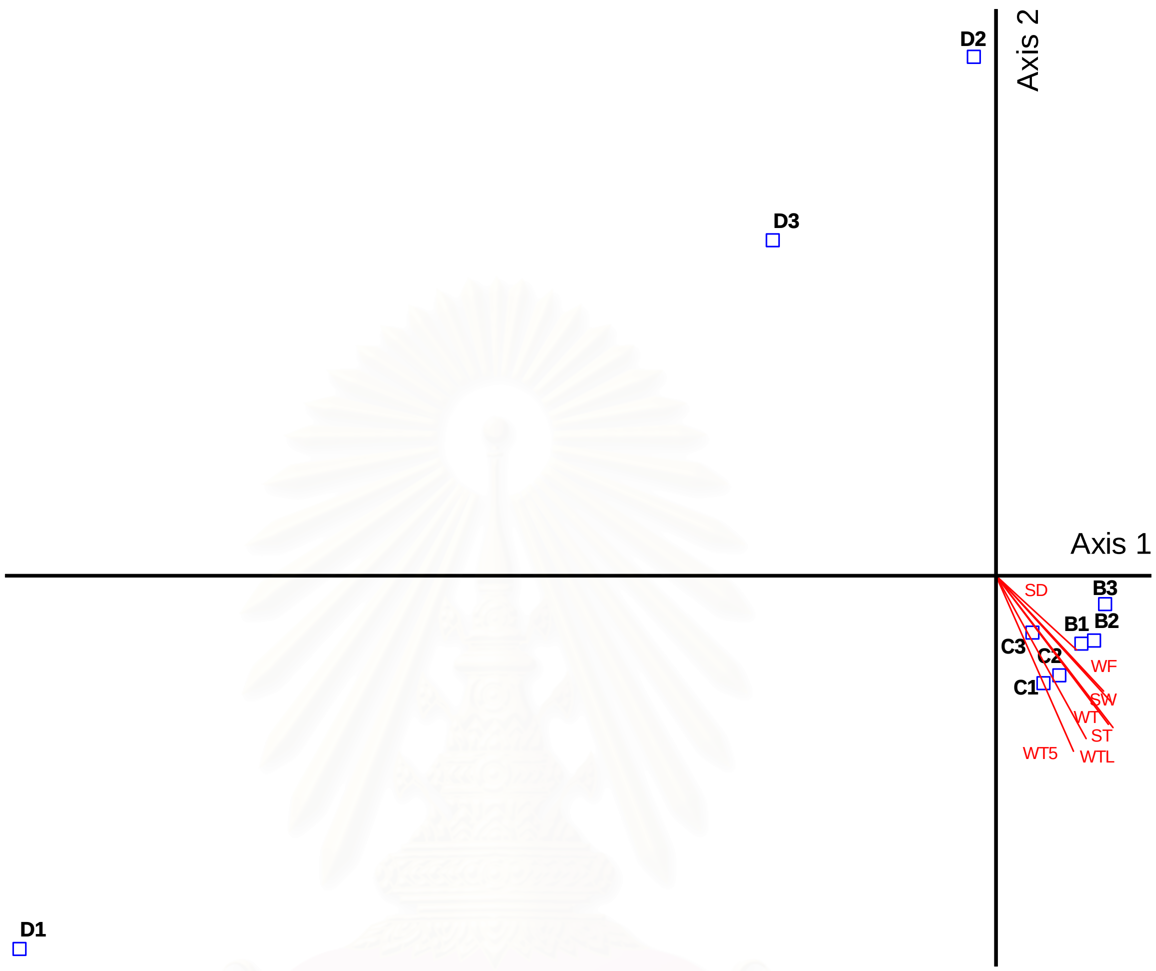
The environmental factors which were significantly different among elevations were grouped among transects by the cluster analysis. The results indicated that among transects were divided in to 2 two groups at 75% of information remaining (Figure 4.2). The first group was composed of 800 and 950 m stream transects (low altitude stream transects) and the second group was composed of 1250 m stream transects (high altitude stream transects). Therefore, environmental factors in the low altitudinal transects were similar and both of them differed from 1250 m stream transects.



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

Figure 4.2 Similarity of environmental factors among transects at different elevations analyzed by cluster analysis, Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

The CCA ordination of environmental factors of all transects was significant in all axes (axis 1-3 $p \leq 0.05$). The accumulation of the percentage variable explanations of 3 axes was 90.5 % and the percentage variable explanation in Figure 4.3 (axes 1 and 2) was 83.8 %. It showed that the low altitudinal transects (800 and 950 m) had stream size, water temperature, and substrate temperature higher than high altitudinal transects (1250 m).



B1 - B3 = 1st-3rd stream transects at 800 m asl; C1 - C3 = 1st-3rd stream transects at 950 m asl;

D1 - D3 = 1st-3rd stream transects at 1250 m asl

WT = 24hrs. data of water temperature; WTL = surface water temperature; WT5 = 5 cm water;

ST = substrate temperature at encountering amphibian; SW= stream width; SD = stream depth;

WF = rate of stream water flow

Figure 4.3 Canonical Correspondence Analysis of the physical factors in all stream transects at Num San Noi stream, Phuluang Wildlife Sanctuary

4.5.1.2 Environmental Factors among Elevations in each Season

Air temperature[1], water temperature[1], stream width, stream depth, and rate of stream water flow in each season were significantly different among elevation whereas other physical factors were not significantly different (Table 4.2). The environmental factors which were significantly different among elevations in each season were grouped among transects by the cluster analysis.

Table 4.2 Comparisons of environmental factors between seasons and among elevations at Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

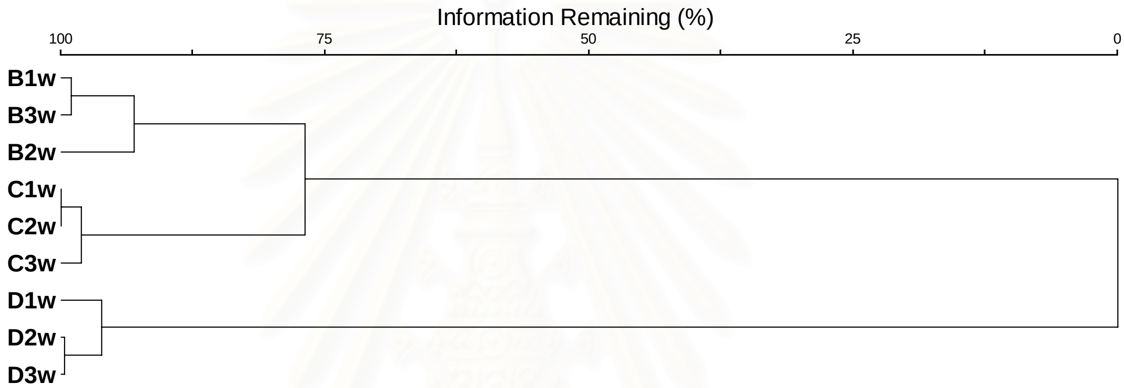
Environmental gradients	**seasons**	800 m	950 m	1250 m
		mean±SE	mean±SE	mean±SE
air temperature [1] (°c) *	wet	22.10±0.34*	21.98±0.26*	20.05±0.20*
	dry	19.43±0.66*	20.37±0.96*	18.57±0.52*
ground level air temperature [1] (°c)	wet	22.06±0.31*	22.00±0.19*	20.22±0.23*
	dry	18.27±0.77*	19.14±0.96*	18.42±0.65*
water temperature [1] (°c) *	wet	20.92±0.17*	20.70±0.13*	19.42±0.18*
	dry	17.47±0.61*	17.89±0.63*	14.90±1.15*
relative humidity [1] (%)	wet	90.19±1.48*	88.55±1.22*	90.38±1.37*
	dry	78.13±2.20*	74.70±2.29*	73.90±2.63*
surface water temperature [2] (°c)	wet	21.94±0.21*	21.35±0.17*	20.27±0.20*
	dry	19.82±0.48*	20.20±0.42*	19.46±0.64*
5 cm water temperature [2] (°c)	wet	20.74±0.15*	20.30±0.11*	19.07±0.12*
	dry	17.82±0.58*	18.11±0.48*	17.22±0.86*
air temperature [2] (°c)	wet	22.87±0.45*	22.45±0.42*	20.95±0.42*
	dry	17.94±0.60*	17.85±0.50*	17.34±0.58*
substrate temperature [2] (°c)	wet	22.18±0.27*	21.65±0.23*	19.80±0.18*
	dry	20.01±0.42*	19.46±0.49*	17.36±0.60*
relative humidity [2] (%)	wet	87.14±1.25	88.86±1.52*	86.72±1.42*
	dry	85.24±1.92	79.32±3.24*	77.56±3.10*
stream width (m) *	wet	11.38±0.90*	8.03±0.45*	3.65±0.31*
	dry	6.19±0.45*	4.24±0.44*	1.01±0.27*
stream depth (m) *	wet	1.17±0.09*	0.52±0.03*	0.37±0.03*
	dry	0.55±0.05*	0.22±0.03*	0.13±0.04*
rate of stream water flow (m/s) *	wet	1.09±0.15*	0.71±0.07*	0.36±0.06*
	dry	0.41±0.07*	0.19±0.05*	0.00±0.00*

[1] 24 hrs. data; [2] encountering amphibian data; * (in column environmental gradients) *Kruskal-Wallis* test, $p \le 0.05$

* (in columns 800 950 and 1250) *Mann-Whitney U*-test, $p \le 0.05$

4.5.1.2.1 Similarity of Environmental Factors among Transects Sampling in Wet Season at Different Elevations

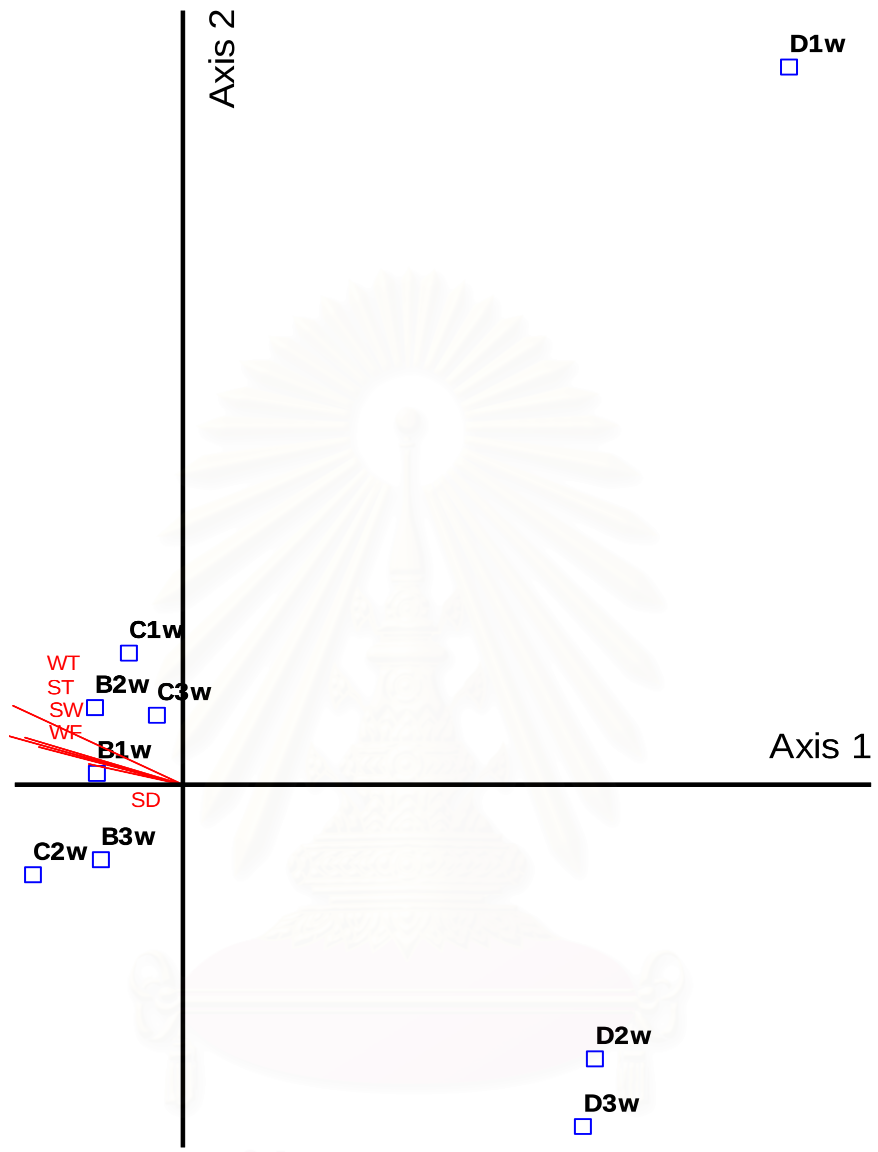
The cluster analysis indicated that physical factors among transects sampling in the wet season were divided in to 2 two groups at 75% of information remaining (Figure 4.4). First group was composed of 800 and 950 m stream transects (low altitude stream transects) and the second group was composed of 1250 m stream transects (high altitude stream transects). Therefore, environmental factors in low altitudinal transects were similar and both of them differed from 1250 m stream transects.



B1w - B3w = 1st-3rd stream transects at 800 m asl; C1w - C3w = 1st-3rd stream transects at 950 m asl; D1w - D3w = 1st-3rd stream transects at 1250 m asl

Figure 4.4 Similarity of environmental factors among transects sampling in wet season at different elevations analyzed by cluster analysis, Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

The CCA ordination of environmental factors of all transects sampling in wet season was significant in first axis. The accumulation of the percentage variable explanations of 3 axes was 71.5% and the percentage variable explanation in Figure 4.5 (axes 1 and 2) was 64.1 %. It showed that the low altitudinal transects (800 and 950 m) had stream size, water temperature, and air temperature higher than high altitudinal transects (1250 m).



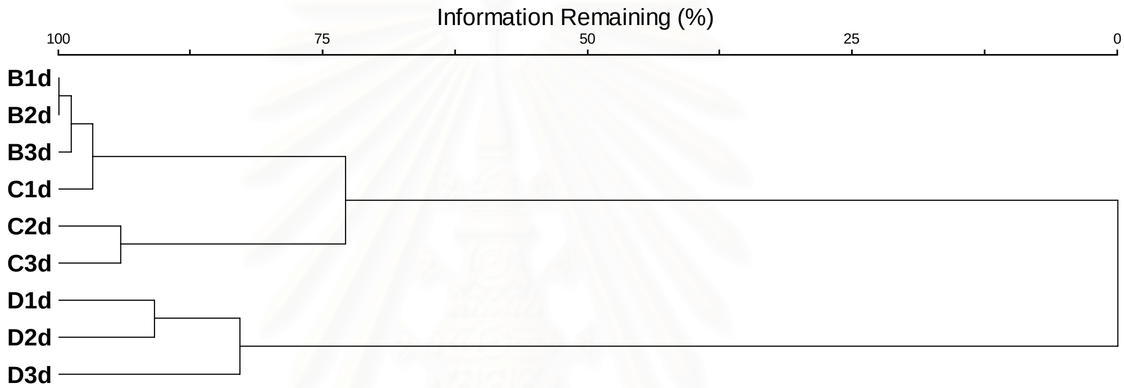
B1w - B3w = 1st-3rd stream transects at 800 m asl; C1w - C3w = 1st-3rd stream transects at 950 m asl; D1w - D3w = 1st-3rd stream transects at 1250 m asl

WT = 24hrs. data of water temperature; ST = substrate temperature at encountering amphibian; SW= stream width; SD = stream depth; WF = rate of stream water flow

Figure 4.5 Canonical Correspondence An alysis of the physical factors sampling in wet s eason in all stream trans ects at Num San Noi str eam, Phulu ang Wildlife Sanctuary

4.5.1.2.2 Similarity of Environmental Factors among Transects Sampling in Dry Season at Different Elevations

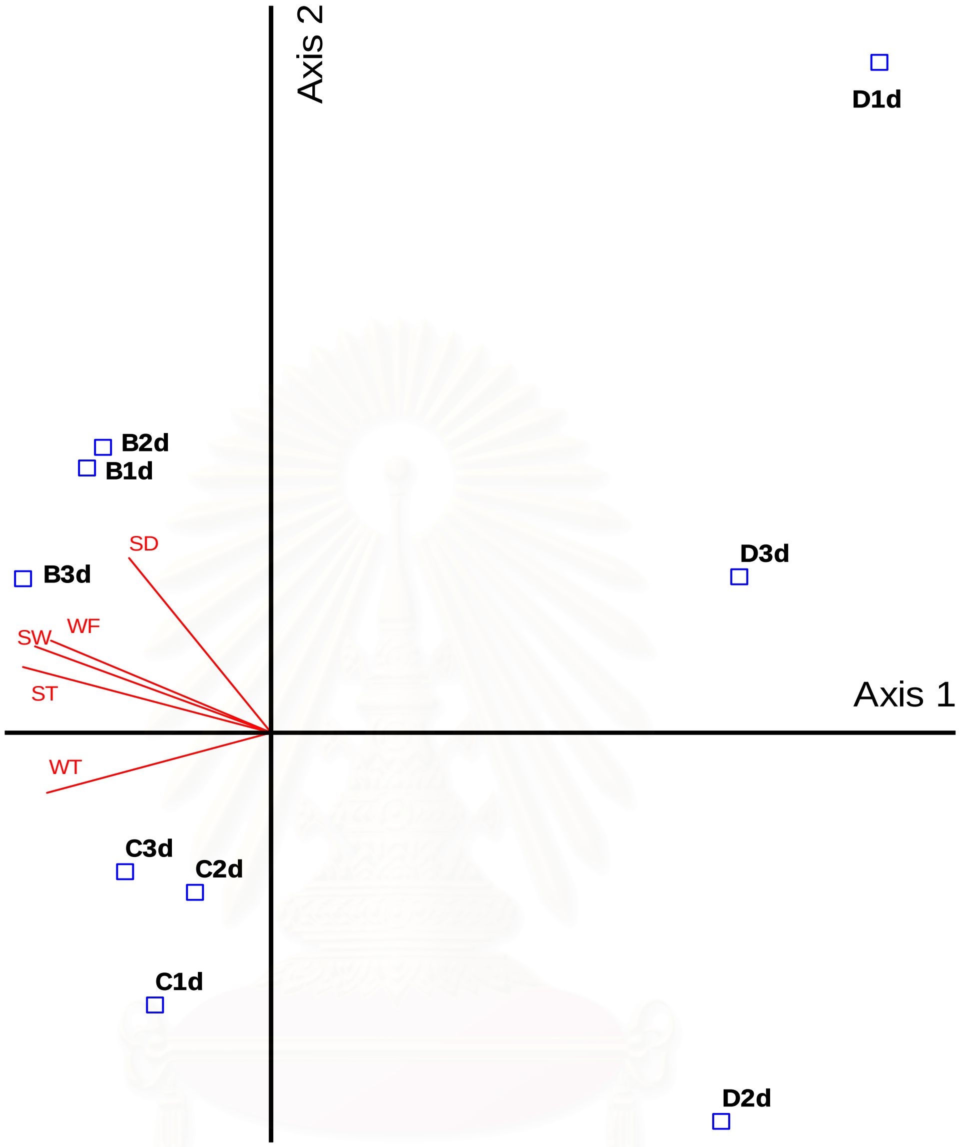
The cluster analysis indicated that physical factors among transects sampling in the dry season were divided in to 2 two groups at 70% of information remaining (Figure 4.6). First group was composed of 800 and 950 m stream transects (low altitude stream transects) and the second group was composed of 1250 m stream transects high altitude stream transects. Therefore, environmental factors in low altitudinal transects were similar and both of them differed from 1250 m stream transects.



B1d - B3d = 1st-3rd stream transects at 800 m asl; C1d - C3d = 1st-3rd stream transects at 950 m asl; D1d - D3d = 1st-3rd stream transects at 1250 m asl

Figure 4.6 Similarity of environmental factors among transects sampling in dry season at different elevations analyzed by cluster analysis, Num San Noi stream, at Phuluang Wildlife Sanctuary from June 2006 to May 2007

The CCA ordination of environmental factors of all transects sampling in dry season was significant in first axis. The accumulation of the percentage variable explanations of 3 axes was 83.7% and the percentage variable explanation in Figure 4.7 (axes 1 and 2) was 81.4 %. It showed that the low altitudinal transects (800 and 950 m) had stream size, water temperature, and air temperature higher than high altitudinal transects (1250 m).



B1d - B3d = 1st-3rd stream transects at 800 m asl; C1d - C3d = 1st-3rd stream transects at 950 m asl; D1d - D3d = 1st-3rd stream transects at 1250 m asl

WT = 24hrs. data of water temperature; ST = substrate temperature at encountering amphibian; SW= stream width; SD = stream depth; WF = rate of stream water flow

Figure 4.7 Canonical Correspondence An alysis of the physical factors sampling in dry season in all stream trans ects at Num San Noi str eam, Phulu ang Wildlife Sanctuary

4.5.1.3 Environmental Factors between Seasons in each Elevation

Most of physical factors between seasons at each elevation were significantly different except the relative humidity[2] at 800 m (Table 4.2). Air temperature[1], ground level air temperature[1], water temperature[1], relative humidity[1], substrate temperature[2], surface water temperature[2], 5 cm water temperature[2], Air temperature[1], relative humidity[2], stream width, stream depth and, and rate of stream water flow in wet season were higher than in dry season.

4.5.2 Species Diversity between Seasons and among Elevations

Twenty two species of amphibians were found at Num San Noi stream, Phuluang Wildlife Sanctuary during the study period from May 2006 to May 2007. The overall diversity index was 1.61. Results showed that the lowest elevation had highest species richness and diversity index whereas the highest elevation had the lowest values (Table 4.3). The Shannon and Wiener's species diversity and evenness index at 3 elevations in wet season were significantly higher than in dry season (Table 4.4-4.6). The species richness in both seasons at 800 and 950 m sites were not significantly different but were significantly different at 1250 m.

Table 4.3 Species richness and diversity index of amphibians, comparing among elevations of Num San Noi stream, Phuluang Wildlife Sanctuary

Elevation (m asl)	800	950	1250
Species richness	17	15	10
Species diversity index	1.54	1.38	0.71

Table 4.4 Species diversity index, species richness, and evenness of amphibians between seasons at 800 m asl of Num San Noi stream, Phuluang Wildlife Sanctuary (***** *Mann-Whitney U*-test, $p \leq 0.05$)

800 m asl	Diversity index*	No. of species	Evenness index*
Wet season	1.64±0.04	9.33±0.88	0.74±0.02
Dry season	1.09±0.18	10.00±1.00	0.48±0.08

Table 4.5 Species diversity index, species richness, and evenness of amphibians between seasons at 950 m asl of Num San Noi stream, Phuluang Wildlife Sanctuary (***** *Mann-Whitney U*-test, $p \leq 0.05$)

950 m asl	Diversity index*	No. of species	Evenness index*
Wet season	1.46±0.09	9.00±0.58	0.66±0.03
Dry season	0.81±0.16	8.00±0.58	0.39±0.07

Table 4.6 Species diversity index, species richness, and evenness of amphibians between seasons at 1250 m asl of Num San Noi stream, Phuluang Wildlife Sanctuary (***** *Mann-Whitney U*-test, $p \leq 0.05$)

1250 m asl	Diversity index*	No. of species*	Evenness index*
Wet season	0.96±0.03	6.00±1.00	0.54±0.05
Dry season	0.25±0.07	3.33±0.33	0.21±0.04

4.5.3 Species Similarity between Seasons and among Elevations

The Morishita's similarity index between 800&950 m, 950&1250 m, and 800&1250 m were 0.99, 0.19, and 0.16, respectively (Table 4.7). The similarity index indicated that the year-round species compositions at 800 and 950 m were very similar but both of them were very different from 1250 m.

Table 4.7 Similarity index between elevations of amphibians at Num San Noi stream, Phuluang Wildlife Sanctuary

Elevation (m asl)	800	950	1250
800	1	-	-
950	0.99	1	-
1250	0.16	0.19	1

Within season, species composition at 800 and 950 m were very similar but both of them were dissimilar to the highest elevation (Table 4.8). The species composition between wet and dry seasons of the highest elevation was most similar (0.90) whereas in the lower elevations were less similar (0.66, 0.57).

Table 4.8 Similarity index between seasons and among elevations of amphibians at Num San Noi stream, Phuluang Wildlife Sanctuary

Similarity		800 m asl		950 m asl		1250 m asl	
		wet	dry	wet	dry	wet	dry
800 m asl	wet	1	-	-	-	-	-
	dry	0.66	1	-	-	-	-
950 m asl	wet	0.97	0.67	1	-	-	-
	dry	0.56	0.98	0.57	1	-	-
1250 m asl	wet	0.31	0.11	0.30	0.15	1	-
	dry	0.23	0.05	0.23	0.10	0.90	1

4.5.4 Abundance of each Species between Seasons at each Elevation

The total abundance of all amphibians at all elevations in dry season was significantly higher than in wet season (Table 4.9). The abundances of 6 species had significant difference between wet and dry seasons. The abundance of *Odorrana aureola* and *Odorrana chloronota* in wet season were higher than dry season whereas *Limnonectes gyldenstolpei, Hylarana nigrovittata, Aquixalus bisacculus,* and *Microhyla berdmorei* peaked in dry season. The abundances of other species were not significantly different between wet an d dry season. However, there were some species found only in one season. *Kaloula pulchra, Leptobrachium smithi, Limnonectes limborgi, Rhacophorus feae, Tylototriton verrucosus,* and *Xenophrys major* were found only in the wet season, while, *Chiromantis vittatus, Microhyla fissipes,* and *Hylarana taipehensis* were found only in the dry season.

Table 4.9 Mean abundance of each amphibian species between seasons at all elevations, Num San Noi stream, Phuluang, Wildlife Sanctuary

All elevations	Species	Wet season	Dry season
No.		Mean±SE (individual/100m)	Mean±SE (individual/100m)
1	*Tylototriton verrucosus* (Tv)	0.01±0.01	0
2	*Leptobrachium smithi* (Ls)	0.08±0.05	0
3	*Leptolalax pelodytoides* (Lp)	2.15±0.41	1.22±0.28
4	*Xenophrys major* (Xm)	0.13±0.07	0
5	*Limnonectes gyldenstolpei* (Lg)*	0.67±0.21	0.98±0.18
6	*Limnonectes kuhlii* (Lk)	3.86±0.65	9.13±2.18
7	*Limnonectes limborgi* (Ll)	0.01±0.01	0
8	*Hylarana cubitalis* (Hc)	0.14±0.06	0.38±0.14
9	*Hylarana nigrovittata* (Hn)*	4.32±0.82	20.07±2.59
10	*Hylarana taipehensis* (Ht)	0	0.04±0.03
11	*Odorrana aureola* (Oa)*	0.69±0.26	0
12	*Odorrana chloronota* (Oc)*	5.08±0.92	1.51±0.40
13	*Aquixalus bisacculus* (Ab)*	0	0.18±0.09
14	*Chiromantis vittatus* (Cv)	0	0.07±0.05
15	*Philautus parvulus* (Pp)	0.01±0.01	0.02±0.02
16	*Polypedates leucomystax* (Pl)*	0.14±0.05	0.16±0.06
17	*Rhacophorus feae* (Rf)	0.01±0.01	0
18	*Kalophrynus interlineatus* (Ki)	0.01±0.01	0.02±0.02
19	*Kaloula pulchra* (Kp)	0.03±0.02	0
20	*Microhyla berdmorei* (Mb)	0.28±0.13	0.71±0.29
21	*Microhyla fissipes* (Mf)	0	0.02±0.02
22	*Micryletta inornata* (Mi)	0.01±0.01	0.02±0.02
	Total abundance*	17.65±1.62	34.53±2.53

* *Mann-Whitney U*-test, $p \leq 0.05$

4.5.4.1 Abundance of each Species between Seasons at 800 m asl

The total abundance of amphibians at 800 m asl in dry season was significantly higher than in wet season (Table 4.10). The abundances of 5 species had significant differences between wet and dry season. The abundance of *Odorrana* *chloronota* in wet season was higher than in dry season whereas *Limnonectes kuhlii, Limnonectes gyldenstolpei, Hylarana nigrovittata,* and *Aquixalus bisacculus* peaked in dry season. The abundances of other species were not significantly different between wet and dry season. However, there were some species found only in one season. *Kaloula pulchra, Leptobrachium smithi, Micryletta inornata,* and *Rhacophorus feae* were found only in the wet season, while *Chiromantis vittatus, Kalophrynus interlineatus, Microhyla fissipes,* and *Hylarana taipehensis* were found only in the dry season.

Table 4.10 Mean abundan ces of each am phibian species, comparing betw een seasons at 800 m asl, Num San Noi stream, Phuluang Wildlife Sanctuary

800 m	Species	Wet season	Dry season
No.		Mean±SE (individual/100m)	Mean±SE (individual/100m)
1	*Leptobrachium smithi*	0.25±0.15	0
2	*Leptolalax pelodytoides*	3.63±088	2.07±0.53
3	*Limnonectes kuhlii**	2.50±0.56	1.0±.04
4	*Limnonectes gyldenstolpei**	0.92±0.51	1.27±0.32
5	*Hylarana cubitalis*	0.04±0.04	0.33±0.23
6	*Hylarana nigrovittata**	5.21±1.36	23.6±1.74
7	*Hylarana taipehensis*	0	0.07±0.07
8	*Odorrana chloronota**	5.63±0.63	3.47±0.9
9	*Aquixalus bisacculus**	0	0.33±0.16
10	*Chiromantis vittatus*	0	0.2±0.14
11	*Polypedates leucomystax*	0.29±0.13	0.27±0.15
12	*Rhacophorus feae*	0.04±0.04	0
13	*Kalophrynus interlineatus*	0	0.07±0.07
14	*Kaloula pulchra*	0.08±0.06	0
15	*Microhyla berdmorei*	0.29±0.16	0.73±0.34
16	*Microhyla fissipes*	0	0.07±0.07
17	*Micryletta inornata*	0.04±0.04	0
	Total abundance*	18.92±2.73	33.47±1.63

* *Mann-Whitney U*-test, $p \leq 0.05$

4.5.4.2 Abundance of each Species between Seasons at 950 m asl

The total abundance of amphibians at 950 m asl in dry season was significantly higher than in wet season (Table 4.11). The significant differences of the abundances between wet and dry season were found in 2 species. The abundance of *Odorrana chloronota* in wet season was higher than in dry season whereas *Hylarana nigrovittata* peaked in dry season. The abundances of other species were not significantly different between wet and dry season. However, there were some species found only in one season. *Limnonectes limborgi, Odorrana aureola, Polypedates leucomystax,* and *Xenophrys major* were found only in the wet season, while *Micryletta inornata, Hylarana taipehensis,* and *Aquixalus bisacculus* were found only in the dry season.

Table 4.11 Mean abundances of each amphibian species, comparing between seasons at 950 m asl, Num San Noi stream, Phuluang Wildlife Sanctuary

950 m	Species	Wet season	Dry season
No.		Mean±SE (individual/100m)	Mean±SE (individual/100m)
1	*Leptolalax pelodytoides*	2.83±0.66	1.53±0.53
2	*Xenophrys major*	0.38±0.19	0
3	*Limnonectes gyldenstolpei*	0.42±0.25	0.53±0.17
4	*Limnonectes kuhlii*	3.42±1.05	3.40±0.65
5	*Limnonectes limborgi*	0.04±0.04	0
6	*Hylarana cubitalis*	0.38±0.16	0.80±0.31
7	*Hylarana nigrovittata**	7.38±1.80	36.40±3.46
8	*Hylarana taipehensis*	0	0.07±0.07
9	*Odorrana aureola*	0.17±0.10	0
10	*Odorrana chloronota**	9.50±2.34	1.07±0.47
11	*Aquixalus bisacculus*	0	0.20±0.20
12	*Philautus parvulus*	0.04±0.04	0.07±0.07
13	*Polypedates leucomystax*	0.04±0.04	0
14	*Microhyla berdmorei*	0.50±0.35	1.40±0.77
15	*Micryletta inornata*	0	0.07±0.07
	Total abundance*	25.08±2.89	45.53±3.83

* *Mann-Whitney U*-test, $p \leq 0.05$

4.5.4.3 Abundance of each Species between Seasons at 1250 m asl

The total abundance of amphibians at 1250 m asl in dry season was significantly higher than in wet season (Table 4.12). The abundances of 2 species had significant difference between wet and dry season. The abundance of *Odorrana aureola* in wet season was higher than in dry season whereas *Limnonectes kuhlii* reached highest abundance in dry season. The abundances of other species were not significantly different between wet and dry season. However, there were some species found only in one season. *Kalophrynus interlineatus, Microhyla berdmorei, Odorrana chloronota,* and *Tylototriton verrucosus* were found only in the wet season, while, *Leptolalax pelodytoides* was found only in the dry season.

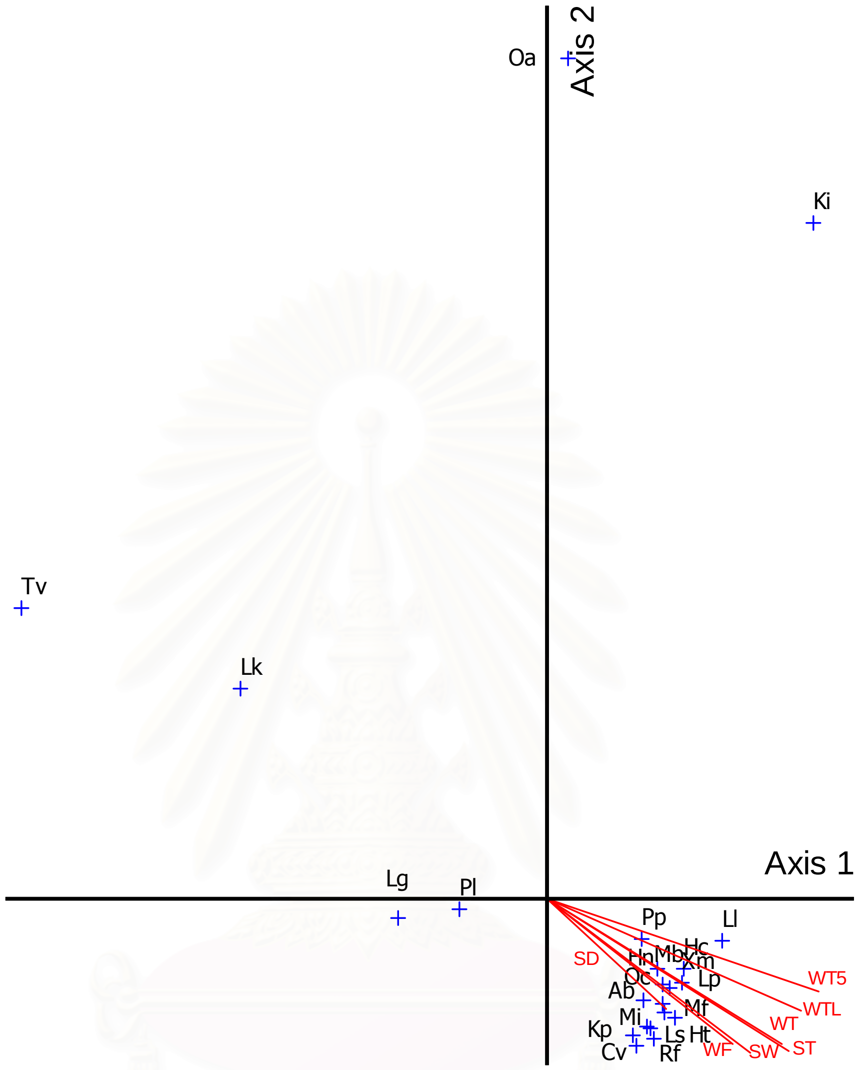
Table 4.12 Abundances of each species of amphibians, comparing between seasons at 1250 m asl, Num San Noi stream, Phuluang Wildlife Sanctuary

1250 m	Species	Wet season	Dry season
No.		Mean±SE (individual/100m)	Mean±SE (individual/100m)
1	*Tylototriton verrucosus*	0.04±0.04	0
2	*Leptolalax pelodytoides*	0	0.07±0.07
3	*Limnonectes gyldenstolpei*	0.67±0.27	1.13±0.40
4	*Limnonectes kuhlii**	5.67±1.50	23.00±4.83
5	*Hylarana nigrovittata*	0.38±0.13	0.20±0.11
6	*Odorrana aureola**	1.92±071	0
7	*Odorrana chloronota*	0.13±0.07	0
8	*Polypedates leucomystax*	0.08±0.06	0.20±0.11
9	*Kalophrynus interlineatus*	0.04±0.04	0
10	*Microhyla berdmorei*	0.04±0.04	0
	Total abundance*	8.96±1.62	24.60±5.23

* *Mann-Whitney U*-test, $p \leq 0.05$

4.5.5 Variations on the Abundance of Amphibian Species along the Gradient of Physical Factors

The CCA ordination of species and environment correlation was significant in all axes (axis 1-3 $p \leq 0.05$). The accumulation of the percentage variable explanations of 3 axes was 90.5 % and the percentage variable explanation in Figure 4.8 (axes 1 and 2) was 83.8 %. The high abundances of most amphibian species were associated with higher stream size, water temperature, air temperature, and substrate temperature. The CCA also showed that the 800 and 950 m stream transects (low altitudinal stream transect) had stream size, water temperature, and substrate temperature higher than in 1250 m stream transects (high altitudinal stream transect) (Figure 4.4).



Full specific names of amphibian were showed in Table 4.9

WT = 24hrs. data of water temperature; WTL = surface water temperature; WT5 = 5 cm water

ST = substrate temperature at encountering amphibian; SW= stream width; SD = stream depth;

WF = rate of stream water flow

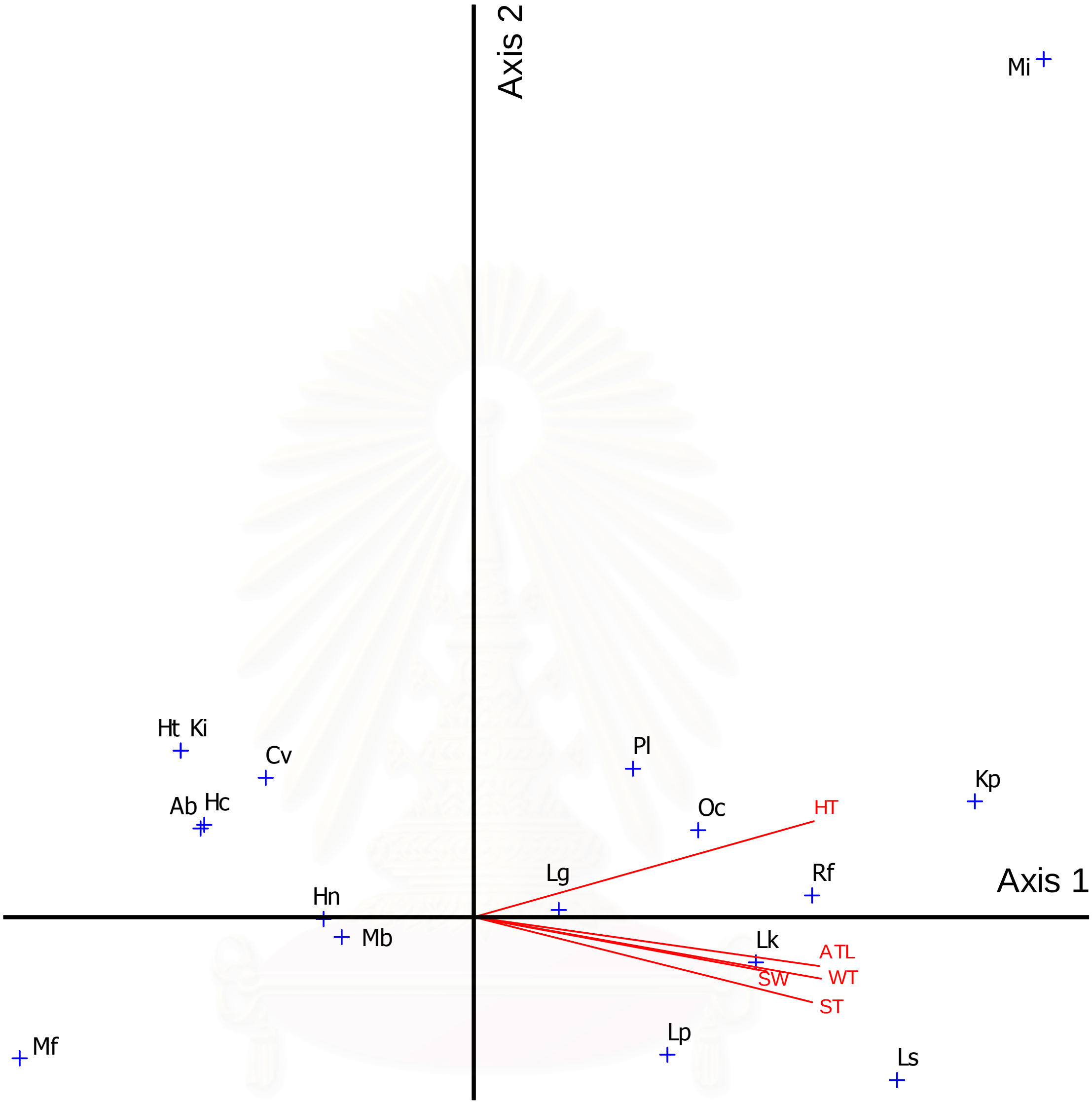
Figure 4.8 Canonical Correspondence Analysis of the abundance of amphibian species associated with physical factors at Num San Noi stream, Phuluang Wildlife Sanctuary

4.5.5.1 Variations on the Abundance of Amphibian Species between Seasonally Physical Factors

Relative humidity, water temperature, air temperature, substrate temperature, and stream width were analyzed together with the abundance of amphibian species to determine the variation of amphibian between seasons.

4.5.5.1.1 Variations on the Abundance of Amphibian Species between Seasons at 800 m asl

The CCA ordination of species and environment correlation was significant in all axes (axis 1-3 $p \leq 0.05$). The accumulation of the percentage variable explanations of 3 axes was 94.6 % and the percentage variable explanation in Figure 4.9 (axes 1 and 2) was 86.7 %. The high abundances of *Micryletta inornata, Polypedates leucomystax, Odorrana chloro nota, Kaloula pulchra, Rhacophorus feae, Limnonectes gyldenstolpei, Limnonecte s kuhlii, Leptolalax pelodytoides,* and *Leptobrachium smithi* were associated with high relative humidity, water temperature, air temperature, substrate temperature, and stream width whereas the abundance of *Kalophrynus interlineatus, Hylarana taipehensis, Chiromantis vittatus, Aquixalus bisacculus, Hylarana cubitalis, Hylarana nigrovittata, Microhyla berdmorei,* and *Microhyla fissipes* were high when the relative humidity, water temperature, air temperature, substrate temperature, and stream width were low.



Full specific names of amphibian were showed in Table 4.9

HT = 24hrs. data of relative humidity; ATL = 24hrs. data of ground level air temperature;

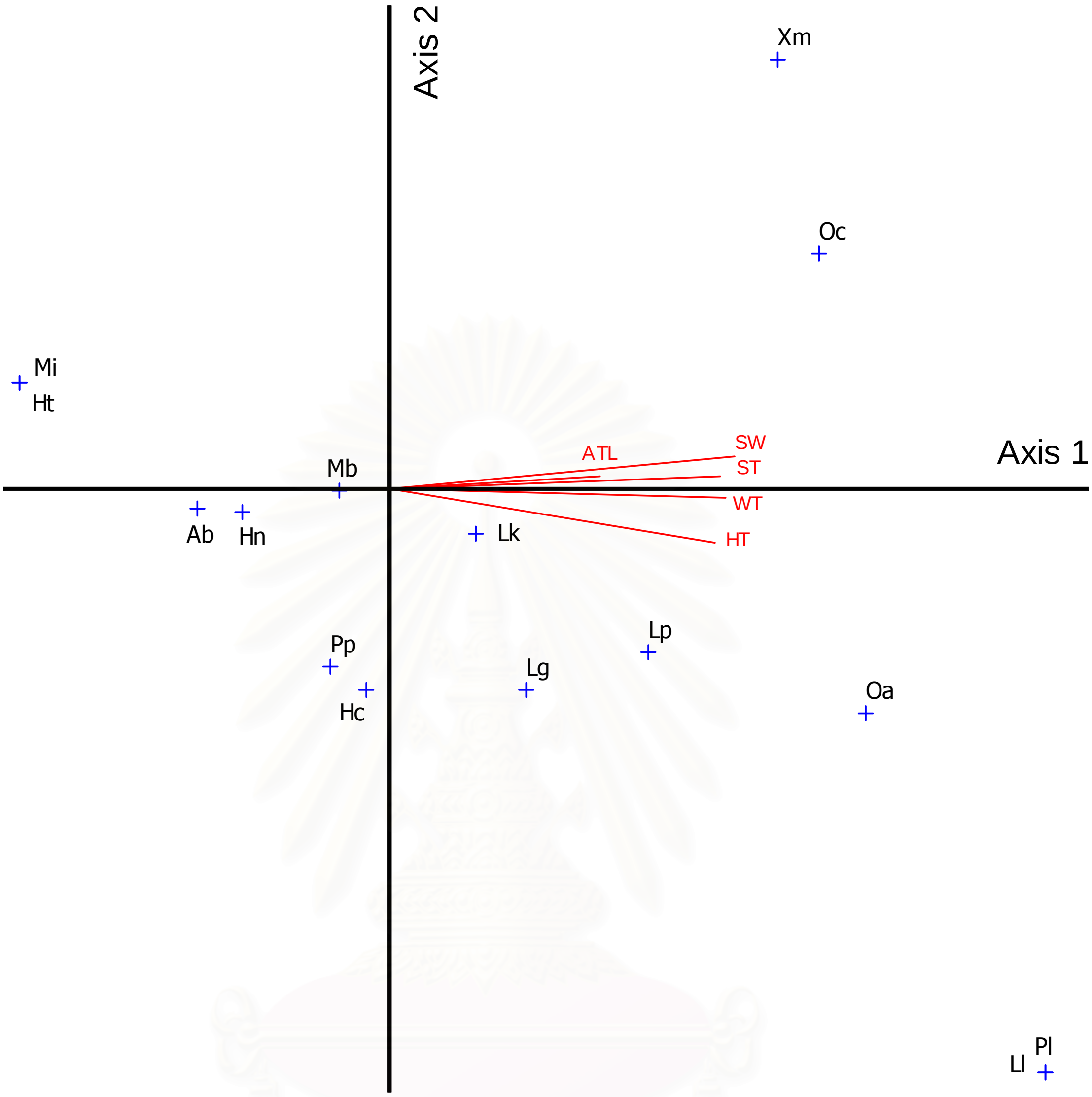
WT = 24hrs. data of water temperature; SW = stream width; SD = stream depth;

WF = rate of stream water flow

Figure 4.9 Canonical Correspondence Analysis of the abundance of amphibian species associated with physical factor s at 800 m asl of Num San Noi stream, Phuluang Wildlife Sanctuary

4.5.5.1.2 Variations on the Abundance of Amphibian Species between Seasons at 950 m asl

The CCA ordination of species and environment correlation was significant in all axes (axis 1-3 *p* $\leq$ 0.05). The accumulation of the percentage variable explanations of 3 axes was 93.3 % and the percentage variable explanation in Figure 4.10 (axes 1 and 2) was 86.2 %. The high abundances of *Xenophrys major, Odorrana chloronota, Limnonectes kuhlii, Leptolalax pelodytoides, Limnonectes gyldenstolpei, Odorrana aureola, Polypedates leucomystax,* and *Limnonectes limborgi* were associated with high relative humidity, water temperature, air temperature, substrate temperature, and stream width whereas the abundance of *Micryletta inornata, Hylarana taipehensis, Microhyla berdmorei, Aquixalus bisacculus, Hylarana nigrovittata, Philautus parvulus,* and *Hylarana cubitalis* were high when the relative humidity, water temperature, air temperature, substrate temperature, and stream width were low.



Full specific names of amphibian were showed in Table 4.9

HT = 24hrs. data of relative humidity; ATL = 24hrs. data of ground level air temperature;

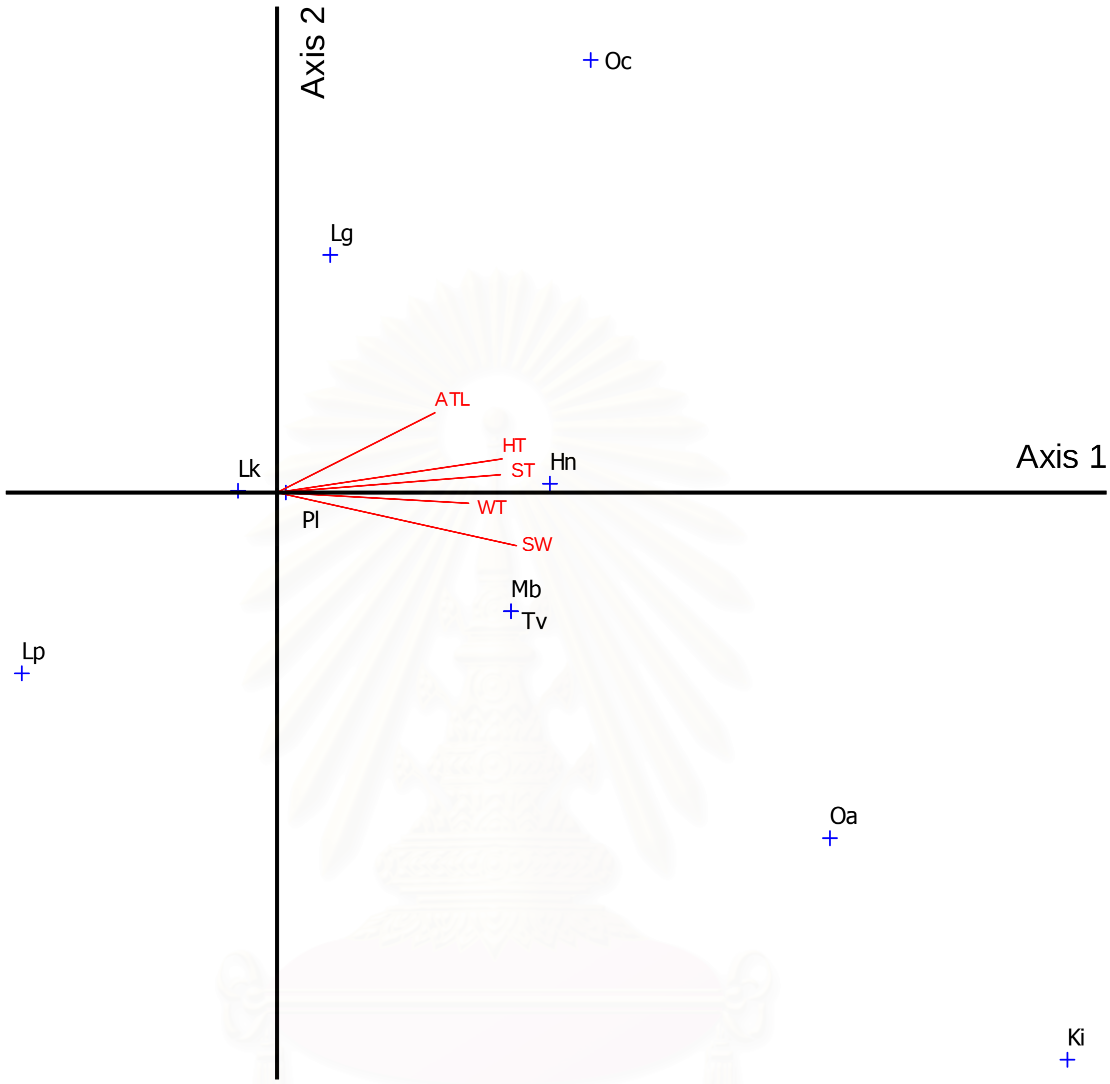
WT = 24hrs. data of water temperature; SW = stream width; SD = stream depth;

WF = rate of stream water flow

Figure 4.10 Canonical Correspondence Analysis of the abundance of amphibian species associated with physical factor s at 950 m asl of Num San Noi stream, Phuluang Wildlife Sanctuary

4.5.5.1.3 Variations on the Abundance of Amphibian Species between Seasons at 1250 m asl

The CCA ordination of species and environment correlation was significant in all axes (axis 1-3 $p \leq 0.05$). The accumulation of the percentage variable explanations of 3 axes was 94.3 % and the percentage variable explanation in Figure 4.11 (axes 1 and 2) was 87.3 %. The high abundances of *Odorrana chloronota, Limnonectes gyldenstolpei, Hylarana nigrovittata, Polypedates leucomystax, Microhyla berdmorei, Tylototriton verrucosus, Odorrana aureola,* and *Kalophrynus interlineatus* were associated with high relative humidity, water temperature, air temperature, substrate temperature, and stream width whereas the abundance of *Limnonectes kuhlii,* and *Leptolalax pelodytoides* were high when the relative humidity, water temperature, air temperature, substrate temperature, and stream width were low.



Full specific names of amphibian were showed in Table 4.9

HT = 24hrs. data of relative humidity; ATL = 24hrs. data of ground level air temperature;

WT = 24hrs. data of water temperature; SW = stream width; SD = stream depth;

WF = rate of stream water flow

Figure 4.11 Canonical Correspondence Analysis of the abundance of amphibian species associated with physical factor s at 1250 m asl of Num San Noi stream, Phuluang Wildlife Sanctuary

4.5.6 Activities of Common Species throughout the Year at each Elevation

Amphibian species which had an abundance higher than 10% were defined as the common species (see Chapter 3). There were three common species at 800 (*Hylarana nigrovittata, Odorrana chloronota,* and *Leptolalax pelodytoides*) and 950 m (*Hylarana nigrovittata, Odorrana chloronota,* and *Limnonectes kuhlii*) whereas at the 1250 m there was only one common species (*Limnonectes kuhlii*).

4.5.6.1 Activities of Common Species at 800 m asl

The calling activities of *Hylarana nigrovittata* started in October and extended to May and their egg masses were found from November to December and March to May (Figure 4.12 a). The breeding activities of *Hylarana nigrovittata* were found together with the high number of individuals observed.

The calling activities of *Odorrana chloronota* was heard for short period from May to June and their high abundance was found during rainy season from May to November (Figure 4.12 b). However, the egg mass of this species was not found.

The calling activities and abundance of *Leptolalax pelodytoides* showed a trend to be highly correlated and these activities were high from April to August and December to February (Figure 4.12 c).

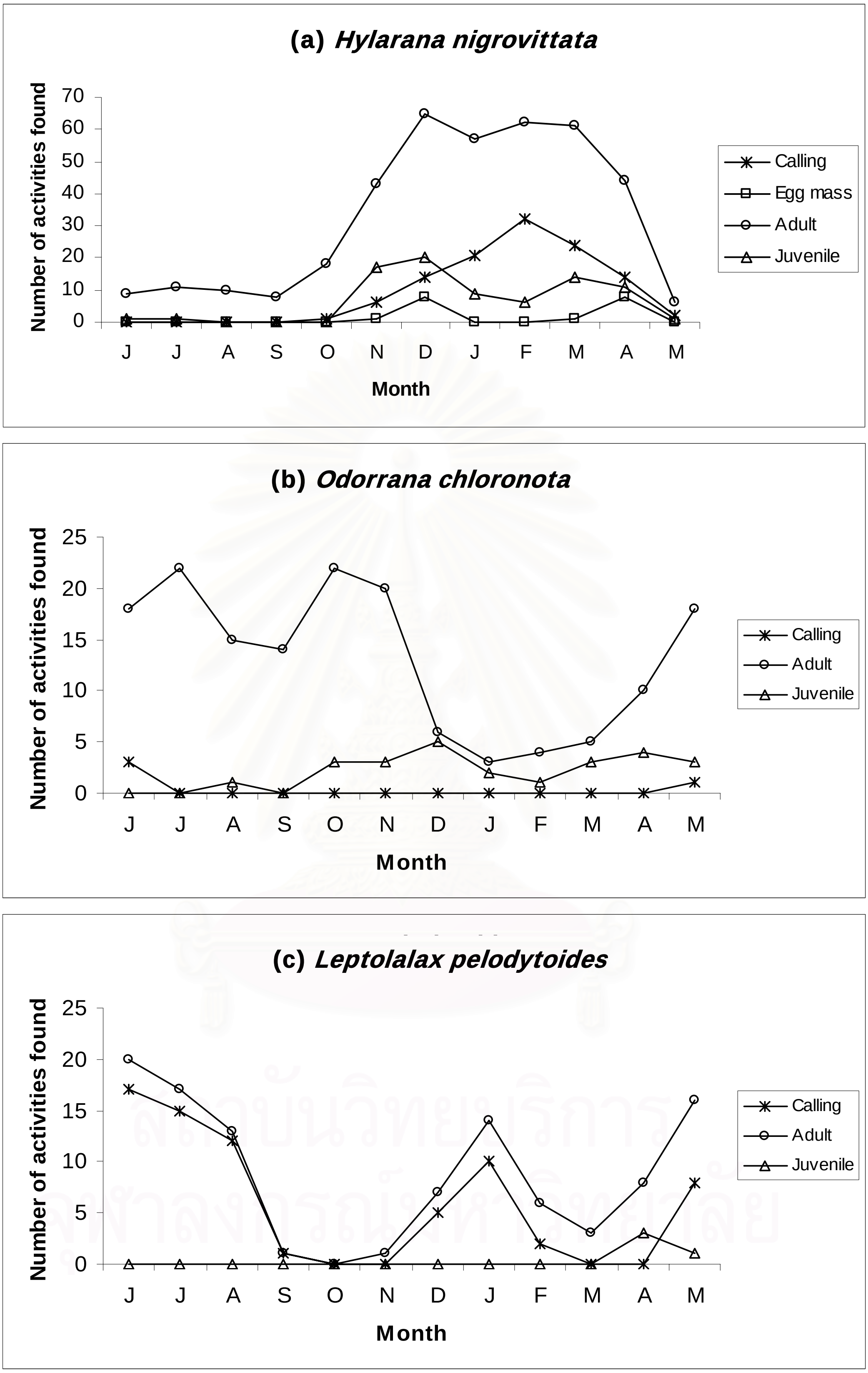


Figure 4.12 a-c Activities of *Hylarana nigrovittata, Odorrana chloronota,* and *Leptolalax pelodytoides,* respectively, at 800 m asl from June 2006 to May 2007 at Num San Noi stream, Phuluang Wildlife Sanctuary

4.5.6.2 Activities of common species at 950 m asl

The calling activity of *Hylarana nigrovittata* at 950 m was similar to that at 800 m which started from October to April and their egg masses were found from December to April (Figure 4.13 a). These breeding activities of *Hylarana nigrovittata* were found together with a very high number of individuals.

The calling and mating activities of *Odorrana chloronota* was found in short period from August to September and their high abundance was found during the rainy season from May to October (Figure 4.13 b). However, the egg mass of this species was not found.

The abundance of *Limnonectes kuhlii* tented to be highest in April (Figure 4.13 c). The egg masses were found from October to April.

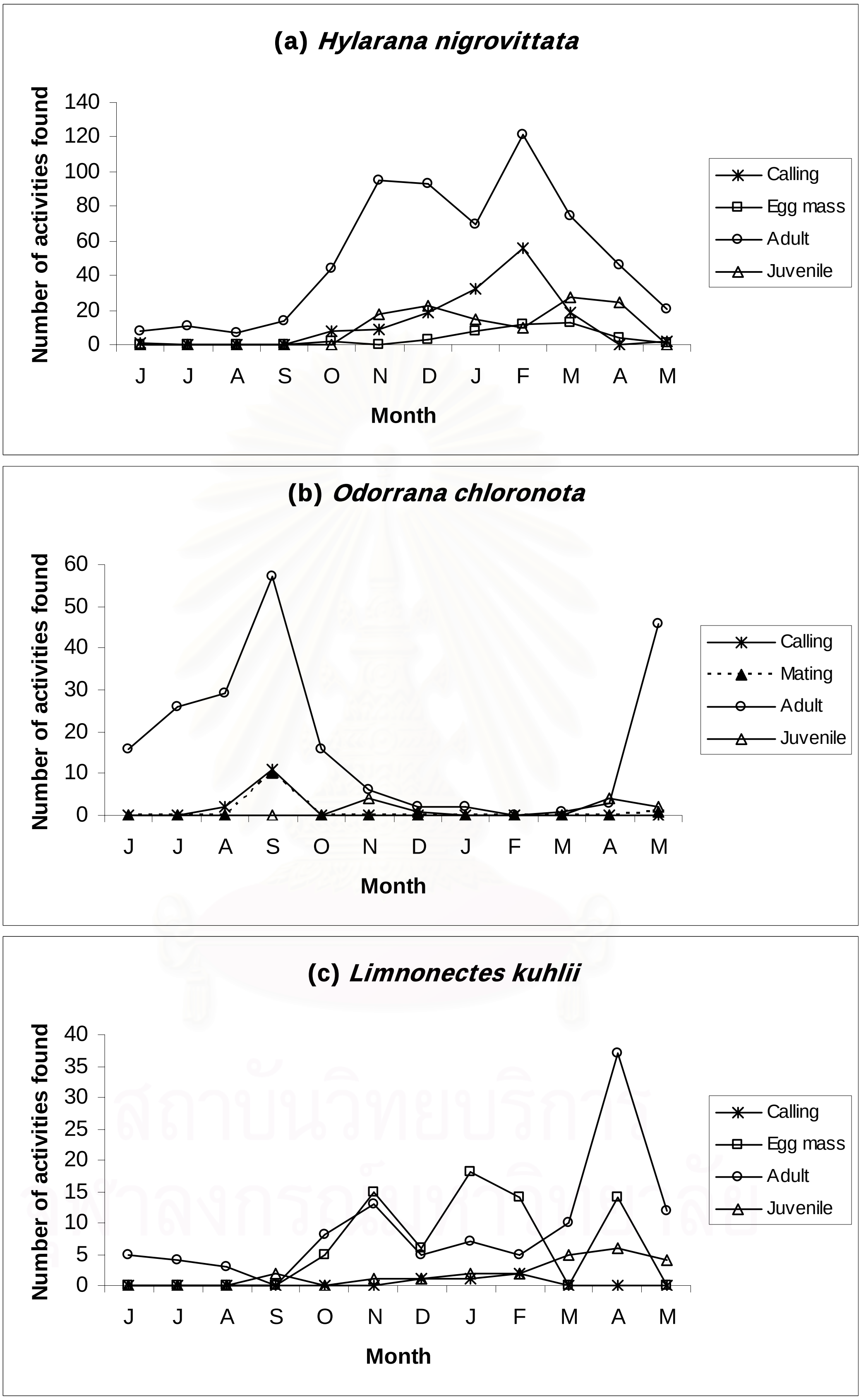


Figure 4.13 a-c Activities of *Hylarana nigrovittata, Odorrana chloronota,* and *Limnonectes kuhlii* , respectively, at 950 m asl from June 2006 to May 2007 at Num San Noi stream, Phuluang Wildlife Sanctuary

4.5.6.3 Activities of Common Species at 1250 m asl

The high abundance of *Limnonectes kuhlii* adult was found from September to December followed by the high abundance of juveniles which started from November to March (Figure 4.14). The egg masses were found in two short periods. The first was in October and the second was in May.

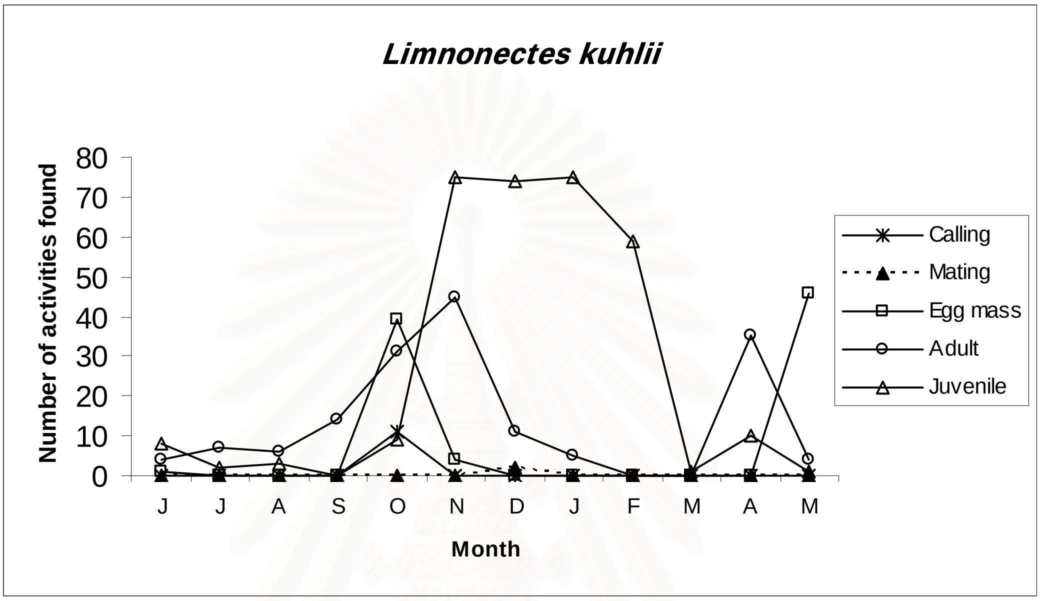


Figure 4.14 Activities of *Limnonectes kuhlii* at 1250 m asl from June 2006 to May 2007 at Num San Noi stream, Phuluang Wildlife Sanctuary

4.6 Discussion

4.6.1 Physical Factors among Elevations and between Seasons

The variation in physical factors both around the year and each season among elevation showed the similar results. The physical factors at low altitudinal transects (800 and 950 m) are similar but are different from high altitudinal transects (1250 m) stream transects. The CCA concluded that the low altitudinal transects had stream size, water temperature, air temperature, and substrate temperature higher than high altitudinal transects.

Most of physical factors; air temperature [1], ground level air temperature [1], water temperature [1], relative humidity [1], substrate temperature [2], surface water temperature[2], 5 cm water temperature [2], air temperature[1], relative humidity[2], stream width, stream depth, and rate of stream water flow in wet season were higher than in dry season in all elevations (Table 4.2).

4.6.2 Species Composition among Elevations

Parris and McCarthy (1999) reported that upstream catchment volume was a significant explanatory variable for the species richness of frog assemblages at forest streams in southeast Queensland, Australia. It is correlated with stream width, stream substrate, permanence of water and rates of water flow. Stream-breeding frogs require a stream that is large enough to hold water for a sufficient length of time for their tadpoles to develop to metamorphosis. Therefore, the larger streams should provide suitable breeding habitat for a greater range of frog species than smaller streams because they may contain water for longer time. It may be speculated that species diversity at 1250 m asl in this study site was lowest because it has lowest stream width, stream depth, and rates of water flow (Figure 4.3).

Some previous studies reported that the composition of frog assemblages on forest streams was correlated with stream size and stream gradient (Inger and Voris, 1993; Parris and McCarthy, 1999). It may be concluded that both 800 and 950 m elevations in this study were similar in stream width and stream gradient whereas both of them differed in stream width and stream gradient from the 1250 m site (Figure 4.2). Therefore, the species compositions at 800 and 950 m were very similar whereas both of them were very different from the composition at 1250 m.

4.6.3 Species Community Structure between Seasons within each Elevation

Some previous studies reported that species diversity, species richness, and total abundance of amphibians along the stream in dry season were higher than in wet season (Khonsue, 1996: Chachoengsao Province, Eastern Thailand; Kongjaroen, 2007: Nakhon Ratchasima Province, Northeastern Thailand). This study had some different results. The total abundance of amphibians in the dry season was higher than in the wet season at all elevations. The species diversity in this study in wet was higher than in dry season at all elevations and species richness was not different between seasons at low elevation (800 and 950 m) whereas species richness at 1250 m in wet season was higher than in dry season.

At 800 and 950 m sites, species diversity index in wet season were higher than in dry season whereas the species richness were not different (Table 4.4-4.5). It may be because the value of species diversity index is influenced by the values of species richness and evenness (Kutintara, 1999). So that, the species evenness in the wet season which was higher than in dry season can directly affects the species diversity index (Table 4.4-4.5). Dry seas on at 800 and 950 m sites had the suitable stream condition for some species (*Hylarana nigrovittata*) to reproduce therefore their abundances increased in this period. The increase in abundance has negative effect to the evenness of this community therefore, the species diversity in wet season was higher than in dry season. At 1250 m site, species diversity index in wet season were higher than in dry season. It may be because of the combination effect of the species richness and evenness. Many species were found only in the wet season and the abundance of *Limnonectes kuhlii* was high in the dry season (Table 4.12) due to the breeding behavior therefore, the species richness was high in the wet season and evenness was low in dry season. This reason can cause the higher diversity in the wet season than in the dry season.

Similarity index indicated that species compositions between seasons at the 1250 m were very similar whereas at 800 and 950 m were quite different. It may be because *Limnonectes kuhlii* was the dominant species in both seasons of the amphibian community at highest elevation site, 1250 m, whereas at the lower elevation sites, 800 and 950 m, were occu pied by different dominant species in different seasons therefore, the amphibian communities at lower elevations, 800 and 950 m, were more different between seasons than at highest elevation (1250 m).

Abundances of 6 species had significant differences between wet and dry seasons. Abundances of *Odorrana aureola* and *Odorrana chloronota* in wet season were higher than in the dry season whereas *Limnonectes gyldenstolpei, Hylarana nigrovittata, Aquixalus bisacculus,* and *Microhyla berdmorei* peaked in the dry season. The high abundance of most species in each season was found together with the presence of their breeding activities. Therefore, it may be concluded that the abundance of these species fluctuate due to their breeding activity in each period of time.

4.6.4 Importance of Long Term Monitoring of Amphibian Population

Six amphibian species, more than 60% of the total abundance, along NSN stream showed differences in seasonal activity and abundance. Therefore, the monitoring of these amphibian species in NSN stream should be concerned about this seasonal variation. This means that the effective monitoring of amphibian populations should include the peak time of each species, for example: *Odorrana aureola* and *Odorrana chloronota* should be monitored during the wet season. *Limnonectes gyldenstolpei, Hylarana nigrovittata, Aquixalus bisacculus,* and

Microhyla berdmorei should be monitored during the dry season. Other monitoring methods should also be conducted such as call count, plot sampling, or pit fall trap because direct comparisons of different amphibian monitoring methodologies at the same site should help researchers to determine which method may be the most sensitive and accurate (Storfer, 2003). This study also demonstrates that amphibian communities can be highly affected by elevation and therefore, the monitoring of amphibian populations should also be concerned with this effect.

CHAPTER V

SPECIES COMPOSITION, OVIPOSITION SITES, AND BREEDING ATTEMPT OF FROGS IN NUM SAN NOI STREAM, FLOWING ACROSS FOREST AND AGRICULTURAL AREAS, PHULUANG WILDLIFE SANCTUARY

5.1 Abstract

Species composition, abundance, oviposition sites and percentage of developing eggs of each species of amphibians in the Num San Noi stream, Phuluang Wildlife Sanctuary was studied. Num San Noi stream flows across both forest and agricultural areas. Visual encounter surveys were conducted from May 2006 to May 2007 along Num San Noi stream. Six 100 m stream transects, 3 in forest and 3 in agricultural areas were surveyed once per month. The first agricultural stream transect (AST) located close to the edge of the forest was followed by the 2nd and 3rd transects with the distance of 250 m intervals far from the forest. All forest stream transects (FST) were located far from the forest edge more than 2 km. All transects were located at 750-800 m asl. The Shannon-Wienner's diversity index indicated that the diversity in ASTs was significantly higher than the FSTs. The Morishita's similarity index indicated that the species composition of the 1st AST, near the forest edge, was the most similar to the FSTs, 0.74 – 0.87, whereas the species composition of the other 2 ASTs (far from the forest edge) were less similar to FSTs, 0.49 – 0.53. In the ASTs, abundances of each of 5 forest species were significantly lower whereas 6 urban species were significantly higher when compared with the FSTs ($p \leq 0.05$). The Canonical Correspondence Analysis (CCA) showed that the abundance of urban species were associated with high solar energy, air temperature, and water temperature whereas the forest species found were associated with high relative humidity and water transparency. It can be concluded that agricultural area had negative effect to the abundance of forest species in NSN stream.

5.2 Introduction

At present, it is well recognized that amphibian population decline is a global problem. Six hypotheses have been proposed to explain this problem (Collins and Storfer, 2003). One of the six hypotheses is habitat destruction. Although many hecters of natural habitat in Thailand have been destroyed, few workers have studied the effect of these changes on amphibian populations. This study compares stream frog assemblages in disturbed and undisturbed habitats to gain insights into the effects of expanding agricultural areas on frog assemblages.

5.3 Objective

The objective is to determine and compare species composition, oviposition sites and breeding attempts of frogs at Num San Noi stream flowing through forest and agricultural areas.

5.4 Methodology

Six 100 m stream transects were loca ted at Nam San Noi (NSM) stream at 750 – 800 m asl. Three stream transects were located in the forest and three stream transects were in an agricultural area. The agricultural area originally was the evergreen forest, as is the forest area. The first agricultural stream transect (AST) located close to the edge of the forest was followed by the 2 nd and 3rd transects with the distance of 250 m intervals far from the forest. The forest stream transects (FST) were located more than 2 km far from the forest edge with 250 m horizontal intervals. The visual encounter surveys were conducted in each transect once per month from May 2006 to May 2007. The surveys were conducted in both day and night to search for the egg masses and frogs, respectively. The species, abundance of each species, egg masses, and number of developing eggs were record to determine species diversity, species comp osition, and breeding attempt. Shannon-Wiener's diversity index and Morishita's sim ilarity index were calculated to determine species diversity in each transect and similarity among transects (Krebs, 1999). The total abundances of each species between FSTs and ASTs were compared using the *Mann-Whitney U*-test. The data of air temperature, relative humidity, and maximum solar energy in the survey day were gathered from weather station (Vantage Pro 2 Davis Weather Station) within 24 hrs. Ma ximum and minimum of ground level and water temperature in the survey day and in oviposition site were collected by maximum and minimum mercury thermometer. Water pH of oviposition site was collected by pH meters (HANNA model HI98128). The variations in the abundance of each species of frog with physical factors (air temperature, water temperature, water transparency, relative humidity, and solar energy) of each transect were determined by Canonical Correspondence Analysis (CCA).

5.5 Results

5.5.1 Environmental Factors between Agricultural and Forest Stream Transects

All environmental factors; air temperature, water temperature, water transparency, relative humidity, and solar energy between ASTs and FSTs were significantly different (Table 5.1). Air temperature, water temperature, and solar energy in ASTs were higher than in FSTs whereas relative humidity and water transparency in ASTs were lower than in FSTs.

Table 5.1 Physical factors between agricultural and forest stream transects at Num San Noi stream, Phuluang Wildlife Sanctuary collected from June 2006-May 2007

Physical factors	Forest stream mean±SE	Agricultural stream Mean±SE
Air temperature (°c)*	20.99±0.40	23.50±0.43
Water temperature (°c)*	19.48±0.39	20.50±0.41
Relative humidity (%)*	85.17±1.60	74.92±1.89
Solar energy (w/m^2)*	61.26±6.74	352.81±49.52
Water transparency (m)*	0.81±0.06	0.64±0.06

***** *Mann-Whitney U*-test, $p \leq 0.05$

5.5.2 Species Diversity

A total of 24 species was found (Table 5.2). Twenty one and seventeen species were found in ASTs and FSTs, resp ectively. The Shannon-Wienner's diversity index and species richness in ASTs were significantly different from FSTs. The Shannon-Wienner's diversity index indicated that the year-round diversity in ASTs were significantly higher than FSTs. The AST which was the farthest from the forest (approximately 600 m) had the largest spec ies diversity index, 2.28. The species diversity indices among the FSTs were quite similar, 1.48-1.55.

Table 5.2 The total number of frogs of each species observed on each stream transect are given. Total abundance, species richness, and the Shannon-Wienner's species diversity index are given at the bottom of the table.

No.	Species	Number of individuals in each transect					
		F1	F2	F3	A1	A2	A3
1	*Leptobrachium smithi*	1	2	3	0	1	0
2	*Leptolalax pelodytoides*	24	36	58	9	5	2
3	*Xenophrys parva*	0	0	0	1	0	0
4	*Duttaphrynus melanostictus*	0	0	0	3	0	1
5	*Fejervarya limnocharis*	0	0	0	5	12	5
6	*Limnonectes gyldenstolpei*	12	18	11	29	15	22
7	*Limnonectes kuhlii*	25	20	30	4	1	0
8	*Limnonectes limborgi*	0	0	0	1	0	1
9	*Occidozyga lima*	0	0	0	0	1	1
10	*Hylarana cubitalis*	1	2	3	5	1	4
11	*Hylarana nigrovittata*	115	181	183	80	35	17
12	*Hylarana taipehensis*	0	1	0	30	59	4
13	*Odorrana chloronota*	73	68	46	76	14	2
14	*Aquixalus bisacculus*	1	3	1	0	0	0
15	*Chiromantis vittatus*	1	2	0	1	0	0
16	*Polypedates leucomystax*	4	6	1	16	15	6
17	*Rhacophorus feae*	0	1	0	0	0	0
18	*Kalophrynus interlineatus*	0	1	0	0	0	0
19	*Kaloula pulchra*	1	0	1	3	1	2
20	*Microhyla berdmorei*	4	3	11	20	1	0
21	*Microhyla butleri*	0	0	0	0	0	7
22	*Microhyla fissipes*	0	0	1	7	3	11
23	*Microhyla heymonsi*	0	0	0	12	1	1
24	*Micryletta inornata*	1	0	0	0	0	1
	Total abundance of all species	263	344	349	302	165	87
	Species richness*	13	14	12	17	15	16
	Shannon-Wienner's index*	1.55	1.51	1.48	2.15	1.93	2.28

**Mann-Whitney U*-test, $p \leq 0.05$

F1-F3 = 1st - 3rd Forest stream transects, A1-A3 = 1st - 3rd Agricultural stream transects

5.5.3 Species Composition

The Morishita's similarity index (Table 5.3) indicated that species composition among FSTs were very similar, 0.94 – 0.98, whereas species composition among ASTs were 0.57 – 0.71. The species composition of 1^{st} AST, forest edged transect, was the highest and most similar to FSTs, 0.74 – 0.87, whereas the species composition of the other 2 ASTs were lower and less similar to FSTs, 0.49 – 0.53.

Table 5.3 The Morishita's similarity index among stream transects on Nam San Noi stream, Phuluang Wildlife Sanctuary are given.

Transect	F1	F2	F3	A1	A2	A3
F1	1	-	-	-	-	-
F2	0.97	1	-	-	-	-
F3	0.94	0.98	1	-	-	-
A1	0.87	0.80	0.74	1	-	-
A2	0.51	0.52	0.49	0.71	1	-
A3	0.50	0.53	0.50	0.63	0.57	1

F1-F3 = 1^{st} - 3^{rd} Forest stream transects, A1-A3 = 1^{st} - 3^{rd} Agricultural stream transects

The total abundance of frogs in FSTs was significantly higher than in ASTs ($p \leq 0.05$) (Table 5.4). The abundances of 11 species were significantly different between FSTs and ASTs. The abundances of 5 species; *Hylarana nigrovittata, Odorrana chloronota, Leptolalax pelodytoides, Limnonectes kuhlii,* and *Aquixalus bisacculus,* were higher in the FSTs than in the ASTs, whereas the abundances of 6 species, *Polypedates leucomystax, Fejervarya limnocharis, Duttaphrynus melanostictus, Hylarana taipehensis, Microhyla heymonsi,* and *Microhyla fissipes* , were higer in the ASTs than in the FSTs.

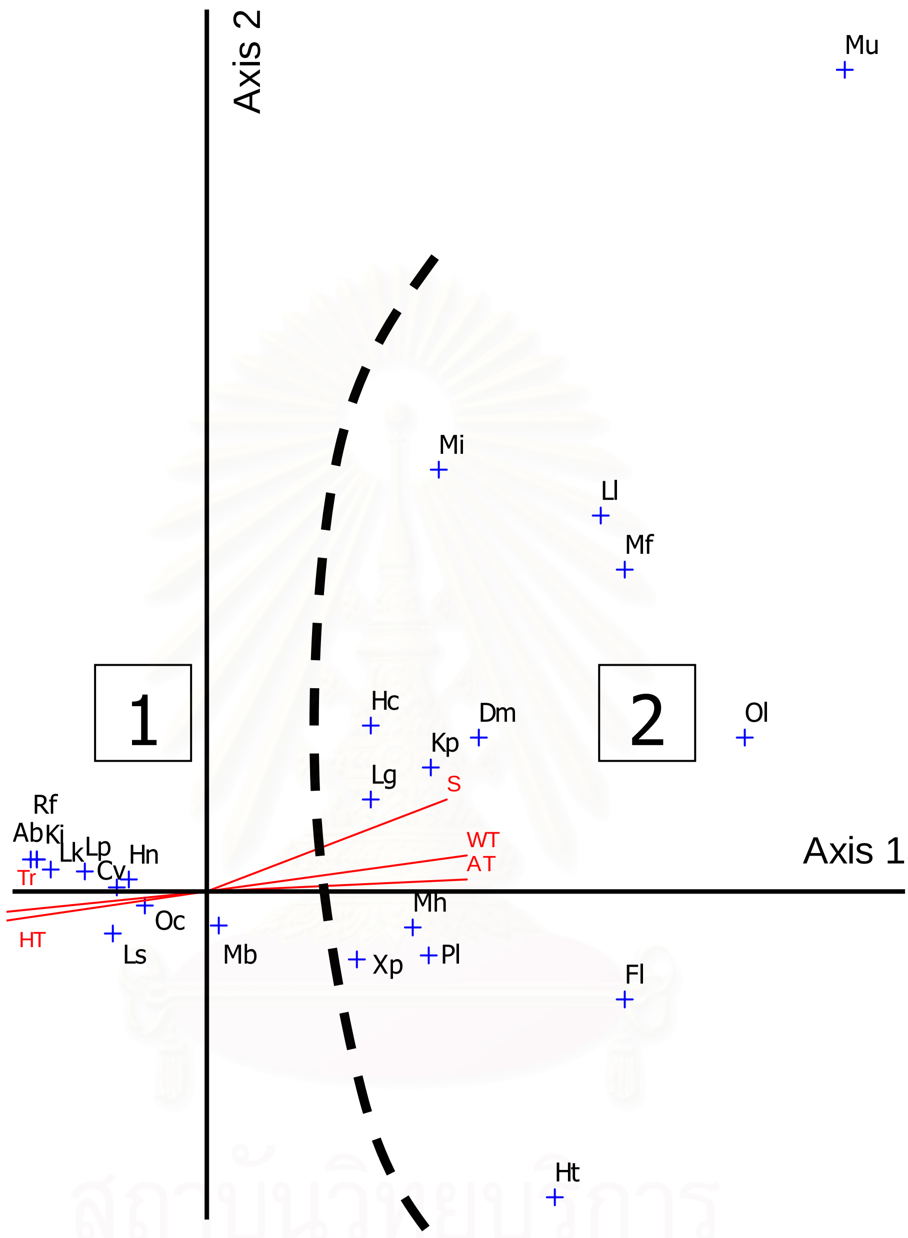
Table 5.4 The mean abundances for each species are given for the ASTs and FSTs of Nam San Noi stream, Phuluang Wildlife Sanctuary

No.	Species	FSTs (Mean±SE: individual/100 m)	ASTs (Mean±SE: individual/100 m)
1	*Leptobrachium smithi* (Ls)	0.15±0.09	0.03±0.03
2	*Leptolalax pelodytoides* (Lp) *	3.03±0.59	0.41±0.13
3	*Xenophrys parva* (Xp)	0	0.03±0.03
4	*Duttaphrynus melanostictus* (Dm) *	0	0.10±0.05
5	*Fejervarya limnocharis* (Fl) *	0	0.56±0.14
6	*Limnonectes gyldenstolpei* (Lg)	1.05±0.33	1.69±0.53
7	*Limnonectes kuhlii* (Lk) *	1.92±0.39	0.13±0.07
8	*Limnonectes limborgi* (Ll)	0	0.05±0.034
9	*Occidozyga lima* (Ol)	0	0.05±0.04
10	*Hylarana cubitalis* (Hc)	0.15±0.09	0.26±0.15
11	*Hylarana nigrovittata* (Hn) *	12.28±1.79	3.39±0.84
12	*Hylarana taipehensis* (Ht) *	0.03±0.03	2.39±0.78
13	*Odorrana chloronota* (Oc) *	4.80±0.54	2.36±0.58
14	*Aquixalus bisacculus* (Ab) *	0.13±0.07	0
15	*Chiromantis vittatus* (Cv)	0.08±0.06	0.03±0.03
16	*Polypedates leucomystax* (Pl) *	0.28±0.10	0.95±0.21
17	*Rhacophorus feae* (Rf)	0.03±0.03	0
18	*Kalophrynus interlineatus* (Ki)	0.03±0.03	0
19	*Kaloula pulchra* (Kp)	0.05±0.04	0.15±0.07
20	*Microhyla berdmorei* (Mb)	0.46±0.17	0.54±0.31
21	*Microhyla butleri* (Mu)	0	0.18±0.18
22	*Microhyla fissipes* (Mf) *	0.03±0.03	0.54±0.18
23	*Microhyla heymonsi* (Mh) *	0	0.36±0.28
24	*Micryletta inornata* (Mi)	0.03±0.03	0.03±0.03
	Total abundance of all species*	24.51±2.11	14.21±2.16

* *Mann-Whitney U*-test, $p \leq 0.05$

5.5.4 Variations in Abundances of Frogs with Physical Factors

The CCA ordination of species and environment correlation was significant in all axes (axis 1-3, $p \leq 0.05$). The accumulation of the percentage variable explanation of 3 axes was 94.1 % and the percentage variable explaination in Figure 5.1 (axes 1 and 2) was 82.0%. The CCA can divide the frog community into two groups (Figure 5.1). The first group (left of an arc) is a group of 10 species which is composed of *Rhacophorus feae, Aquixalus bisacculus, Kalophrynus interlineatus, Limnonectes kuhlii, Leptolalax pelodytoides, Hylarana nigrovittata, Chiromantis vittatus, Odorrana chloronota, Leptobrachium smithi,* and *Microhyla berdmorei* found in high abundance when the solar energy, air temperature, and water temperature were low and relative humidity and water transparency were high. In contrast, the second group (right of an arc) is a group of 14 species which is composted of *Microhyla butleri* , *Micryletta inornata, Limnonectes limborgi, Microhyla fissipes, Hylarana cubitalis, Duttaphrynus melanostic tus, Occidozyga lima, Kaloula pulchra, Limnonectes gyldenstolpei, Microhyla heymonsi, Polypedates leucomystax, Xenophrys parva, Fejervarya limnocharis,* and *Hylarana taipehensis* found in high abundance when the solar energy, air temperature, and water temperature were high and relative humidity and water transparency were low.



Full specific names of amphibian were showed in Table 5.4

HT = relative humidity; Tr = water transparency; AT = air temperature; WT = water temperature; and S = solar energy

Figure 5.1 Canonical Correspondence Analysis of frog abundance associate with physical factors at Num San Noi stream, Phuluang Wildlife Sanctuary; 1. Species located at the left of an arc = first group of species; 2. Species located at the right of an arc = second group of species

5.5.5 Oviposition Site and Breeding attempt

Egg masses of 3 species were found in the FSTs whereas no egg masses were found in the ASTs. The observed egg masses belonged to *Microhyla berdmorei* (51.72%), *Hylarana nigrovittata* (44.83%) and *Limnonectes kuhlii* (3.45%). Percentages of developing eggs of 3 species were higher than 90 % (Table 5.5). *Limnonectes kuhlii* was a species which laid eggs on the stream bed whereas the other 2 species laid their eggs close to the water surface. The egg masses of *Microhyla berdmorei* were usually found in pools near the main stream whereas *Limnonectes kuhlii* and *Hylarana nigrovittata* were usually found near the stream bank.

Table 5.5 Percentages of egg development in *Limnonectes kuhlii*, *Microhyla berdmorei*, and *Hylarana nigrovittata* and characteristics of oviposition sites in FSTs of Num San Noi stream, Phuluang Wildlife Sanctuary

Species	***L. kuhlii* (n=1)**	***M. berdmorei* (n=15)**	***H. nigrovittata* (n=13)**
Egg developed (%)	98.71	100 ± 00	99.70 ± 0.30
Water temp. MIN (°c)	20.5	18.70 ± 0.16	19.67 ± 0.28
Water temp. MAX (°c)	22	19.90 ± 0.05	21.46 ± 0.46
Air temp. MIN (°c)	19	16.54 ± 0.13	18.23 ± 0.39
Air temp. MAX (°c)	24	19.26 ± 0.03	22.51 ± 0.56
Dist. from water surface to egg (cm)	13.5	0	0
Dist. from water bed to egg (cm)	0	38.47 ± 5.53	24.02 ± 4.86
pH	6.39	8.90 ± 0.26	7.16 ± 0.34
Laid egg in stream (%)	100	0	61.54
Laid egg in pool near the stream edge (%)	0	100	38.46

5.6 Discussion

5.6.1 Species Diversity and Abundance of Frogs between the Agricultural and Forest Stream Transects

Species diversity in ASTs was higher than in FSTs. This result may be because ASTs were located near the forest area and some forest species can disperse to the lower stream transect from the edge of the forest. The FSTs were located more than 2 km from the forest edge and therefore they were not exposed to emigration from an adjacent agricultural area. In a ddition, ASTs were located at the crop field which was the open area therefore the weather in that area had higher solar energy and air temperature and lower relative humidity. It is well recognized that amphibians have permeable skin (Dullman and Trueb, 1994) therefore, they will lose a lot of water in the open area. Only stream area has water body year-round therefore, amphibians may move from crop field to the stream for balancing their water.

Eleven species found in ASTs and FSTs had difference in abundance. In the ASTs, abundances of 5 species, *Leptolalax pelodytoides, Limnonectes kuhlii, Hylarana nigrovittata, Odorrana chloronota,* and *Aquixalus bisacculus,* were significantly lower whereas 6 species, *Duttaphrynus melanostictus, Fejervarya limnocharis, Hylarana taipehensis, Polypedates leucomystax, Microhyla heymonsi,* and *Microhyla fissipes*, were significantly higher when compared with the FSTs. This result is similar to many previous studies of Chan-ard, 2003; Inger, 1966; Inger and Stuebing, 2005 who reported that *Duttaphrynus melanostictus, Fejervarya limnocharis, Polypedates leucomystax, Microhyla heymonsi,* and *Microhyla fissipes* were urban species whereas *Leptolalax pelodytoides, Limnonectes kuhlii, Hylarana nigrovittata, Odorrana chloronota,* and *Aquixalus bisacculus* were forest species in Thailand and Southeast Asia. In addition, the decrease in abundance of some forest species may be a result of predation. *Limnonectes kuhlii* are frequently eaten by local people and other species may be predated by some domestic animals. Therefore, an increase in predation and habitat change may be responsible for the decrease in abundance of these forest species.

5.6.2 Oviposition Site Characteristic and Breeding Attempt

The egg masses of *Microhyla berdmorei* and *Hylarana nigrovittata* were found in high number in FSTs whereas they were not found in ASTs. It may be concluded that the environmental factors in ASTs are not suitable for egg laying of these two species. Perhaps, these species just dispersed from the forest but they can not recruitment in the agricultural stream. The number of developing eggs was counted at the early stage of development and therefore, the breeding attempt estimated at this stage was very high.

5.6.3 Reproduction of Frogs on Streams Flowing through Agricultural Areas

Gray, Smith and Leyva (2004) reported that agricultural cultivation increased sedimentation in Playa wetlands, Southern High Plains, USA. The decrease of water transparency resulting from the sediment load in ASTs of NSN stream may have negative impact to the photosynthesis of the algae which is the primary food of the stream tadpole. Therefore, stream frogs may not reproduce successfully in this part of the stream. Thus, they can present in agricultural stream due to dispersal from the forest only. This cause can affect the abundance of the stream breeding species which were most abundant on the FSTs.

5.6.4 Conservation Aspects

This study may not confirm the negative effect of agricultural areas on frog diversity in the streams. However, it is an evidence to confirm the negative effect of agricultural area to the abundance of forest stream species. Moreover, the composition of frog assemblages was different between both sites. de Lima and Gascon (1999) surveyed small mammal and litter-frog communities in linear remnants of primary rainforest along watercourses ranging from 140 to 190 m in width, and in adjacent continuous rainfo rest, to compare their species richness, composition, and abundance. No significant differences were found in any aspect of community structure or species abundance. This suggests that linear remnants along watercourses provide suitable habitat fo r at least some forest vertebrates, a conclusion reinforced by the fact that many frogs and small mammals were found reproducing and moving in the remnants. Therefore, the linear remnants of forest area along the stream should be protected to conserve at least the forest frog and other small vertebrates. Moreover, the linear remnants of primary forest can reduce the effect of soil erosion in the open area as agricultural area on the stream therefore, the water quality in that stream should be better and they may function as corridors for some species to increase landscape connectivity in this country.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

A total of 22 species was found during a study of seasonal activity of amphibians in the forest area at Nam San Noi stream. Species diversity index values indicated that the species diversity in the wet season were higher than in the dry season at three elevations. Similarity index values indicated that species composition between seasons at 1250 m were similar whereas at 800 and 950 m they were different. The total abundance of all species and the abundance of 6 species had significant difference between the wet and dry seasons. The abundances of *Odorrana aureola* and *Odorrana chloronota* were high during the wet season while the number of *Limnonectes gyldenstolpei, Hylarana nigrovittata, Aquixalus bisacculus,* and *Microhyla berdmorei* and the total abundance of all species peaked in the dry season. The highest abundances of the most common species were found to be associated with breeding activity. The canonical correspondence analysis (CCA) indicated that the abundances of most amphibians through the year among elevations were associated with stream size, water temperature, and substrate temperature whereas the variation in amphibian abundance between seasons in each elevation were associated with relative humidity, water temperature, air temperature, substrate temperature, and stream width.

Shannon-Wiener's diversity index indicated that species diversity at the lowest elevation (800 m) had the highest diversity whereas the highest elevation (1250 m) had the lowest diversity. Morishita's similarity index showed that species compositions at 800 and 950 m were very similar but both were different from the highest elevation, 1250 m. Seven species with high percentages of total abundance over all elevations had low abundance at the highest elevation (1250 m) with the exception of *Limnonectes kuhlii* and *Odorrana aureola* which were found to have maximum abundance at the highest elevation. The abundance values for *Limnonectes gyldenstolpei* fluctuated across these elevations. *Xenophrys major* was a species found only at one elevation, 950 m. These results indicated that species diversity of amphibians tend to be higher at the lower elevations.

The species diversity of agricultural stream transects was significantly higher than the forest stream transects. Morishita's similarity index indicated that the species composition of the 1st AST, located near the forest edge was the most similar to the FSTs, 0.744 – 0.867, whereas the species composition of the other 2 ASTs (far from the forest edge) were less similar to FSTs, 0.493 – 0.527. In the ASTs, abundances of each of 5 forest species were significantly lower whereas 6 urban species were significantly higher when compared with the FSTs ($p \leq 0.05$). The CCA showed that the abundance of urban species was associated with high solar energy, air temperature, and water temperature whereas the forest species were found associated with high relative humidity and water transparency. The results showed that the agricultural area had a negative effect on the abundance of forest species.

The results from these studies indicate that the occurrences of amphibians along the spatial (elevation) and time (season) gradient were quite different. Therefore, the long term monitoring of amphibian population in the future should take in to consideration both the space and time factors that influence the local species. In addition, other survey methods should also be conducted to find the methods which are suitable for each species. If surveys using suitable methods were conducted to monitor amphibian populations in Thailand then the data from these surveys would be sufficient to develop a long term monitoring program for amphibian populations in Thailand.

In addition, *Rhacophorus feae* was found only one time during this study. Nabhitabhata and Chan-ard 2005 reported that *Rhacophorus feae* was found only in three localities; Pa Sue Falls in Mae Hong Son province, Doi Inthanon in Chiang Mai province, and Phuluang in Loei province and also classified this species as the near threatened species. Therefore, these three localities should be protected and the study on microhabitat used should be conducted. Then their microhabitat use data will suggest that what habitat should be managed extensively to conserve this species. *Tylototriton verrucosus* (Himalayan newt) was also found in few localities which were covered by montane forest and located above 1000 m asl in northern and northeastern part of Thailand. Salamander and newt usually have complex courtship behavior in the specific site therefore, the information on mating site is important for salamander conservation management.

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APPENDICES

APPENDIX A

Number of Species and Abundance of Amphibians in Each Study Site

No	Family	Species	Thai name	Abundance of amphibians (individuals)			
				Agricultural stream (750 m asl)	Forest stream (800 m asl)	Forest stream (950 m asl)	Forest stream (1250 m asl)
1	Salamandridae	*Tylototriton verrucosus*	กระท่าง	-	-	-	1
2	Megophryidae	*Leptobrachium smithi*	อึ่งกรายลายเลอะ	1	6	-	-
3		*Leptolalax pelodytoides*	อึ่งกรายหนังปุ่ม	16	118	91	1
4		*Xenophrys major*	อึ่งกรายห้วยใหญ่	-	-	9	-
5		*Xenophrys parva*	อึ่งกรายห้วยเล็ก	1	-	-	-
6	Bufonidae	*Duttaphrynus melanostictus*	คางคกบ้าน	4	-	-	-
7	Dicroglossidae	*Fejervarya limnocharis*	กบหนอง กบโม่	22	-	-	-
8		*Limnonectes gyldenstolpei*	กบหงอน	66	41	18	33
9		*Limnonectes kuhlii*	กบห้วยขาปุ่ม กบมื่น	5	75	133	481
10		*Limnonectes limborgi*	กบกา	2	-	1	-
11		*Occidozyga lima*	เขียดจะนา	2	-	-	-
12	Ranidae	*Hylarana cubitalis*	เขียดหูดำ	10	6	21	-
13		*Hylarana nigrovittata*	เขียดอ่อง	132	479	723	12
14		*Hylarana taipehensis*	เขียดไต้หวัน	93	1	1	-
15		*Odorrana aureola*	กบชะง่อนภูหลวง	-	-	4	46
16		*Odorrana chloronota*	กบชะง่อน	92	187	244	3
17	Rhacophoridae	*Aquixalus bisacculus*	ปาดลายเลอะอีสาน	-	5	3	-
18		*Chiromantis vittatus*	ปาดจิ๋วสีม่วง	1	3	-	-
19		*Philautus parvulus*	ปาดแคระป่า	-	-	2	-
20		*Polypedates leucomystax*	ปาดบ้าน	37	11	1	5
21		*Rhacophorus feae*	ปาดดอยอินทนนท์	-	1	-	-
22	Microhylidae	*Kalophrynus interlineatus*	อึ่งปุ่มหลังลาย	-	1	-	1
23		*Kaloula pulchra*	อึ่งอ่างบ้าน	6	2	-	-
24		*Microhyla berdmorei*	อึ่งแม่หนาว	21	18	33	1
25		*Microhyla butleri*	อึ่งลายเลอะ	7	-	-	-
26		*Microhyla fissipes*	อึ่งน้ำเต้า	21	1	-	-
27		*Microhyla heymonsi*	อึ่งข้างดำ	14	-	-	-
28		*Micryletta inornata*	อึ่งหลังจุด	1	1	1	-
Total abundance				554	956	1285	584
Species richness				21	17	15	10

APPENDIX B

Photographs of Study Sites at Different Elevations Showing Habitats

Agricultural site (700 m asl)

Forest site (800 m asl)

Forest site (950 m asl)

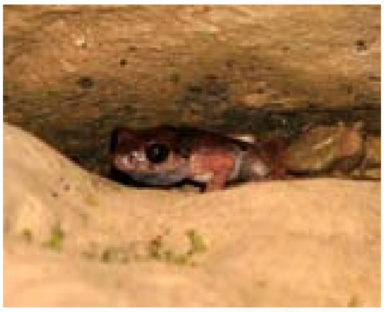
Forest site (1250 m asl)

APPENDIX C

Photographs of Amphibian Species Found at Num San Noi Stream, Phuluang Wildlife Sanctuary


Tylototriton verrucosus
กระท่าง


Leptobrachium smithi
อึ่งกรายลายเลอะ


Leptolalax pelodytoides
อึ่งกรายหนังปุ่ม


Xenophrys major
อึ่งกรายห้วยใหญ่


Xenophrys parva
อึ่งกรายห้วยเล็ก


Duttaphrynus melanostictus
คางคกบ้าน


Fejervarya limnocharis
กบหนอง กบโม่


Limnonectes gyldenstolpei
กบหงอน

Limnonectes kuhlii
กบห้วยขาปุ่ม กบมื่น

Limnonectes limborgi
กบกา

Occidozyga lima
เขียดจะนา

Hylarana cubitalis
เขียดหูดำ

Hylarana nigrovittata
เขียดอ่อง

Hylarana taipehensis
เขียดไต้หวัน

Odorrana aureola
กบชะง่อนภูหลวง

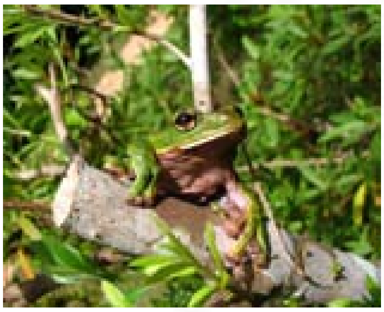
Odorrana chloronota
กบชะง่อน

Aquixalus bisacculus
ปาดลายเลอะอีสาน

Chiromantis vittatus
ปาดจิ๋วสีม่วง

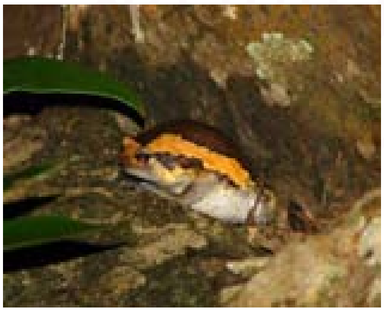
Philautus parvulus
ปาดแคระป่า

Polypedates leucomystax
ปาดบ้าน



Rhacophorus feae
ปาดดอยอินทนนท์

Kalophrynus interlineatus
อึ่งปุ่มหลังลาย



Kaloula pulchra
อึ่งอ่างบ้าน

Microhyla berdmorei
อึ่งแม่หนาว

Microhyla butleri
อึ่งลายเลอะ

Microhyla fissipes
อึ่งน้ำเต้า

Microhyla heymonsi
อึ่งข้างดำ

Micryletta inornata
อึ่งหลังจุด

APPENDIX D

Photographs of Frog Egg Masses in Num San Noi Stream, Phuluang Wildlife Sanctuary

Egg mass of *Microhyla berdmorei*

Egg mass of *Hylarana nigrovittata*

Egg mass of *Limnonectes kuhlii*

BIOGRAPHY

Mr. Ratchata Phochayavanich was born on November 5, 1983. He received his Bachelor's Degree of Science (Forestry) from the Department of Forest Biology, Faculty of Forestry, Kasetsart University in 2005. His Master's degree study in Zoology, Department of Biology, Faculty of Science, Chulalongkorn University was supported by the John D. and Catherine T. MacArthur Foundation under the collaboration between Field Museum of Natural History, Chicago, USA and the Department of Biology, Faculty of Science, Chulalongkorn University; the Center of Excellence in Biodiversity, Faculty of Science, Chulalongkorn University, under the Research Program on Conservation and Utilization of Biodiversity (CEB_M_24_2006); and TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT T_250002.