POPULATION SIZE, POPULATION STRUCTURE AND HABITAT UTILIZATION OF Eufo aspar Gravenhorst, 1829 IN TARN LORD NOI CAVE, KANCHANABURI PROVINCE

Miss Tassanee Hamkamon

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Zoology
Department of Biology
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ขนาดประชากร โครงสร้างประชากร และการใช้พื้นที่ของจงโคร่ง *Bufo asper* Gravenhorst, 1829 ในถ้ำธารลอดน้อย จังหวัดกาญจนบุรี

นางสาวทัศนีย์ เอี่ยมกมล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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(Suthep Boonprakong)

ทัศนีย์ เอี่ยมกมล: ขนาดประชากร โครงสร้างประชากร และการใช้พื้นที่ของจงโคร่ง *Bufo asper* Gravenhorst, 1829 ในถ้ำธารลอดน้อย จังหวัดกาญจนบุรี (POPULATION SIZE, POPULATION STRUCTURE AND HABITAT UTILIZATION OF *Bufo asper* Gravenhorst, 1829 IN TARN LORD NOI CAVE, KANCHANABURI PROVINCE) อาจารย์ที่ปรึกษา: ผศ. ดร. กำธร ธีรคุปต์, อาจารย์ที่ปรึกษาร่วม: ผศ. ผุสดี ปริยานนท์; 112 หน้า ISBN 974-17-2189-7

การสำรวจและติดตามประชากรของจงโคร่ง *Bufo asper* ที่อาศัยอยู่ในถ้ำธารลอดน้อย จังหวัดกาญจนบุรีได้กระทำติดต่อกันทุกเดือน เดือนละ 15 ครั้ง ตั้งแต่เดือนกรกฎาคม 2544 ถึงเดือนมิถุนายน 2545 เพื่อศึกษาขนาดประชากร โครงสร้างประชากร และการใช้พื้นที่ โดยจงโคร่งทุกตัวที่พบถูกทำเครื่องหมายโดยการตัดนิ้ว ข้อมูลที่บันทึกประกอบด้วยเพศ วัย น้ำหนัก ความยาวจากปลายจมูกถึงช่องเปิดทวาร พฤติกรรมการสืบพันธุ์ และตำแหน่งของจงโคร่งแต่ละตัวที่พบ หลังจากนั้นปล่อยจงโคร่งยังบริเวณที่จับได้ การคำนวณขนาดประชากรด้วย Jolly-Seber model of population estimation พบว่า ขนาดประชากรแปรผันอยู่ในช่วง 71.9 $\pm$ 7.9 ถึง 91.9 $\pm$ 8.5 ตัว โดยตัวผู้มีจำนวนมากกว่าตัวเมียและตัวที่ยังไม่ถึงวัยสืบพันธุ์ในทุกครั้งของการสำรวจ ยกเว้นในช่วงฤดูสืบพันธุ์ในเดือนพฤษภาคม 2545 ซึ่งตัวเมียมีจำนวนมากกว่าตัวผู้ และสัดส่วนระหว่างเพศในเดือนนั้นเป็น 1:1.27 ส่วนในช่วงเดือนอื่นๆ สัดส่วนระหว่างเพศแปรผันอยู่ในช่วง 1: 0.22 ถึง 1: 0.75 ความยาวจากปลายจมูกถึงช่องเปิดทวารของจงโคร่งตัวผู้ ตัวเมีย และตัวที่ยังไม่ถึงวัยสืบพันธุ์ที่พบมากอยู่ระหว่าง 90 ถึง 110 มม., 110 ถึง 140 มม. และ 30 ถึง 90 มม. ตามลำดับ ขนาดประชากรของตัวผู้และตัวเมียสัมพันธ์กับอุณหภูมิ โดยการเปลี่ยนแปลงของขนาดประชากรของตัวเมียแปรผันตามการเปลี่ยนแปลงของอุณหภูมิ ส่วนการเปลี่ยนแปลงของขนาดประชากรเพศผู้แปรผกผันกับการเปลี่ยนแปลงของอุณหภูมิ จงโคร่งส่วนมากแสดงการเคลื่อนที่ระหว่างภายในและภายนอกถ้ำทั้งในช่วงเวลาและนอกช่วงเวลาของการสืบพันธุ์ นอกจากนั้นจงโคร่งส่วนใหญ่แสดงพฤติกรรมการใช้ที่ประจำ(Chi-square: $P<0.05$) โดยไม่พบความแตกต่างในการใช้พื้นที่ระหว่างจงโคร่งตัวผู้และตัวเมีย และระหว่างตัวผู้ที่มีขนาดแตกต่างกันทั้งในและนอกช่วงเวลาของการสืบพันธุ์ การสืบพันธุ์และการอยู่รอด คาดว่ามีบทบาทสำคัญต่อการเปลี่ยนแปลงของขนาดประชากรและการใช้พื้นที่ จากการศึกษาช่วงเวลาในการสืบพันธุ์ตั้งแต่เดือนมีนาคม 2544 ถึงกรกฎาคม 2545 ชี้ให้เห็นว่าช่วงเวลาในการสืบพันธุ์ของจงโคร่งอยู่ในช่วงฤดูฝนและมีระยะเวลาประมาณ 5 เดือน ซึ่งช่วงเวลาในการสืบพันธุ์มีความใกล้เคียงกันทั้ง 2 ปี คือตั้งแต่เดือนเมษายนถึงเดือนสิงหาคม 2544 และตั้งแต่เดือนมีนาคมถึงเดือนกรกฎาคม 2545 ผลจากการศึกษาเรื่องประชากร การใช้พื้นที่ และช่วงเวลาในการสืบพันธุ์แสดงให้เห็นถึงความสำคัญของถ้ำธารลอดน้อยในการเป็นแหล่งสืบพันธุ์ของประชากรนี้

ภาควิชา.....ชีววิทยา.....
สาขาวิชา.....สัตววิทยา.....
ปีการศึกษา.....2545.....

ลายมือชื่อนิสิต.....
ลายมือชื่ออาจารย์ที่ปรึกษา.....
ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....

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KEY WORD: POPULATION/ HABITAT USE/ BUFO ASPER

TASSANEE EAMKAMON: POPULATION SIZE, POPULATION STRUCTURE AND HABITAT UTILIZATION OF *Bufo asper* Gravenhorst, 1829 IN TARN LORD NOI CAVE, KANCHANABURI PROVINCE. THESIS ADVISOR: ASST PROF. KUMTHORN THIRAKHUPT, Ph.D., THESIS COADVISOR: ASST PROF. PUTSATEE PARIYANONTH, M.S. 112 pp. ISBN 974-17-2189-7

A total of 15 surveys were carried out monthly from July 2001 to June 2002 to investigate population size, population structure, and habitat utilization of Asian giant toad, *Bufo asper*, inhabiting Tarn Lord Noi Cave, Kanchanaburi Province. The toads that were found in any survey were captured and individually marked using toe-clipping method. Sex, age, weight, snout to vent length, breeding behavior, and location were recorded for all toads. After the toads had been examined, they were released at the point of capture. Using the Jolly-Seber model of population estimation, the estimated population size varied from 71.9 $\pm$ 7.9 to 91.9 $\pm$ 8.5 individuals. The male was dominant in number relative to the female and the young almost throughout the sampling period. However, the population size of the male was smaller than the population size of the female during the breeding time in May 2002 in which the sex ratio was 1:1.27. For the other sampling time, the sex ratio varied from 1: 0.22 to 1: 0.75. The size that was frequently found for the male, the female, and the young were between 90 to 110 mm, 110 to 140 mm, and 30 to 90 mm, respectively. Population sizes of the male and the female correlated with the temperature but the correlation was on the opposite way. The change of female population size coincided with the temperature but conversely related for the male. A large number of the toads showed movement between inside and outside of the cave for both breeding and non-breeding time. Most of the toads exhibited highly area fidelity behavior for both breeding and non-breeding time (Chi-square: $P<0.05$). There was no significant difference in habitat utilization between sexes and between the male of different sizes for both breeding and non-breeding time. Reproduction and survival seemed to play the important role for the population change and habitat utilization of them. The obtained data during March 2001 to July 2002 suggested that the toad inhabiting Tarn Lord Noi Cave was not explosive breeder. They took about 5 months in rainy season for each breeding time. The breeding times were quite similar for 2 successive years that were during April to August 2001 and March to July 2002. The result from the study of population, habitat utilization and breeding time revealed that Tarn Lord Noi Cave was important as a breeding site for this population.

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Field of study.....ZOOLOGY.....
Academic year.....2002.....

Student's signature...Tassanee Eamkamon
Advisor's signature...K. Thirakhupt
Co-Advisor's signature...P. Pariyanonth

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Chapter I

Introduction

Recently, several studies demonstrate that many species of amphibians throughout the world have declined markedly in numbers (e. g., Blaustein and Wake, 1990; Crump, 2002; Lehtinen, 2002) due to habitat destruction, water pollution, ultraviolet light, acid rain, and toxic substances in the environment (Duellman and Trueb, 1994; Friedl and Klump, 1997; Langhelle, Lindell, and Nystrom, 1999; Bille, 2000). Some species have become extinct from the area (e. g., Magnusson et al., 1999). This phenomenon has raised the urgent need in population study and habitat utilization examination (Monello and Wright, 1999).

The knowledge on population ecology including size, structure, and movement of a population is important to describe population fluctuation and their natural cause (e. g., Friedl and Klump, 1997; Pechmann and Wilbur, 1994). Moreover, the knowledge can be applied in conservation management, because the variation in population characteristics can be directly related to physical and biological factors that prevail in time. According to habitat utilization, habitat components are believed to play an important role in amphibian distribution, abundance, or reproduction (Monello and Wright, 1999). Thus, the information on the use of habitat is also invaluable for conservation scheming (Seebacher and Alford, 1999).

Bufo asper is one of the protected amphibians of Thailand. However, the information on population ecology and habitat utilization of this species is less known. The population ecology of *B. asper* living in Tarn Lord Noi Cave, Chaloem Rattana Kosin National Park, Kanchanaburi Province was attractive for examination due to the survival of this population has been directly affected by tourist activity. Thus, the information of this population should be urgently examined.

Here, the analysis of population size and population structure of *Bufo asper* living in Tarn Lord Noi Cave is presented. It is hypothesized that climatic factors, reproduction, and strategies for survival are determinants for changing in number of individuals, sex ratio, and size composition found among months. In addition, habitat utilization,

including movement and area utilization are examined to demonstrate survival strategies and the important of the cave for this population. Moreover, breeding seasons of them were figured out for two consecutive years.

The results from this study will provide basic information on population ecology, variation in habitat utilization of individuals and breeding season of them that can be applied for conservation and ecotourism management and can be compared with findings on other amphibian species.

Scope of the Study

1. The study on the population of *Bufo asper* was conducted in Tarn Lord Noi Cave, Chaloem Rattana Kosin National Park, Kanchanaburi Province and lasted for one year from July 2001 to June 2002.
2. The presented data on area utilization were selected from the individual of which the location was recorded at least 25 times during July 2001 to June 2002. The observed area outside the cave was approximately 50 m for both entrances.

Objectives

1. To figure out population size, population structure, and related climatic factors of *Bufo asper* inhabiting Tarn Lord Noi Cave.
2. To examine habitat utilization, including movement and area utilization.
3. To examine the breeding season.

Anticipated Benefits

This study will provide basic knowledge on population ecology, habitat utilization, and breeding season of *Bufo asper* in Tarn Lord Noi Cave that can be used for status assessment, conservation scheming, ecotourism management, and for the study of other amphibians in the future.

Chapter II

Literature Review

2.1 Genus *Bufo*

Genus *Bufo* is in:

Kingdom Animalia

Phylum Chordata

Class Amphibia

Order Anura

Family Bufonidae

Bufo is one of about 35 genera in family Bufonidae. It is suggested to be ancestor of some other genera in the family. The genus contains about 200 species which commonly known as toad. However, it will not be possible to state the exact number in the foreseeable future due to two major reasons. First, there is at present no possibility of estimating the number of cryptic species that have not been revealed by morphological studies. Second, it is highly probable that additional species remain to be discovered in addition to the cryptic species (Taylor, 1962; Inger, 1966; Blair, 1972; Duellman, 1999).

In general, *Bufo* has thick, glandular skin with or without pustular warts. Parotoid gland is present and conspicuous. Tongue is oval and free behind. Neither vomerine nor maxillary teeth is present. Tympanum is distinct or hidden by skin and rarely absent. There is no web on fingers. In contrast to fingers, toes are present with a thickened web, which is a slightly widened digit-tip. Outer metatarsal is united. *Bufo* usually has only a single slit, which enters vocal sac. Pupil is horizontal. Most species are terrestrial or fossorial and have short limbs. Digits are reduced and shortened (Taylor, 1962; Duellman and Trueb, 1994).

The further distinct character of *Bufo* is egged string. Toads of the genus *Bufo* characteristically deposit eggs in paired strings. Each string is from each oviduct. The numerous, small, pigmented eggs are laid in standing or slowly moving water. The

larvae have spheoidal bodies, rather narrow lips, horny beaks, highly coiled intestines, and deep fins (Inger, 1966; Duellman and Trueb, 1994).

Bufo has nearly cosmopolitan distribution but do not occur in the Australo-Papuan Realm, Madagascan and Oceanic regions. However, become a pest species, *Bufo marinus* has been introduced into Australia, New Guinea and many other islands in 1930s. According to fossil history, the genus *Bufo* is known from the upper Tertiary and Quaternary deposits of North America, South America, Europe and Africa. The genus is most speciose in the Neotropical (74 species), and Ethiopian (56 species) Realm, followed by the Oriental Realm (47 species), Palearctic Realm (24 species) and Nearctic Realm (21 species) (Taylor, 1962; Inger, 1966; Blair, 1972; Duellman and Trueb, 1994; Freeland and Kerin, 1988; Seebacher and Alford, 1999; Duellman, 1999).

Blair (1972) suggested that the major evidences that are expected to influence the spread of *Bufo* are the earth features, including:

1. Isolation of the continental landmasses by water gaps at various times in the Tertiary and Quaternary.
2. Existence of climatic zones that might serve as barrier or alternatively as dispersal routs for group with restrictive adaptation to climatic type.
3. Shift of the climatic zones under the influence of Pliocene and Pleistocene continental glaciations and interglacial conditions.
4. Existence of south-to-north-oriented mountain ranges which might act as dispersal routes for cold-adapted types.
5. Existence of east-west-trending mountain chains which would act as lethal traps for warmth-adapted types, that might be forced southward by climatic cooling.
6. Continental mass and environmental diversity which would provide a template for the adaptive radiation of the genus on the respective continents.

In Thailand, four species of *Bufo* are found. The first is *B. melanostictus* which probably occurs in every province. The second is *B. macrotis* which is found in western Thailand. The third is *B. parvus* which has a distribution in southern Thailand and the last is *B.* asper which disperse in peninsular and western Thailand (Taylor,

1962). Except *B. melanostictus*, all of them are protected species in Thailand underly WARPA, 1992.

2.2 *Bufo asper* Gravenhorst, 1829

Figure 2.1 *Bufo asper* Gravenhorst, 1829.

Bufo asper is a member of genus *Bufo*. It's English common names are Asian Giant Toad , Cave toad, or River toad and it's Thai common names are จงโคร่ง (Chong Krong), กง (Kong), or หมาน้ำ (Mha Nam). Snout to vent length of male is 69.5-98.2 mm and 95.2-120.8 mm for female. To identify this toad from other species in genus *Bufo*, the toad is moderately stocky. Its limbs are relatively long. Head is wider than long. Supraorbital crest is usually low. Parietal crest is absent. Supratympanic crest is thick. The snout is truncate or obtusely pointed. Furthermore, it is vertical in profile or projecting slightly. Nostril is at the end of snout. Canthus is rounded and distinct. Interorbital is wider than upper than eyelid. Tympanum is distinct and about one-third diameter of eye (Taylor, 1962; Inger, 1966).

Fingers are moderately long. Tips are swollen but not wider than other parts of the fingers. The first finger is usually slightly longer than the second finger. Subarticular

tubercles are large and simple. Supernumerary metacarpal tubercles are present. The tips of toes like those of fingers. The third toe is slightly longer than the fifth. All toes except the fourth are webbed to the swollen tips. The fourth toe is 1-2 phalanges free. The subarticular tubercle is conspicuous, round, and simple. Inner metatarsal tubercle is low, oval and half in length of first toe. The outer metatarsal tubercle is round or oval, and smaller than the inner. Tarsal ridge is sharp (Inger, 1966).

Skin of back is covered with large round warts. There are numerous small tubercles on the skin between warts. Top of head, sides, and dorsal surfaces of limbs are present with many small, conical warts. The most of warts and many small tubercles are persent with melanic tips. There is one (or two) large, conical rictal wart. Ventral is cover with coarsely granular and the granule is usually tipped with melanin. The parotoid gland is round or subtriangular (Inger, 1966).

There is much variation in general coloration. The color may be light clay, olive, blackish or occasionally (probably in the breeding season) may be spotted with orange or crimson (Taylor, 1962). The color of *B. asper* preserved in alcohol is dark brown above, immaculate or with a few black spots in juvenile specimens. The ventral is yellowish brown. Throat, chest, and underside of legs are spotted with black (Inger, 1966).

In Thailand, the species is known in peninsular and western Thailand. In Malaysia, the species is present from sea level to an elevation of 4,500 feet and also found in caves deep in the mountains. Moreover, it has been found in southern Myanmar, Sumatra, Java, and Borneo.

Taylor (1962) studied amphibian fauna of Thailand and reported that *B. asper* usually remains close to small stream. Numerous specimens were acquired from clumps of bamboo growing in the edge of small stream.

Inger (1966) figured out the systematic and zoogeography of amphibia of Borneo and reported that hundreds of collected adults *B. asper* were observed on the banks of small streams and rivers. Furthermore, all of those streams flowed through rain forest.

Berry (1970) investigated food of *B. asper* inhabiting in Malaysia and found that *B. asper* fed upon a wide range of invertebrates, but there was little or no marked seasonal variation in diet.

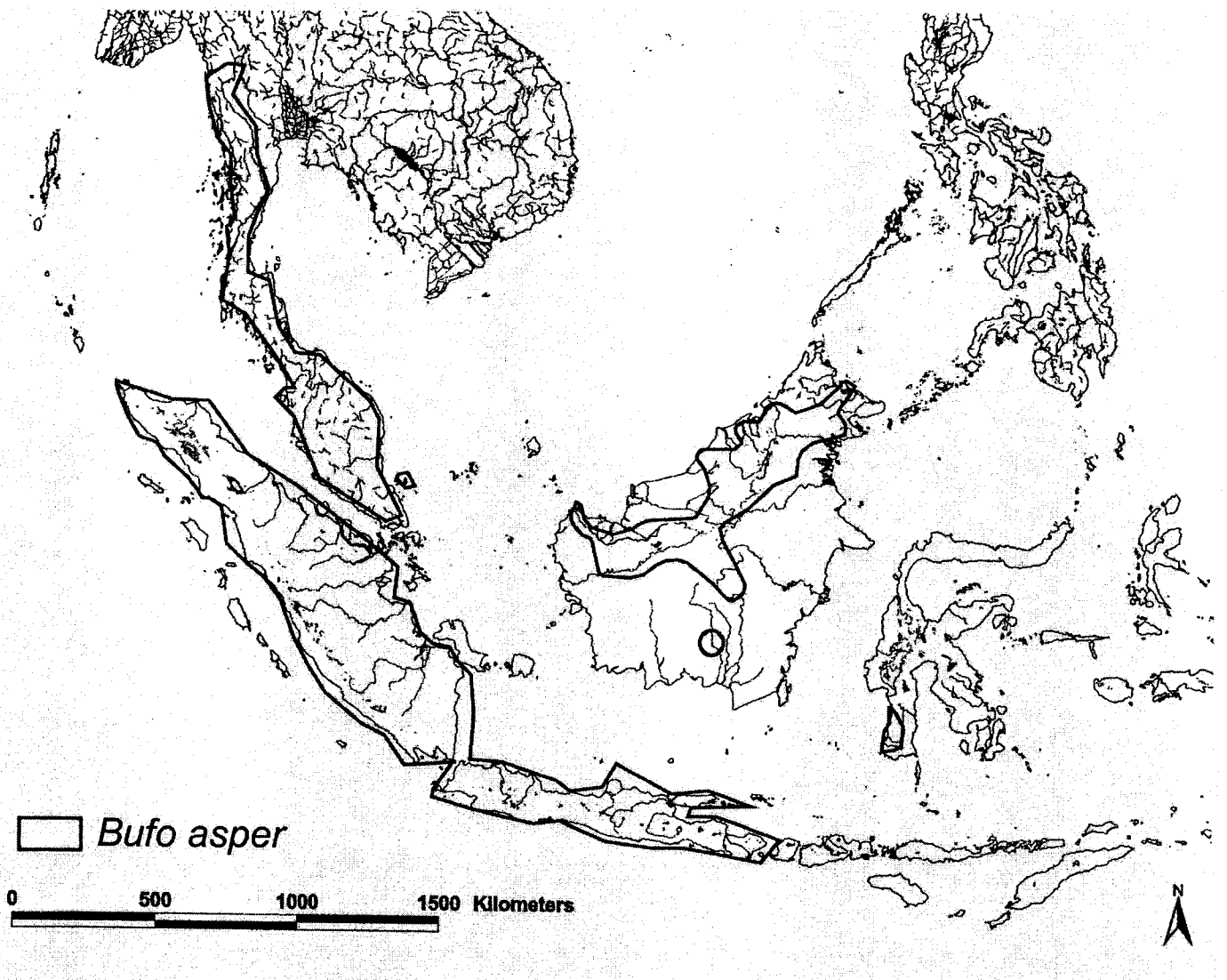


Figure 2.2 Distribution range of *Bufo asper* Gravenhorst, 1829 (modified from IUCN, 2002).

2.3 Population

Population is a collection of organisms of the same species occupying a defined geographic area. A species which is itself a population may consist of local populations. Those populations are separated in distance and that exchange migrants with one another (Ehrlich and Roughgarden, 1987).

Beklemishev (1960) classified populations into 6 types as the followings:

Independent population: population which can persist without any immigration, and its numbers do not depend on immigration.

Semi-dependent population: population which can persist without any immigration, however, its numbers depend on immigration. If there is no immigration, the abundance is much lower than in the presence of immigration.

Dependent population: population that can not persist without immigration. Organisms can reproduce in the area but the reproduction is not sufficient to sustain population numbers.

Pseudopopulation: population that can not reproduce at all. All organisms are immigrants.

Temporary population: In contrast to the first 4 types, this population always gets extinct after a while. Re-colonization is a rare event. For some period of time, the population is absent. Temporary populations may reproduce however it is not sufficient.

Hemipopulation: this is a population that consists of individuals in specific stages. Only those species have hemipopulations that change their environment during the life cycle. Example: a hemipopulation of dragonfly larvae in the lake.

For many ecological studies and conservation planning, the estimate of the abundance of a particular population and the population structure are necessary (Krebs, 1989; Friedl and Klump, 1997).

Ehrlich and Roughgarden (1987) suggested that the size of a population is rarely measured by counting the individuals in it, because all of individuals can not be located and their number may be too large. Instead, the size of a population is usually

measured by counting the number in some subset of the population and then statistically estimating for the total size and the common techniques that are used for measure population size in many species are mark and recapture or resight.

Krebs (1989) reviewed and concluded the method for estimation the size of population as the followings:

- Mark-recapture methods
- Removal methods and resight methods
- Quadrat counts
- Line transects and distances methods

Moreover, the population can be classified into:

- Closed population: the population that does not change in size during the study period. The effects of births, deaths, and movements are negligible and populations are typically closed over only a short period of time.
- Open population: the population that changes in size and composition from births, deaths, and movements. Open population is the more usual case.

Monitoring for amphibian population is the topic of increasing interest due to many species in many parts of the world have been considered as in decline (e. g., Blaustein and Wake, 1990; Crump, 2002; Lehtinen, 2002).

Wake (1994) concluded that species of amphibians in many parts of the world that once were common or occurred in dense populations had indeed declined and some possibly to the point of extinction. No single factor or set of factors could be advance to explain the decline, although habitat destruction and general environmental degradation were clearly implicated in many instances. Especially disturbing was the disappearance of certain celebrated species, such as the gastric-brooding frog and the golden toad, from well protected and large nature preserves.

Houlahan et al. (2001) studied on 936 amphibian populations that are representative of the global amphibian fauna and concluded that amphibians have been and are still declining.

Crump (2002) reported that most herpetologists now agree that amphibians are declining worldwide and reports from five continents reveal that population sizes have decreased, entire populations have disappeared, and some species have gone extinct.

However, Heyer et al. (1994) reviewed and provided a compilation of standardized methods for measuring amphibian biological diversity due to some of the information on amphibian declines was anecdotal and standard methods for documenting population changes did not exist or were not generally known. The methods that were proposed for measuring the population size were mark-recapture method and removal method.

Concerning conservation and other objectives, population ecology of amphibian in many parts of the world were examined.

Thornton (1961) investigated population dynamics in two sympatric species *Bufo woodhousei* and *Bufo valliceps* in Austin, Texas using toe-clipping method to study the habits and population structure with special attention to population size and movements of individuals. It was found that the size of breeding populations of both species was small (less than 200) and individual male toads tended to remain in their original breeding site from season to season.

Frazer (1967) monitored a breeding colony of *Bufo bufo* in Kent from 1955 to 1961 using toe-clipping and bead-sewing method to elucidate the factors concerned in the timing of breeding of the toad. It was reported that the population of breeding males varied between 900 and 2,000 individuals. The female numbers were only half to two-thirds those of the males. Only eleven per cent of the male present one year normally appeared during the next breeding season.

Berven (1990) followed two populations of *Rana sylvatica* in Maryland for 7 years to examine population regulation and reported that the breeding population size fluctuated by a factor of 10. Variation in the adult population among years was largely due to variation in juvenile recruitment. Most variation in the proportion of individual surviving to adulthood was due to variation in larval survival. Adult population size also negatively affected total clutch volume. Mean monthly rainfall positively affected adult survival.

Green (1992) studied population sizes and trend of *Bufo woodhousei* at Long Pont, Ontario using toe-clipping method and found that the calling male abundance rose markedly from 11 toads in the survey area in 1988 to over 245 in 1991. Non calling males, adult females, and juveniles showed a similar trend. The high water levels in Lake Erie in the mid-1980s that could have produced less favorable conditions for tadpole development and survivorship may have been responsible for the previous decline in toad abundance.

Alford et al. (1995) figured out population biology of *Bufo marinus* in Northern Australia since 1986 for examining the possibilities for biological control of this species and reported that no difference in rate of reproduction, growth, and survival between old and recently colonised populations was found.

Barreto and Moreira (1996) studied age structure of savanna larva anurans in central Brazil to obtain basic information for understanding ecological aspects of the adult phase and reported that *Scinax* sp. and *Hyla albopunctata* showed seasonal variation in size structure of their tadpole populations. The juvenile recruitment only occurred during the rainy season although the larva recruitment occurred throughout the year.

Green (1997) investigated abundance of *Bufo foweri* at Long Point, Ontario by tracking and using removal sampling during the breeding season in 1988 to 1994 and reported that the number of captured and marked males rose markedly from 12 toads in 1988 to 294 in 1991 then declined to 83 in 1994. Spring field studies and reference to weather records failed to identify factors correlated with the either the increase in adult males beginning in 1990 to 1991 or the decline of 1994.

Friedl and Klump (1997) examined population aspects of *Hyla arborea* in southern Germany during the breeding seasons in 1990 and 1991 using toe-clipping method and found that males outnumbered females at the breeding site in breeding site in both years. The observed sex ratio was 1.52: 1 and 2.15: 1 in 1990 and 1991, respectively. The age structure of the breeding population differed between the two study years. This difference in the age structure was correlated with yearly difference in the amount of rainfall during the reproductive season.

Magnusson et al. (1999) monitored a population of *Hyla boans* in central Amazonian rainforest during 15 years and reported that the population declined to zero density after nine years of study and the size still had not been recolonized six years later. The exponential rate of decline of the population (-0.58) was more than three times the exponential rate of increase (0.15) at the beginning of the study.

Lowe (2001) studied population structure of two sympatric species salamanders *Plethodon elongatus* and *Ensatina eschscholtzii* in the Klamath Mountains of northern California and found that *E. eschscholtzii* were twice as numerous as *P. elongatus* but both species had similar survival rates.

Patto and Pie (2001) investigated population dynamics of *Hylodes asper* in Southeastern Brazil and reported that there was clear seasonal variation in population structure and the population was characterized by the high juvenile recruitment.

2.4 Habitat Utilization

The need to gain a comprehensive understanding of the habitat utilization of amphibian is increasing in the light of apparent declines of some species. Moreover, the data on movement and habitat utilization are invaluable for management and restoration plan (Matthews and Pope, 1999; Monello and Wright, 1999; Seebacher and Alford, 1999).

Many studies have characterized or examined movement and habitat utilization of amphibians because the habitat is believed to play a role in distribution, abundance, and reproduction of them (Monello and Wright, 1999). Furthermore, movement and aggregation of individuals in the habitat of which the resource distribute have important effects on breeding behavior and survival of them (Marsh, Rand, and Ryan, 2000).

Semlitsch (1981) investigated terrestrial activity of *Ambystoma talpoideum* and reported that emigration of adults from breeding sites occurred in summer. Adults spent 237-354 days in terrestrial habitats before returning to breeding sites during autumn and early winter. Females spent significantly more time in terrestrial habitats than males.

Reading, Loman, and Madsen (1991) examined movement of *Bufo bufo* and found that the degree of relocation between ponds was negatively correlated to the distance between ponds. In any year, between 79% and 96% of adults that survived to breed the following year returned to the original pond.

Schlupp and Podloucky (1994) studied change in breeding site fidelity of a population of strong site fidelity species *Bufo bufo* for 7 years and found that a majority of the adult population became attached to the substitute breeding pond after only two to three years. The migration directed at the old breeding site dropped to approximately 15% after four years and subsequently to less than 1 %.

Spieler and Linsenmair (1998) figured out migration pattern of *Hoplobatrachus occipitalis* using radio transmitters from 1993 to 1995 and found that the frogs were found in diurnal shelters that offered favorable temperature and humidity conditions as well as protection against predators.

Matthews and Pope (1999) investigated movement of *Rana muscosa* using radio transmitters and found that *R. muscosa* had different movement patterns and habitat associations during the summer period compared to the winter when the dormancy period began.

Seebacher and Alford (1999) studied movements and microhabitat use of *Bufo marinus* and found that seasonal patterns in movement and microhabitat use were primarily related to soil moisture, rather than air temperature or relative humidity. Occasionally, toads returned to the same shelter site after activity at night, but the activity of homing was not greater than expected from a random model.

Marsh et al. (2000) investigated movement and aggregation of Physalaemus pustulosus and reported that male site fidelity increased with inter-pond distance and male aggregation decreased with distance. Phonotactic limits might play an important role in movements and spacing patterns.

Miaud, Sanuy, and Avrillier (2000) investigated terrestrial movement of *Bufo calamita* and reported that during the breeding season toads moved distances of up to

500 m between breeding sites. No significant difference in movement patterns was found between sexes but males showed higher terrestrial site fidelity than females.

Griffin and Case (2001) found significant differences between sex in land use and vegetation-type preferences of *Bufo microscaphus californicus*.

Mazerolle (2001) investigated the activity and direction of movement of amphibians in pristine and fragmented bogs of southeaster New Brunswick and found that seasonal activity patterns of amphibians in bogs corresponded to movements of adults and juveniles from adjacent wetlands and suggested that climatic variables, either *precipitation or minimum air temperature generally good predictors of amphibian activity.*

Chapter III

Study Site

3.1 Location

The study site was Tarn Lord Noi Cave. This cave, a popular cave for tourist is located in Chaloem Rattana Kosin National Park, Khao Jode Subdistrict, Si Sawat District, Kanchanaburi Province. Following the geological classification, this cave is in the western range of Thailand.

Tarn Lord Noi Cave is located in the middle area of the national park. It is about 100 m from the park headquarter. The location of the upstream entrance is 0533144E, 1620969N and 0533252E, 1620701N for the downstream exit. The elevation at the upstream entrance is about 317 m from the average sea level. The width and the height of this entrance are about 35 and 7 m, respectively. The elevation at the downstream exit is about 300 m from the average sea level. The width and the height at this exit are about 25 and 7 m. This cave is about 320 m in length. It can be divided into 3 major parts, including one main cave and two minor caves. The main cave is about 280 m long and its passage is in the northwest to the southeast direction. Each of the minor caves is about 20 m in length.

3.2 Topography

The topography inside the cave is not too steep. The floor slopes down from the west to the east. The height of the ceiling varies throughout the cave. Thus the ceiling is against the flow of water in some parts of the cave.

3.3 Type

This cave is a stream cave. There is a rocky permanent stream, Huai Mae Kraphroi, flows through. Most of the stalactite and the other environments in the cave above the normal water level are quite dry. Hence, this cave is considered to be a dead cave or a dry cave in the future.

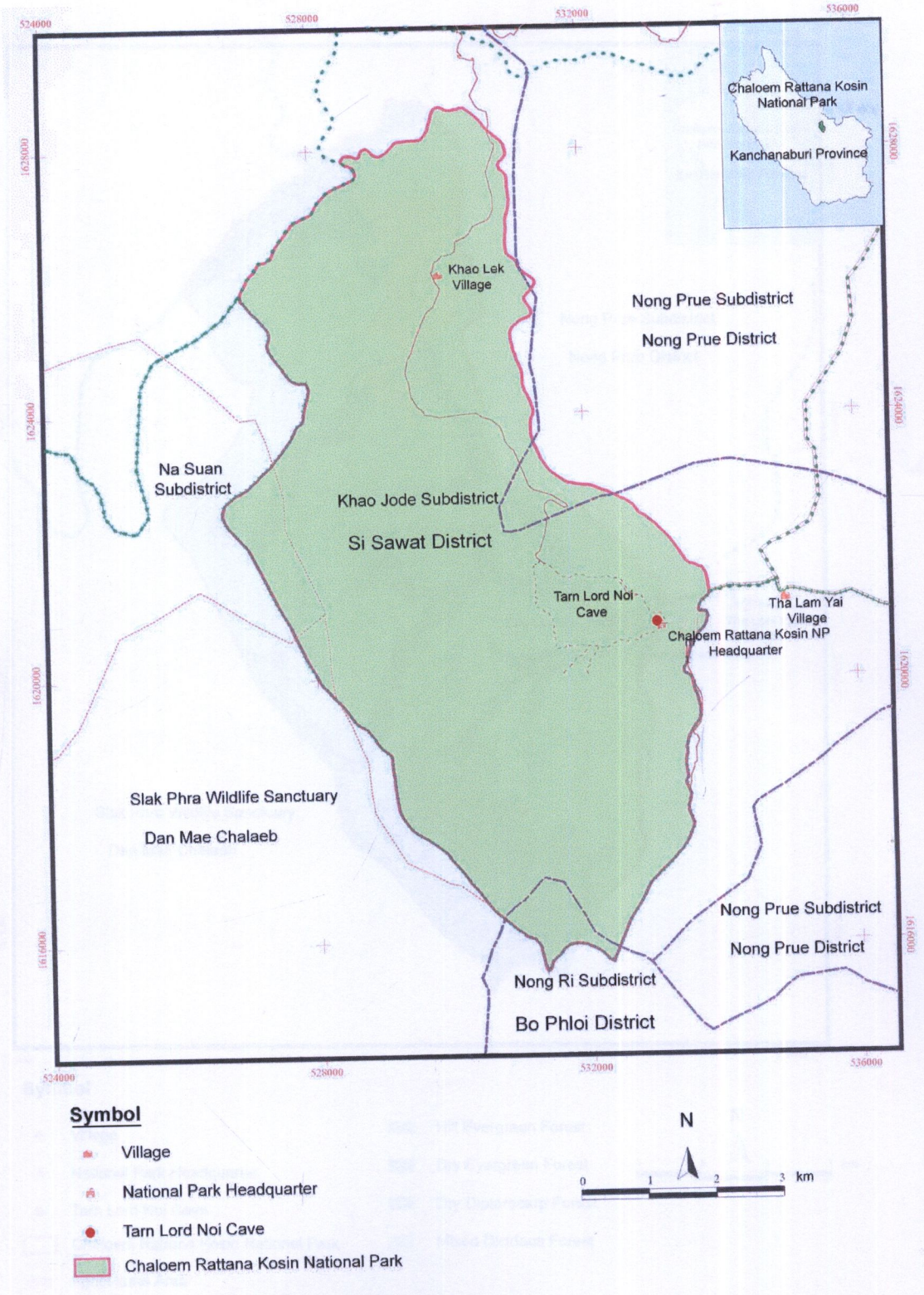


Figure 3.1 Map of Chaloem Rattana Kosin National Park and location of Tarn Lord Noi Cave (Modified from C-Tech International Co, Ltd., 2002).

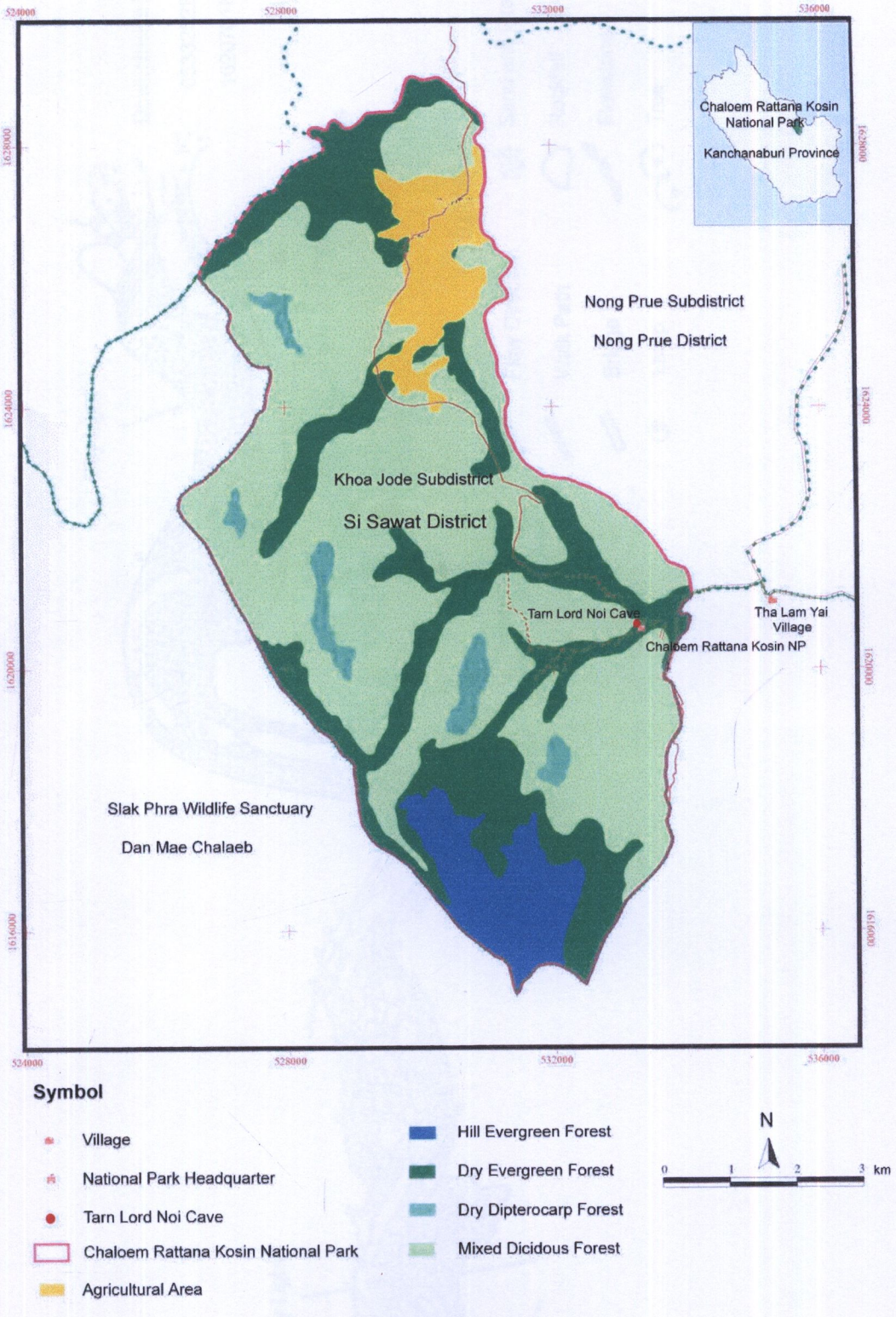


Figure 3.2 Map of forest types at Chaloem Rattana Kosin National Park (Modified from C-Tech International Co, Ltd., 2002).

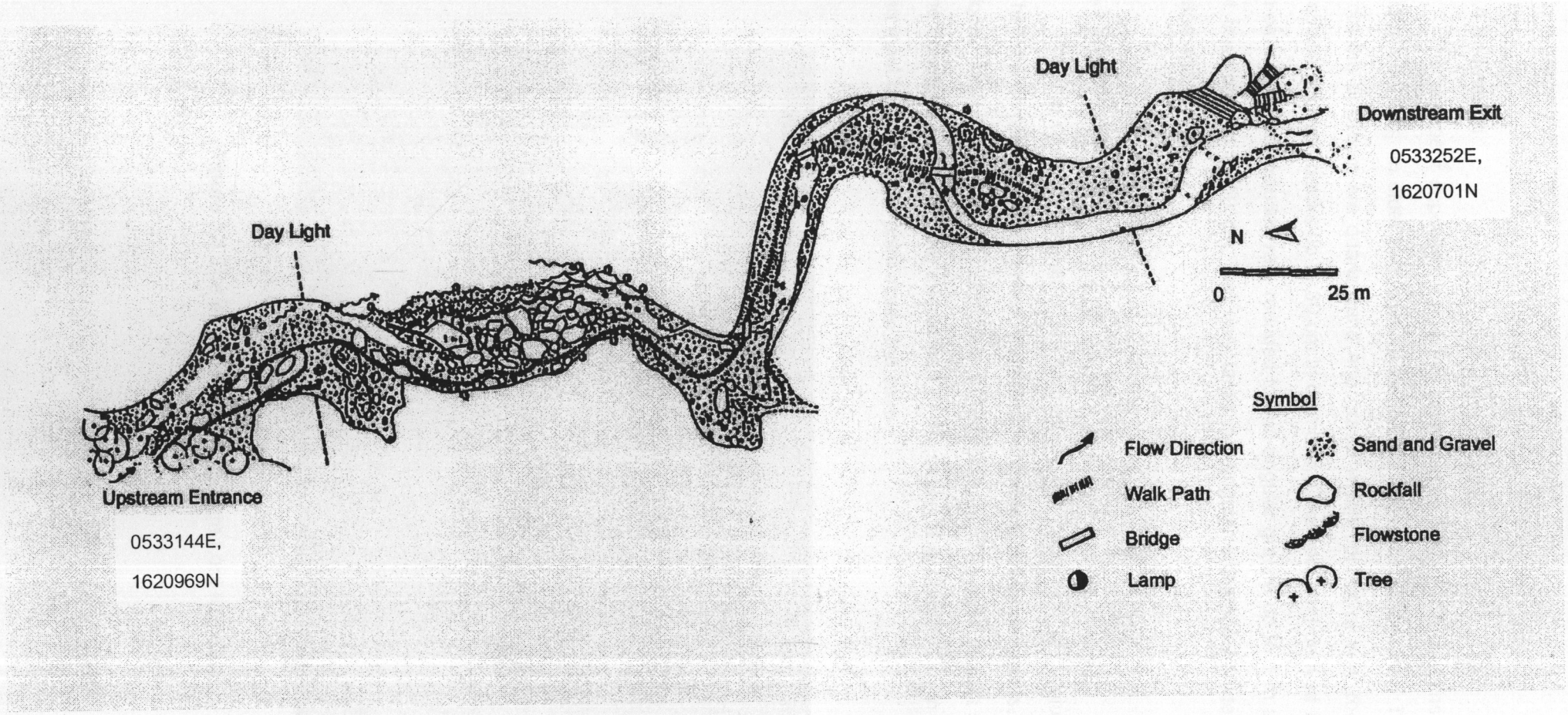


Figure 3.3 Map of Tarn Lord Noi Cave, Chaloem Rattana Kosin National Park, Kanchanaburi Province (Modified from C-Tech International Co, Ltd., 2002).

3.4 Sediments

The sediment deposited inside the cave comes from the mountains upstream by water and from an older sequence of sediments within the cave itself. The sediments from the upstream are quartz sand and gravel which consist of very rounded granite pebbles and rare blocks up to 30 cm in diameter. The sediment derived from the older in-cave deposits included rare rounded to sub-angular granite up to 1 m across, pieces of flowstone up to 50 cm, and very large sub-angular limestone boulders as well as sand and gravel.

3.5 Speleothems

For this cave, speleothems are formed by the deposition of calcium carbonate. They are consisted of stalagmites, stalactites, draperies, flowstone sheets, and rimstone pools. Most of them are dry and covered with powder. The most distinct speleothem is the flowstone located at the middle part of the cave. It is about 50 m in length and is the most beautiful view point inside the cave.

Figure 3.4 The environment inside Tarn Lord Noi Cave.

3.6 Stream

Huai Mae Kraphroi is a permanent rocky stream that flow throughout the cave. The stream varies in its width due to the water level. In March 2002, before the rainy season, the narrowest part of the stream inside the cave was about 1 m. The water level was highest in May 2002 that caused by heavy rain and the widest part of the stream inside was about 10 m.

Figure 3.5 Stream width at the downstream entrance in November 2001.

Figure 3.6 Stream width at the downstream entrance in April 2002.

Figure 3.7 Stream width at the downstream entrance in May 2002.

Chapter IV

Materials and Methods

4.1 Materials

4.1.1 Vernier caliper (15 cm)

4.1.2 Spring balance (3 kg)

4.1.3 Operation materials

4.1.4 Vial bottles

4.1.5 Head lamp

4.1.6 GPS

4.1.7 Compass

4.1.8 Thermometer

4.1.9 Wet-dry hygrometer

4.1.10 Latex gloves

4.1.11 10% Formaldehyde

4.1.12 Antibiotic medicine

4.2 Collection of Data

A total of 15 surveys were carried out monthly from July 2001 to June 2002. Due to the high water level and the danger of entering the cave in rainy season, the survey in October 2001 and May 2002 were done only 5 and 13 times, respectively.

In the cave, the area inside was divided into 9 sections (30 m interval) along the length of the cave (270 m) for the study of habitat utilization (Appendix A).

The toads that were found in any survey were collected by hand or sweep net and individually marked using toe-clipping method. All of them were weighed to the nearest 5 g with a spring balance and the snout to vent length was measured to the nearest 0.1 mm with a vernier caliper. Sex, age, breeding behavior, and location were recorded for all toads.

The toads could be sexed and aged using their sizes (snout to vent length), secondary sexual characters (Figure 4.1 to Figure 4.3), and breeding behavior. Because of smaller size and had no secondary sexual character or breeding behavior, juveniles could be separated from adults. Male toads could be identified using the appearance of nuptial pads on their thumbs and the opening of vocal sac. In contrast, female toads had neither vocal sac opening nor nuptial pad and were larger than male toads.

Figure 4.1 Male with vocal sac opening.

In any survey, every time a toad was found, it was caught to check its number, location and breeding behavior. Normally, a marked toad was weighed and measured once a month. After the toad had been examined, it was released at the point of capture. Moreover, eggs and tadpoles were also searched to examine their breeding season from March 2001 to July 2002.

Environmental factors including air temperature, soil surface temperature, water temperature, relative humidity, and relative humidity at soil surface were recorded for both inside and outside the cave every time the survey was done.

Figure 4.2 Male with dark nuptial pads on the base of thumbs.

Figure 4.3 Female without nuptial pad.

4.3 Data Analysis

4.3.1 Population Study

4.3.1.1 Population Estimation

Population parameters including proportion of marked toads, population size, probability of survival, and number of new toads joining the population were estimated using Jolly-Seber Program (Krebs, 1989). The formulas are as follows:

- **Proportion of marked toads**

$$\alpha_t = \frac{m_t+1}{n_t+1}$$

where

α_t = Proportion of marked toads at sample t

m_t = Number of marked toads caught in sample t

n_t = Total number of toads caught in sample t

- **Size of marked population**

$$M_t = \frac{(s_t+1)Z_t}{R_t+1} + m_t$$

Where

M_t = Estimated size of the marked population just before sample time t

s_t = Total number of toads released after sample t

Z_t = Number of toads marked before sample t, not caught in sample t, but caught in some sample after sample t

m_t = Number of marked toads caught in sample t

R_t = Number of the s_t toads released at sample t and caught again in some later sample

- **Population size**

$$N_t = \frac{\text{Size of marked population}}{\text{Proportion of marked toads}}$$

$$N_t = \frac{M_t}{\alpha_t}$$

Where

N_t = Estimated population size just before sample time t

M_t = Estimated size of the marked population just before sample time t

α_t= Proportion of marked toads at sample t

- **Probability of survival**

$$\phi_t = \frac{\text{Size of marked population at start of sample time t+1}}{\text{Size of marked population at end of sample time t}}$$

$$\phi_t = \frac{M_{t+1}}{M_t+(s_t-m_t)}$$

where

ϕ_t = Probability of survival from sample time t to sample time t+1

M_{t+1} = Estimated size of the marked population just before sample time t+1

M_t = Estimated size of the marked population just before sample time t

s_t = Total number of toads released after sample t

m_t = Number of marked toads caught in sample t

- **Number of new toads joining the population**

$$B_t = N_{t+1} - \phi_t(N_t-(n_t-s_t))$$

B_t = Number of new animals joining the population between time t and t+1 and still alive at time t+1

N_{t+1} = Estimated population size just before sample time t

N_t = Estimated population size just before sample time t

ϕ_t = Probability of survival from sample time t to sample time t+1

n_t = Total number of toads caught in sample t

s_t = Total number of toads released after sample t

Calculations were performed using Microsoft Excel version 7.0 for Windows 98. Statistical analysis was performed using SPSS version 10.0 for Windows.

4.3.1.2 Correlation between Population Size and Climatic Factor

The correlation between population size and each climatic factor (temperature and relative humidity) was examined using Spearman's correlation analysis at $P<0.05$ (SPSS version 10.0).

4.3.1.3 Population Structure

- Proportion of population size among sexes and age was calculated.

- Size distribution was examined considering the number of individuals of each size-class.

4.3.2 Habitat Utilization

4.3.2.1 Movement

Movement of the toad was considered from the location in which the toad was found.

4.3.2.2 Area Utilization

The toad of which the location was recorded at least 25 times was used in the study of area utilization.

4.3.2.2.1 Area Fidelity

- Due to the area inside the cave was divided into 9 sections, the difference in appearance of each toad in its utilized sections was tested using Chi-square test at $P<0.05$.

- Shannon-Weiner's diversity index (Krebs, 1989) was used to examine individual niche width in term of area utilization. The difference in the mean of diversity index between sexes and between breeding and non-breeding season was examined using t-test for equality of means. The formula of Shannon-Weiner's diversity index is as follow:

- **Shanon-Weiner index**

$$H = -\sum_{i=1}^{s} Pi \log Pi$$

where

H = Shannon-Weiner Index

= Index of area utilization diversity

S = Number of utilized areas

Pi = Proportion of locations in area i to the total location of each toad

- Calculations were performed using Microsoft Excel version 7.0 for Windows 98. Statistical analysis was performed using SPSS version 10.0 for Windows.

4.3.2.2.2 Favored Area

Chi-square test was used to examine the difference in proportion of toad found in the most frequently utilized area.

4.3.3 Breeding Season

The breeding season of them was determined using the appearance of mating, eggs, and tadpoles.

Chapter V

Results and Discussion

5.1 Fluctuation of Relative Humidity and Temperature during the Study Period

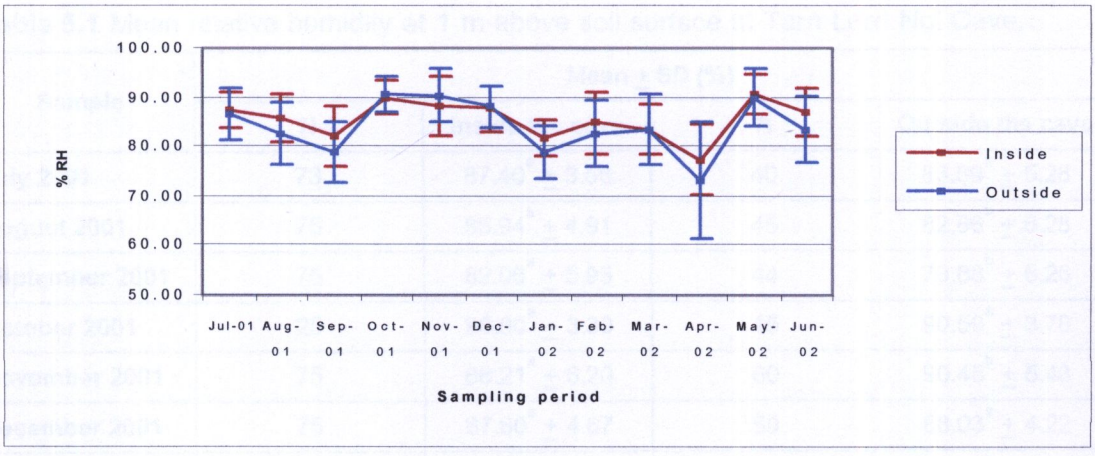
During July 2001 to June 2002, the fluctuation of relative humidity in the cave was quite similar to the relative humidity outside as shown in Figure 5.1. Both inside and outside of the cave, the mean relative humidity remained relatively high throughout the year. Huai Mae Kraphroi, the permanent stream flow through the cave, might cause this condition by supporting humidity both inside and outside the cave. The average humidity about 1 m above surface varied from 77.43 to 90.73 % for the inside and varied from 73.12 to 90.59 % for the outside. At soil surface, the average relative humidity inside varied from 79.30 to 91.22 % and from 73.45 to 91.78 % for the outside.

There were significant differences (t-test: $P<0.05$) in the mean relative humidity between inside and outside of the cave in some periods of the year. In August, September and November 2001 and January, April and June 2002, the relative humidity about 1 m above the surface was significantly different between the inside and the outside (Table 5.1). Those times, except in November 2001, the relative humidity inside was higher than the relative humidity outside. During the sampling in November, the heavy rain just was over and there was little rain during the survey. The evaporation from the stream and the soil outside as well as the rain itself might cause the higher humidity.

For the relative humidity at soil surface, there was a significant difference between inside and outside the cave in August and September 2001 and January, February, April and June 2002 (Table 5.2). All of those times the relative humidity at soil surface inside the cave was higher than the outside.

The higher relative humidity inside the cave throughout the study time could be due to the evaporation from the stream and the soil circulated in the limited area of the cave and slowly leaked to the outside.

a.



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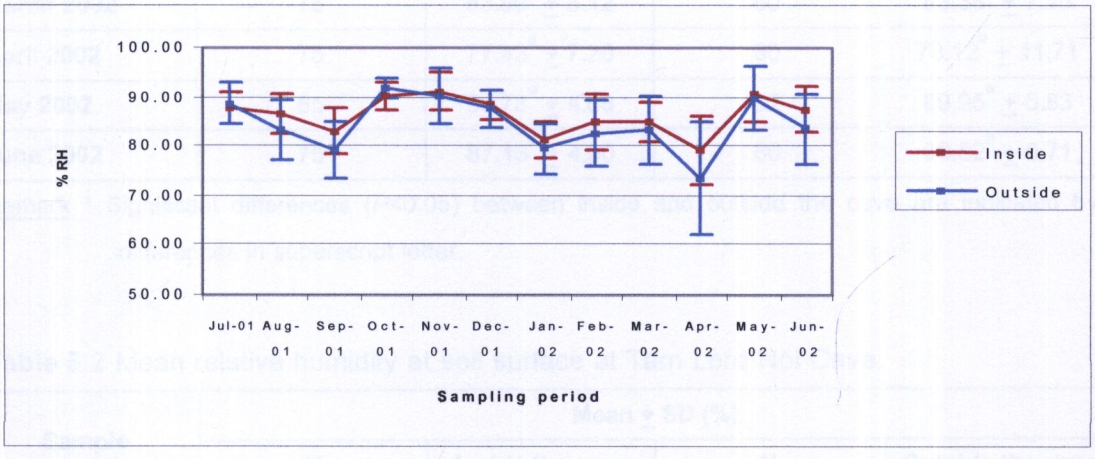


Figure 5.1 Mean (± SD) relative humidity at Tarn Lord Noi Cave during July 2001 to June 2002. a. at 1 m above soil surface b. at soil surface

Table 5.1 Mean relative humidity at 1 m above soil surface at Tarn Lord Noi Cave.

Sample	Mean ± SD (%)			
	N	Inside the cave	N	Outside the cave
July 2001	73	$87.40^{a} \pm 3.56$	40	$86.69^{a} \pm 5.26$
August 2001	75	$85.94^{a} \pm 4.91$	45	$82.66^{b} \pm 6.28$
September 2001	75	$82.06^{a} \pm 5.95$	44	$78.88^{b} \pm 6.26$
October 2001	25	$90.00^{a} \pm 3.30$	15	$90.59^{a} \pm 3.76$
November 2001	75	$88.21^{a} \pm 6.20$	60	$90.45^{b} \pm 5.43$
December 2001	75	$87.60^{a} \pm 4.67$	59	$88.03^{a} \pm 4.22$
January 2002	75	$81.57^{a} \pm 3.60$	60	$79.04^{b} \pm 5.27$
February 2002	75	$84.77^{a} \pm 6.37$	60	$82.62^{a} \pm 6.69$
March 2002	75	$83.50^{a} \pm 5.12$	60	$83.38^{a} \pm 7.15$
April 2002	75	$77.43^{a} \pm 7.20$	60	$73.12^{b} \pm 11.71$
May 2002	65	$90.73^{a} \pm 4.08$	52	$89.95^{a} \pm 5.83$
June 2002	75	$87.13^{a} \pm 4.90$	60	$83.52^{b} \pm 6.71$

Remark * Significant differences ($P<0.05$) between inside and outside the cave are indicated by differences in superscript letter.

Table 5.2 Mean relative humidity at soil surface at Tarn Lord Noi Cave.

Sample	Mean ± SD (%)			
	N	Inside the cave	N	Outside the cave
July 2001	73	$87.84^{a} \pm 3.40$	30	$88.71^{a} \pm 4.21$
August 2001	70	$86.55^{a} \pm 4.21$	28	$83.18^{b} \pm 6.10$
September 2001	74	$83.04^{a} \pm 4.58$	29	$79.32^{b} \pm 5.81$
October 2001	25	$90.30^{a} \pm 2.72$	10	$91.78^{a} \pm 1.95$
November 2001	75	$91.22^{a} \pm 3.75$	43	$90.37^{a} \pm 5.66$
December 2001	72	$88.45^{a} \pm 3.12$	46	$87.76^{a} \pm 3.82$
January 2002	75	$81.47^{a} \pm 3.64$	46	$79.50^{b} \pm 4.93$
February 2002	75	$85.07^{a} \pm 5.62$	60	$82.63^{b} \pm 6.78$
March 2002	75	$84.97^{a} \pm 4.06$	60	$83.24^{a} \pm 7.02$
April 2002	75	$79.30^{a} \pm 6.82$	60	$73.45^{b} \pm 11.38$
May 2002	65	$90.77^{a} \pm 5.72$	52	$89.76^{a} \pm 6.59$
June 2002	75	$87.50^{a} \pm 4.59$	60	$83.56^{b} \pm 7.03$

Remark * Significant differences ($P<0.05$) between inside and outside the cave are indicated by differences in superscript letter.

The mean temperature in the cave was quite parallel to the mean temperature outside as shown in Figure 5.2. The mean temperature was quite stable from July to October 2001 then it decreased sharply to the minimum in the winter (January 2002). The minimum air temperature, soil surface temperature, and water temperature inside the cave were 16.96, 16.91, 17.10 ^{o}C, respectively and were 17.07, 16.86, 17.20 ^{o}C, respectively for the outside. Then the temperature increased sharply and raised to the maximum in the summer (May to June 2002). The maximum air temperature, soil surface temperature, and water temperature inside the cave were 24.85, 24.28, 24.31 ^{o}C, respectively and were 25.60, 25.08, 24.93 ^{o}C, respectively for the outside.

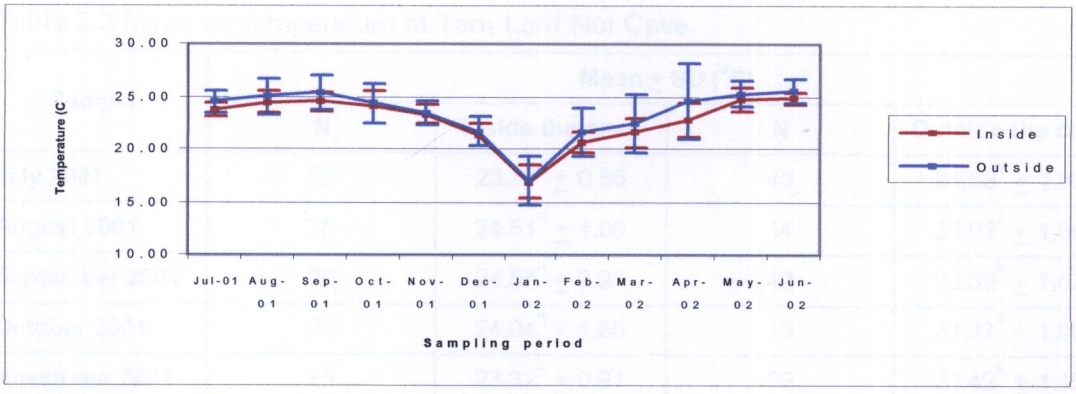
There were significant differences (t-test: $P<0.05$) in the mean temperature between inside and outside of the cave for some periods of the study. The air temperature inside was significantly lower than the temperature outside in July and September 2001 and February to June 2002 (Table 5.3).

The temperature at soil surface was significantly different between inside and outside in July, August, September, and December 2001 and February to June 2002 (Table 5.4). In all of these months, the temperature inside was lower than the temperature outside.

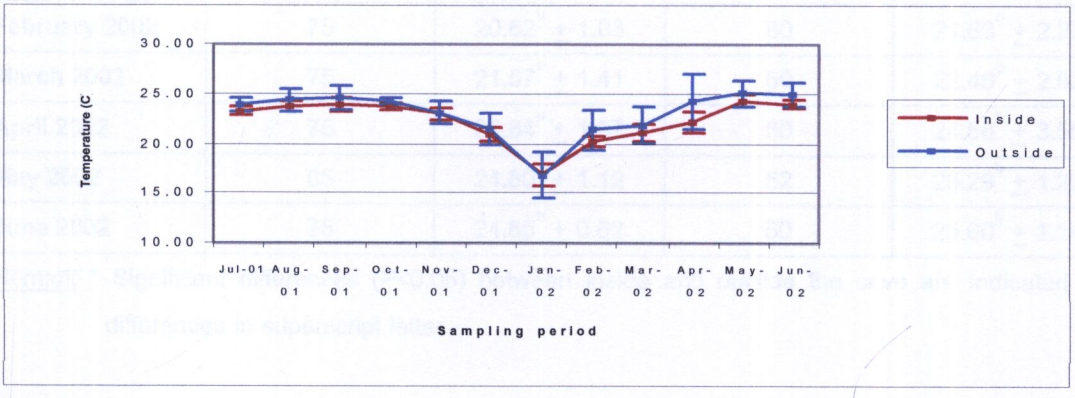
The water temperature inside was significantly lower than the water temperature outside only in April and May 2002 (Table 5.5).

The lower temperature inside the cave could be due to the sun did not directly shine to the cave. Thus, air mass, water, as well as the soil surface could not absorb the heat as much as the environment outside did. For the water temperature, the water upstream flowing through the cave might cause the same condition between inside and outside throughout the sampling period.

a.



b.



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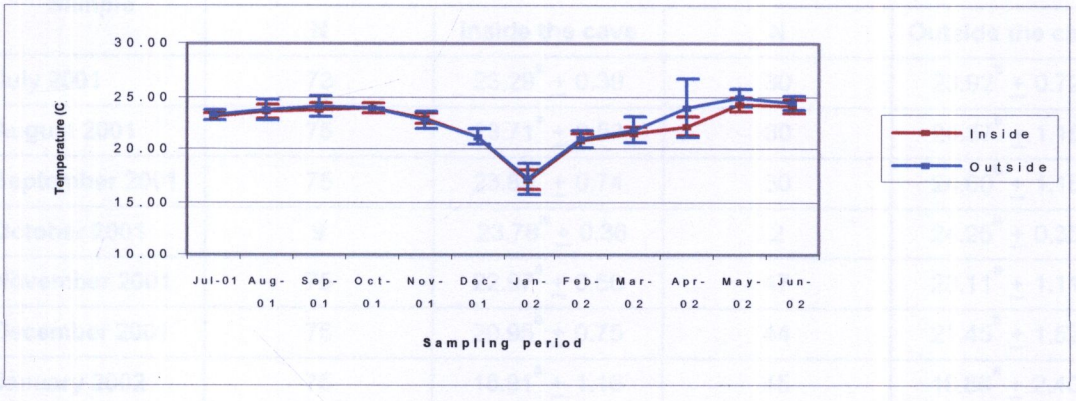


Figure 5.2 Mean (+SD) temperature at Tarn Lord Noi Cave during July 2001 to June 2002. a. air b. soil surface c. water

Table 5.3 Mean air temperature at Tarn Lord Noi Cave.

Sample	Mean ± SD (°C)			
	N	Inside the cave	N	Outside the cave
July 2001	73	$23.77^{a} \pm 0.66$	43	$24.53^{b} \pm 1.09$
August 2001	75	$24.51^{a} \pm 1.05$	44	$25.03^{a} \pm 1.68$
September 2001	75	$24.57^{a} \pm 0.91$	42	$25.38^{b} \pm 1.67$
October 2001	25	$24.04^{a} \pm 1.55$	15	$24.37^{a} \pm 1.93$
November 2001	75	$23.32^{a} \pm 0.91$	59	$23.42^{a} \pm 1.16$
December 2001	75	$21.36^{a} \pm 1.03$	60	$21.68^{a} \pm 1.43$
January 2002	75	$16.96^{a} \pm 1.51$	60	$17.07^{a} \pm 2.35$
February 2002	75	$20.62^{a} \pm 1.03$	60	$21.63^{b} \pm 2.27$
March 2002	75	$21.57^{a} \pm 1.41$	60	$22.49^{b} \pm 2.83$
April 2002	75	$22.84^{a} \pm 1.67$	60	$24.56^{b} \pm 3.56$
May 2002	65	$24.80^{a} \pm 1.12$	52	$25.29^{b} \pm 1.23$
June 2002	75	$24.85^{a} \pm 0.62$	60	$25.60^{b} \pm 1.14$

Remark * Significant differences ($P<0.05$) between inside and outside the cave are indicated by differences in superscript letter.

Table 5.4 Mean soil surface temperature at Tarn Lord Noi Cave.

Sample	Mean ± SD (°C)			
	N	Inside the cave	N	Outside the cave
July 2001	73	$23.29^{a} \pm 0.39$	30	$23.92^{b} \pm 0.72$
August 2001	75	$23.71^{a} \pm 0.53$	30	$24.37^{b} \pm 1.16$
September 2001	75	$23.89^{a} \pm 0.74$	30	$24.60^{b} \pm 1.18$
October 2001	9	$23.78^{a} \pm 0.36$	2	$24.25^{a} \pm 0.35$
November 2001	75	$22.97^{a} \pm 0.56$	47	$23.11^{a} \pm 1.11$
December 2001	75	$20.95^{a} \pm 0.75$	44	$21.45^{b} \pm 1.52$
January 2002	75	$16.91^{a} \pm 1.16$	45	$16.86^{a} \pm 2.40$
February 2002	75	$20.27^{a} \pm 0.53$	45	$21.44^{b} \pm 1.97$
March 2002	75	$21.06^{a} \pm 0.86$	45	$21.88^{b} \pm 1.85$
April 2002	75	$22.17^{a} \pm 1.11$	45	$24.28^{b} \pm 2.75$
May 2002	65	$24.28^{a} \pm 0.59$	39	$25.08^{b} \pm 1.29$
June 2002	75	$23.95^{a} \pm 0.42$	45	$24.97^{b} \pm 1.17$

Remark * Significant differences ($P<0.05$) between inside and outside the cave are indicated by differences in superscript letter.

Table 5.5 Mean water temperature at Tarn Lord Noi Cave.

Sample	Mean ± SD (°C)			
	N	Inside the cave	N	Outside the cave
July 2001	56	$23.17^{a} \pm 0.32$	15	$23.30^{a} \pm 0.46$
August 2001	59	$23.58^{a} \pm 0.65$	15	$23.77^{a} \pm 0.94$
September 2001	59	$23.80^{a} \pm 0.61$	17	$24.09^{a} \pm 1.02$
October 2001	8	$23.94^{a} \pm 0.42$	2	$24.00^{a} \pm 0.00$
November 2001	59	$22.96^{a} \pm 0.52$	29	$22.86^{a} \pm 0.82$
December 2001	60	$21.16^{a} \pm 0.73$	30	$21.22^{a} \pm 0.81$
January 2002	60	$17.10^{a} \pm 0.86$	30	$17.20^{a} \pm 1.50$
February 2002	58	$20.83^{a} \pm 0.61$	30	$21.05^{a} \pm 0.81$
March 2002	56	$21.46^{a} \pm 0.75$	28	$21.88^{a} \pm 1.17$
April 2002	60	$22.19^{a} \pm 0.91$	30	$23.96^{b} \pm 2.81$
May 2002	52	$24.31^{a} \pm 0.65$	26	$24.93^{b} \pm 0.80$
June 2002	60	$24.10^{a} \pm 0.66$	29	$24.45^{a} \pm 0.64$

Remark * Significant differences ($P<0.05$) between inside and outside the cave are indicated by differences in superscript letter.

5.2 Population

5.2.1 Population Size

5.2.1.1 Estimated Population Size, Probability of Survival, and Number Joining

A total of 167 *Bufo asper* founded in the cave were marked from July 2001 to June 2002. The number of recaptured toads were shown in Table 5.6. There were 54 individuals that never been caught anymore in the later samplings and there was only one individual that was recaptured every surveys.

Table 5.6 Number of recaptured *Bufo asper* in Tarn Lord Noi Cave during July 2001 to June 2002.

Number of recapture	0	1	2	3	4	5	6	7	8	9	10	Total
Number of toad	54	33	15	20	12	8	9	2	8	5	1	167

Using the Jolly-Seber model of population estimation (Krebs, 1989), the proportion marked, the estimated population size, the probability of survival and the number of new toads joining the population could be estimated as indicated in Table 5.7 and Figure 5.3.

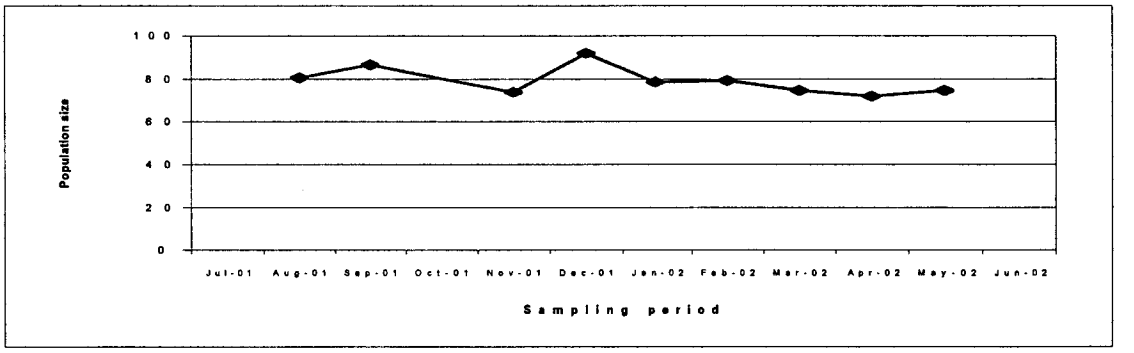
Due to the limitation of Jolly-Seber method, the estimate of population size and the number joining could not be obtained for the first sample and neither of them could be estimated for the last sample. In addition, the probability of survival can not be estimated for the last two samples.

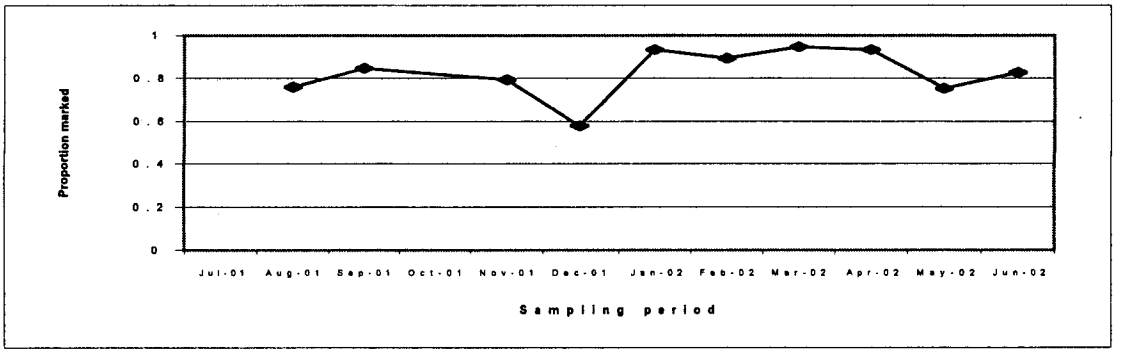
Table 5.7 Population estimates of *Bufo asper* in Tarn Lord Noi Cave.

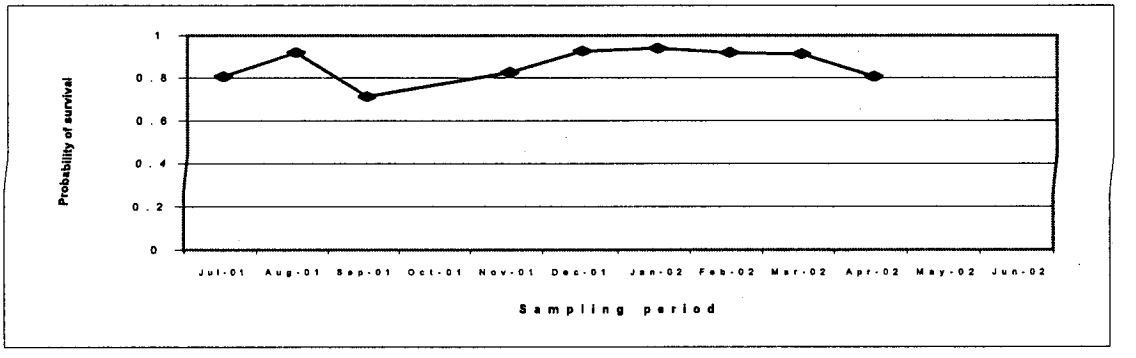
Sample	Proportion marked	Estimated population size (± S. E.)	Probability of survival (± S. E.)	Number joining (± S. E.)
July 2001	---	---	0.809 ± 0.046	---
August 2002	0.759	80.9 ± 3.8	0.919 ± 0.065	12.6 ± 3.0
September 2001	0.850	87.0 ± 7.2	0.715 ± 0.087	12.4 ± 6.1
November 2001	0.793	73.8 ± 9.7	0.827 ± 0.083	30.9 ± 7.6
December 2001	0.581	91.9 ± 8.5	0.928 ± 0.060	-6.4 ± 6.4
January 2002	0.933	78.9 ± 7.5	0.937 ± 0.061	5.6 ± 3.7
February 2002	0.891	79.6 ± 6.5	0.920 ± 0.052	1.5 ± 2.3
March 2002	0.947	74.7 ± 6.4	0.913 ± 0.080	3.7 ± 2.0
April 2002	0.936	71.9 ± 7.9	0.806 ± 0.127	17.1 ± 4.9
May 2002	0.756	75.0 ± 12.8	---	---
June 2002	0.829	---	---	---

Remark --- means that no estimate can be made of this parameter from the available data.

The data from Table 5.7 revealed that estimated population parameters of *B. asper* from July 2001 to June 2002 were dynamic. The proportion of marked toads indicated that the unmarked or new toads were found in every sampling time due to the values of proportion marked were lower than 1.000 for all sampling times. Hence, it could be inferred that there were births or immigrants joining this cave-inhabiting population, or both.







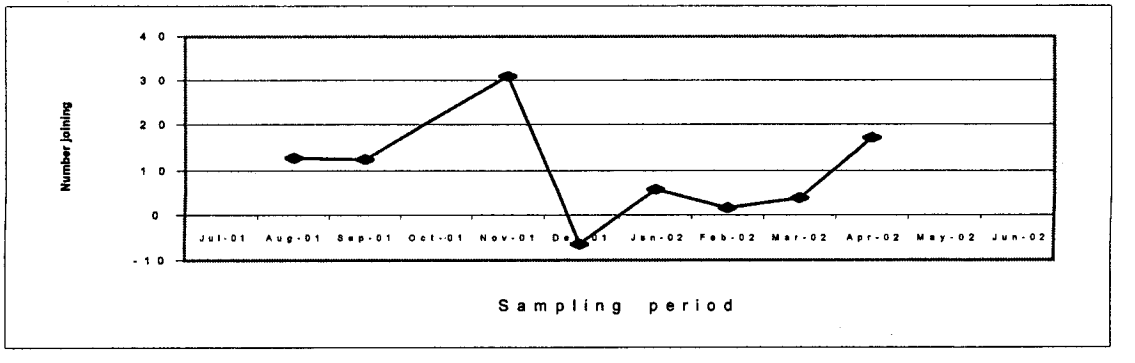


Figure 5.3 Estimated population size, proportion of marked toads, probability of survival, and estimated number of unmarked toad joining the population in Tarn Lord Noi Cave during July 2001 to June 2002.

The estimated population size varied from 71.9 ± 7.9 to 91.9 ± 8.5 individuals. It was largest in December 2001 and smallest in April 2002. The variations of the population sizes during the study period might be due to emigration, immigration, birth, as well as death of the toads. The obtained data on the habitat utilization indicated that there were migrations in this population. Moreover, from the study on the breeding season, the eggs of them were found in the cave.

According to the probability of survival, the survival determined using Jolly-Seber method means staying alive on the study area. Individuals that emigrated were counted as losses in the same way as individuals that died (Krebs, 1989). Moreover, it was determined by the population size of marked toads only. Therefore, the probability of survival belonged to the marked toad, not for all in the population. From the obtained data, the probability of survival varied from 0.715 ± 0.087 to 0.937 ± 0.061. Due to the values were higher than 0.500 for all sampling times, it could be concluded that most of the toads found at the time of interest remained in the cave and found again at the next sampling time. However, it was found that there was 1 dead toad found in September 2001 and another one in June 2002.

The number joining that represented the estimated number of unmarked individuals entering the population varied from -6.4 ± 6.4 to 30.9 ± 7.6 individuals during the study period that, probably by birth, migration, or both as discussed in the results on estimated population size. The number joining was dependent parameter of the size of marked population, the estimated population size, and the probability of survival (the formula is in chapter 4). The values that lower than zero caused by the estimated population size at the time of interest was larger than the estimated population size of the time next to the time of interest or the probability of survival of marked population that time was very high. Although the value was lower than zero but the new individual was found.

5.2.1.2 Population Size, Probability of Survival, and Number Joining as Separated by Sexes

Using secondary sexual characters and snout to vent lengths of all marked toads, the toads could be divided into three groups. The first was a group of male toads. Males were undoubtedly identified because of the distinct nuptial pad on the base of thumb and the opening of vocal sacs in the mouth. Throughout the study period, a total of 70 male toads found in the cave were marked. The second and the third groups were females and young or unidentified sex group. Unlike males, the secondary sexual characters could not be noticed in female and young toads. Because of this reason, the snout to vent length was used to classify the two latter groups.

The snout to vent length of the male was used as a criteria in classification (Green, 1992). From 453 SVL measurements of 86 males (from March 2001 to July 2002), the smallest and the biggest male are 86.7 and 111 mm, respectively. Due to the studies of Taylor (1962) and Inger (1966), males of this species were smaller than females and in many studies reported that nuptial pads are present in adult male toads of some species in genus *Bufo* (e. g., Inger, 1966; Matsui, 1984). So, the toad that was bigger than 111 mm was stated as female and the toad of which size was smaller than or equal to 111 mm was stated as young. For 12 months of data collection, there were 50 female and 51 young toads that were marked. Furthermore, there were 4 marked young became adults (2 males and 2 females) during the study.

As indicated in Table 5.8, after released, most of marked toads were recaptured in the later sampling times. Nevertheless, 13 males, 25 females, and 16 young were not caught again. There was only one male that was recaptured in every sampling time after released (10 times). For females, there was no female that was recaptured more than 6 times. Moreover, none of young toads was recaptured more than 5 times.

Table 5.8 Number of recaptured male, female, and young *Bufo asper* in Tarn Lord Noi Cave during July 2001 to June 2002.

Number of recapture	0	1	2	3	4	5	6	7	8	9	10	Total
Number of male	13	8	4	14	7	5	5	1	7	5	1	70
Number of female	25	10	2	4	4	2	3	0	0	0	0	50
Number of young	16	17	10	4	3	1	0	0	0	0	0	51

Figure 5.4 Female, male, and young *Bufo asper*.

5.2.1.2.1 Population Estimates of the Male

The proportion of marked males, the estimated population size, the probability of survival, and the number of new males joining this population were shown in Table 5.9 and Figure 5.5.

Table 5.9 Population estimates of male *Bufo asper* in Tarn Lord Noi Cave.

Sample	Proportion marked	Estimated population size (± S. E.)	Probability of survival (± S. E.)	Number joining (± S. E.)
July 2001	---	---	0.868 ± 0.055	---
August 2002	0.895	36.9 ± 2.1	0.883 ± 0.059	1.4 ± 0.7
September 2001	0.962	34.0 ± 2.9	1.048 ± 0.102	6.3 ± 3.4
November 2001	0.842	41.9 ± 5.8	0.795 ± 0.100	22.7 ± 4.4
December 2001	0.543	56.0 ± 4.9	0.974 ± 0.051	-4.4 ± 3.4
January 2002	1.000	50.1 ± 4.1	0.944 ± 0.060	2.6 ± 1.0
February 2002	0.947	49.9 ± 4.0	0.928 ± 0.057	0.6 ± 1.1
March 2002	0.975	46.9 ± 4.2	0.875 ± 0.094	-0.2 ± 0.4
April 2002	1.000	40.9 ± 5.3	0.667 ± 0.108	0.0 ± 0.0
May 2002	1.000	27.3 ± 5.0	---	---
June 2002	1.000	---	---	---

Remark --- means that no estimate can be made of this parameter from the data available.

The estimated population parameters of male *B. asper* varied throughout the study period. The proportion of marked males indicated that new males were found in the cave during the study period due to the proportion values were lower than 1.000. However, it was found that none of new male was found in January and April to June 2002 due to the proportion marked was equal to 1.000. It might be concluded that very few or none of unmarked male entered to the cave after the sampling in December 2001 to the later sampling in January 2002 and also after the sampling in March to June 2002.

The estimated population size of the male varied from 27.3 ± 5.0 to 56.1 ± 4.9 individuals. The largest population size was found in December 2001 and the smallest population size was found in May 2002. The dynamic of population size of the male could be from several factors, including immigration, emigration, growth of young to be adult male, and death. However, from July 2001 to June 2002, none of the male was found dead in the cave.

The probability of survival varied from 0.795 ± 0.100 to 1.048 ± 0.102 and that might be due to the emigration and death of the marked male. However, the

value was higher than 0.500 for all sampling times, that means most of the marked male at the time of interest remained in the cave and found again in the next sampling time.

The number joining varied from -4.4 ± 3.4 to 22.7 ± 4.4 individuals. The highest number of new males joined the cave population was found in November to December 2001. The smallest number of new males shared the cave was found in December 2001 to January 2002. The variation of the number joining was influenced by immigration and growth of the young as discussed in the part of estimated population size because the number joining was the dependent parameter of the estimated population size.

5.2.1.2.2 Population Estimates of the Female

The proportion of marked females, the estimated population size, the probability of survival, and the number of unmarked females joining this population were shown in Table 5.10 and Figure 5.6.

Table 5.10 Population estimates of female *Bufo asper* in Tarn Lord Noi Cave.

Sample	Proportion marked	Estimated population size (± S. E.)	Probability of survival (± S. E.)	Number joining (± S. E.)
July 2001	---	---	0.786 ± 0.110	---
August 2002	0.600	18.3 ± 1.8	0.967 ± 0.183	7.7 ± 2.6
September 2001	0.722	25.4 ± 5.4	0.440 ± 0.125	3.1 ± 3.1
November 2001	0.714	14.0 ± 3.9	1.167 ± 0.177	-0.3 ± 3.7
December 2001	0.875	16.0 ± 4.3	0.733 ± 0.172	-0.7 ± 1.3
January 2002	1.000	11.0 ± 2.6	1.000 ± 0.000	3.1 ± 1.8
February 2002	0.778	14.1 ± 3.1	1.115 ± 0.108	0.2 ± 2.2
March 2002	0.909	15.9 ± 3.4	0.820 ± 0.197	2.5 ± 1.7
April 2002	0.818	15.5 ± 3.9	0.992 ± 0.443	19.3 ± 10.8
May 2002	0.421	34.7 ± 16.5	---	---
June 2002	0.636	---	---	---

Remark --- means that no estimate can be made of this parameter from the data available

The estimated population parameters of female *B. asper* varied considerably during July 2001 to June 2002. The proportion of marked females demonstrated that there were unmarked females found during the sampling period due to the value was lower than 1.000. However, none of female was found in January due to the value was equal to 1.000. It could be inferred that none of the female came to the cave after the sampling in December 2001 until the sampling in January 2002.

The estimated population size varied from 11.0 $\pm$ 2.6 to 34.7 $\pm$ 16.5 individuals. The smallest population size was found in January 2002 and the biggest was found in May 2002. The factor affected the variation of the proportion of marked females could be migration, growth, and death. The data on habitat utilization revealed that some of the females were found outside the cave. Moreover, two females were found dead in the cave after released.

The probability of survival of the female varied from 0.440 $\pm$ 0.125 to 1.167 $\pm$ 0.177. The sampling time that the ability of survival lower than 0.500 mean that the female found in that sampling time of interest were found again in the next sampling time but in small number due to emigration and/ or death. From July 2001 to June 2002, the value was lower than 0.500 only in September 2001. It could be explained that most of the female found at the time of interest remained and stayed alive in the cave at the next sampling time.

The number joining of the female varied from -0.7 $\pm$ 1.3 to 19.3 $\pm$ 10.8 individuals. The lowest number of new females joining the population was found in December 2001 to January 2002 and the smallest was found in April to May 2002. The variation of the number joining could be influenced by immigration and growth of the young as discussed in the part of estimated population size because the number joining was the dependent parameter of the estimated population size.

5.2.1.2.3 Population Estimates of the Young

For the young, the proportion of marked young, the population size, the probability of survival, and the number of unmarked young joining this population were shown in Table 5.11 and Figure 5.7.

Table 5.11 Population estimates of young *Bufo asper* in Tarn Lord Noi Cave.

Sample	Proportion marked	Estimated population size (± S. E.)	Probability of survival (± S. E.)	Number joining (± S. E.)
July 2001	---	---	0.745 ± 0.103	---
August 2002	0.696	25.7 ± 3.1	0.997 ± 0.309	4.1 ± 2.9
September 2001	0.833	29.8 ± 9.5	0.372 ± 0.228	6.2 ± 7.5
November 2001	0.600	17.2 ± 11.0	0.707 ± 0.363	9.6 ± 9.3
December 2001	0.400	21.8 ± 9.4	0.816 ± 0.280	2.2 ± 10.3
January 2002	0.600	20.0 ± 10.2	0.976 ± 0.325	-2.4 ± 8.1
February 2002	0.800	17.1 ± 5.1	0.574 ± 0.168	2.2 ± 2.2
March 2002	0.750	12.0 ± 3.1	1.182 ± 0.180	0.4 ± 2.4
April 2002	0.889	14.6 ± 4.1	1.214 ± 0.928	-0.8 ± 1.6
May 2002	1.000	17.0 ± 13.0	---	---
June 2002	0.750	---	---	---

Remark --- means that no estimate can be made of this parameter from the data available

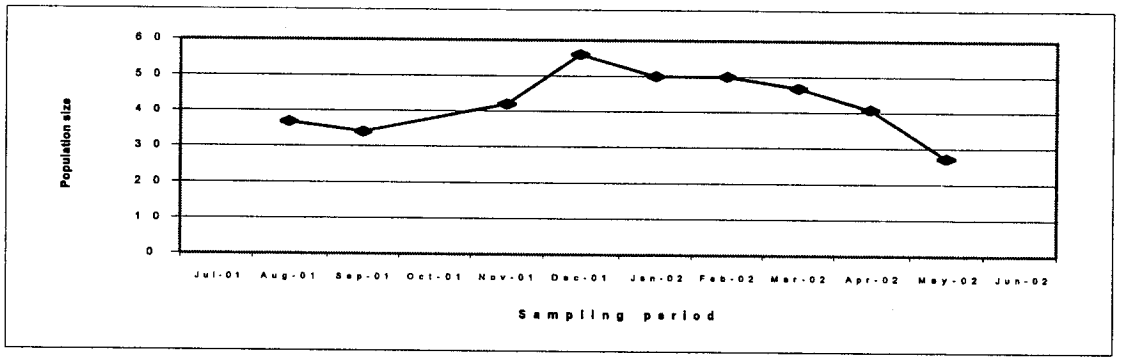
The proportion of marked young revealed that there was new young entered the cave during the sampling period due to the proportion marked was lower than 1.000. However, the new young was not found in May 2002 due to the proportion marked value was equal to 1.000. It could be concluded that none of the new young entered the cave after the sampling time in April to May 2002.

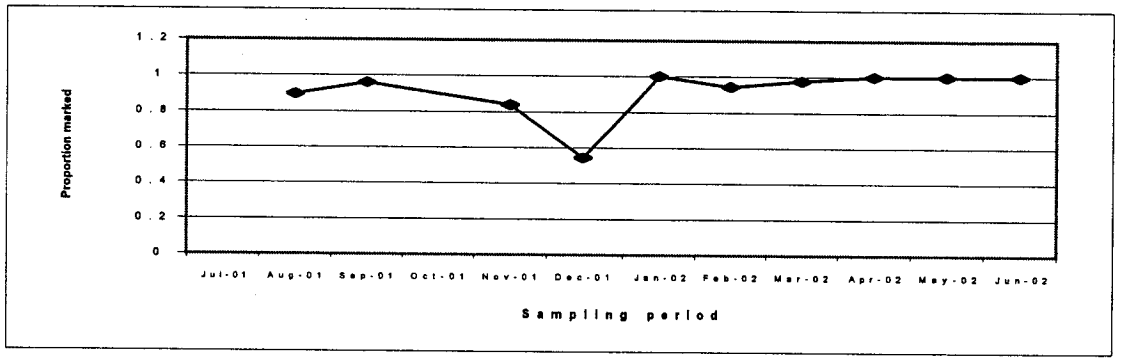
The estimated population size varied from 12.0 ± 3.1 to 29.8 ± 9.5 individuals. The largest population size was found in September 2001 and the smallest was found in March 2002. The factors influenced the proportion of marked young were migration, growth of the young to be adult, birth, and death. The data on habitat utilization revealed that many of the young went out the cave. Moreover, four individuals of the young became adult (2 males and 2 females) were found during the study period. In addition, eggs were found in April to June 2002 that could affect the population size. However, none of the young found dead inside the cave.

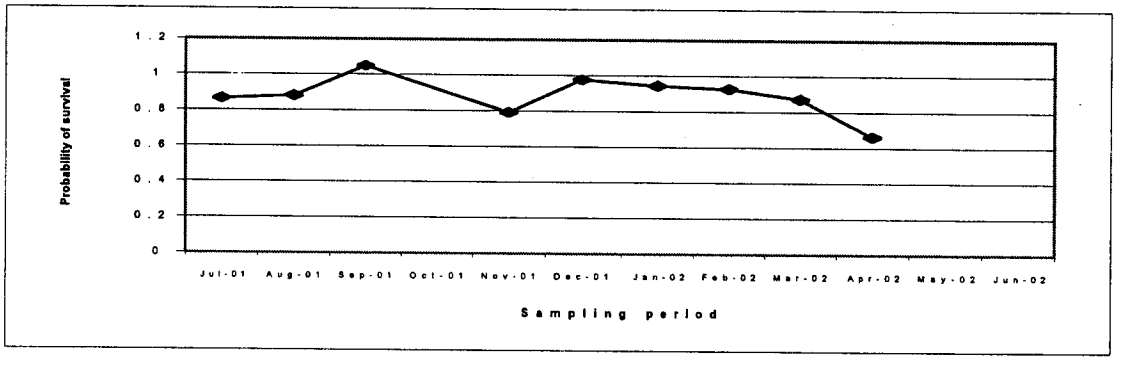
The probability of survival of the young varied from 0.372 ± 0.228 to 1.214 ± 0.928. The probability of survival was quite low in September 2001 that might be due to some of the young left the cave or died after the sampling time in September

2001. However, the probability of survival was over 0.500 in other sampling times. It indicated that most of the young at the time of interest remained in the cave and were found again in the next sampling time.

The number joining of the young varied from 9.6 $\pm$ 9.3 to -2.4 $\pm$ 8.1 individuals. The smallest number of new young joining this population was found in January to February 2002. The highest number of new young entered the cave was found in November to December 2001. The variation of the number joining could be influenced by immigration and birth of the young as discussed in the part of estimated population size because the number joining was the dependent parameter of the estimated population size.







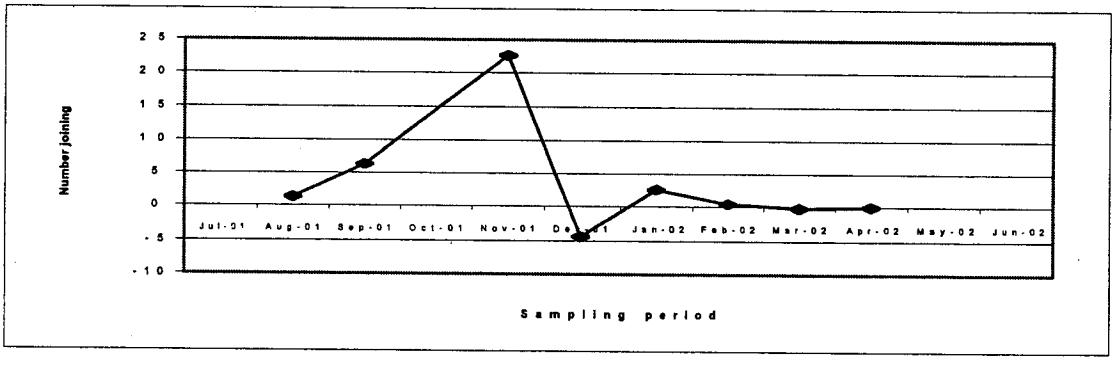
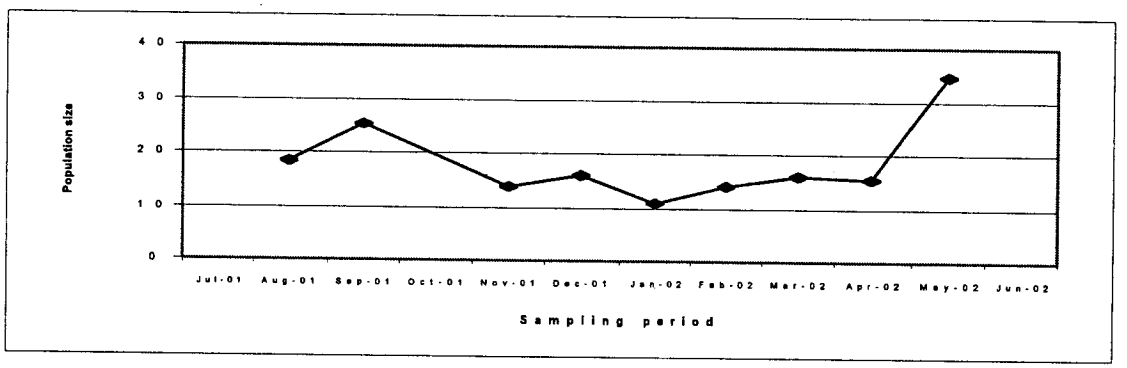
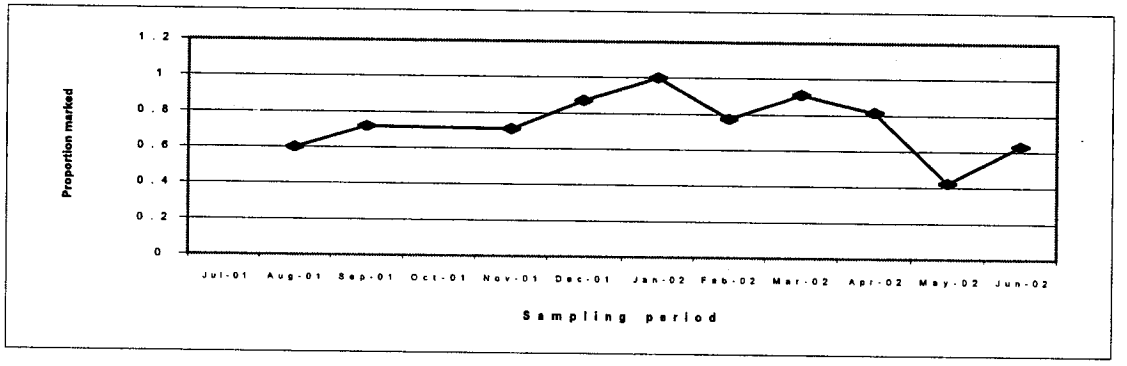
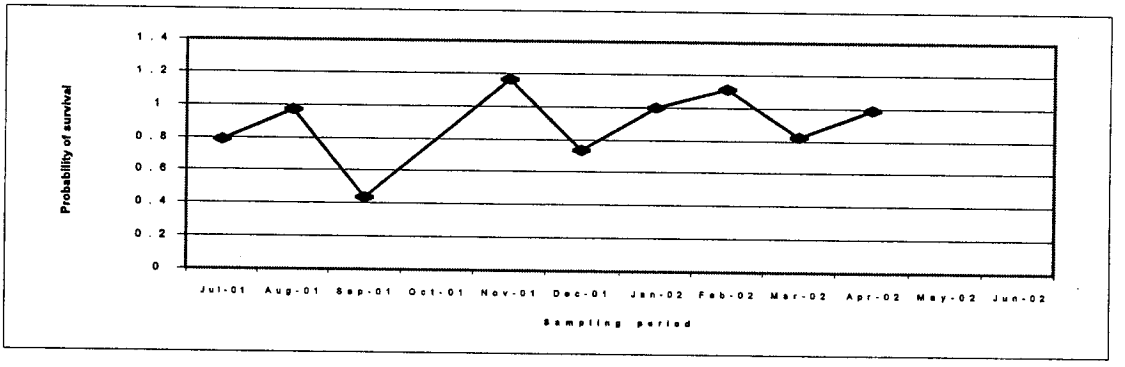


Figure 5.5 Estimated male population size, proportion of marked and unmarked males, probability of survival, and estimated number of unmarked males joining the population in Tarn Lord Noi Cave during July 2001 to June 2002.







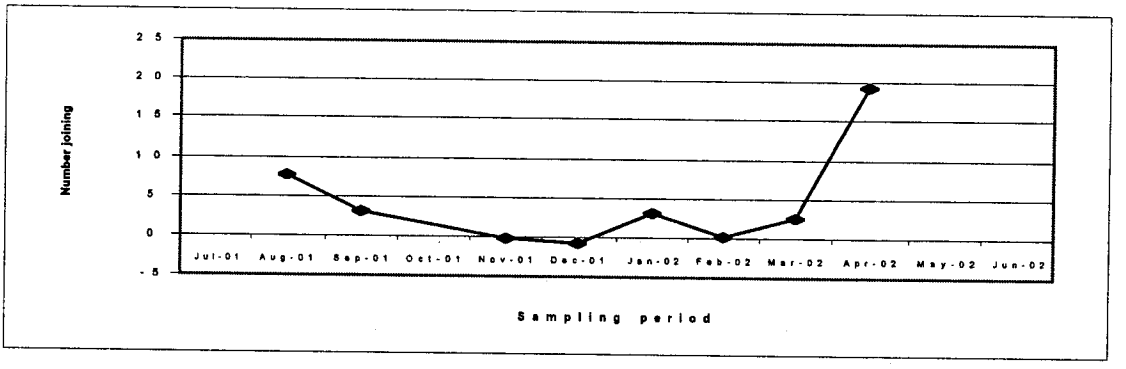
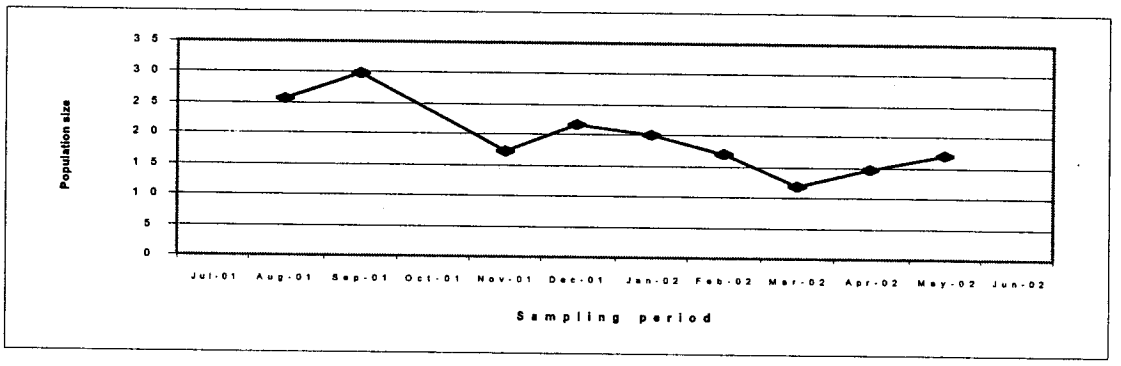
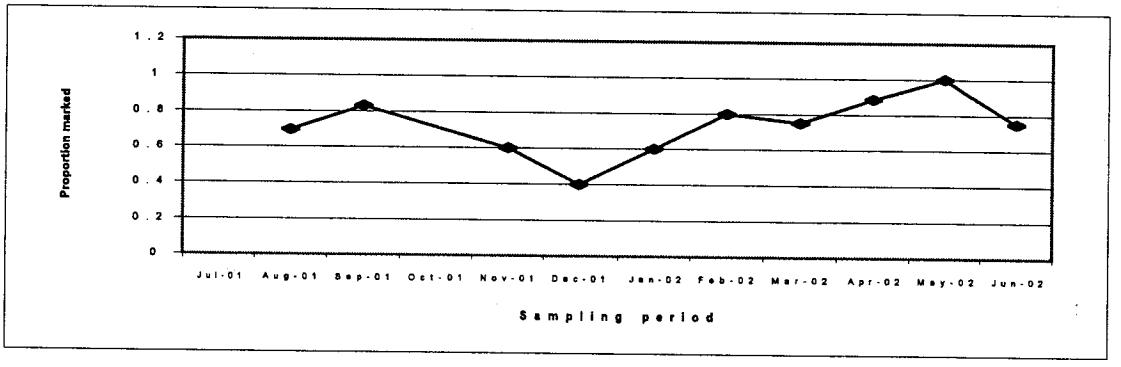
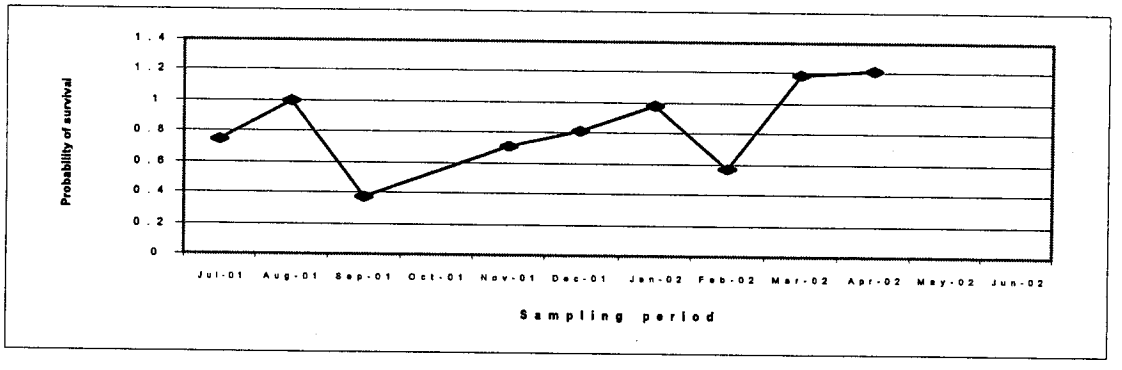


Figure 5.6 Estimated female population size, proportion of marked and unmarked females, probability of survival, and estimated number of unmarked females joining the population in Tarn Lord Noi Cave during July 2001 to June 2002.







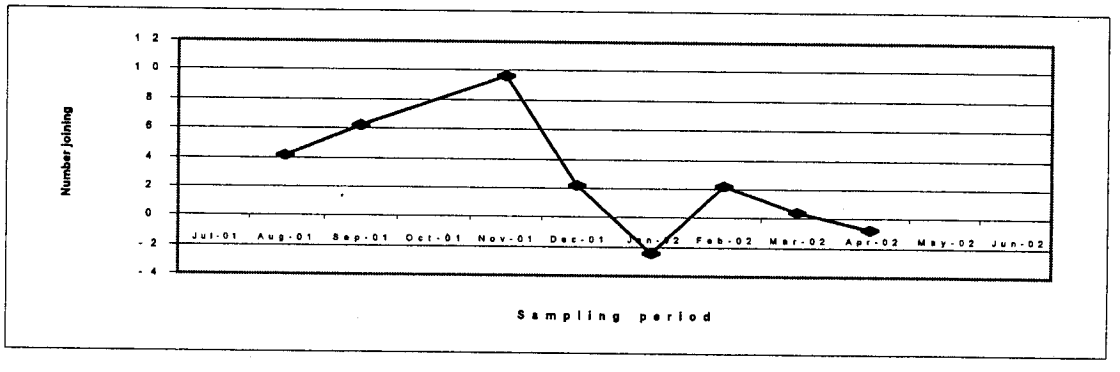


Figure 5.7 Estimated young population size, proportion of marked and unmarked young, probability of survival, and estimated number of unmarked young joining the population in Tarn Lord Noi Cave during July 2001 to June 2002.

Figure 5.8. showed the dynamic of estimated population sizes of the toad throughout the study period.

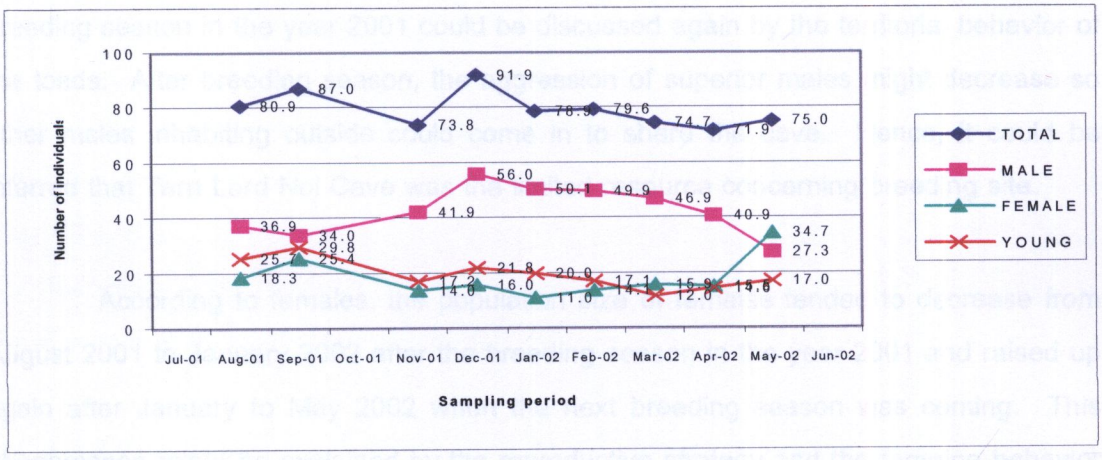


Figure 5.8 Dynamic of estimated population size of *Bufo asper* in Tarn Lord Noi Cave during July 2001 to June 2002.

Dynamics of population size are common and have been reported for several anuran species (e. g., Berven, 1990; Moreira and Lima, 1991; Augert and Joly, 1993; Barreto and Moreira, 1996; Friedl and Klump, 1997; Patto and Pie, 2001; this study). In animals, the population dynamic was caused by immigration, emigration, birth, and death (Krebs, 1989; Squire and Newman, 2002). From this study, however, the determinants, such as the reproductive strategy and the survival strategy, of the migration might play different roles among males, females, and young.

From this study, the population size of males tended to increase during August to December 2001 after the breeding season (April to August 2001) and tended to decrease after December 2001 to May 2002 when the next breeding season was arriving (March to July 2002). In many anuran species such as *Rana catesbeiana, R. clamitans*, *Mantella laevigata*, the male had territorial behavior (Bee and Gerhardt, 2001; Bee et al., 2001; Heying, 2001; Bee, 2002; Shepard, 2002) and this behavior is very aggressive when the male of *Mantella laevigata* was interested by the female in the breeding season (e. g., Heying, 2001). Although the behavior was not directly observed in this study, the movement of the male *B. asper* in Tarn Lord Noi Cave might be explained by its territorial behavior. The emigration of male toads before the breeding season in the year 2002 might be due to superior males defended resources

necessary for their reproductive success, inferred as mates and breeding sites in the cave, through calling and/ or visual displays (e. g., Shepard, 2002). Therefore, the inferior males had to leave the cave. The higher number of males in the cave after the breeding season in the year 2001 could be discussed again by the territorial behavior of the toads. After breeding season, the aggression of superior males might decrease so other males inhabiting outside could come in to share the cave. Hence, it could be inferred that Tarn Lord Noi Cave was the limited resource concerning breeding site.

According to females, the population size of females tended to decrease from August 2001 to January 2002 after the breeding season in the year 2001 and raised up again after January to May 2002 when the next breeding season was coming. This phenomenon might be explained by the reproductive strategy and the foraging behavior of the toads. The higher number of females found in the cave might be due to the female came to select superior males and suitable sites to mate and deposit eggs. This phenomenon was common and had been reported in many amphibians such as *B. americanus* (Howard, Whiteman, and Schueller, 1994), *B. bufo* (Duellman and Trueb, 1994), *Hyla rosenbergi* (Duellman and Trueb, 1994), *Desmognathus ochrophaeus* (Houck, Arnold, and Thisted, 1985, cited in Howard et al., 1994). Some of the female dispersed from the cave after breeding was probably due to the female had spent high energy in breeding and foods in the cave might be limited. The dispersal of females from the breeding site was also found in *B. japonicus formosus* (Kusano, Maruyama, and Kaneko, 1995).

For young, the estimated population size raised up during August to September 2001, tended to decrease after that to the minimum size in March 2002, and raised up again after March 2002 when the breeding season in the year 2002 started. The larger population size of young after breeding season might be due to the offspring recruitment. The decrease in population size after September might be because of food limitation in the cave. The data on the habitat utilization encouraged this discussion. Moreover, growth of the young could affect the population change. There were 4 young became adults during the study time. Therefore, the recaptured data of them were classified as the data of adults. The increase in number after March 2002 might be also caused by the offspring recruitment and will be discussed in the result of population structure.

5.2.2 Population Size and Climatic Factors

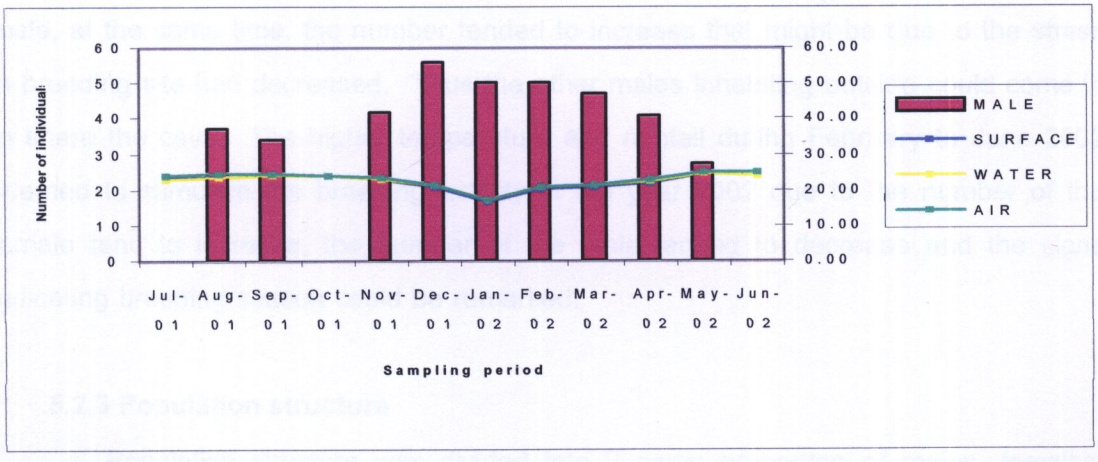
As indicated in Table 5.12, the climatic factors, including relative humidity at 1 m above ground, relative humidity at soil surface, air temperature, soil surface temperature, and water temperature were tested. Spearman's correlation revealed that population size of all and the young toads did not correlate with any climatic parameters. For the male and the female, it was found that the population sizes of them correlated with the temperature. However, the correlation was on the opposite way. The change of female population size coincided with the temperature fluctuation. On the other hand, when the temperature increased, the population size of male conversely related as shown in Figure 5.9.

Table 5.12 Spearman's correlation coefficients showing the relationship between the population size and environmental factors at Tarn Lord Noi Cave from July 2001 to June 2002. Significant values were in parentheses.

Climatic factor	Population size			
	All toads	Male	Female	Young
Relative humidity-1 m	0.150 (0.700)	-0.167 (0.668)	0.350 (0.356)	0.067 (0.865)
Relative humidity-Soil Surface	0.117 (0.765)	-0.100 (0.798)	0.233 (0.546)	0.100 (0.739)
Temperature-Air	-0.050 (0.898)	-0.933 (0.000)	0.767 (0.016)	0.150 (0.700)
Temperature-Soil Surface	-0.050 (0.898)	-0.933 (0.000)	0.767 (0.016)	0.150 (0.700)
Temperature-Water	-0.050 (0.898)	-0.933 (0.000)	0.767 (0.016)	0.150 (0.700)

Remark Correlation was significant at the 0.05 level (2-tailed).

a.



b.

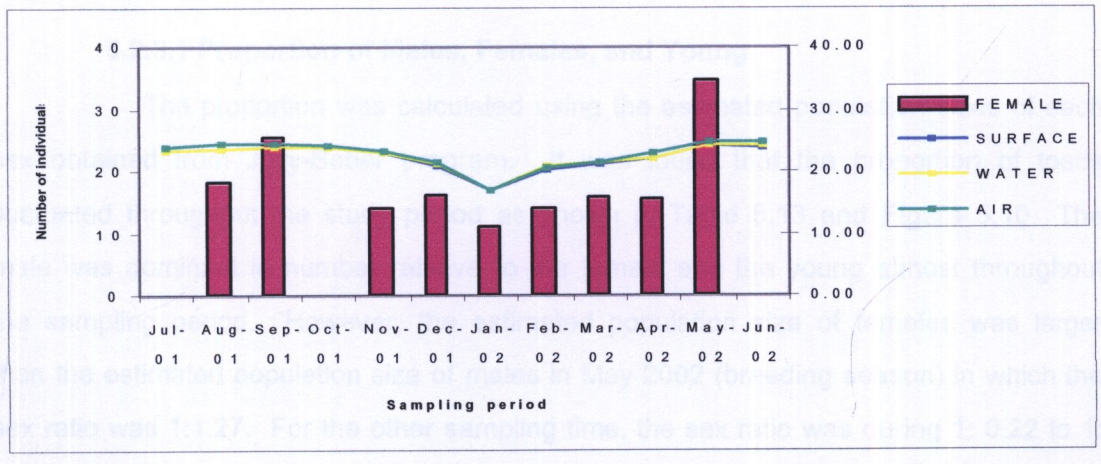


Figure 5.9 Population size of *Bufo asper* and temperature (°C) in Tarn Lord Noi Cave throughout the study period. a. Female b. Male

Although the role of temperature on the population size was not directly examined, the result could be inferred that the temperature in relation to reproduction should be one of the factors that influenced the change of population size of the male and the female.

Temperature and rainfall were considered as the primary extrinsic factor initiating breeding activity in amphibians (Duellman and Trueb, 1994). According to the result from this study, the number of the female tended to decrease in cool period (November 2001 to January 2002) that might be due to the breeding season (April to August 2001) had been over and some of the female dispersed from the cave. For the

male, at the same time, the number tended to increase that might be due to the stress in breeding site had decreased. Thus the other males inhabiting outside could come in to share the cave. The higher temperature and rainfall during February to June 2002 seemed to stimulate the breeding activity in the year 2002 due to the number of the female tend to increase, the number of the male tended to decrease and the signs indicating breeding season could be remarked.

5.2.3 Population structure

Population structure was divided into 2 parts; proportion of males, females, and young and size distribution.

5.2.3.1 Proportion of Males, Females, and Young

The proportion was calculated using the estimated population sizes of each sex obtained from Jolly-Seber program. It was found that the proportion of toads fluctuated throughout the study period as shown in Table 5.13 and Figure 5.10 The male was dominant in number relative to the female and the young almost throughout the sampling period. However, the estimated population size of females was larger than the estimated population size of males in May 2002 (breeding season) in which the sex ratio was 1:1.27. For the other sampling time, the sex ratio was during 1: 0.22 to 1: 0.75.

Table 5.13 Proportion of *Bufo asper* inhabiting Tarn Lord Noi Cave.

Sampling period	Proportion (male:female:young)
July 2001	---[a]
August 2001	1:0.50:0.70
September 2001	1:0.75:0.88
October 2001	---[a]
November 2001	1:0.33:0.41
December 2001	1:0.29:0.39
January 2002	1:0.22:0.40
February 2002	1:0.28:0.34
March 2002	1:0.34:0.26
April 2002	1:0.38:0.36
May 2002	1:1.27:0.62
June 2002	---[a]

Remark [a]--- no estimation can be made due to the data was not available.

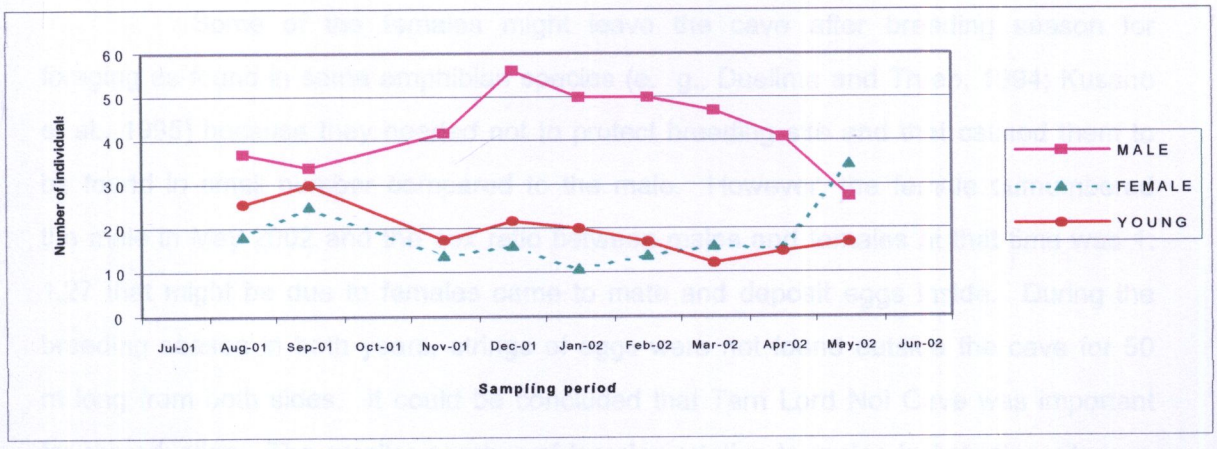


Figure 5.10 Proportion of males, females, and young *Bufo asper* in Tarn Lord Noi Cave during July 2001 to June 2002.

Fluctuations in the population structure are common in amphibians (Friedl and Klump, 1997). The change in sex ratio in a given area was influenced by the change of population size and usually found in anurans (e. g., Green, 1992). The dynamic of *B. asper* population size, including of the increase and decrease in number of males, females, and young revealed that dispersal, birth, and death occurred in all sex groups inhabiting Tarn Lord Noi Cave. However, the male found in the cave outnumbered the female and the young almost the study period. This character might be due to the importance of the cave as a breeding site. Berven (1990) suggested that the male-biased sex ratio found in breeding choruses of *Rana sylvatica* was caused by earlier maturation of males relative to females. Some of males remained in the cave that might be to protect sites for mating (e. g., Duellma and Trueb, 1994; Heying, 2001) and this caused them more frequently found than the female and the young. In addition the data on habitat utilization demonstrated that males exhibited site fidelity. From the result, although the breeding season had ended, many males still remained in the cave (Appendix B: Table 2). The site fidelity behavior in male *B. asper* agreed with some amphibian species, such as Fowler's Toad, *B. woodhousei fowleri* and *Hyla arborea*. Green (1992) reported that males of Fowler's Toad exhibited considerable site fidelity during the breeding season and left only for foraging. Friedl and Klump (1997) found that *Hyla arborea* demonstrated a high degree of breeding site fidelity, only few individuals migrated to other spawning sites within breeding seasons or between year. The site fidelity behavior will be discussed in the part of habitat utilization.

Some of the females might leave the cave after breeding season for foraging as found in some amphibian species (e. g., Duellma and Trueb, 1994; Kusano et *al.*, 1995) because they needed not to protect breeding site and that caused them to be found in small number compared to the male. However, the female outnumbered the male in May 2002 and the sex ratio between males and females at that time was 1: 1.27 that might be due to females came to mate and deposit eggs inside. During the breeding season in both years, strings of eggs were not found outside the cave for 50 m long from both sides. It could be concluded that Tarn Lord Noi Cave was important for reproduction. The smaller number of females relative to males in breeding site was also found in Fowler's Toad at Long Point, Ontario (Green, 1992). Nevertheless, the operational sex ratio should be studied in *B. asper.*

The change of proportion of young was also caused by the change in estimated population size. Due to the body size of the young varied from 30 to 120 mm that meant the young group was composed of many stages. The result could not be discussed by compiling the data of all young. Thus, it will be discussed in the part of size distribution. However, it could be concluded that migration, birth, and death influenced the population size of them. The number of young was lower than the number of males for all sampling time even at the time during or at the end of reproductive season (September 2001). This result suggested that the population size of *B. asper* inhabiting Tarn Lord Noi Cave was mostly determined by the population size of males and the cave was important habitat for them.

5.2.3.2 Size Distribution

The population structure was also analyzed in the term of size distribution. As indicated in Table 5.14 to Table 5.16, using snout to vent length with 10 mm interval, males and females could be divided into 4 classes. For the young, it could be divided into 3 classes of 30 mm interval.

Table 5.14 Number of the male *Bufo asper* of each size class inhabiting Tarn Lord Noi Cave.

Sampling period	Number of male				
	80<SVL≤90 (mm)	90<SVL≤100 (mm)	100<SVL≤110 (mm)	110<SVL≤120 (mm)	All size classes
July 2001	2	25	10	1	38
August 2001	1	21	14	1	37
September 2001	1	16	8	0	25
October 2001	---[a]	---[a]	---[a]	---[a]	---[a]
November 2001	0	11	7	0	18
December 2001	0	14	31	0	45
January 2002	0	8	16	0	24
February 2002	0	13	24	0	37
March 2002	0	15	24	0	39
April 2002	0	9	19	0	28
May 2002	0	8	13	0	21
June 2002	0	9	8	0	17

Remark [a]--- means that no data was available.

Breeding season = July-August 2001 and March-June 2002

Non-breeding season = September 2001-February 2002

The minimum and maximum size of the male found during July 2001 to June 2002 were 88.4 mm and 111.0 mm, respectively. However, the size of toads that more frequently found was 90 to 110 mm. The number of toads belonged to 80-90 mm class was absent due to the toad grew to larger size, however still remained in the cave. On the other hand, the absent data of the largest size class might be caused by emigration or death. Large size males (100-110 mm) outnumbered small size males (90-100 mm) in December 2001 to May 2002, the result was opposite to the finding in July to November 2001. The growth of small males and immigration of large males caused an increase in large male frequencies. The number of large male during December 2001 to March 2002 was larger than the number during April to June 2002 might be due to the male came into the cave to search for territories before the breeding season. Both the small and the larger male tended to decrease in number after April to June 2002 that might be due to the stress in breeding site during breeding season as discussed in the study of population size.

Table 5.15 Number of the female *Bufo asper* of each size class inhabiting Tarn Lord Noi Cave.

Sampling period	Number of female				
	110<SVL≤120 (mm)	120<SVL≤130 (mm)	130<SVL≤140 (mm)	140<SVL≤150 (mm)	All size classes
July 2001	6	3	3	2	14
August 2001	5	9	4	1	19
September 2001	7	4	5	1	17
October 2001	---[a]	---[a]	---[a]	---[a]	---[a]
November 2001	5	1	0	0	6
December 2001	1	2	3	1	7
January 2002	1	0	0	0	1
February 2002	5	2	1	0	8
March 2002	7	2	1	0	10
April 2002	6	1	2	1	10
May 2002	5	6	5	2	18
June 2002	2	4	4	0	10

Remark [a]--- means that no data was available.

Breeding season = July-August 2001 and March-June 2002

Non-breeding season = September 2001-February 2002

The minimum and the maximum size of females were 112.0 mm and 147.0 mm, respectively. The size of females that more frequently found was between 110 to 140 mm. Female belonged to 140-150 mm class were rarely found. However, they were found in July, August, September, and December 2001, and April to May 2002. From the result, it could be concluded that there was no distinct variation in size structure of the female, however the number of females in breeding season was larger than the number in non-breeding season. The change of frequencies of females was also caused by growth, dispersal, and death. For largest females, the absent from the cave was caused by dispersal and death only.

The importance of the female size may not as same as the importance of the male size for reproduction, that was probably due to the male was chosen by the female and the female might preferred the larger male as reported in *B. americanus* (Howard et al.,1994).

Table 5.16 Number of the young *Bufo asper* of each size class inhabiting Tarn Lord Noi Cave.

Sampling period	Number of young			
	30<SVL≤60 (mm)	60<SVL≤90 (mm)	90<SVL≤120 (mm)	All size classes
July 2001	8	6	10	24
August 2001	5	9	8	22
September 2001	2	11	4	17
October 2001	---[a]	---[a]	---[a]	---[a]
November 2001	1	3	0	4
December 2001	6	2	1	9
January 2002	2	2	0	4
February 2002	2	6	1	9
March 2002	1	5	1	7
April 2002	3	4	1	8
May 2002	1	4	0	5
June 2002	3	1	3	7

Remark [a]--- means that no data was available.

Breeding season = July-August 2001 and March-June 2002

Non-breeding season = September 2001-February 2002

The smallest and the largest size of the young toads were 34.3 mm and 110.4 mm, respectively. The change of frequencies of young was also caused by growth, immigration, emigration, birth and death. The number of young was quite small during the beginning and the mid of breeding season. Although eggs were deposited in the cave, the number of small size that assumed as newborn (30-60 mm) did not dominate the other group of the young as well as the male and the female. The small number of newborns might be due to death or dispersal after hatching. Death of very young toads might be due to small size and poorly developed features such as heart, lung, and aerobic capacity (Clark, 1974; Pough and Kamel, 1984, cited in Cohen and Alford, 1993). In addition, the survival of the young might be affected by biotic factors such as competition, predation or pathogens (Licht 1974; Berven 1990; Freeland and Kerin 1991). The frequency of toads in other size classes (60-90 mm and 90-120 mm) did not show distinct variation. From the result of males, females, and young, it could be concluded that the male was dominant in number relative to the other groups throughout the study period.

5.3 Habitat Utilization

5.3.1 Movement of the Toads in the Study Area

5.3.1.1 Movement throughout the study period

The data of 193 marked toads found inside and outside of the cave revealed that the toad could be divided into 6 groups by its locations. The first was the group of toads that were found only at the downstream outside of the cave (D). The second was the group of toads that were found only at the upstream outside (U). The third was the group of toads that were found only inside (I). The fourth was the group of toads that were found inside and at the downstream outside (ID). The fifth was the group of toads that were found inside and at the upstream outside (IU) and the last was the group of toads that were found inside and both outsides (IDU).

During July 2001 to June 2002, most of the toad was found only inside the cave (I=47.15%). There were 25.39% (ID) and 13.99% (IU) of them exhibited movement between inside and outside the cave and 1.04% of them moved between inside and both outsides (IDU) (Table 5.17).

Table 5.17 Percent frequency of *Bufo asper* at Tarn Lord Noi Cave found at various locations during July 2001 to June 2002

Group of the toad	Percent frequency (n=193)
D	7.77
U	4.66
I	47.15
ID	25.39
IU	13.99
IDU	1.04

Remark D = found at the downstream outside, U = found at the upstream outside, I = found inside, ID = found inside and at the downstream outside, IU = found inside and at the upstream outside, IDU = found inside and both upstream and downstream outside, n = number of individuals

Table 5.18, most of the male was found inside the cave and at the downstream outside (I=16.16% and ID=14.65%). The number of male that found both inside and at the upstream outside was quite small (IU=5.05%). Very few of them were found only outside (D=1.01% and U=0.51%) and none exhibited movement between inside and both outsides of the cave.

Most of the female was also found only inside (16.16%) and none of them was found only outside. There were 3.03%(ID) and 5.05% (IU) of them moving between inside and outside of the cave and 1.01% of them moved between inside and both outsides (IDU).

The young were mainly found inside the cave. There were 6.57% (D) and 4.04% (U) of them that were found only outside. 8.59% (ID) and 4.55% (IU) of them showed movement between inside and outside of the cave but none of them moved between inside and both outsides (IDU). The number of the young found only outside that was higher than the number of the male and the female could indicate the importance of the area around the cave mouth for their survival.

Table 5.18 Percent frequency of male, female, and young *Bufo asper* at Tarn Lord Noi Cave found at various locations during July 2001 to June 2002.

Group of the toad	Percent frequency* (n=198**)		
	MALE	**FEMALE**	**YOUNG**
D	1.01	0	6.57
U	0.51	0	4.04
I	16.16	16.16	13.64
ID	14.65	3.03	8.59
IU	5.05	5.05	4.55
IDU	0	1.01	0

Remark * The percent frequency was calculated from the number of the toad in each group and the total number of the toad (N=198).

** The total number of the toad was not equal to the total number in Table 5.17 due to some young became adults during the study period.

D = found at the downstream outside, U = found at the upstream outside, I = found inside, ID = found inside and at the downstream outside, IU = found inside and at the upstream outside, IDU = found inside and both upstream and downstream outside, n = number of individuals

Of 78 individuals (40.42% of the total: ID=25%, IU=13.99%, IDU=1.04%) that showed movement between inside and outside of the cave, 57 (73.08%) individuals *demonstrated two-way movement. This group was composed of 27 males, 9 females,* 14 young, 4 young that became to female, and 3 young that became to male. The one-way movement was also found in 21 individuals (26.92%). This group included 9 males, 5 females, and 7 young. However, it could not be concluded that the toad in this group exhibited only one-way movement because none of them could be recaptured for all the sampling times.

Although most of the male, the female and the young were found only inside the cave, it did not imply that they all spent their time only in the cave. Of 91 (I=47.15%) individuals, 90 individuals could not be caught for all 12 samplings. Except death and camouflage, dispersal should be the reason for disappearance from the cave. Thus, it should be better to conclude that most of them spent their times in the cave for at least part of the life cycle. The evidence that supported the absent from the cave caused by dispersal was the moving individual.

5.3.1.2 Movement in breeding season

Table 5.19, in breeding season, the toad was rarely found outside of the cave (D=7.65%, U=5.29%) most of them was found inside (I=50.59%). However, there were 23.53% (ID) and 12.94% (IU) of them exhibited movement between inside and outside of the cave and none of them was found inside and at both outsides.

Table 5.19 Percent frequency of *Bufo asper* at Tarn Lord Noi Cave found at various locations during breeding season (July-August 2001 and March-June 2002).

Group of the toad	Percent frequency (N=170)
D	7.65
U	5.29
I	50.59
ID	23.53
IU	12.94
IDU	0.00

Remark D = found at the downstream outside, U = found at the upstream outside, I = found inside, ID = found inside and at the downstream outside, IU = found inside and at the upstream outside, IDU = found inside and both upstream and downstream outside, n = number of individuals

As shown in Table 5.20, most of the male was found inside the cave and at the downstream outside (I=17.54% and ID=12.87%). The number of male that found both inside and at the upstream outside was quite small (IU=4.09%). Very few of them were found outside (D=2.34% and U=0.58%) and none exhibited movement between inside and both outsides of the cave.

Most of the female was also found only inside (18.13%) and none of them was found only outside. Some of them showed movement between inside and outside of the cave (ID=3.51%) and (IU=5.26%) but none of them moved between inside and two outsides.

The young were frequently found only inside the cave (I=14.62). There were 5.26% (D) and 4.68% (U) were found only outside. 7.02% (ID) and 4.09% (IU) showed movement between inside and outside of the cave but none of them moved between inside and both outsides.

Table 5.20 Percent frequency of male, female, and young *Bufo asper* at Tarn Lord Noi Cave found at various locations during breeding season (July-August 2001 and March-June 2002).

Group of the toad	Percent frequency* (n=171**)		
	MALE	FEMALE	YOUNG
D	2.34	0.00	5.26
U	0.58	0.00	4.68
I	17.54	18.13	14.62
ID	12.87	3.51	7.02
IU	4.09	5.26	4.09
IDU	0.00	0.00	0.00

Remark * The percent frequency was calculated from the number of the toad in each group and the total number of the toad (N=198).

** The total number of the toad was not equal to the total number in Table 5.19 due to some young became adults during the study period.

D = found at the downstream outside, U = found at the upstream outside, I = found inside, ID = found inside and at the downstream outside, IU = found inside and at the upstream outside, IDU = found inside and both upstream and downstream outside, n = number of individuals

Of 62 toads (36.47% of the total: ID=23.53%, IU=12.94%) that showed movement between inside and outside of the cave, 45 (72.58%) toads demonstrated two-way movement. This group was composed of 25 males, 8 females, 7 young, 3 young that became female, and 2 young that became male. The one-way movement was also found in 17 individuals (27.42%). This group included 4 males, 4 females, 7 young, 1 young that became female, and 1 young that became male. However, it could not be concluded that the toad in this group exhibited only one-way movement because none of them were recaptured in other sampling periods.

5.3.1.3 Movement in non-breeding season

During non-breeding season, the toad was mainly found only inside the cave (I=63.08%). A few of them were found outside (D=6.15%, U=3.85%). There were 18.46% (ID) and 8.46% (IU) of them exhibited movement between inside and outside of the cave and none of them was found inside the cave and at both downstream and upstream outsides of the cave (IDU=0.00% (Table 5.21).

Table 5.21 Percent frequency of *Bufo asper* at Tarn Lord Noi Cave found at various locations during non-breeding season (September 2001 to February 2002).

Group of the toad	Percent frequency (n=130)
D	6.15
U	3.85
I	63.08
ID	18.46
IU	8.46
IDU	0.00

Remark D = found at the downstream outside, U = found at the upstream outside, I = found inside, ID = found inside and at the downstream outside, IU = found inside and at the upstream outside, IDU = found inside and both upstream and downstream outside, n = number of individuals

Table 5.22 shows that, most of the male was found inside the cave and at the downstream outside (I=28.89% and ID=11.85%). They was rarely found both inside and at the upstream outside (IU=3.7%) and very few of them were found outside (D=0.74% and U=0.74%). None of them was found inside and at both outsides of the cave.

Most of the female was found only inside the cave (15.56%) and none of them was found only outside the cave. There were 0.74%(ID) and 3.7 % (IU) of them showed movement between inside and outside of the cave but none of them moved between inside and both outsides of the cave.

The young were frequently found inside the cave (I=16.30%). There were 5.19% and 2.96% of them found at the downstream and upstream outsides of the cave respectively. There were 6.67% (ID) and 2.96% (IU) showed movement between inside

and outside of the cave but none of them were found to move between inside and both outsides.

Table 5.22 Percent frequency of male, female, and young *Bufo asper* at Tarn Lord Noi Cave found at various locations during non-breeding season (September 2001 to February 2002).

Group of the toad	Percent frequency* (n=135**)		
	MALE	FEMALE	YOUNG
D	0.74	0.00	5.19
U	0.74	0.00	2.96
I	28.89	15.56	16.30
ID	11.85	0.74	6.67
IU	3.70	3.70	2.96
IDU	0.00	0.00	0.00

Remark * The percent frequency was calculated from the number of the toad in each group and the total number of the toad (N=198).

** The total number of the toad was not equal to the total number in Table 5.21 due to some young became adults during the study period.

D = found at the downstream outside, U = found at the upstream outside, I = found inside, ID = found inside and at the downstream outside, IU = found inside and at the upstream outside, IDU = found inside and both upstream and downstream outside, n = number of individuals

Of 35 toads (26.92% of the total: ID=18.46%, IU=8.46%) that showed movement between inside and outside of the cave, 22 (62.86%) individuals demonstrated two-way movement. This group was composed of 14 males, 1 females, 3 young, 2 young that became females, and 2 young that became males. The one-way movement was also found in 13 individuals (37.14%). This group included 5 males, 2 females, 4 young, 1 young that became female, and 1 young that became male. However, it could not be concluded that the toad in this group exhibited only one-way movement because none of them could be recaptured for all the sampling times.

From the result, it could be concluded that most of the toads that were found during the study period used Tarn Lord Noi Cave as their habitat for at least part of their life span. The data of twenty five toads that demonstrated movement between

inside and outside the cave in both breeding and non-breeding season suggested that the cave might serve this population both the breeding site and the shelter site. The 2-way movement of them during breeding and non-breeding season could confirm these function of Tarn Lord Noi Cave. The toad moved outside and found to come inside again might be due to they left the cave to forage and came inside to be sheltered, breed, or protect their breeding sites. One male that was frequently found at about 40 m far inside from the downstream exit was found feeding on termites at the mouth of the cave. One male that exhibited 2-way movement during breeding and non-breeding season was found mating inside the cave. In January, all of the toad were found only inside of the cave and this might be due to their avoidance of the cool and dry weather outside. Similarly in some anurans, Resetarits and Aldridge (1988, cited in Prather and Brigger, 2001) reported that *Rana palustris* used wet caves for breeding. Joglar (1998, cited in Prather and Brigger, 2001) reported that the Puerto Rican frog, *Eleuthrodactylus cooki*, spent nearly its entire life deep in caves, leaving primarily during the night to forage in and around the cave mouth. Barr (1953) and Prather and Briggler (2001) suggested that in order to avoid hot and dry condition outside the caves several anuran species entered the caves due to the temperature inside was lower and the humidity inside was higher than outside.

The number of young found only outside was larger than the number of males and females. It could indicate the importance of the area around the cave mouth for the survival of the young.

5.3.2 Area utilization in Tarn Lord Noi Cave

Due to the number of locations in the cave of each toad was set for at least 25 times as the criteria for the study of area utilization, seven females and 23 males were considered.

5.3.2.1 Area Fidelity

5.3.2.1.1 Area Fidelity throughout the Study Period

During July 2001 to June 2002, Table 5.23 revealed that each toad was not found in every parts of the cave. Of 7 females and 23 males, 6 females (85.71%) and 18 males (78.62) showed significant differences in their appearances (Chi-square test: $P<0.05$) and one of the male was found only at the same area during July 2001 to

June 2002. It could be concluded that each of them used its specific area or exhibited highly area fidelity behavior. For the toad that did not showed differences in the appearance underlying statistical analysis, they also used their own specific area.

The diversity index was considered as the niche width in term of area utilization of the toad. Table 5.23 and Table 5.24, the index indicated that there was variety in habitat utilization among individuals. The index varied from 0.204 to 0.608 for the female and 0.000 to 0.745 for the male. However, t-test for the equality of means revealed that there was no difference in the mean of diversity index between sexes (P=0.302) and between the small male (90$\leq$SVL<100 mm) and the larger male (100 $\leq$SVL<110) (P=0.121). Thus, the result could be inferred that there was no difference in habitat utilization between the male and the female and between the male of different size.

Table 5.23 Percent of appearance, significant value indicating the degree of difference in area utilization, and Shannon-Weiner diversity index indicating the diversity in area utilization of *Bufo asper* in Tarn Lord Noi Cave during July 2001 to June 2002.

Number	SVL (mm)	Appearance (%)									Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9		
F246 (26)	115.70	7.69	42.31	0.00	0.00	0.00	15.38	0.00	7.69	26.92	0.023*	0.608
F68 (26)	118.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.92	73.08	0.019*	0.253
F206 (38)	118.80	2.63	0.00	0.00	36.84	0.00	5.26	0.00	50.00	5.26	0.000*	0.486
F54 (38)	120.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.68	76.32	0.001*	0.238
F28 (28)	123.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.86	82.14	0.001*	0.204
F2027 (32)	125.80	0.00	40.63	0.00	0.00	0.00	0.00	0.00	31.25	28.13	0.67	0.472
F2010 (43)	136.60	2.33	0.00	9.30	44.19	9.30	34.88	0.00	0.00	0.00	0.000*	0.546
M2 (34)	90.60	67.65	32.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.273
M7000 (27)	93.00	0.00	0.00	0.00	7.41	37.04	29.63	22.22	0.00	3.70	0.027*	0.598
M38 (44)	93.50	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**	0.000
M10 (58)	94.40	5.17	24.14	70.69	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.322
M30 (72)	94.40	0.00	0.00	0.00	0.00	76.39	0.00	1.39	6.94	15.28	0.000*	0.320

Number	SVL (mm)	Appearance (%)									Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9		
M2015 (66)	94.90	1.52	0.00	13.64	12.12	21.21	0.00	0.00	51.52	0.00	0.000*	0.548
M74 (59)	95.30	18.64	18.64	11.86	16.95	27.12	6.78	0.00	0.00	0.00	0.13	0.745
M98 (45)	95.60	0.00	0.00	0.00	0.00	15.56	46.67	0.00	20.00	17.78	0.010*	0.553
M37 (31)	96.50	64.52	35.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.282
M15 (41)	100.00	2.44	2.44	2.44	4.88	87.80	0.00	0.00	0.00	0.00	0.000*	0.232
M16 (53)	100.90	1.89	11.32	5.66	1.89	79.25	0.00	0.00	0.00	0.00	0.000*	0.323
M83 (52)	101.10	17.31	17.31	65.38	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.384
M95 (50)	101.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	84.00	16.00	0.000*	0.191
M7 (55)	102.10	7.27	90.91	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.152
M401 (28)	102.10	7.14	3.57	7.14	0.00	10.71	64.29	0.00	7.14	0.00	0.000*	0.525
M2000 (50)	102.20	4.00	96.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.073
M51 (26)	102.30	0.00	0.00	0.00	0.00	11.54	0.00	3.85	57.69	26.92	0.001*	0.454
M237 (25)	102.70	8.00	4.00	4.00	84.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.263
M70 (31)	102.80	80.65	19.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.001*	0.213
M227 (41)	103.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.02	60.98	0.16	0.290
M89 (36)	103.20	83.33	2.78	13.89	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.228
M222 (52)	104.00	11.54	1.92	7.69	78.85	0.00	0.00	0.00	0.00	0.00	0.000*	0.308

Number	SVL (mm)	Appearance (%)									Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9		
M23 (40)	104.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	95.00	5.00	0.000*	0.086

Remark The total number of appearance is in parentheses.

* means there was significant difference in appearance in each section of the cave that the toad was found (Chi-square, $P<0.05$).

** means the significant value could not be obtained from the available data.

Table 5.24 Shannon-Weiner diversity index indicating diversity in area utilization of *Bufo asper* in Tarn Lord Noi Cave during July 2001 to June 2002. The total number of individuals is in parentheses.

Sex	Shanon-Weiner Index		
	Min	Max	Mean ± SD
Female (7)	0.204	0.608	0.401 ± 0.165
Male (23)	0.000	0.745	0.320 ± 0.182
Small male (90-100 mm) (9)	0.000	0.745	0.404 ± 0.227
Large male (100-110 mm) (14)	0.073	0.525	0.265 ± 0.129

5.3.2.1.2 Area Fidelity during breeding season

In breeding season, each of the toads was not found in every parts of the cave. Table 5.25, of 7 females and 23 males, 4 females (57.14%) and 13 males (69.57%) demonstrated significant differences in the appearance in their own specific areas (Chi-square test: $P<0.05$) and 2 of the male were found in only one section of the cave. The result indicated that most of the toad still exhibited highly fidelity in breeding season.

Table 5.25 and Table 5.26, the diversity index revealed individual variations in habitat utilization. The index of the female was during 0.069 to 0.633 and 0.000 to 0.647 for the male. However, the difference in the mean of diversity index between sexes (t-test: $P=0.659$) and between sizes of the male (t-test: $P=0.108$) was not found. Thus, the result could be inferred that there was no difference in habitat utilization between sexes and between the male of different size.

Table 5.25 Percent of appearance, significant value indicating the degree of difference in area utilization, and Shannon-Weiner diversity index indicating the diversity in area utilization of *Bufo asper* in Tarn Lord Noi Cave during breeding season (July to August and March to June 2002).

Number	SVL (mm)	Appearance (%)									Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9		
F246 (26)	115.70	8.70	34.78	0.00	0.00	0.00	17.39	0.00	8.70	30.43	0.15	0.633
F68 (26)	118.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.33	86.67	0.005*	0.171
F206 (38)	118.80	14.29	0.00	0.00	0.00	0.00	28.57	0.00	42.86	14.29	0.67	0.555
F54 (38)	120.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.70	96.30	0.000*	0.069
F28 (28)	123.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.18	81.82	0.003*	0.206
F2027 (32)	125.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.63	47.37	0.82	0.300
F2010 (43)	136.60	5.56	0.00	16.67	55.56	22.22	0.00	0.00	0.00	0.00	0.019*	0.486
M2 (34)	90.60	33.33	66.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.276
M7000 (27)	93.00	0.00	0.00	0.00	13.33	33.33	26.67	20.00	0.00	6.67	0.50	0.647
M38 (44)	93.50	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**	0.000
M10 (58)	94.40	2.44	31.71	65.85	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.317

Number	SVL (mm)	Appearance (%)									Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9		
M30 (72)	94.40	0.00	0.00	0.00	0.00	75.51	0.00	0.00	6.12	18.37	0.000*	0.302
M2015 (66)	94.90	3.13	0.00	28.13	25.00	43.75	0.00	0.00	0.00	0.00	0.013*	0.510
M74 (59)	95.30	16.00	12.00	0.00	16.00	44.00	12.00	0.00	0.00	0.00	0.06	0.633
M98 (45)	95.60	0.00	0.00	0.00	0.00	9.52	52.38	0.00	9.52	28.57	0.015*	0.497
M37 (31)	96.50	66.67	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.276
M15 (41)	100.00	3.13	3.13	0.00	0.00	93.75	0.00	0.00	0.00	0.00	0.000*	0.120
M16 (53)	100.90	2.56	15.38	7.69	2.56	71.79	0.00	0.00	0.00	0.00	0.000*	0.396
M83 (52)	101.10	9.68	6.45	83.87	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.239
M95 (50)	101.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81.48	18.52	0.001*	0.208
M7 (55)	102.10	8.70	86.96	4.35	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.204
M401 (28)	102.10	0.00	0.00	12.50	0.00	18.75	68.75	0.00	0.00	0.00	0.010*	0.361
M2000 (50)	102.20	2.78	97.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.055
M51 (26)	102.30	0.00	0.00	0.00	0.00	18.75	0.00	6.25	31.25	43.75	0.17	0.527
M237 (25)	102.70	66.67	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.276
M70 (31)	102.80	73.33	26.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.252
M227 (41)	103.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	66.67	33.33	0.25	0.276
M89 (36)	103.20	62.50	6.25	31.25	0.00	0.00	0.00	0.00	0.00	0.00	0.022*	0.361

Number	SVL (mm)	Appearance (%)								Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	
M222 (52)	104.00	31.58	0.00	10.53	57.89	0.00	0.00	0.00	0.00	0.00	0.040*	0.398
M23 (40)	104.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	**	0.000

Remark The total number of appearance is in parentheses.

* means there was significant difference in appearance in each section of the cave that the toad was found (Chi-square, $P<0.05$).

** means the significant value could not be obtained from the available data.

Table 5.26 Shannon-Weiner diversity index indicating diversity in area utilization of *Bufo asper* in Tarn Lord Noi Cave during breeding season (July to August and March to June 2002). The total number of individuals is in parentheses.

Sex	Shanon-Weiner Index		
	Min	Max	Mean ± SD
Female (7)	0.069	0.633	0.346 ± 0.214
Male (23)	0.000	0.647	0.310 ± 0.177
Small male (90-100 mm) (9)	0.000	0.647	0.386 ± 0.206
Large male (100-110 mm) (14)	0.000	0.527	0.264 ± 0.143

5.3.2.1.3 Area Fidelity during non-breeding season

Table 5.27, during non-breeding season, of 7 females and 23 males, 2 females (28.57%) and 10 males (43.48%) showed significant differences in their appearances (Chi-square test: $P<0.05$). Two of the female and 5 of the male was found in only one section of the cave. The result showed that some of the toad still exhibited area fidelity but the number of them was smaller compared to the number in breeding season.

Table 5.27 and Table 5.28, the diversity index of the female varied from 0.000 to 0.352 and from 0.000 to 0.731 for the male. There was no difference in the mean of diversity index between the male and the female (t-test: $P=0.736$) and between the small male and the large male (t-test: $P=0.164$). Thus, the result could be inferred that there was no difference in habitat utilization between the male and the female and between the male of different size.

Table 5.27 Percent of appearance, significant value indicating the degree of difference in area utilization, and Shannon-Weiner diversity index indicating the diversity in area utilization of *Bufo asper* in Tarn Lord Noi Cave during non-breeding season (September 2001 to February 2002).

Number	SVL (mm)	Appearance (%)									Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9		
F246 (26)	115.70	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**	0.000
F68 (26)	118.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45.45	54.55	0.76	0.299
F206 (38)	118.80	0.00	0.00	0.00	45.16	0.00	0.00	0.00	51.61	3.23	0.002*	0.352
F54 (38)	120.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	72.73	27.27	0.13	0.254
F28 (28)	123.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67	83.33	0.10	0.196
F2027 (32)	125.80	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**	0.000
F2010 (43)	136.60	0.00	0.00	4.00	36.00	0.00	60.00	0.00	0.00	0.00	0.003*	0.349
M2 (34)	90.60	86.36	13.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.001*	0.173
M7000 (27)	93.00	0.00	0.00	0.00	0.00	41.67	33.33	25.00	0.00	0.00	0.78	0.468
M38 (44)	93.50	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**	0.000
M10 (58)	94.40	11.76	5.88	82.35	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.251

Number	SVL (mm)	Appearance (%)									Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9		
M30 (72)	94.40	0.00	0.00	0.00	0.00	78.26	0.00	4.35	8.70	8.70	0.000*	0.327
M2015 (66)	94.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	**	0.000
M74 (59)	95.30	20.59	23.53	20.59	17.65	14.71	2.94	0.00	0.00	0.00	0.36	0.731
M98 (45)	95.60	0.00	0.00	0.00	0.00	20.83	41.67	0.00	29.17	8.33	0.13	0.546
M37 (31)	96.50	60.00	40.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.292
M15 (41)	100.00	0.00	0.00	11.11	22.22	66.67	0.00	0.00	0.00	0.00	0.10	0.369
M16 (53)	100.90	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	**	0.000
M83 (52)	101.10	28.57	33.33	38.10	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.474
M95 (50)	101.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.96	13.04	0.000*	0.168
M7 (55)	102.10	6.25	93.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000*	0.102
M401 (28)	102.10	16.67	8.33	0.00	0.00	0.00	58.33	0.00	16.67	0.00	0.06	0.486
M2000 (50)	102.20	7.14	92.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.001*	0.112
M51 (26)	102.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	**	0.000
M237 (25)	102.70	0.00	0.00	4.55	95.45	0.00	0.00	0.00	0.00	0.00	0.000*	0.080
M70 (31)	102.80	87.50	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.003*	0.164
M227 (41)	103.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.59	72.41	0.016*	0.256
M89 (36)	103.20	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**	0.000

Number	SVL (mm)	Appearance (%)									Significant Value (Chi-square)	Shanon-Weiner Diversity Index
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9		
M222 (52)	104.00	0.00	3.03	6.06	90.91	0.00	0.00	0.00	0.00	0.00	0.000*	0.157
M23 (40)	104.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	71.43	28.57	0.26	0.260

Remark The total number of appearance is in parentheses.

* means there was significant difference in appearance in each section of the cave that the toad was found (Chi-square, $P<0.05$).

** means the significant value could not be obtained from the available data.

Table 5.28 Shannon-Weiner diversity index indicating diversity in area utilization of *Bufo asper* in Tarn Lord Noi Cave during non-breeding season (September 2001 to February 2002). The total number of individuals was in parentheses.

Sex	Shanon-Weiner Index		
	Min	Max	Mean + SD
Female (7)	0.000	0.352	0.207 ± 0.152
Male (23)	0.000	0.731	0.236 ± 0.202
Small male (90-100 mm) (9)	0.000	0.731	0.310 ± 0.244
Large male (100-110 mm) (14)	0.000	0.486	0.188 ± 0.164

T-test for the equality of means revealed that there was no difference in the mean of diversity index of any sex groups between breeding and non-breeding season (female: P=0.187; male: P=0.190; small male: P=0.761; large male: P=0.365) (Table 5.29).

Table 5.29 Mean ± SD of Shannon-Weiner diversity index indicating the diversity in area utilization of *Bufo asper* in Tarn Lord Noi Cave during breeding season (July to August 2001 and March to June 2002) and non-breeding season (September 2001 to February 2002).

Sex	Mean ± SD of Shannon-Weiner Index	
	Breeding season	Non-breeding season
Female (7)	0.346 ± 0.214	0.207 ± 0.152
Male (23)	0.310 ± 0.177	0.236 ± 0.202
Small male (90-100 mm) (9)	0.386 ± 0.206	0.310 ± 0.244
Large male (100-110 mm) (14)	0.264 ± 0.143	0.188 ± 0.164
Remark None of any sex groups showed difference in the mean diversity indexes between breeding and non-breeding season (t-test: P>0.05).		

From the result, it might be concluded that *B. asper* inhabiting Tarn Lord Noi Cave exhibited some degrees of area fidelity behavior. Most of the toads were found in their own specific areas and some of them were found in only one section of the cave. The result from Chi-square test confirmed the high degree in area fidelity for most of them (P<0.05).

The indistinctness in area utilization between sexes, size classes, and times might be due to the toad exhibited area fidelity behavior and this behavior could be discussed by the reproductive and the survival strategy. Each of the toads was frequently found in its own specific areas that might be due to the advantage of them to use familiar area in the cave that provided mates, shelters, or food, rather than incurring the unknown and potentially more expensive cost of locating alternative areas (Seebacher and Alford, 1999). Especially for mating as discussed in the part of population study, the number of toads that exhibited highly area fidelity behavior in breeding season was lager than the number in non-breeding season. The male might remain or return to the same area to protect their sites for their reproductive fitness. The fidelity behavior of *B. asper* coincided with the behavior of some anurans. Reading, Loman, and Madsen (1991) reported the breeding pond fidelity in the common toad, *B. bufo*, during the year 1987 to the year 1990, between 79% and 96% of the adults that survived to breed in the following year, returned to the original pond. Green (1992) reported that, males of Fowler's Toad *B. woodhousei fowleri* exhibited considerable site fidelity during the breeding season and left only for foraging. Friedl and Klump (1997) reported breeding site fidelity in *Hyla arborea*, most of them remained at the spawning site during the breeding seasons in 1990 and 1991. Miaud, Sanuy, and Avrillier (2000) reported that males of *B. calamita* were more often detected in the same place during breeding season.

Three of the male demonstrated flexibility in area utilization (Chi-square test: $P>0.05$) for both breeding and non-breeding season and all of them belonged to the small size group ($90 \leq SVL < 100$ mm). One of them was found in only two consecutive areas but the others were found in 5 and 6 areas in the cave. The latter might be the wanderers or inferior males in the population.

5.3.2.2 Favored area

Except the section 7, the other sections of the cave were considered as the most frequently used area of the males due to their appearances. The difference in the proportion of males among the most frequently used sections was not found (Chi-square test: $P>0.05$) as indicated in Table 5.30.

Table 5.30 Frequency of the most frequently utilized area male *Bufo asper* and significant value indicating the degree of difference in proportion of the male among the most frequently utilized areas in Tarn Lord Noi Cave during July 2001 to June 2002.

Sampling period	Frequency									Significant Value (Chi-square)
	Sect-1	Sect-2	Sect-3	Sect-4	Sect-5	Sect-6	Sect-7	Sect-8	Sect-9	
Throughout (23)	5	2	2	2	5	2	0	4	1	0.555
Breeding season* (23)	5	3	2	1	6	2	0	3	1	0.336
Non-breeding season (23)**	6	3	1	2	4	2	0	4	1	0.402

Remark The number of individuals are in parentheses.

* July to August 2001 and March to June 2002.

** September to February 2002.

For the female, section 2, section 4, section 6, section 8, and section 9 were considered as the most frequently used area of them. Table 5.31, Chi-square test revealed that there was no difference in the proportion of the female among the most frequently used sections (P>0.05).

Table 5.31 Frequency of the most frequently utilized area female *Bufo asper* and significant value indicating the degree of difference in proportion of the female among the most frequently utilized areas in Tarn Lord Noi Cave during July 2001 to June 2002.

Sampling period	Frequency									Significant Value (Chi-square)
	Sect-1	Sect-2	Sect-3	Sect-4	Sect-5	Sect-6	Sect-7	Sect-8	Sect-9	
Throughout (7)	0	2	0	1	0	0	0	1	3	0.666
Breeding season* (7)	0	1	0	1	0	0	0	2	3	0.666
Non-breeding season (7)**	0	2	0	0	0	1	0	2	2	0.934

Remark The number of individuals are in parentheses.

* July to August 2001 and March to June 2002.

** September to February 2002.

Section 7 was not the most frequently used area for both the male and the female and none of the female had been caught in this section. This phenomenon was probably discussed by the importance of the stream for their reproduction due to this species mate and lay the string of eggs in the stream. In section 7, the stream was absent due to it flowed behind the wall of the cave. For the other sections, the stream flowed along the total length of the area. Due to the difference in proportion of toads was not found, it might be inferred that the importance of the 8 areas inside the cave were not significantly different.

5.4 Breeding Season

The breeding season was examined using the appearance of matings, eggs, and tadpoles. The result was shown in Table 5.32.

Table 5.32 The sign that indicated breeding season of *Bufo asper* inhabiting Tarn Lord Noi Cave.

Sampling time	Sign		
	Mating	Egg laying	Tadpole
March 2001	-	-	-
April 2001	+	-	-
May 2001	-	+	+
June 2001	---[a]	---[a]	---[a]
July 2001	+	+	-
August 2001	+	-	-
September 2001	-	-	-
October 2001	-	-	-
November 2001	-	-	-
December 2001	-	-	-
January 2002	-	-	-
February 2002	-	-	-
March 2002	+	-	-
April 2002	-	+	+
May 2002	-	+	+
June 2002	+	+	+
July 2002	-	+	+

Remark + the sign appeared.
- that the sign did not appear.
---[a] the data were not collected.

For calling behavior, male toads called almost year round. However, the call could not be noticed in the survey in December 2001 and January 2002. The low temperature at those sampling times might affect calling behavior of the male as reported in Fowler's toad, *Bufo woodhousei fowerli* and *Colosthetus subpunctatus*. Green (1992) found that calling activity of male Fowler's toad coincided with suitable temperature. The male of Fowler's toad would not call with body temperature below 14 ^{o}C and ambient temperature fell to 5 ^{o}C. For *Colosthetus subpunctatus*, Navas (1996)

reported that the vocal activity was positively correlated with microhabitat temperature. According to the surface temperature at Tarn Lord Noi Cave, it was about 20 and 16 °C for December 2001 and January 2002, respectively, and was lower than the other surface temperature during the study period. Due to different types of call in anurans served for varieties of functions (Duellman and Trueb, 1994) and the advertisement call, included courtship call and territorial call were not directly observed, it could not determine the breeding season using only their calls from this study. Nevertheless, the other signals, including mating, egg, and tadpole that indicated the breeding season were obtained.

Calling in the cave should be advantageous for the male that probably due to the call inside was louder than the call outside and it might attract the female choice.

In the cave, males and females in amplexus were found in April, July, and August 2001. However, only one couple was seen in each month. In July 2001, 2 males trying to copulate one female were found in the side pool. In March and June 2002, the couple was not directly found but the male and the female with small fragments of egg string on their backs were caught. So it was assumed that, they had just finished mating.

For the egg, double strings of eggs were deposited in both standing water and strong current. Two clutches were found in the year 2001 and 4 clutches were found in the year 2002. Moreover, a few small fragments of egg strings were obtained from the nets trapped across the stream. Neither amplexus nor egg string was found outside the cave, which is about 50 m long from the both entrances of the cave.

Newly hatched tadpoles were found near the site that egg strings were deposited. Nevertheless, the older stage could not be collected even using the net trap (in June and July 2002) that might be due to the dispersal in the strong current (Inger, 1966).

a.

b.

Figure 5.11 a. Two males and one female in amplexus.

b. Egg strings laid in side pool.

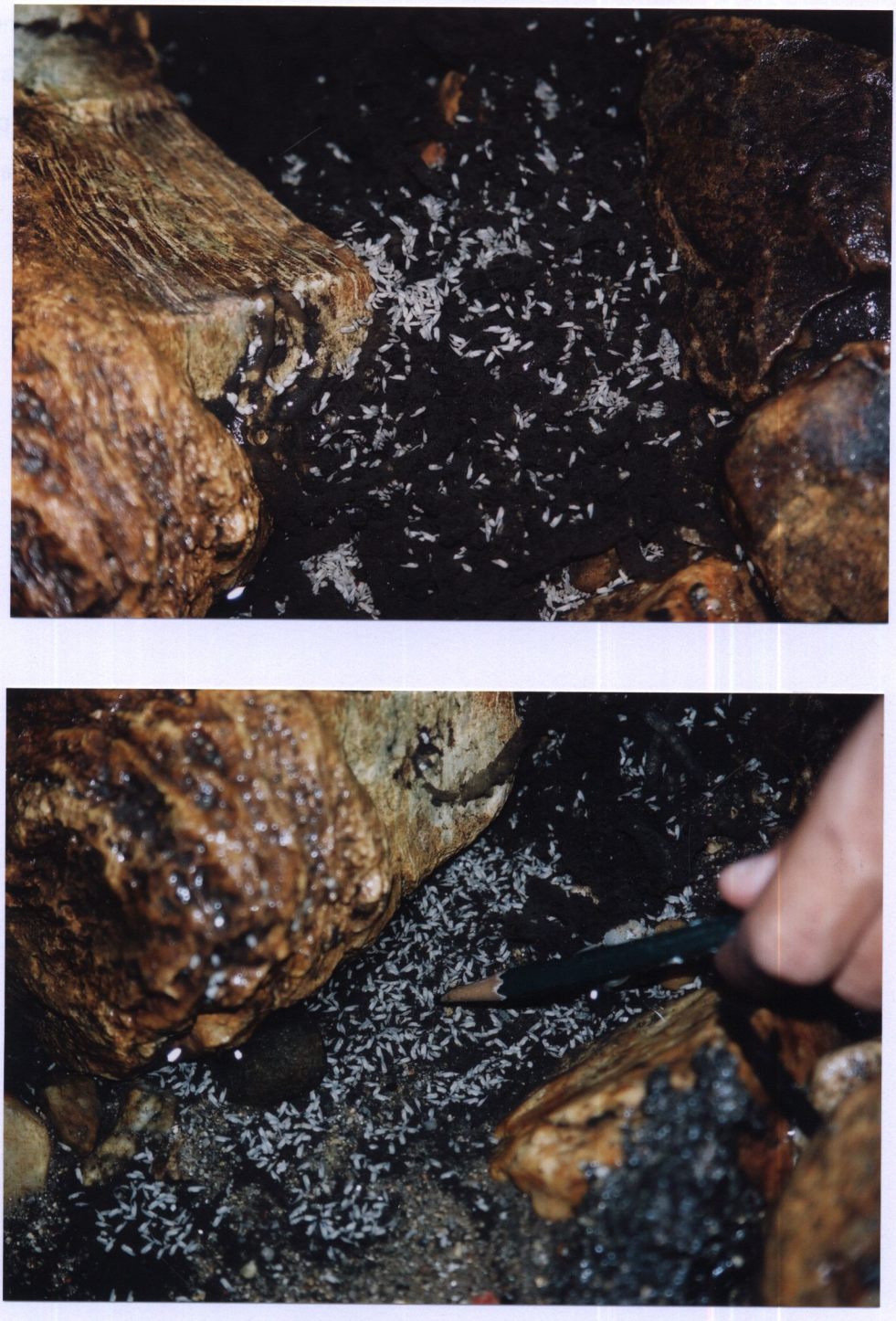


Figure 5.12 Newly hatched white tadpoles of *Bufo asper*.

From the obtained data, it can be concluded that *B. asper* inhabiting Tarn Lord Noi Cave was not explosive breeder. They took about 5 months in rainy season for each breeding season. From the present study, the breeding seasons were quite similar for 2 successive years that were during April to August 2001 and March to July 2002.

Chapter VI

Conclusions and Recommendation

6.1 Conclusions

6.1.1 Fluctuation of Relative Humidity and Temperature during the Study Period

The mean relative humidity at Tarn Lord Noi Cave was relatively high throughout the study period. The mean relative humidity inside the cave was quite parallel to the mean relative humidity outside but the difference was found in some periods of the year. Most of the sampling times, the mean relative humidity inside the cave was higher than the mean relative humidity outside.

The mean temperature inside the cave quite coincided with the mean temperature out side. All of the sampling time of which the mean temperature between inside and outside was different, the mean temperature inside was lower than the mean temperature outside.

6.1.2 Population

A total of 167 toads, including, 68 males, 48 females, 47 young, 2 young became to males, and 2 young became to females, was found inside the cave.

Using the Jolly-Seber model of population estimation, the population size of all toads varied from 71.9 $\pm$ 7.9 to 91.9 $\pm$ 8.5 individuals. The population size of the male varied from 27.3 $\pm$ 5.0 to 56.0 $\pm$ 4.9 individuals. The population size of the female varied from 11.0 $\pm$ 2.6 to 34.7 $\pm$ 16.5 individuals. The population size of the young varied from 12.0 $\pm$ 3.1 to 29.8 $\pm$ 9.5 individuals.

Population size of the male and the female correlated with the temperature but the correlation was on the opposite way. The change of female population size coincided with the temperature. On the other hand, when the temperature increased, the population size of male conversely related.

The male was dominant in number relative to the female and the young almost throughout the sampling period. However, the estimated population size of the male was smaller than the estimated population size of the female in May 2002 (in breeding season) in which the sex ratio was 1:1.27. For the other sampling time, the sex ratio varied from 1: 0.22 to 1: 0.75.

The minimum and maximum size of the male were 88.4 mm and 111.0 mm, respectively and the size that was frequently found was during 90 to 110 mm. The minimum and the maximum size of the female were 112.0 mm and 147.0 mm, respectively and the size that was frequently found was between 110 to 140 mm. The smallest and the largest size of the young toads were 34.3 mm and 110.4 mm, respectively and the size that was frequently found was between 30 to 90 mm.

6.1.3 Habitat Utilization

Most of the toad was found inside the cave but it could not concluded that they spent their time only inside the cave due to they were not caught for every sampling time. A large number of them showed movement between inside and outside the cave for both breeding and non-breeding season and most of them showed 2-way movement.

Most of them exhibited area fidelity behavior for both breeding and non-breeding season. There was no difference in habitat utilization between sexes and between the male of different sizes for both breeding and non-breeding season.

Section 7 (180-210 m from the downstream exit) was not the most frequently used area for both the male and the female. There was no difference in the proportion of the toad among the most frequently used sections for both breeding and non-breeding season. The result suggested that the importance of the 8 areas inside the cave were not different.

6.1.4 Breeding Season

The result suggested that *B. asper* in Tarn Lord Noi Cave was not explosive breeder. They took about 5 months in rainy season for each breeding season. The

breeding seasons were quite similar for 2 successive years that were during April to August 2001 and March to July 2002.

6.2 Recommendations

1. To properly identify sex, various sexually dimorphic traits should be examined. Multivariate analysis methods could be powerful tools for the identification and should be further investigated.

2. Although the result of this study provides more information on *Bufo asper* population in Tarn Lord Noi Cave, it requires more long-term study for the better conclusion. Due to the small population size of *B. asper*, the population monitoring both inside and outside of the cave should be conducted regularly to examine the fluctuation of the population.

3. In order to understand the population structure in term of age structure, individual age should be figured out and the skeletochronological study should be applied.

4. Based on the data of population and habitat utilization that indicate the importance of the cave as their breeding and shelter site, the result can be applied for conservation management.

References

Alford, R. A., Cohen, M. P., Crossland, M. R., Hearnden, M. N., James, D., and Schwarzkopf, L. 1995. Population biology of *Bufo masinus* in northern Australia. In Finlayson, M. (ed.). Wetland Research in the Wet-Dry Tropics of Australia. Supervising scientist report. pp. 173-181. Canberra: Office of the supervising scientist.

Augert, D., and Joly, P. 1993. Plasticity of age at maturity between two neighbouring populations of the common frog (*Rana temporaria* L.). Canadian Journal of Zoology 71: 26-33.

Barr, T. C. (Jr.). 1953. Notes on the occurrence of ranid frog in caves. Copeia 1953:60-61.

Barreto, L., and Moreira, G. 1996. Seasonal variation in age structure and spatial distribution of a savanna larval anuran assemblage in Central Brazil. Journal of Herpetology 30(1): 87-92.

Bee, M. A. 2002. Territorial male bullfrogs (*Rana catesbeiana*) do not assess fighting ability based on size-related variation in acoustic signals. Behavioral Ecology 13 (1): 109-124.

Bee, M. A., and Gerhardt, H. C. 2001. Neighbour-stranger discrimination by territorial male bullfrogs (*Rana catesbeiana*): II. perspective basis. Animal behavior 62: 1141-1150.

Bee, M. A., Korzich, C. E., Blackwell, K., and Gerhardt, H. C. 2001. Individual variation in advertisement calls of territorial male green frogs, *Rana clamitans*: Implications for Individual Discrimination. Ethology 107: 65-84.

Beklemishev, V.N. 1960. "Spatial and Functional Structure of Populations". Bulletin MOIP section Biology 65(2): 41-50.

Berry, P. Y. 1970. "The food of the Giant Toad *Bufo asper*". Zoological Journal of the Linnean Society. 49: 61-68.

Berven, K. A. 1990. Factors affecting population fluctuations in larval and adult stages of the wood frog (*Rana sylvatica*). Ecology 71: 1599-1608.

Bille, T. 2000. Microhabitat Utilization of the Mexican Salamander, *Pseudoeurycea leprosa*. Journal of Herpetology 34(4): 588-590.

Blair, W. F. (ed.). 1972. Evolution in the genus *Bufo*. Austin: University of Texas Press. 460 pp.

Blaustein, A. R., and Wake, D. B. 1990. Declining amphibian populations: global phenomenon? Trends Ecology Evolution 5: 203-204.

Brattstrom, B. H. 1979. Amphibian temperature regulation studies in the field and in the laboratory. American Zoology 19: 345-356.

Clarke, R. D. 1974. Postmetamorphic growth rates in a natural population of Fowler's toad, *Bufo woodhousei fowleri*. Canadian Journal of Zoology 52: 1489-1498.

Cohen, M. P., and Alford, R. A. 1993. Growth, survival and activity patterns of recently metamorphosed *Bufo marinus*. Wildlife Rersearch 20: 1-13.

Crump, M. L. 2002. Amphibian Monitoring in Latin America: a protocol manual. Herpetological Review 33(3): 233-235.

C-Tech International Co., Ltd. 2002. Chaloem Rattana Kosin National Park Management Project. Basic Information Report. Bangkok. (Mimeographed)

Duellman, W. E. 1999. Pattern of distribution of amphibians. Baltimore: The John Hopkins University Press. 633 pp.

Duellman, W. E. and Trueb, L. 1999. Biology of amphibians. Baltimore: The Johns Hopkins University Press. 670 pp.

Ehrlich, P. R., Roughgarden, J. 1987. The science of Ecology. New York: Macmillan Publishing Company. 710 pp.

Finlayson, M. (ed.). 1995. Wetland Research in the Wet-Dry Tropics of Australia. Supervising scientist report. Canberra: Office of the supervising scientist.

Frazer, J. F. D., 1967. A breeding colony of toads (*Bufo bufo* (L.)) in Kent. British Journal of Herpetology 3(2): 236-252.

Freeland, W. J., and Kerin, S. H. 1988. Within-habitat relationships between invading *Bufo marinus* and Australian species of frog during the tropical dry season. Australian Wildlife Research 15: 293-305.

Freeland, W. J., and Kerin, S. H. 1991. Ontogenetic alteration of activity and habitat selection by *Bufo marinus*. Wildlife Research 18: 431-443.

Friedl, T. W. P., and Klump, G. M. 1997. Some aspects of population biology in the European treefrog, *Hyla arborea*. Herpetologica 53(3): 321-330.

Green, D. M. 1992. Fowler's Toads (*Bufo woodhousei fowleri*) at Long Point, Ontario: changing abundance and implications for conservation. Canadian Wildlife Service Occasional Paper 76: 37-43.

Green, D. M. 1997. Temporal variation in abundance and age structure in Fowler's toad, *Bufo foweri*, at Long Point, Ontario. Herpetological Conservation 1: 45-56.

Griffin P. C., and Case, T. J. 2001. Terrestrial habitat preferences of adult arroyo southwestern toads. Journal o f Wildlife Management 65(4): 633-644.

Heyer, W. R., Donnelly, M. A., McDiarmid, R. W., Hayek, L. A. C., and Foster, M. S. (ed.). 1994. Measuring and monitoring biological diversity: standard methods for amphibians. Washington: Smithsonian Institution Press. 364 pp.

Heying, H. E. 2001. Social and reproductive behaviour in the Madagascan poison frog, *Mantella laevigata*, with comparison to the dendrobids. Animal behaviour 61: 567-577.

Houck, L. D., Arnold, S. J., and Thisted, R. A. 1985. A statistical study of mate choice: Sexual selection in a plethodontid salamander (*Desmognathus ochriphaeus*). Evolution 39: 370-386. Cited in Howard, R. D., Whiteman, H. H., and Schueller, T. I. 1994. Sexual selection in American toads: a test of a good-genes hypothesis. Evolution 48(4): 1286-1300.

Houlahan, J. E., Findlay, C. S., Meyer, A. H., Kuzmins, S. L., and Schmidt, B. R. 2001. Brief communication. Nature 412: 500.

Howard, R. D., Whiteman, H. H., and Schueller, T. I. 1994. Sexual selection in American toads: a test of a good-genes hypothesis. Evolution 48(4): 1286-1300.

Inger, R. F. 1966. "The Systematics and Zoogeograaphy of the amphibia of Borneo". Fieldiana: Zoology. 52: 402 pp.

IUCN. 2002. Global Amphibian Assessment: Species Asia Summarize. Southeast Asia workshop. XX pp. Sep. 30 to Oct. 4, 2002. Bangkok. (Mimeographed)

Joglar, R. L. 1998. Los Coquies de Puerto Rico: Su historia natural y conservation. Universidad de Puerto Rico, San Juan. 232 pp. Cited in Prather, J. W., and Briggler, J. T. 2001. Use of small caves by anurans during a drough period in the Arkansa Ozarks. Journal of Herpetology 35(4): 675-678.

Kellner A., and Green, D. M. 1995. Age structure and age at maturity in Fowler's toads, *Bufo woodhousii fowleri*, at their northern range limit. Journal of Herpetologica 29 (3): 485-489.

Krebs, C. J. 1989. Ecological Methodology. New York: Harper & Row. 654 pp.

Kusano, T., Maruyama, K., and Kaneko, S. 1995. Post-breeding dispersal of the Japanese Toad, *Bufo japonicus formosus*. Journal of Herpetology. 29(4): 633-638.

Langhelle, A., Lindell, M. J., and Nystrom, P. 1999. Effects of ultraviolet radiation on amphibian embryonic and larval development. Journal of Herpetology 33(3): 449-456.

Lehtinen, R. M. 2002. A historical study of the distribution of Blanchard's Cricket Frog (*Acris crepitans blanchardi*) in Southeastern Michigan. Herpetological Review 33 (3): 194-197.

Licht, L. E. 1974. Survival of embryos, tadpoles, and adults of the frog *Rana aurota aurota* and *Rana pretiosa pretiosa* sympatric in southwestern British Columbia. Canadian Journal of Zoology 52: 613-627.

Lowe, J. 2001. Population structure and habitat relationships of sympatric populations of the terrestrial salamanders *Plethdon elongatus* and *Ensatina eschscholtzii* a prescribed fire. Master's Thesis, Department of Biology, Faculty of Humboldt State University. 77 pp.

Magnusson, W. E., Lima, A. P., Hero, J. M., and Araujo, M. C. 1999. The rise and fall of a population of *Hyla boans*: reproduction in a neotropical gladiator frog. Journal of Herpetology 33(4): 647-656.

Marsh, D. M, Rand, A. S., and Ryan, M. J. 2000. Effects of inter-pond distance on the breeding ecology of tungara frogs. Oecologia 122: 505-513.

Matsui, M. 1984. Morphometric variation analyses and revision of the Japanese Toads (Genus *Bufo*, Bufonidae). Contributions from the Biological Laboratory, Kyoto University 26(3): 209-428.

Matthews, K. R., and Pope, K. L. 1999. A telemetric study of the movement patterns and habitat use of *Rana muscosa*, the mountain yellow-legged frog, in a high-elevation basin in Kings Canyon National Park, California. Journal of Herpetology 33(4): 615-624.

Mazerolle, M. J. 2001. Amphibian activity, movement patterns, and body size in fragmented peat bogs. Journal of Herpetology 35(1): 13-20.

Miaud, C., Sanuy, D., and Avrillier, J. N. 2000. Terrestrial movements of natterjack toad *Bufo calamita* (Amphibia, Anura) in a semi-arid, agricultural landscape. Amphibia-Reptilia 21: 357-369.

Monello, R. J., and Wright, R. G. 1999. Amphibian habitat preferences among artificial ponds in the Palouse region of northern Idaho. Journal of Herpetology 33(2): 1999.

Moreira, G., and Lima, A. P. 1991. Seasonal patterns of juvenile recruitment and reproduction in four species of leaf litter frogs in central Amazonia. Herpetologica 47: 295-300.

Navas, C. A. 1996. The effect of temperature on the vocal activity of tropical anurans: a comparison of high and low-elevation species. Journal of Herpetology 30(4): 488-497.

Navas, C. A., and Bevier, C. R. 2001. Thermal dependency of calling performance in the eurythermic frog *Colostethus subpunctatus*. Herpetologica 57(3): 384-395.

Patto, C. E. G., and Pie, M. R. 2001. Notes on the population dynamics of *Hylodes asper* in Southeastern Brazil (Anura: Leptodactylidae). Journal of Herpetology. 35(2): 684-686.

Pechmann, J. H. K., and Wilbur, H. M., 1994. Putting declining amphibian population in perspective: Natural fluctuations and human impacts. Herpetologica 50: 65-84.

Pough, F. H., and Kamel, S. 1984. Post-metamorphic change in activity metabolism of anurans in relation to life history. Oecologia 65: 138-144. Cited in Cohen, M. P., and Alford, R. A. 1993. Growth, survival and activity patterns of recently metamorphosed *Bufo marinus*. Wildlife Rersearch 20: 1-13.

Prather, J. W., and Briggler, J. T. 2001. Use of small caves by anurans during a drough period in the Arkansa Ozarks. Journal of Herpetology 35(4): 675-678.

Reading, C. J., Loman, J., and Madsen, T. 1991. Breeding pond fidelity in the common toad, *Bufo bufo*. The Zoological Society of London 225: 201-211.

Resetarits, W. J. (Jr), and Aldridge, R. D. 1988. Reproductive biology of a cave-asociated population of the frog *Rana palustris*. Canadian Journal of Zoology 66:329-333. Cited in Prather, J. W., and Briggler, J. T. 2001. Use of small caves by anurans during a drough period in the Arkansa Ozarks. Journal of Herpetology 35(4): 675-678.

Schlupp I., and Podloucky, R. 1994. Changes in breeding site fidelity: a combined study of conservation and behavior in the common toad *Bufo bufo*. Biological Conservation 69: 285-291.

Seebacher, F. and Alford, R. A. 1999. Movement and microhabitat use of a terrestrial amphibian (*Bufo marinus*) on a tropical island: seasonal variation and environmental correlates. Journal of Herpetology. 33 (2): 208-214.

Semlitsch, R. D. 1981. Terrestrial activity and summer home range of the mole salamander (*Ambystoma talpoideum*). Canadian Journal of Zoology 59: 315-322.

Shepard, D. B. 2002. Spatial relationships of male green frogs (*Rana clamitans*) throughout the activity season. American. Midland. Naturalist. 148: 394-400.

Spieler, M., and Linsenmair K. E. 1998. Migration patterns and diurnal use of shelter in a ranid frog of a West African savannah: A telemetric study. Amphibia-reptilia 19 (1): 43-64.

Squire, T., and Newman, R. A. 2002. Fine-scale population structure in the wood frog (*Rana sylvatica*) in a northern woodland. Herpetologica 58(1): 119-130.

Taylor, E. H. 1962. "The amphibian fauna of Thailand". The University of Kansas Science Bulletin. 43(8): 265-599.

Thornton, W. A., 1961. Popualtion dynamics in *Bufo woodhousei* and *Bufo valliceps*. The Texas Journal of Science 12 (3/4): 176-200.

Wake, D. B., 1994. Foreword. In Heyer, W. R., Donnelly, M. A., McDiarmid, R. W., Hayek, L. A. C., and Foster, M. S. (ed.). Measuring and monitoring biological diversity: standard methods for amphibians. pp xv-xvi. Washington: Smithsonian Institution Press.

Appendices

Appendix A

Area Characteristics inside Tarn Lord Noi Cave

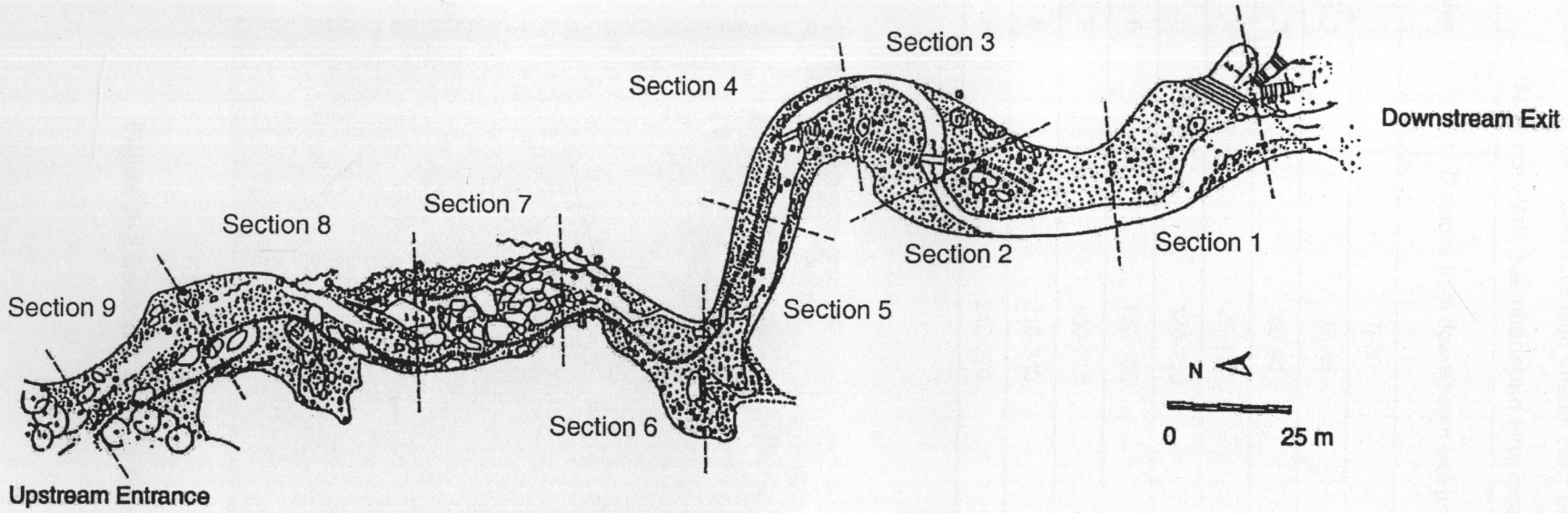


Figure A-1 The nine sections inside Tarn Lord Noi Cave (Modified from C-Tech International Co, Ltd., 2002).

Table A-1 The area characteristic inside Tarn Lord Noi Cave, Chaloem Rattana Kosin National Park, Kanchanaburi Province during July 2001 to June 2002.

Section	Distance from downstream exit (m)	Stream appearance	Dominant Sediment
1	0-30	+	Rock and gravel
2	30-60	+	Rock and gravel
3	60-90	+	Rock and gravel
4	90-120	+	Sand and gravel
5	120-150	+	Sand
6	150-180	+	Rock
7	180-210	--	Rockfall
8	210-240	+	Rockfall
9	240-270	+	Rockfall

Figure A-2 Section 1 (0-30 m from the down stream exit).

Figure A-3 Section 2 (30-60 m from the down stream exit).

Figure A-4 Section 3 (60-90 m from the down stream exit).

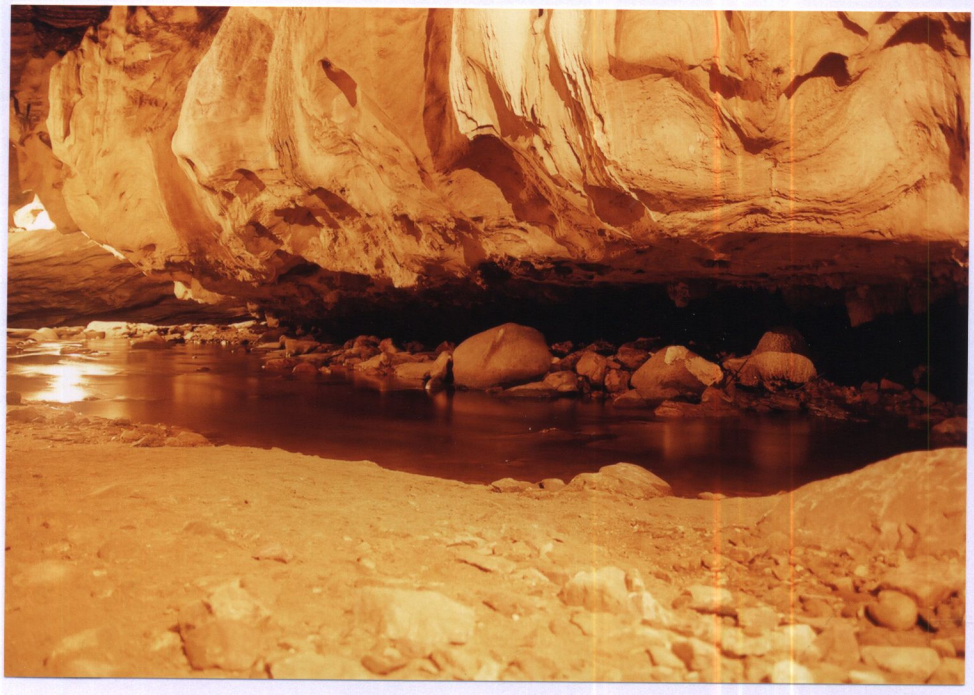


Figure A-5 Section 4 (90-120 m from the down stream exit).

Figure A-6 Section 6 (150-180 m from the down stream exit).

Figure A-7 Section 7 (180-210 m from the down stream exit).

Figure A-8 Section 8 (210-240 m from the down stream exit).

Figure A-9 Section 9 (240-270 m from the down stream exit).

Appendix B

Mark and Recapture Data

Table B-1 Mark-recapture data for a series of 11 samples of a total population of *Bufo asper* inhabiting Tarn Lord Noi Cave.

Time of last capture	Time of capture										
	Jul-01	**Aug-01**	**Sep-01**	**Nov-01**	**Dec-01**	**Jan-02**	**Feb-02**	**Mar-02**	**Apr-02**	**May-02**	**Jun-02**
Jul-01		59	1	0	0	0	1	0	0	0	0
Aug-01			49	4	8	0	1	0	0	1	0
Sep-01				18	12	2	1	1	2	0	0
Nov-01					15	2	2	2	1	0	0
Dec-01						23	24	3	1	2	0
Jan-02							19	5	1	0	1
Feb-02								42	4	1	0
Mar-02									34	7	3
Apr-02										22	6
May-02											18
Total marked	0	59	50	22	35	27	48	53	43	33	28
Total unmarked	76	19	9	6	26	2	6	3	3	11	6
Total caught	76	78	59	28	61	29	54	56	46	44	34
Total released	76	78	58	28	61	29	54	56	46	44	33

Remark Fifteen surveys were carried out each month except in April 2002, 13 surveys were done.

Table B-2 Mark-recapture data for a series of 11 samples of a male population of *Bufo asper* inhabiting Tarn Lord Noi Cave.

Time of last capture	Time of capture										
	Jul-01	**Aug-01**	**Sep-01**	**Nov-01**	**Dec-01**	**Jan-02**	**Feb-02**	**Mar-02**	**Apr-02**	**May-02**	**Jun-02**
Jul-01		33	0	0	0	0	0	0	0	0	0
Aug-01			24	2	5	0	1	0	0	0	0
Sep-01				13	7	2	0	1	0	0	0
Nov-01					12	1	0	0	1	0	0
Dec-01						21	17	3	0	1	0
Jan-02							17	5	0	0	0
Feb-02								29	3	1	0
Mar-02									24	4	2
Apr-02										15	2
May-02											13
Total marked	0	33	24	15	24	24	35	38	28	21	17
Total unmarked	38	4	1	3	21	0	2	1	0	0	0
Total caught	38	37	25	18	45	24	37	39	28	21	17
Total released	38	37	25	18	45	24	37	39	28	21	17

Remark Fifteen surveys were carried out each month except in April 2002, 13 surveys were done.

Table B-3 Mark-recapture data for a series of 11 samples of a female population of *Bufo asper* inhabiting Tarn Lord Noi Cave.

Time of last capture	Time of capture										
	Jul-01	Aug-01	Sep-01	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02
Jul-01		11	0	0	0	0	0	0	0	0	0
Aug-01			12	1	1	0	0	0	0	1	0
Sep-01				3	3	0	0	0	1	0	0
Nov-01					2	1	2	1	0	0	0
Dec-01						0	3	0	1	1	0
Jan-02							1	0	0	0	0
Feb-02								8	0	0	0
Mar-02									6	0	1
Apr-02										5	1
May-02											4
Total marked	0	11	12	4	6	1	6	9	8	7	6
Total unmarked	14	8	5	2	1	0	2	1	2	11	4
Total caught	14	19	17	6	7	1	8	10	10	18	10
Total released	14	19	16	6	7	1	8	10	10	18	9

Remark Fifteen surveys were carried out each month except in April 2002, 13 surveys were done.

Table B-4 Mark-recapture data for a series of 11 samples of a young population of *Bufo asper* inhabiting Tarn Lord Noi Cave.

Time of last capture	Time of capture										
	Jul-01	Aug-01	Sep-01	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02
Jul-01		15	1	0	0	0	1	0	0	0	0
Aug-01			13	1	1	0	0	0	0	0	0
Sep-01				1	1	0	1	0	1	0	0
Nov-01					1	0	0	1	0	0	0
Dec-01						2	4	0	0	0	0
Jan-02							1	0	1	0	1
Feb-02								4	1	0	0
Mar-02									4	3	0
Apr-02										2	3
May-02											1
Total marked	0	15	14	2	3	2	7	5	7	5	5
Total unmarked	24	7	3	2	6	2	2	2	1	0	2
Total caught	24	22	17	4	9	4	9	7	8	5	7
Total released	24	22	17	4	9	4	9	7	8	5	7

Remark Fifteen surveys were carried out each month except in April 2002, 13 surveys were done.

Biography

Miss Tassanee Eamkamon was born on the 18th of September 1976 in Chaiyaphume Province. She graduated her bachelor's degree of Science in Biology in 1998 from the Department of Biology, Faculty of Science, Chulalongkorn University. She continued her graduated study for a master's degree of science in zoology at the same University in 1999.