Chapter V

Results and Discussion

5.1 Fluctuation of Relative Humidity and Temperature during the Study Period

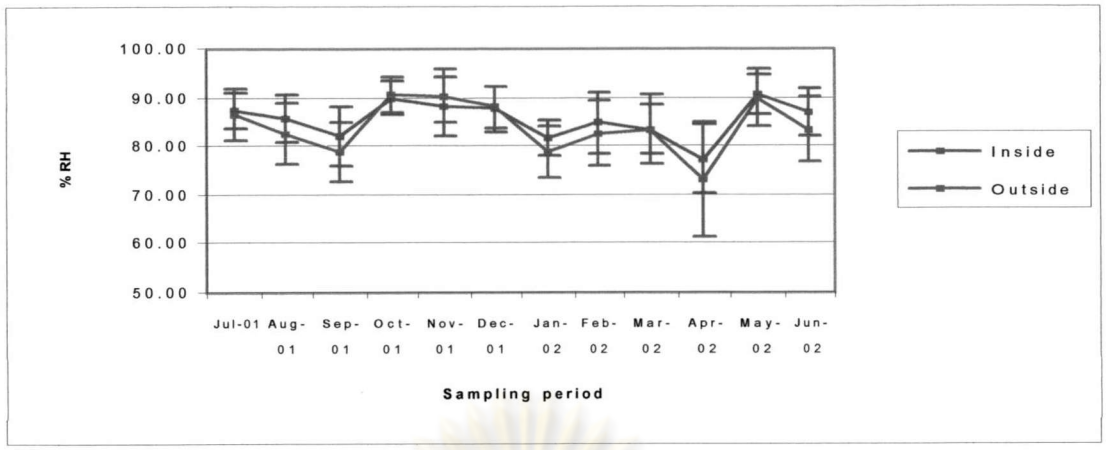
During July 2001 to June 2002, the fluctuation of relative humidity in the cave was quite similar to the relative humidity outside as shown in Figure 5.1. Both inside and outside of the cave, the mean relative humidity remained relatively high throughout the year. Huai Mae Kraphroi, the permanent stream 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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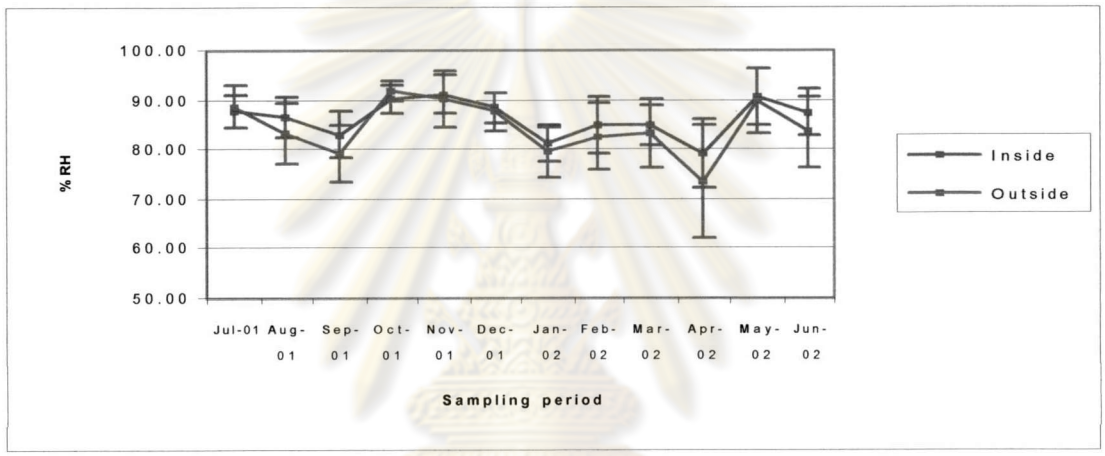

Figure 5.1 Mean (± SD) relative humidity at Tarn Lord Noi Cave during July 2001 to June 2002. a. at 1 m above soil surface b. at soil surface

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 $^{\circ}$C, respectively and were 17.07, 16.86, 17.20 $^{\circ}$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 $^{\circ}$C, respectively and were 25.60, 25.08, 24.93 $^{\circ}$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.

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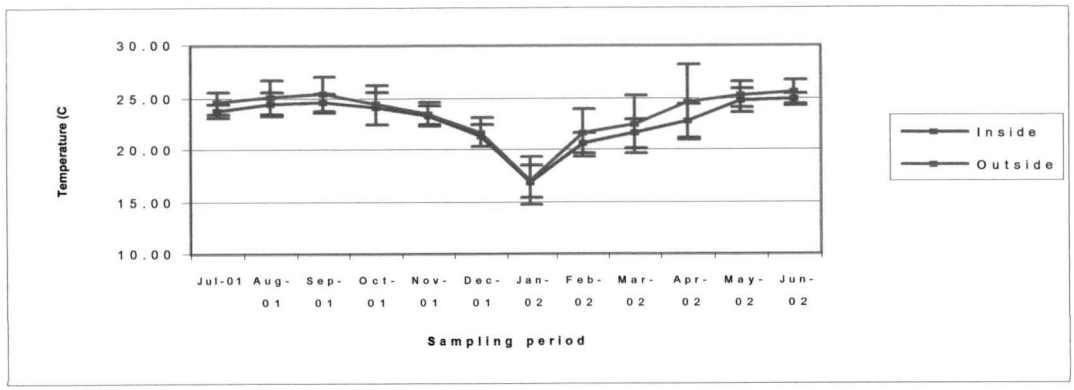

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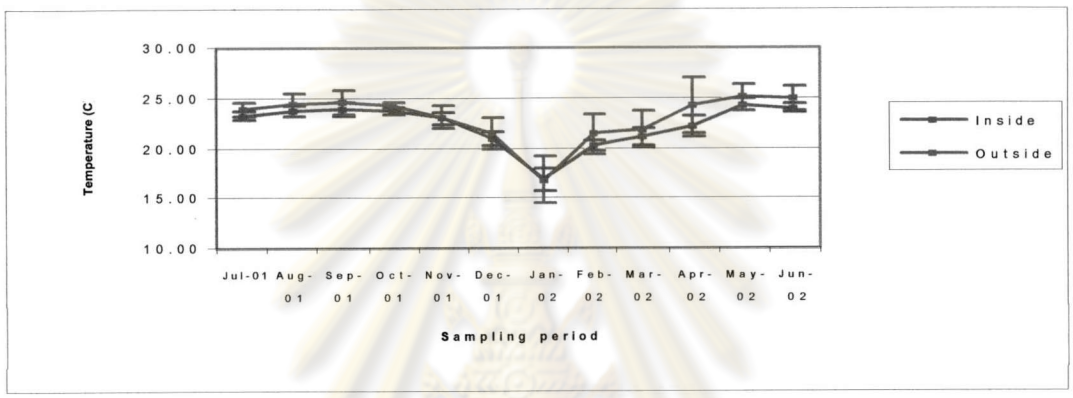

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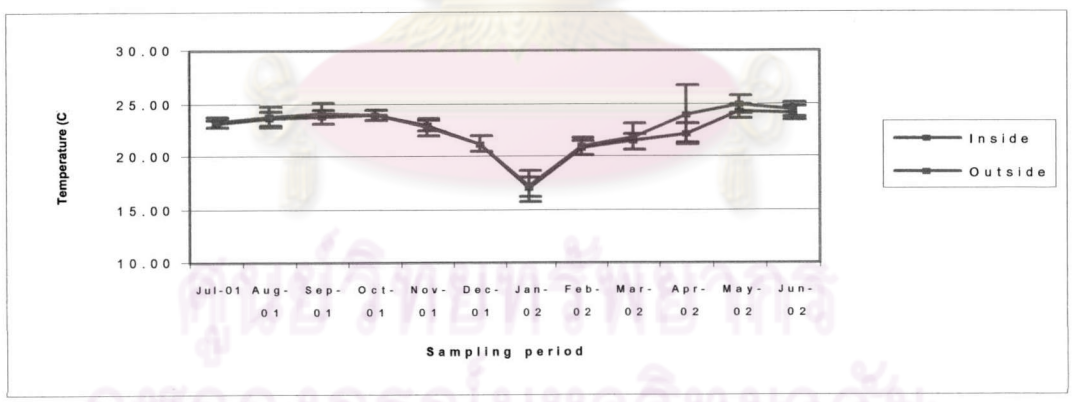


Figure 5.2 Mean (+SD) temperature at Tarn Lord Noi Cave during July 2001 to June 2002. a. air b. soil surface c. water

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.

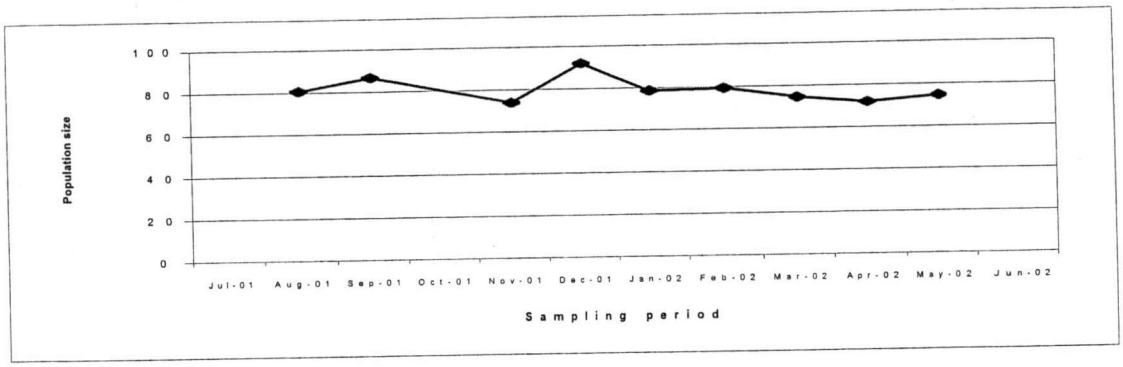
Due to the limitation of Jolly-Seber method, the estimate of population size and the number joining could not be obtained for the first sample and neither of them could be estimated for the last sample. In addition, the probability of survival can not be estimated for the last two samples.

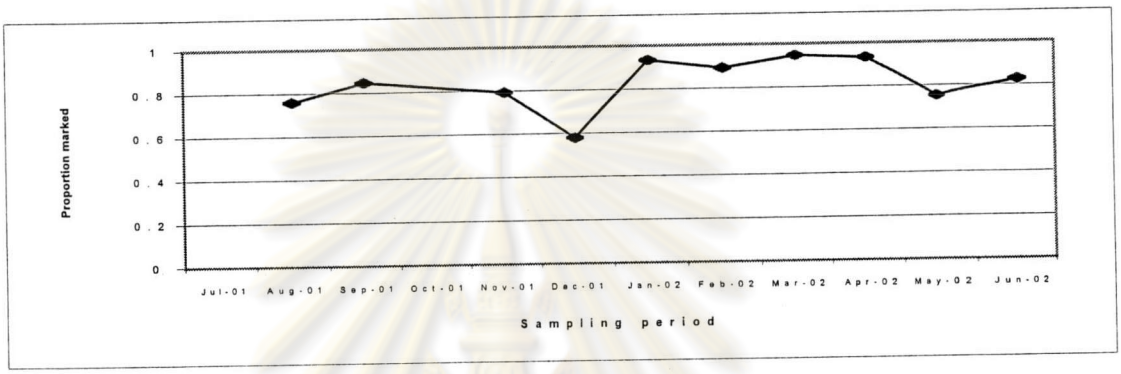
Table 5.7 Population estimates of *Bufo asper* in Tarn Lord Noi Cave.

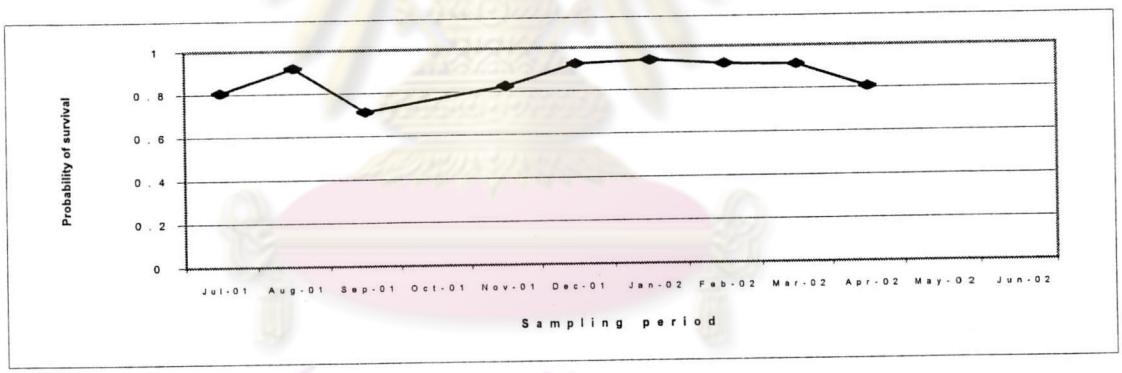
Sample	Proportion marked	Estimated population size (± S. E.)	Probability of survival (± S. E.)	Number joining (± S. E.)
July 2001	---	---	0.809 ± 0.046	---
August 2002	0.759	80.9 ± 3.8	0.919 ± 0.065	12.6 ± 3.0
September 2001	0.850	87.0 ± 7.2	0.715 ± 0.087	12.4 ± 6.1
November 2001	0.793	73.8 ± 9.7	0.827 ± 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.







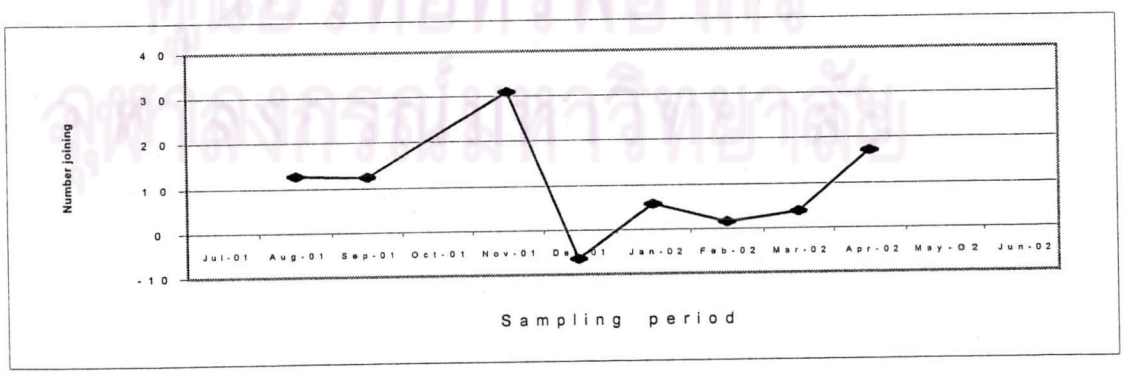


Figure 5.3 Estimated population size, proportion of marked toads, probability of survival, and estimated number of unmarked toad joining the population in Tarn Lord Noi Cave during July 2001 to June 2002.

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

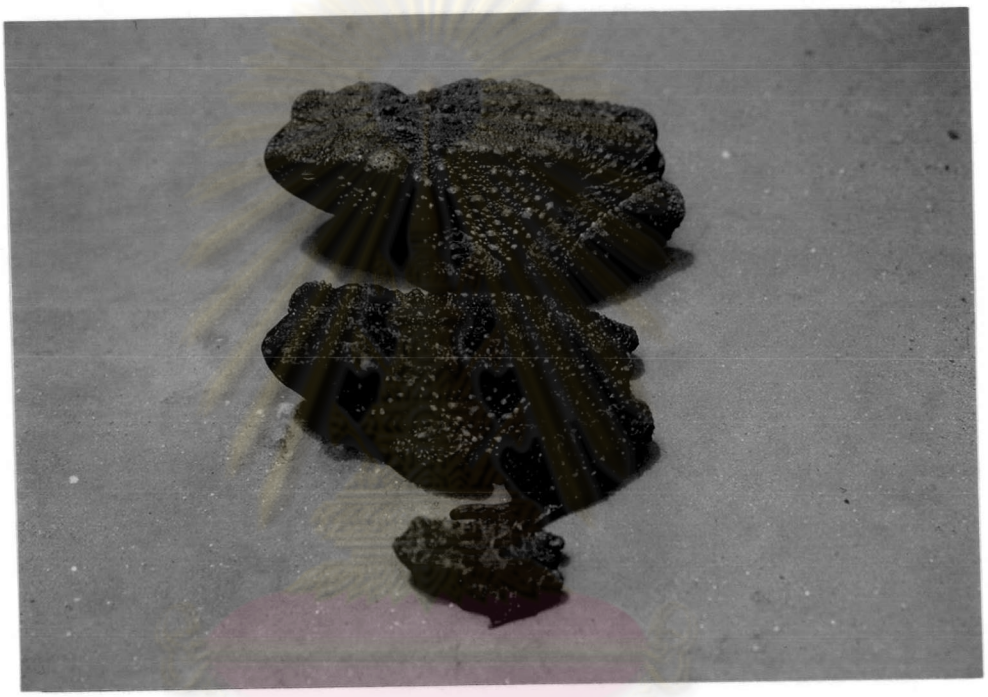


Figure 5.4 Female, male, and young *Bufo asper*.

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

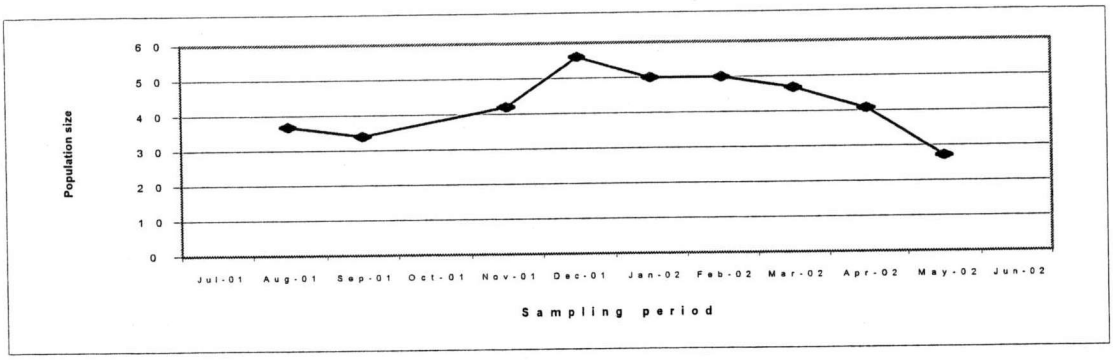
The proportion of marked young revealed that there was new young entered the cave during the sampling period due to the proportion marked was lower than 1.000. However, the new young was not found in May 2002 due to the proportion marked value was equal to 1.000. It could be concluded that none of the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

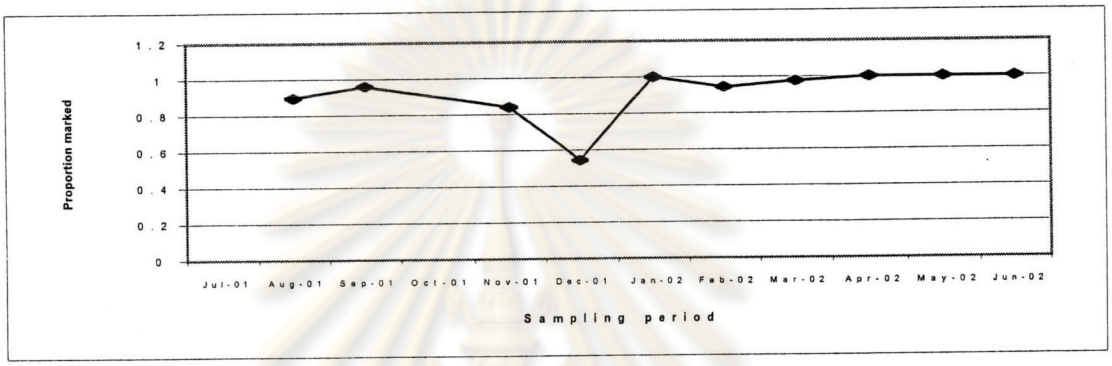
The estimated population size varied from 12.0 ± 3.1 to 29.8 ± 9.5 individuals. The largest population size was found in September 2001 and the smallest was found in March 2002. The factors influenced the proportion of marked young were migration, growth of the young to be adult, birth, and death. The 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.

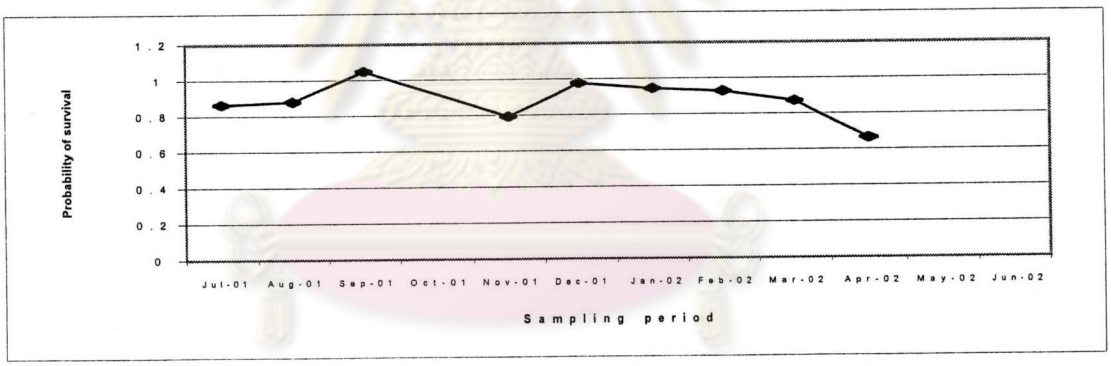
The probability of survival of the young varied from 0.372 ± 0.228 to 1.214 ± 0.928. The probability of survival was quite low in September 2001 that might be due to some of the young left the cave or died after the sampling time in September

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.







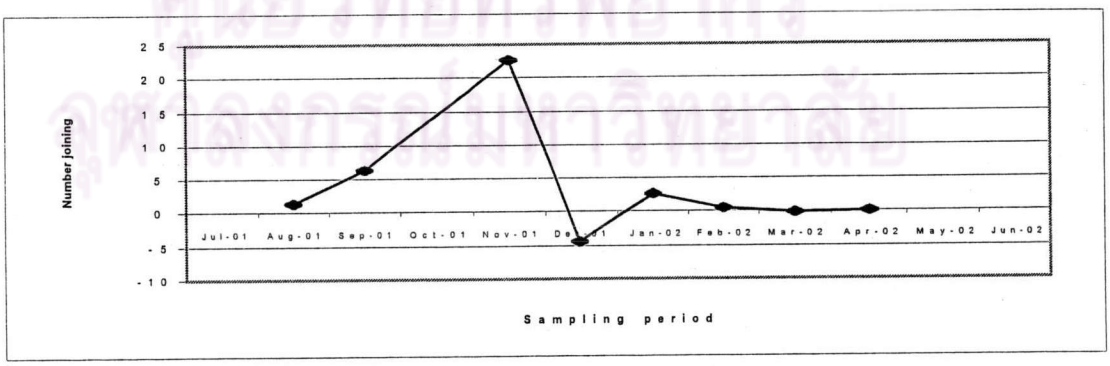
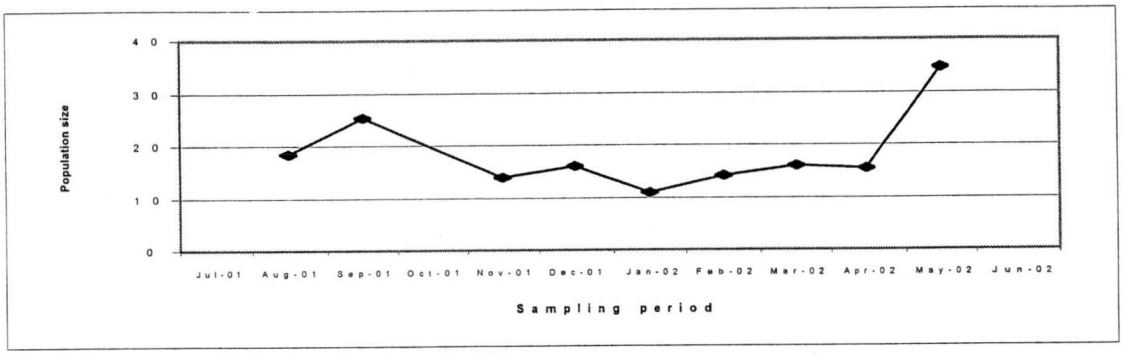
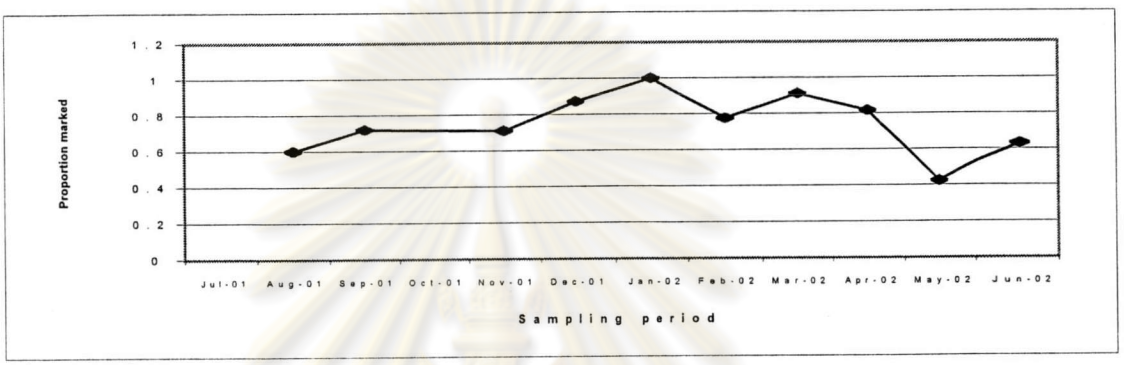
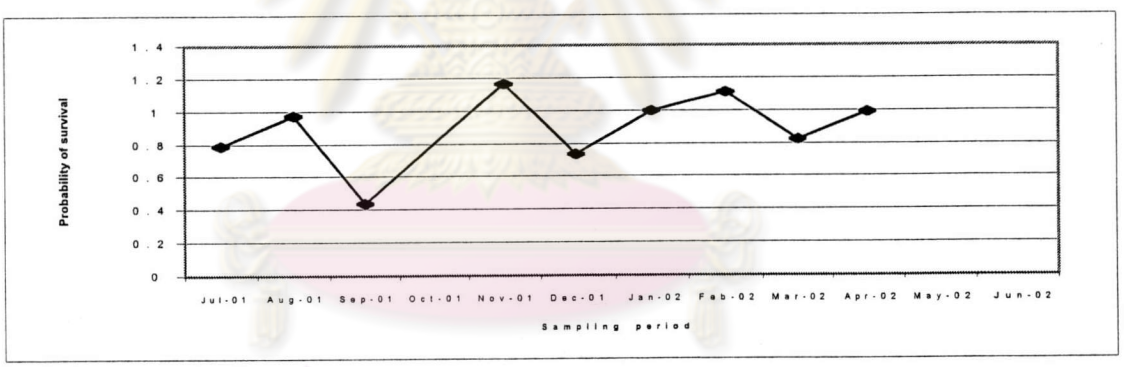


Figure 5.5 Estimated male population size, proportion of marked and unmarked males, probability of survival, and estimated number of unmarked males joining the population in Tarn Lord Noi Cave during July 2001 to June 2002.







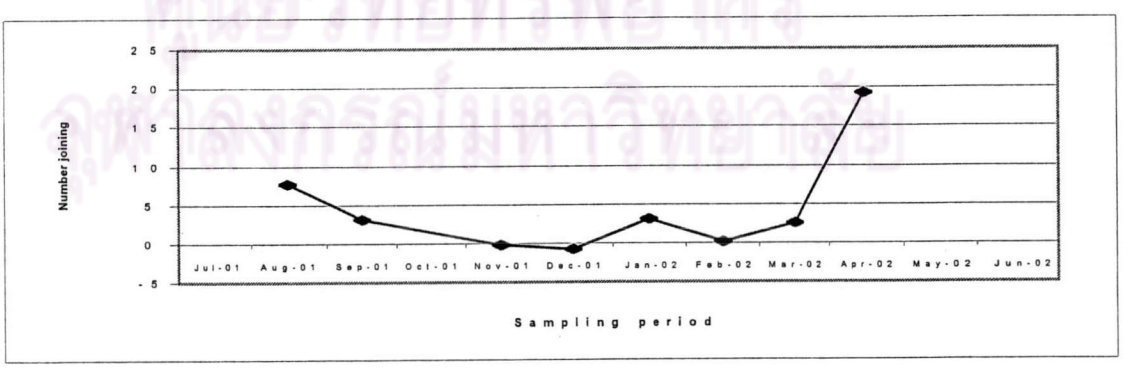


Figure 5.6 Estimated female population size, proportion of marked and unmarked females, probability of survival, and estimated number of unmarked females joining the population in Tarn Lord Noi Cave during July 2001 to June 2002.

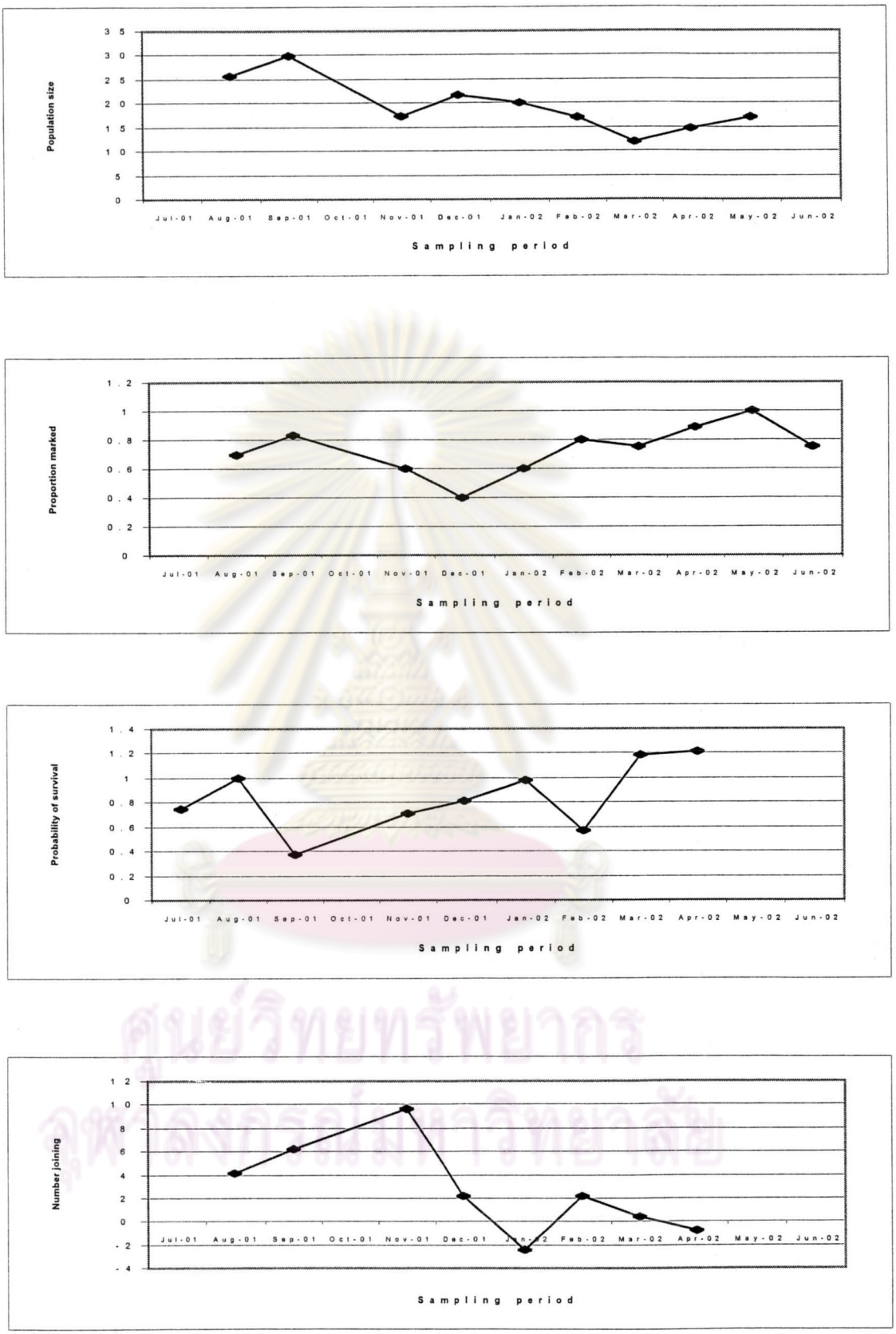


Figure 5.7 Estimated young population size, proportion of marked and unmarked young, probability of survival, and estimated number of unmarked young joining the population in Tarn Lord Noi Cave during July 2001 to June 2002.

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

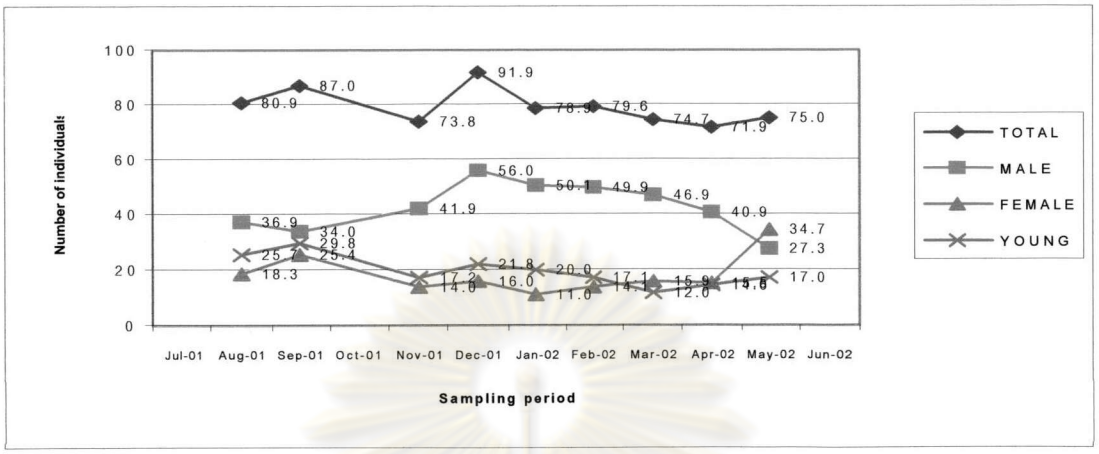


Figure 5.8 Dynamic of estimated population size of *Bufo asper* in Tarn Lord Noi Cave during July 2001 to June 2002.

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

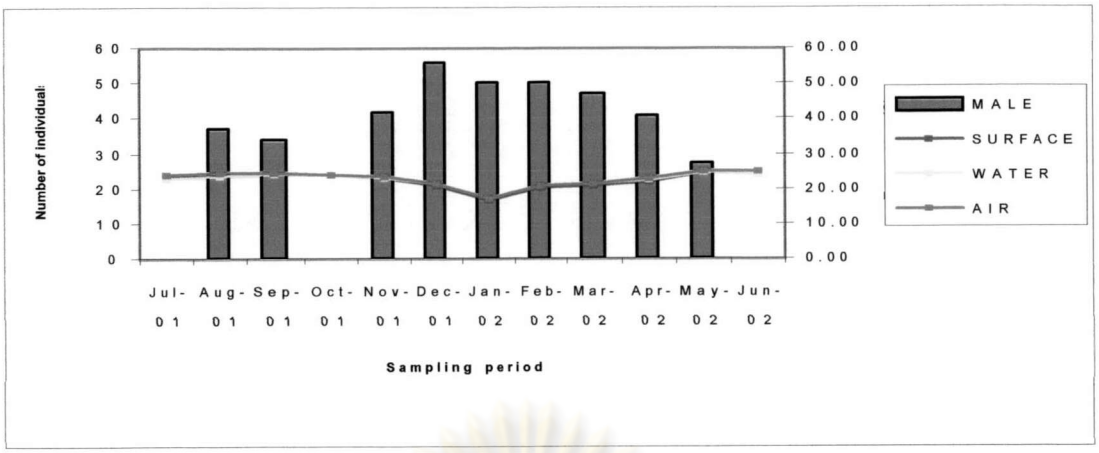
As indicated in Table 5.12, the climatic factors, including relative humidity at 1 m above ground, relative humidity at soil surface, air temperature, soil surface temperature, and water temperature were tested. Spearman's correlation revealed that population size of all and the young toads did not correlate 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.



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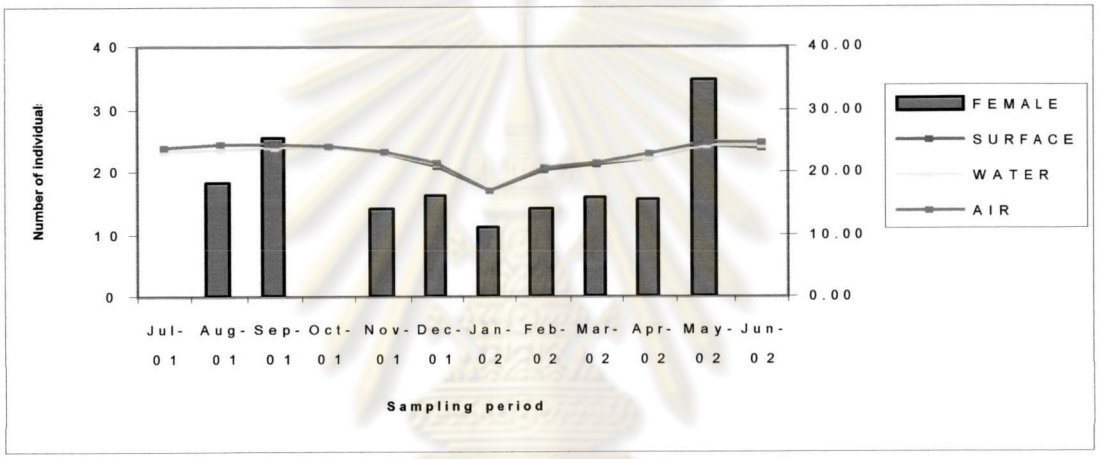


Figure 5.9 Population size of *Bufo asper* and temperature (^{o}C) in Tarn Lord Noi Cave throughout the study period. a. Female b. Male

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.

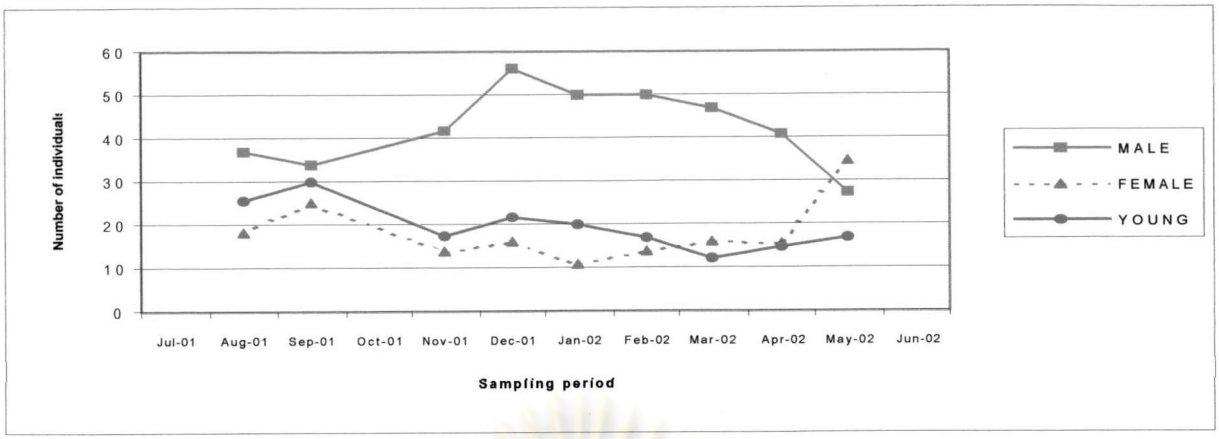


Figure 5.10 Proportion of males, females, and young *Bufo asper* in Tarn Lord Noi Cave during July 2001 to June 2002.

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≤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 $^{\circ}$C and ambient temperature fell to 5 $^{\circ}$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.

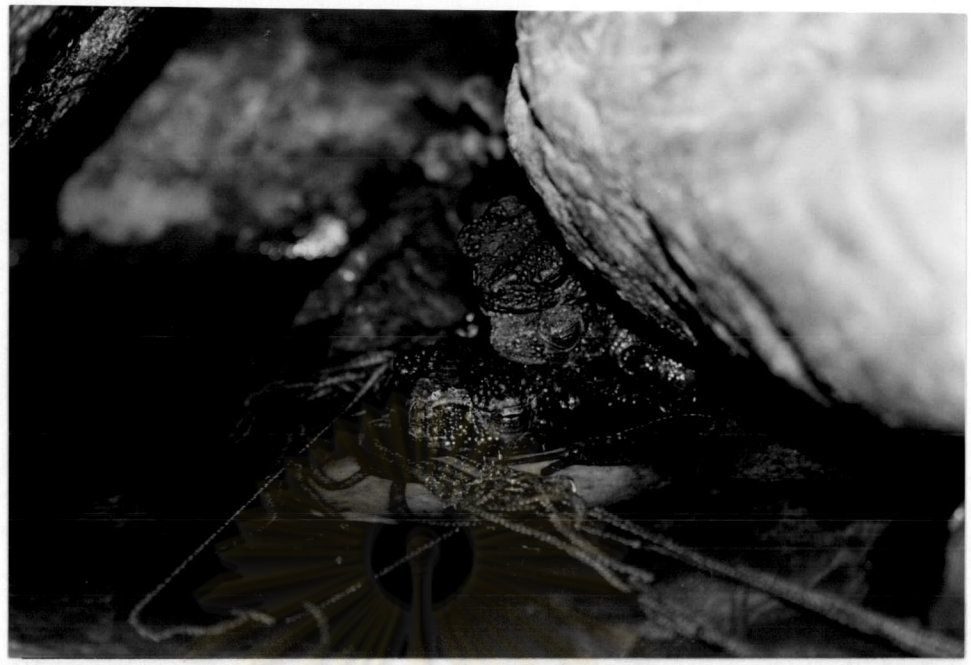
Calling in the cave should be advantageous for the male that probably due to the call inside was louder than the call outside and it might attract the female choice.

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.

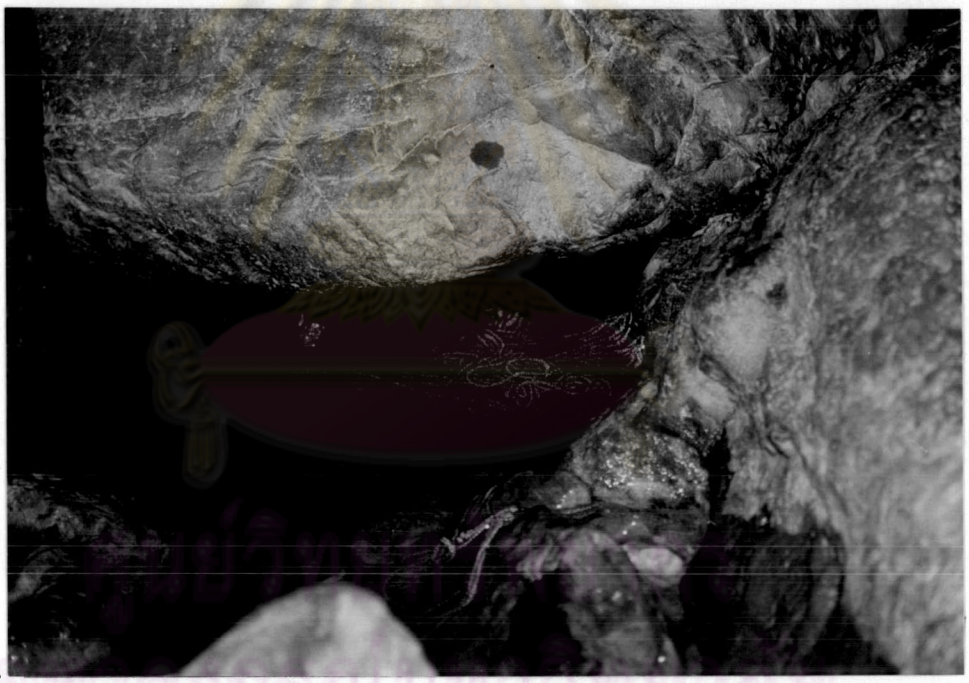


Figure 5.11 a. Two males and one female in amplexus.

b. Egg strings laid in side pool.

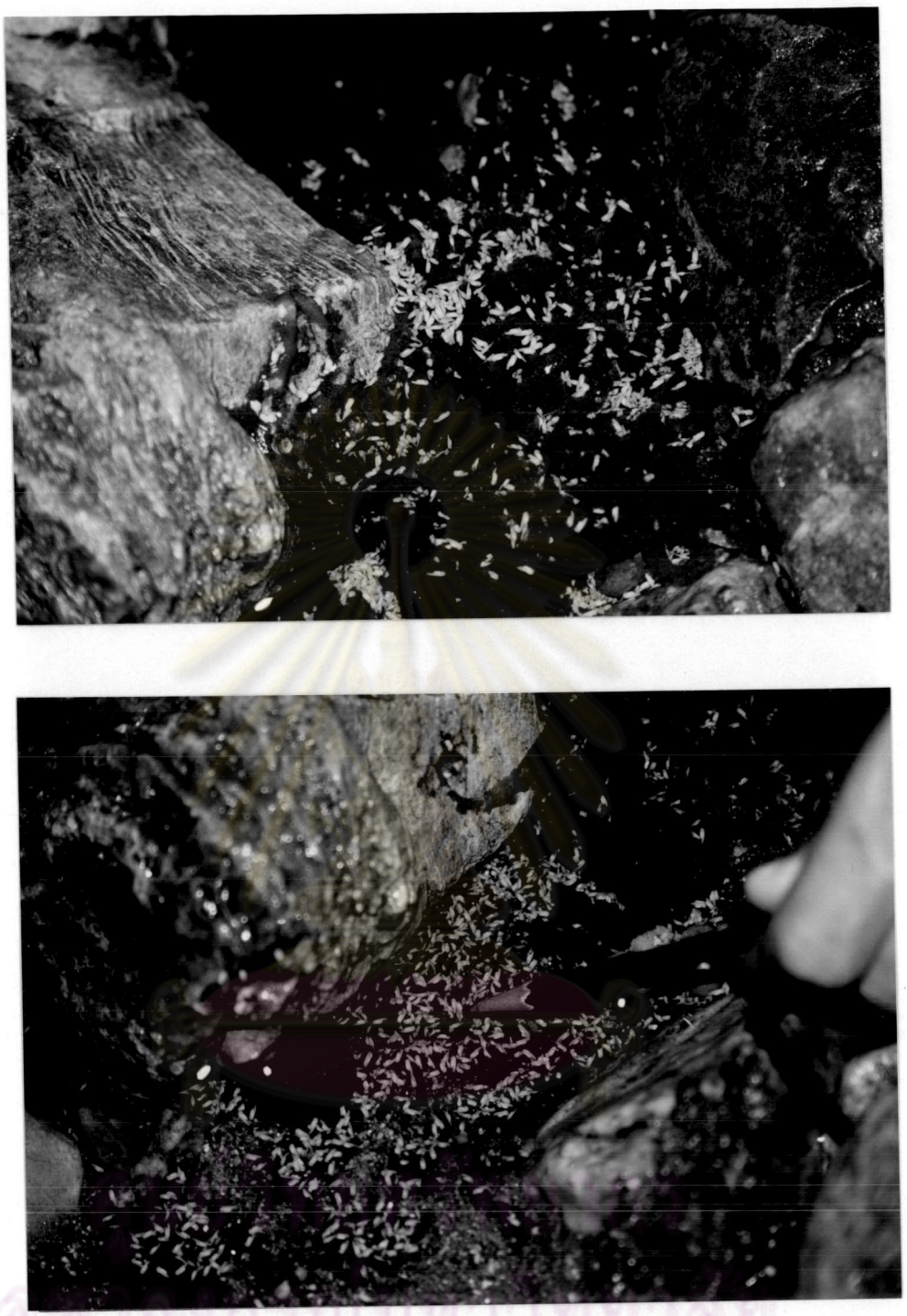


Figure 5.12 Newly hatched white tadpoles of *Bufo asper*.

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.