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THESIS

EXTERNAL MORPHOLOGICAL CHARACTERS OF SOME TADPOLES AS RELATED TO DIFFERENT HABITAT TYPES IN CHIANG DAO, CHIANG MAI PROVINCE

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Ruthairat Songchan 2007: External Morphological Characters of Some Tadpoles as Related to Different Habitat Types in Chiang Dao, Chiang Mai Province. Master of Science (Forestry), Major Field: Forest Biology, Department of Forest Biology. Thesis Advisor: Mr. Jarujin Nabhitabhata, Ph.D. 103 pages

The external morphological characters of some tadpoles related to different habitat types in Chiang Dao, Chiang Mai Province were intended to explain the relationship between environmental variables and external morphologies. This research was conducted in Chiang Dao, Chiang Mai Province between January – December 2005. Data were collecting in different habitat types for six times in 61 sample points by random sampling techniques. Sample points were also recorded for environmental data. Nineteen tadpole species were encountered during the entire study. Four (*Amolops marmoratus*, *Brachytarsophrys carinensis*, *Huia melasma* and *Leptobrachium chapaense*) species were recorded only in permanent water, three (*Microhyla heymonsi*, *Microhyla ornata* and *Rana livida*) species only in temporary ponds, and twelve species occurred in both kinds of water body. *Rhacophorus bipunctatus* occurred in many sites more than other species.

The result of cluster analysis could be categorized in five groups based on 21 external morphological characters at 62.5 percent difference. The ordination technique showed the relationship among tadpole appearance and 3 abiotic factors in 3 axes and correlation between Axis 1 and 3 was the strongest. Each individual have different linear regression model and being correlated with their external morphologies. *A. marmoratus* was most related to current water. *Rana cubitalis* was most related to dissolved oxygen. *Leptolalax pelodytoides* was most related to temperature. *Polypedates leucomystax* was most related to rainfall.

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TABLE OF CONTENTS

	Page
TABLE OF CONTENTS	i
LIST OF TABLES	ii
LIST OF FIGURES	iv
LIST OF ABBREVIATIONS	vi
INTRODUCTION	1
OBJECTIVES	2
LITERATURE REVIEWS	3
Morphological Characters	3
External Morphology	3
Tadpole Habitats	6
Factors of Tadpole System	7
Tadpole Morphology and Habitat Studied	9
Study Area	10
MATERIALS AND METHODS	16
Materials	16
Methods	17
RESULTS AND DISCUSSION	22
CONCLUSION AND RECOMMENDATION	78
Conclusion	78
Recommendation	80
LITERATURE CITE	82
APPENDIXES	87

LIST OF TABLES

Table		Page
1	The axis summary of total variance (“inertia”) in the species data.	28
2	The correlation among variable and axes.	29

Appendix Table

1	List of tadpoles in Chiang Dao, Chiang Mai.	88
2	External morphological average measuresment of tadpoles.	89
3	Measurement of external tadpole morphologies.	92
4	Relative tadpole external morphologies of *Leptobrachium chapaense* related to dissolved oxygen	95
5	Relative tadpole external morphologies of *Leptolalax pelodytoides* related to temperature	95
6	Relative tadpole external morphologies of *Brachytarsophrys carinensis* related to current water	96
7	Relative tadpole external morphologies of *Xenophrys lateralis* related to current water	96
8	Relative tadpole external morphologies of *Amolops marmoratus* related to current water	97
9	Relative tadpole external morphologies of *Huia melasma* related to current water	97
10	Relative tadpole external morphologies of *Fejervaya limnocharis* related to rainfall	98
11	Relative tadpole external morphologies of *Limnonectes kuhlii* related to rainfall	98
12	Relative tadpole external morphologies of *Rana cubitalis* related to dissolved oxygen	99

LIST OF TABLES (Continued)

Appendix Table

13	Relative tadpole external morphologies of *Rana nigrovittata* related to dissolved oxygen	99
14	Relative tadpole external morphologies of *Rhacophorus bipunctatus* related to rainfall	100
15	Relative tadpole external morphologies of *Polypedates leucomystax* related to rainfall	100
16	Relative tadpole external morphologies of *Kaloula pulchra* related to rainfall	101
17	Relative tadpole external morphologies of *Microhyla berdmorei* related to temperature	101
18	Relative tadpole external morphologies of *Microhyla heymonsi* related rainfall	102
19	Relative tadpole external morphologies of *Microhyla pulchra* related to temperature	102
20	Relative tadpole external morphologies of *Microhyla ornata* related to dissolved oxygen	103
21	Relative tadpole external morphologies of *Micryletta inornata* related to temperature	103

LIST OF FIGURES

Figure		Page
1	Mapping of landuse of Chiang Dao District, Chiang Mai Province	11
2	Average monthly temperature and rainfall in Chiang Dao Distrcit, Chiang Mai Province.	13
3	External Tadpole morphology and body plan.	18
4	Mouthparts (Oral apparatus) of Anuran tadpoles.	20
5	Relative frequency of tadpole species in permanent and temporary waters.	22
6	Tadpole species appearance	24
7	Tadpoles among external morphological characters dendrogram.	27
8	Representing the constrained CCA of tadpole data between Axis 1 and Axis 3	30
9	*Leptobrachium chapaense* (Bourret, 1937)	32
10	Habitat of *Leptobrachium chapaense* tadpole	33
11	*Leptolalax pelodytoides* (Boulenger, 1893)	35
12	Habitat of *Leptolalax pelodytoides* tadpole	36
13	*Brachytarsophrys carinensis* (Boulenger, 1899)	37
14	Habitat of *Brachytarsophrys carinensis* tadpole	38
15	*Xenophrys lateralis* (Anderson, 1871)	39
16	Habitat of *Xenophrys lateralis* tadpole	41
17	*Amolops marmoratus* (Blyth, 1855)	42
18	Habitat of *Amolops marmoratus* tadpole	43
19	*Huia melasma* Stuart and Chan-ard, 2005	44
20	Habitat of *Huia melasma* tadpole	46
21	*Fejervarya limnocharis* (Boie, 1835)	47
22	Habitat of *Fejervarya limnocharis* tadpole	48
23	*Limnonectes kuhlii* (Tschudi, 1838)	49
24	Habitat of *Limnonectes kuhlii* tadpole	50

LIST OF FIGURES (Continued)

Figure **Page**

Figure		Page
25	*Rana cubitalis* Smith, 1917	52
26	Habitat of *Rana cubitalis* tadpole	53
27	*Rana livida*, (Blyth, 1856)	54
28	Habitat of *Rana livida* tadpole	56
29	*Rana nigrovittata* (Blyth, 1856)	56
30	Habitat of *Rana nigrovittata* tadpole	57
31	*Rhacophorus bipunctatus* Ahl, 1927	59
32	Habitat of *Rhacophorus bipunctatus* tadpole	60
33	*Polypedates leucomystax* (Gravenhorst, 1829)	61
34	Habitat of *Polypedates leucomystax* tadpole	62
35	*Kaloula punlchra* Gray, 1831	64
36	Habitat of *Kaloula punlchra* tadpole	65
37	*Microhyla berdmorei* (Blyth, 1856)	66
38	Habitat of *Microhyla berdmorei* tadpole	67
39	*Microhyla heymonsi* Vogt, 1911	68
40	Habitat of *Microhyla heymonsi* tadpole	69
41	*Microhyla pulchra* (Hallowell, 1861)	71
42	Habitat of *Microhyla pulchra* tadpole	72
43	*Microhyla ornate* (Dumeril and Bibro, 1841)	73
44	Habitat of *Microhyla ornate* tadpole	74
45	*Micryletta inornata* (Boulenger, 1890)	75
46	Habitat of *Micryletta inornata* tadpole	77

LIST OF ABBREVIATIONS

BD	=	Body depth;
BL	=	Body length.
BW	=	Body width
EO	=	Position of eyes
FIL	=	Filament length
IND	=	Internarial distance.
IOD	=	Interorbital distance.
IOS	=	Distance from IOD to IND
Jaw	=	Beak of tadpoles
LM	=	Length of bi-tri angular mouth
LS	=	Length of sucker muscle
LTRF	=	Abbreviation for labial tooth row formula
MTH	=	Maximum tail height.
NO	=	Position of narials
ODW	=	Width of oral disc
SS	=	Distance of tip of snout to upper corner of spiracle
TAL	=	Tail length.
TL	=	Total length.
TMH	=	Tail muscle height.
WLF	=	Width of lower tailfin muscle
WM	=	Width of bi-tri angular mouth
WS	=	Width of sucker muscle
WTF	=	Width of upper tailfin muscle

EXTERNAL MORPHOLOGICAL CHARACTERS OF SOME TADPOLES AS RELATED TO DIFFERENT HABITAT TYPES IN CHIANG DAO, CHIANG MAI PROVINCE

INTRODUCTION

Amphibians were the first animal groups that in the far past moved to live on the land but their styles of living are still not completely dependent from their former aquatic habitats; their breeding behaviour, site of eggs laying and the larva period are in water and respiration of adults depending upon the dissolved oxygen in the water for gas exchange. In addition, the larval period of almost all amphibians dwell solely in aquatic environment, after hatching through metamorphosising until moving to the land. Ecologically, tadpoles are also important in natural food-chain relationship, they acting as predators and also preys. Moreover, they can be utilised as indicators of watershed quality; since some tadpoles are able to survive in the natural media of moderate to high dissolved oxygen.

Most studies on amphibians so far in Thailand have been conducted mainly on the aspects of classification and biodiversity. Although among them, they are some studied on the larval stages, which can be identified in the same ways as those of the adult stages. Dealing with the feeding behaviour of tadpole, Inthara (2003) had studied on the diversity and feeding behaviour of tadpole, however the discoveries are not sufficient. Particularly in the north of Thailand where the researches have been insufficiently done.

OBJECTIVES

This present study differs substantially from those of described earlier in the point that ecological parameters were determined to ascertain their relatedness to external morphological characters that utilized as taxonomic characters. The study has three main objectives:

1. To study external morphological characters of some tadpoles that have adapted to survive in available habitats.
2. To know the ecology of the tadpole species in each different habitats.
3. To determine the relationship of their external morphological characters and the obtained environmental factors in different habitats.

LITERATURE REVIEWS

Morphological Characters

Since the tadpoles and adult frogs have quite different body plans and associated parts, so their morphological characters will remarkably different too. The natural selection which can operate on these characters for the ultimate survival of species in different types of habitat can be detected and studied. Naturally there are the external and internal characters to be determined for selective effects on them in each habitat type, but here the external ones will be examined in details. On the kind of the tadpoles, Orton (1953) recognized four basic types designated as designated as Type I-IV depending on the structure of the opercular chamber and its opening(s) form the body, and the nature of the larval mouthpart.

External Morphology

Generally a tadpole is look like a small fish, however, they are distinguished from those fish by several morphological features (Wassersug, 1989). For example, with their globose, scaleless bodies and laterally compressed tails, tadpoles are morphologically simpler than most teleost fish. In addition, viewing from the left side the different can be seen by its possession of a spiracle not know from any fish (McDiarmid and Altig, 1999).

Body Morphology

Typically, are short and generally ovoid. It is characterized by slightly protuberant, lidless eyes, wide nares, and a terminal mouth, which is highly variable in form and position. Variations in body shape apparently correlate with phylogeny, ecology and feeding behaviour. The most consistent measurement of body length among all body shapes and with discrete landmark is taken from the tip of the snout, giving consideration to placement of the oral disc, to the junction of the posterior body wall with the axis of the myotomes (McDiarmid and Altig, 1999).

Tail Morphology

Tail next to body and have different sizes and features, support locomotion and escape predators. Fin extended from various points on the body and tail posterior to slightly beyond the tip of the notochord and tail muscle. Dorsal fin originates at or near the tail body junction, at various point anterior to the dorsal tail body junction as far forward as the plane of the eyes. The same description apply to the ventral fin, which most commonly originate at ventral terminus of the body but may originate anywhere on the tail or anterior to the vent tube at various point on the abdomen. The tail tips take many shapes: broadly or narrowly rounded to various degrees or extended into a filament. The filament comprises the terminal of tail muscles and reduced fins.

Limbs

The hind limbs of tadpoles exposed during a later period of tadpole development and after the previously present front limbs

Oral Apparatus

Mouthparts differ in each age period until complete mouth parts are present only between stages 29 and 40 (Porter, 1972). The mouth part certainly consists of many structures. Oral disc of typical tadpole is round to transversely elliptical and its margin free form the body wall. Margin of the labia usually are defined by the papillae that vary in density .The margin papillae occur in four basic patterns on the disc (McDiarmid and Altig, 1999). Denticles occur keratinized that arrangement of tooth row on the oral disc of tadpole is species specific and different in each species. Jaw sheaths are formed by the fusion of palisades of keratinized cells along lateral margins. Commonly, jaw sheaths have a serrated edge. Some torrent living-tadpole have developed a suctorial ventral disc with which they adhere to rock. Their suctorial discs are sufficiently effective. Such a disc is present in the tadpoles of *Ascaphus*, the bufonids *Ansonia* and *Atelopus*, and the ranids *Amolops* and *Huia*. The adaptive radiated tadpoles are able to survive in the torrential streams (Inger, 1992; Taksintum, 2003; Meewattana, 2005). Although Inger (1966) has shown the relationship among tooth row formulation and body length. Suggesting that the mouth structure has changed by body length and it has several variable forms in each stages and species.

Furthermore, the position and /or direction of body structure such as nares, eyes, a spiracle etc. are related to behaviour and ecology that found in a live tadpole (Anstis, 2002). Eye position and eye orientation are viewed in different concepts. Position indicates where the structures are located on the head and orientation describes their manner of placement or alignment. Dorsal eyes exemplify benthic tadpoles in both lentic and lotic systems, while lateral eyes are common in lentic forms. In addition, external nares are situated at various points on the snout. Both external and internal nares usually are present during ontogeny, but the external nares of most microhylid tadpoles do not open until metamorphosis. A left side view of body tadpole mostly present a spiracle which exists for respiration in water, form as result of the growth and fusion pattern of the operculum with the body wall (McDiarmid and Altig, 1999) but in some microhylids and megophrys present on belly under the body. The number, location, and morphological configuration of the spiracle(s) depend on where and how opercular fold fuses with the body wall. Starrett (1973) observed a frequency association of spiracular position related to feeding mode and fin shape, especially of mid water and surface feeding tadpole. She commented that an excurrent spiracular flow from a single sinistral spiracle would tend to rotate and thereby decrease the efficiency of a tadpole feeding in the water column and observed that mid water filter–feeding tadpoles have a single spiracle in the mid of ventral. Another aperture opening of tadpole is vent tube which is the end of a digestive tract and opening middle: in line with the plan of the ventral fin or opening dextral: to the right of the plan of the ventral fin (McDiarmid and Altig, 1999).

Tadpole Habitats

Not only anurans larval characters have several different features but also habitats are diverse and different. Habitat diversities are a result of breeding season and breeding site. Amphibians tend to fall into three general categories in regard to their breeding habitats: First group breeds in permanent bodies of water, the second one in temporary bodies water, and the third one breeds out of water (Porter, 1972).

Nabhitabhata (1988) categorized 4 period patterns of anurans breeding in Thailand

1. Early rainy season: species always hide in ground and breed in the first heavy rainy during in late April to early May and then they again hind in the ground after spawning.
2. Two times a rainy season: species breed and lay eggs in early and late periods in the rainy season.
3. Breeding though-out the rainy season: species always breed thought the rainy season and spawn more plentiful in the early season.
4. Breeding in winter: species always live in and along stream with strong water in the rainy time then quite slow water current in winter.

Tadpoles dwell in a variety of different aquatic habitat system comprising those developed in water and some inhabit only the flowing stream or small temporary watercourses.

Altig and Johnston (1989) categorized and revised ecomorphological diversity of anuran tadpole by the development of energy as the ultimate discriminator of the anuran development mode. Exotroph development tadpole was categorized along with body structure and feeding behaviour in three groups; lentic and lotic habitat, lentic only and lotic only.

Permanent aquatic environments are bodies of water which do not dry up and so are always present. They include rivers, wetlands, mountain streams, lakes, permanent desert pools and springs, and more recently, reservoirs and other man-made bodies of water. As in most areas of the earth, permanent aquatic environments provide homes to fish, crustaceans, mollusks, and waterfowl, and the young of amphibians (New Mexico Stat University, 2007). Kalff (2002) divided 2 aquatic systems as;

Lentic system; standing water systems (ponds, lakes) in which the flow is primarily by wind and heat and is not primarily unidirectional.

Lotic system; primarily unidirectional flowing water systems (stream and rivers) imposed by gravity.

Factors of Tadpole Ecosystem

Tadpole ecosystem is not only consisting of biotic and abiotic factors but also interacts between them. Effects of ecological conditions are supposed influence to, such as growth rate, developmental rate and survival. Therefore individual tadpole select suitable habitat used.

Abiotic factors

Temperature; it also affect differentiation and growth rates, body size at metamorphosis, mechanism of gas exchange, rate of energy metabolism, and undoubtedly many other physiological parameters in other ectothermic vertebrates. In nature environments, tadpoles of several anuran species select microhabitats and aggregate in apparent response to temperature .Temperature is probably responsible for seasonal changes in growth, and for differences in the number of seasons such as *Rana catesbeiana* tadpoles need to metamorphose (Brattstrom, 1962). In addition, in at least some natural populations, environmental temperature is correlated to growth rates and feeding rates (Bervan, 1982; Warkentin, 1992). For many anurana, breeding and eggs laying take place in shallow, temporary pools where eurythermal condition often develop. Brown (1969) who studied the heat resistance of anuran tadpoles could be increased by acclimation to high temperature and tadpole heat resistance could be correlated to the species' s geographic distribution and breeding habitats.

Dissolved Oxygen; tadpoles use both gills respond to changes in dissolved oxygen (DO) concentration by varying the rate of air breathing. Noland and Ultsch (1981) studied relationships between dissolved oxygen and temperature including measured the levels of oxygen and temperature in selected breeding sites of frog (*Rana pipiens*) and toad (*Bufo terrestris*). *B.terrestris* breeds in temporary ponds partly because such ponds have both a high temperature and high DO. As both high DO and high temperature will increase the already relatively high metabolic rate and increase probability of metamorphosis before pond drying. *Rana*, on the another hand, breed in more permanent ponds that will tend to have lower DO levels, and the tadpoles compensate by breathing air during the whole length of the developmental period.

Biotic factors

Plants; vegetations flourish near the water sources, floating on the water surface and growing on the bottom. Not only are benefit to them as hiding homes from predators but also a source for feeding. Plants able to support filter stuff for funnel mouth species. Diaz-Paniagua (1987) seperrated habitat use in 5 vegetation zones within ponds (1) grass, (2) slow floating vegetations, (3) emergent vegetation, (4) submergent vegetation, and (5) no vegetation. Diaz-Paniagua suggested that differeces in zone use were related to differences in feeding method among species. In addition, Alford (1986) studied habitat use and positional behavior of anuran larvae in four species; *Rana utricularia*, *Limnaoedus ocularis*, *Pseudacris ornata*, dwelling in temporary pond. These species differed in habitat use and were related to percent of ground cover by the aquatic microphyte (*Sagittaria subulata*).

Animals; competition and predation have strong effects on the development, growth, and survival of tadpoles. In natural systems, tadpoles are commonly exposed to both these factors. Azevedo-Ramos *et al*. (1999) reported assemblage of tadpoles to being effected from fishes more than the invertebrates. At the same time turtles have strong impact on the survival of tadpoles (Van Buskirk and McCollum, 2000). Moreover, predator has some impact to morphological aspect of tadpole tail. Many tadpoles respond to insect predators by developing deeper, and sometime longer, tails. The larger tail enhances aspects of swimming performance because deep-tail tadpoles survive well when confronted with hunting predators (Van Buskirk and McCollum, 2000).

Tadpole Morphology and Habitat Studied

Few studies described or explained about the relationship between tadpole morphology and habitat in tropical forest. Heyer (1974) studied niche parameter of breadth and overlap in a seasonal tropical location in Thailand to determine what adaptive strategy characterizes seasonal tropical anurans. He suggested the variation obvious in three living larvae probably adaptation to stream life and serve to attract predators to most dispensable part of the body in the turbid water of the pound. They are well adapted to uncertain environments and are excellent colonizers. In another hand, Inger (1986) suggested the responses of morphotypes to physical conditions certain shapes and morphological modifications are clearly associated with particular environment conditions. In addition, Nelson and Valencia (1985) studied larval morphology and phenetic relationships among species in leptodactylids and used comparative morphological and ecological characters of about the larvae to estimated taxonomic relationships among these species.

Warkentin (1992) examined the relationships between microhabitat-specific feeding rates and microhabitat use patterns of *Rana clamitans* tadpole in natural pond. Moreover, ecomorphological classifications were established base on various ecological, geographic, and taxonomic assemblages (Altig and Johnson, 1986).

External Morphology Studies in Thailand

Early study on the tadpole morphology was started by Smith (1916a; 1917), who studied the coloration of the external morphological feature in 5 species of anurans tadpoles including studied the comparative mouthparts and external morphology of *Occidozyga* for identification (Smith, 1916b). Later, Heyer (1971) studied the same set of external morphology and then classified this frog genus into *O. laevis* and *O. martensii*. Inthara (2000) studied the mouthparts of anuran tadpoles emphasis on feeding behavior and arranged them into the key classification. Furthermore, Noikotr (2001) and Taksintum (2003) researched in the diversity of frogs and their tadpoles. Then, Meewattana (2005) studied both the external and internal morphologies for constructing identification keys to the tadpoles in different habitat types.

Study Area

The study area Chiang Dao district, Chiang Mai Province is part of Ping watershad with an total area of about 1,882 km^2. It comprises of 7 subdistricts, Chiang Dao, Muang Nah, Muang Ngai, Muang Kong, Ping Kong, Thung Khao Pong and Mae Nah. The adjoining areas are bounded in the north by the Union of Myanmar, in the south by Kudchang and Inthakhin subdistricts and Mae Taeng district; in the east by Sri Dong Yen, Chai Prakan, San Tray and Phrao districts; in the west by Pieng Loang district, Chiang Mai province, Veing Hang and Mae E district Muang Pai, Mae Hong Son Provice (figure 1).

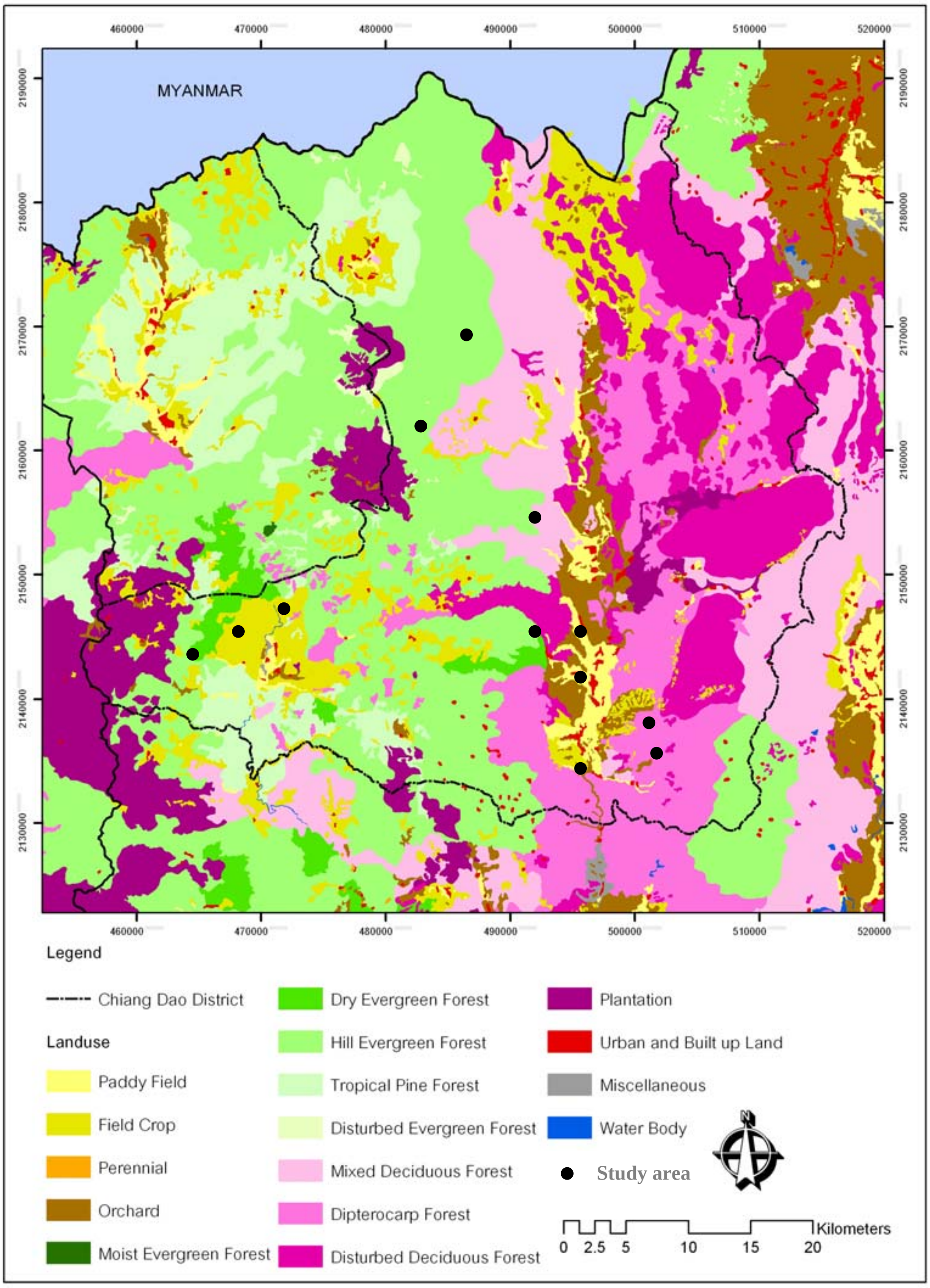


Figure 1 Mapping of landuse of Chiang Dao District, Chiang Mai Province

Source: Land Development Department (2003)

Topography

Almost all areas in Chiang Dao District are cover by forests growing profusely throughout a complex of mountain ranges. It most spectacular feature is the limestone masiff, Doi Chiang Dao, Thailand's 3rd highest peak at 2,175 meters above mean sea level (MSL). Here there are numerous deep ravines and limestone caves (Royal Forest Department, 2003).

Climate

The climate of Chiang Dao is classified as Tropical Savanna Climate type : AW (tropical wet dry climate). There are 3 prevailing seasons. The wet season (Southwest Monsoon) rains start from the middle of May and continue into the middle of October, which bring the moist and heavy rainfall from the India Ocean; the amount of mean annual rainfall was 1,354 mm, and highest was in September, with the mean rainfall 204.9 mm. In the cool season (Northeast Monsoon) starts from early November to February, the humid tropical air will giving way to the cold and dry from the centimental Asia. In hot season from February to May, with the highest temperature in April (Royal Forest Department, 2003). The minimum mean air temperature is 15.59 °C, while the maximum mean temperature is 26.11°C, and the mean relative humidity is 82.94%. The dry season lasts from November to March (5 months) and the wet season lasts from April to October (7 months) (Figure 2).

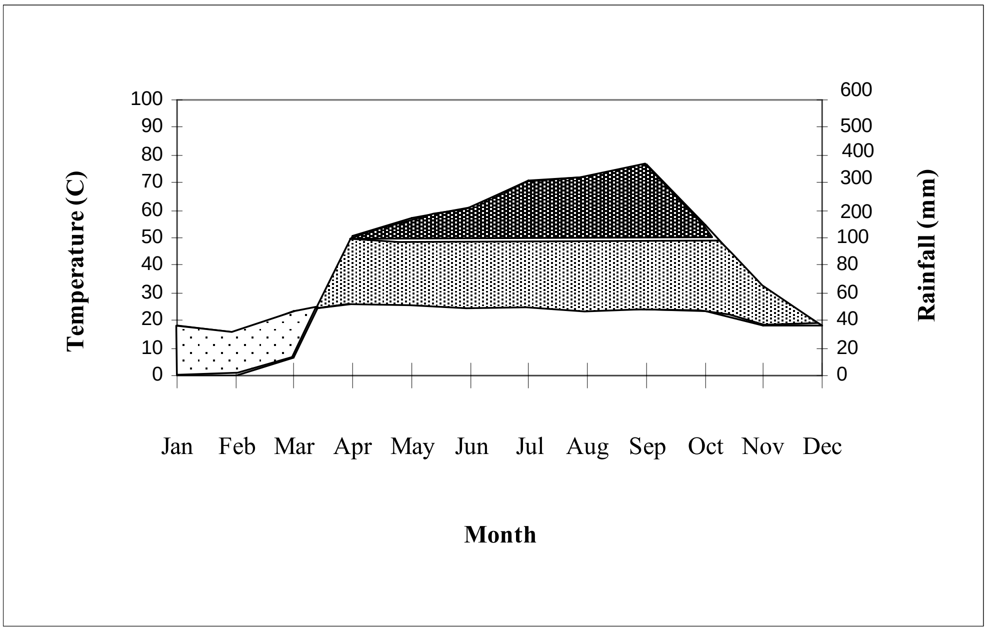


Figure 2 Average monthly temperature and rainfall in Chiang Dao District, Chiang Mai Province

Source: Environmental Factors Effecting to Biodiversity Project (National Park, Wildlife and Plant Conservation Department, 2005)

Natural Resources

Vegetation Type in Chiang Dao includes several plant communities, which can be classified into 4 types (Royal Forest Department, 2003).

1. Dry Evergreen Forest; it prevails in areas between at during 350-600 MSL. The type distributes as narrow parallel patches at a foot of a hill. The dominant tree species are *Dipterocarpus turbinatus, Shorea thorelii*, *Spondias pinnata*, *Dillenia aurea*, *Markhamia stipulate*, *Berrya cordifolia*.

2. Moist Upper Mixed Deciduous Forest: this forest type changes gradually from moist evergreen forest in the upper level of more than 600 m MSL. The dominant tree species are *Dendocalamus strictus*, *Berrya cordifolia*, *Pterocymbium*

sp., *Haldina cordifolia*. Moreover, between 700-800 m MSL consisting of Teak (*Tectona grandis*) mixed in the type.

3. Hill Evergreen Forest; it distributes in narrow parallel at a foot of a hill and high levels 1,500-2,000 m MSL. Compared to the others it has much air humidity. The dominant tree species are *Lithocarpus spicatus*, *Calophyllum polyanthum*, *Vitex quinata*, *Sloanea tomentosa*.

4. Open Hill Evergreen Forest: including grassland, fire effected to hill evergreen forest becaming to grassland. Distributing is in 2 parts, the lower 1,100-1,300 mMSL and the upper 1,500- 2,000 mMSL. The dominant plant species are *Terminalia franchetii*, *Sterculia siamensis*, *Zanthoxylum acanthopodium*, *Fiemiana tomentosa*, *Ficus microaperma*.

In addition, the ecosystem in the higher level looked similar to alpine vegetation and consisting of some *Geranium*, *Primula*, *Saxifraga*. As a result of being limestone in higher mountain and variable climate have made it to a subalpine vegetation. Moreover, the upper of area 900 mMSL occurred tree of temperate species, such as *Cephalotaxus griffithii*, *Betula alnoides*, *Thalictrum foliosum*, *Corydalis siamensis*, *Polygala lacei*, *Silene burmanica*, *Hypericum nepaulense*.

Wildlife Resource of Chiang Dao has a diverse array of animal species. , Royal Forest Department reported the less number of animals surveyed about 340 species, 233 genera, 97 families. They can be sorted out in 5 groups (Royal Forest Department, 1999).

1. Mammals; they are at least about 42 species, 43 genera, 18 families such as *Capricornis sumatraensis, Naemorhedus griseus, Neofelis nebulosa, Cuon alpinus* and *Hystrix brachyura*.

2. Birds; they are at least about 69 species, 56 genera, 32 families Interesting birds species such as *Pycnonotus jocosus, Syrmaticus humiae, Buceros bicornis,*

Picus cantus and *Lophura nycthemera*. In addition, reported the number of winter visisting birds of 34 species.

3. Reptiles; they are at least about 35 species, 29 genera, 12 families such as *Platysternon megacephalum*, *Monouria impressa*, *Ophiophagus Hannah*, *Amyda cartilaginea, Varanus nebulosus* and *Indotestudo elongate*.

4. Amphibians; they are at least about 32 species, 13 genera, 7 families such as *Tylototrition verrucosus*, *Kaloula pulchra*, *Microhyla pulchra* and *Rana limnonectes*.

5. Fresh Water Fishs; they are at least about 25 species, 23 genera, 11 Families such as *Acrossocheilus schroederi*, *Taralaubuca riveroi* and *Thynnicthys thynnoides*.

MATERIALS AND METHODS

Materials

1. Topographic map of the study area in Chiang Dao District, Chaing Mai Province, scale 1:50,000, map sheet no. 4747I
2. Flashlights and flash-light batteries
3. Camera
4. Hand magnifying glass
5. Stereoscope
6. Dipnets
7. Boxes and bottles
8. Air pumps
9. Aquariums or fish bowls
10. Thermometer
11. GPS-receiver
12. Measuring tapes
13. Dissolved Oxygen Kid
14. 1 % Formalin and 95 % Alcohol
15. Specimen bottles
16. Vernier calipers
17. Stationeries
18. Commercial fish food and fresh vegetables
19. Set of computer
20. R and PC-ord solfwares
21. Foam rubber and stop watch

Methods

Data collection

1. Literature reviewed on the research of amphibians in studied area. Preliminary field survey searching for water resources and selecting suitable areas.
2. The data collection carried out 6 times in every 2 months from January to December 2005.
3. Collecting the specimens of tadpole by using dipnets in daytime (10.00 AM.-4 PM.) and nighttime (7 PM-11 PM.) including recording their body color, belly pattern and other remarkable structures.
4. Each habitat was recorded of the flowing parameter water temperature (T), dissolved oxygen (DO), habitat types (HT), water current (CW), mean sea level (MSL), surface covers (SC) and condition of bottom (B) before collecting tadpoles. The data on rainfall and humid were refered to the Environmental Factors Effect to Biodiversity Project (National Park, Wildlife and Plant Conservation Department, 2005).

Laboratory study

1. The tadpoles were identified by using according the key of Inthara (2000); Noikotr(2001); Taksintum(2003) and Meewattana (2005) (Figure 4). From each species some tadpoles (15-30) were preserved in formalin 1% for 5 days and then transferred to 95 % alcohol.
2. Measuring external morphology bases on McDiarmid and Altig (1999). The mouth part structures were identified as described following Inger (1966) and the all details see in Figure 3.
3. Some tadpoles those could not be identified. They were kept in the laboratory fed them with commercial fish foods and boiled vegetables until transformed into froglets and later identified by the adult key characters.

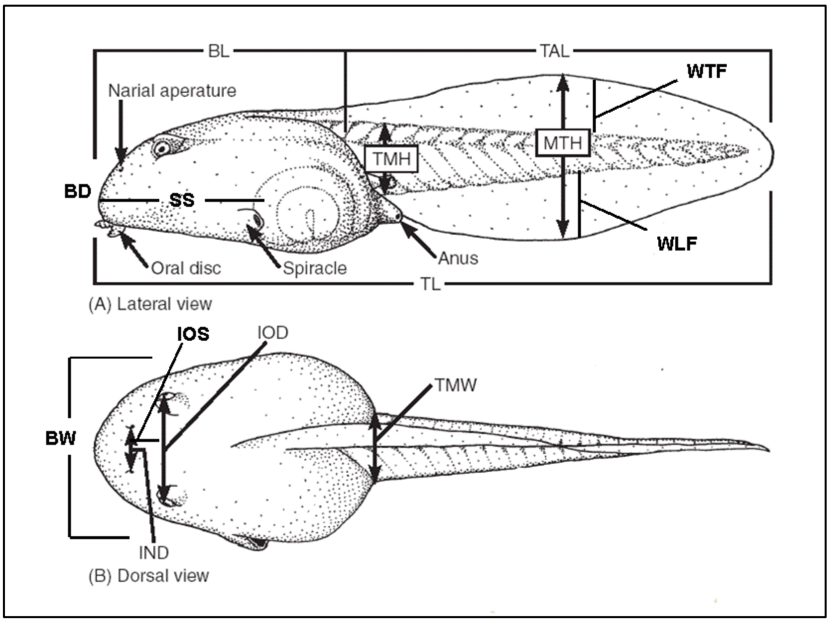


Figure 3 External Tadpole morphology and body plan

Source:McDiarmid and Altig (1999)

Primary features and measurements of tadpole body. (A) Lateral view. (B) Dorsal view (Figure 3). The abbreviations are as follow;

BD	=	Body depth
BL	=	Body length; tip of head to the end of body.
BW	=	Body width
EO	=	Position of eyes
FIL	=	Filament length
IND	=	Internarial distance; measured between centers of narial apertures.
IOD	=	Interorbital distance; measured between centers of eyes.
IOS	=	Distance from IOD to IND
Jaw	=	Beak of tadpole

LM	=	Length of bi-tri angular mouth
LS	=	Length of sucker muscle
LTRF	=	Abbreviation for labial tooth row formula
MTH	=	Maximum tail height; upper to lower rims at the broadcast point.
NO	=	Position of narials
ODW	=	Width of oral disc
SS	=	Distance of tip of snout to upper corner of spiracle
TAL	=	Tail length
TL	=	Total length; head to tip tail
TMH	=	Tail muscle height; upper to lower of tail muscles at the level of the end of body
WLF	=	Width of lower tailfin
WM	=	Width of bi-tri angular mouth
WTF	=	Width of upper tailfin

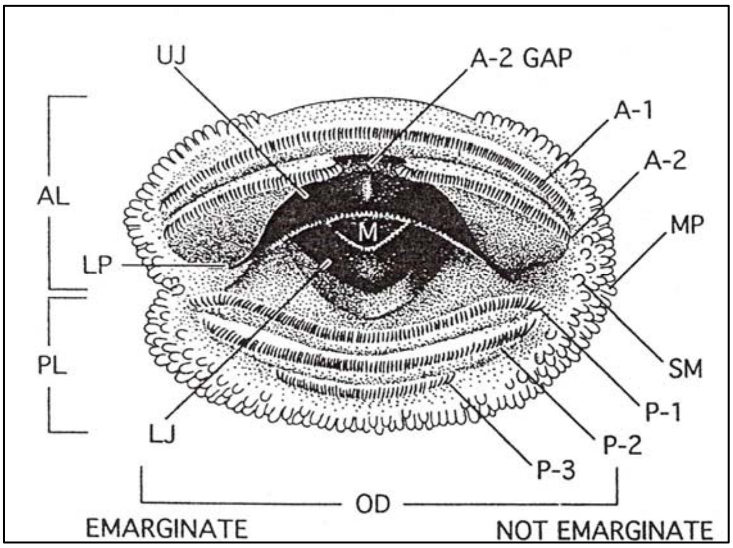


Figure 4 Mouthparts (Oral apparatus) of Anuran tadpoles

Source: Dubois (1995)

The oral disc is one of the major diagnostic characters in the identification of tadpoles. The structures showing emarginated (left side) and not emarginated (right side) condition of the oral disc. The abbreviations for descriptive terminology of oral apparatus are as follow;

AL	=	Anterior (upper) labium
A-1, A-2	=	First and second anterior (upper) tooth rows
A-2-GAP	=	Medial gap of second anterior (upper) tooth rows
LJ	=	Lower jaw sheath
LP	=	Lateral process of upper jaw sheath
M	=	Month
MP	=	Marginal papillae
OD	=	Oral disc
PL	=	Posterior (lower) labium
P-1, P-2 and P-3	=	First second and third posterior (lower) tooth rows
SM	=	Sub-marginal papillae
UJ	=	Upper jaw sheath

Example of LTRF (Figure 4) are I:1+1/III (Inger, 1966) that means, I:1+1 are upper tooth with two rows, I is the cantiavous first row, 1+1 are left and right rows of the second rows because with a median gap and III are three lower tooth rows and they are complete.

Data Analysis

1. The data of tadpoles constructed a dendrogram. Data analysis were used amount the average of external tadpole morphological characters and the average of environmental factors were log (x+1) before quantitative analysis. The cluster analysis by Sorensen Distance (1-2w / (A+B)) and Group Average method were compatible.
2. The ordination techniques were used to invent dimentionality by creating

vectors of environmental factors. Canonical Correspondence Analyses (CCA) were used to ordinate sample water resources (n=61) based on abiotic characteristics and relative frequency of tadpole species

3. Multiple regression models were used to explain the relationship among each dependent environmental factors and external mophologies.

For the analysis of multiple linear models, the whole data were selected by stepwise variable selection and pick models that are smaller than desirable for prediction purposes. The linear multiple regression models recommended the following equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_\kappa X_\kappa$$ ....Equation

Where, Y = linear combination (dependent variable)

X = independent variable

β_0 = intercept term

β_i , i = $1,2,3\ldots k$ are unknown parameters

RESULTS AND DISCUSSION

Nineteen tadpole species belong to fourteen genera in four families were found in the study site. Species of tadpoles are 46.34 percent of adult frogs in this study area and including are shown in Appendix table 1. Four species were recorded only in permanent water habitat, there were composed of *Amolops mramoratus*, *Brachytarsophrys carinensis*, *Huia melasma* and *Leptobrachium chapaense* and three species only found in temporary pools, there were of *Microhyla heymonsi, M. ornata* and *Rana livida*. Twelve species occurred in both kinds of water body, there were *Xenophrys lateralis, Leptolalax pelodytoides, Limnonectes kuhlii, Fejervarya limnocharis, Rana cubitalis, R. livida, R. nigrovittata, Kaloula pulchra, Micryletta inornata, Microhyla berdmorei, M. pulchra, Polypedates leucomystax* and *Rhacophorus bipunctatus* (Figure 5), especially *R. bipunctatus* occurred in several sites more than other species.

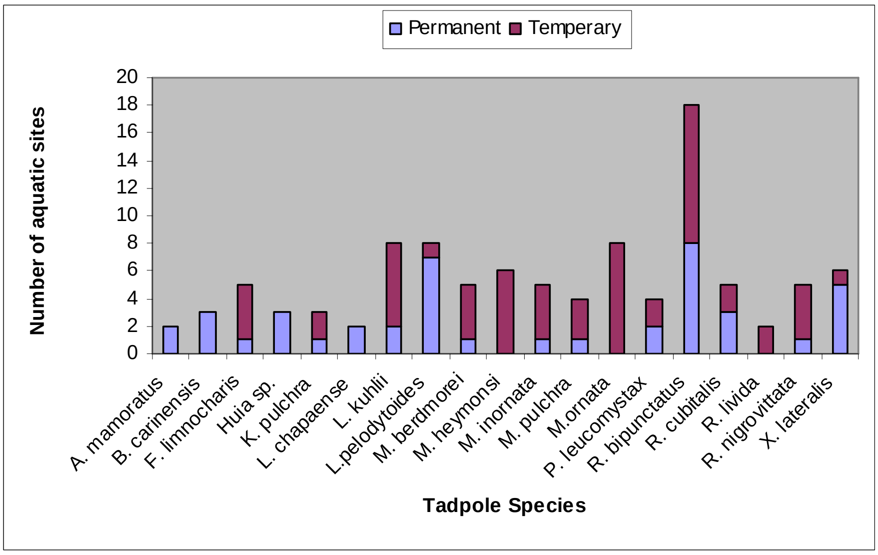


Figure 5 Relative frequency of tadpole species in permanent and temporary waters

Relationship between species and climatic factors

The total numbers of tadpole species in this study over the time period, were l a very few different. Species were maximum in three period of this studied January-February, March-April, May-Jun and then they decreased in number until the end of the study.

Seven species only found in wet season (April-October), there are *M. heymonsii*, *M.inornata*, *F. limocharis*, *R. bipunctatus*, *P leucomystrac*, *K. punlchra* and *M. pulchra*. Seven species only found in dry season (November-March), there are *L. chapraense*, *B. carinrnsis*, *X. lateralis*, *R. livida*, *M. berdmorei*, *H. melasma* and *A. marmoratus* and five species found in both seasons. The late dry season, transition between dry season and wet season found twelve species were overlapped.
Because of anuran assembled breeding such as winter breeding species, critical first rain breeding. There are limiting factors restricting the present of species that deposit their eggs directly in water (Figure 6).

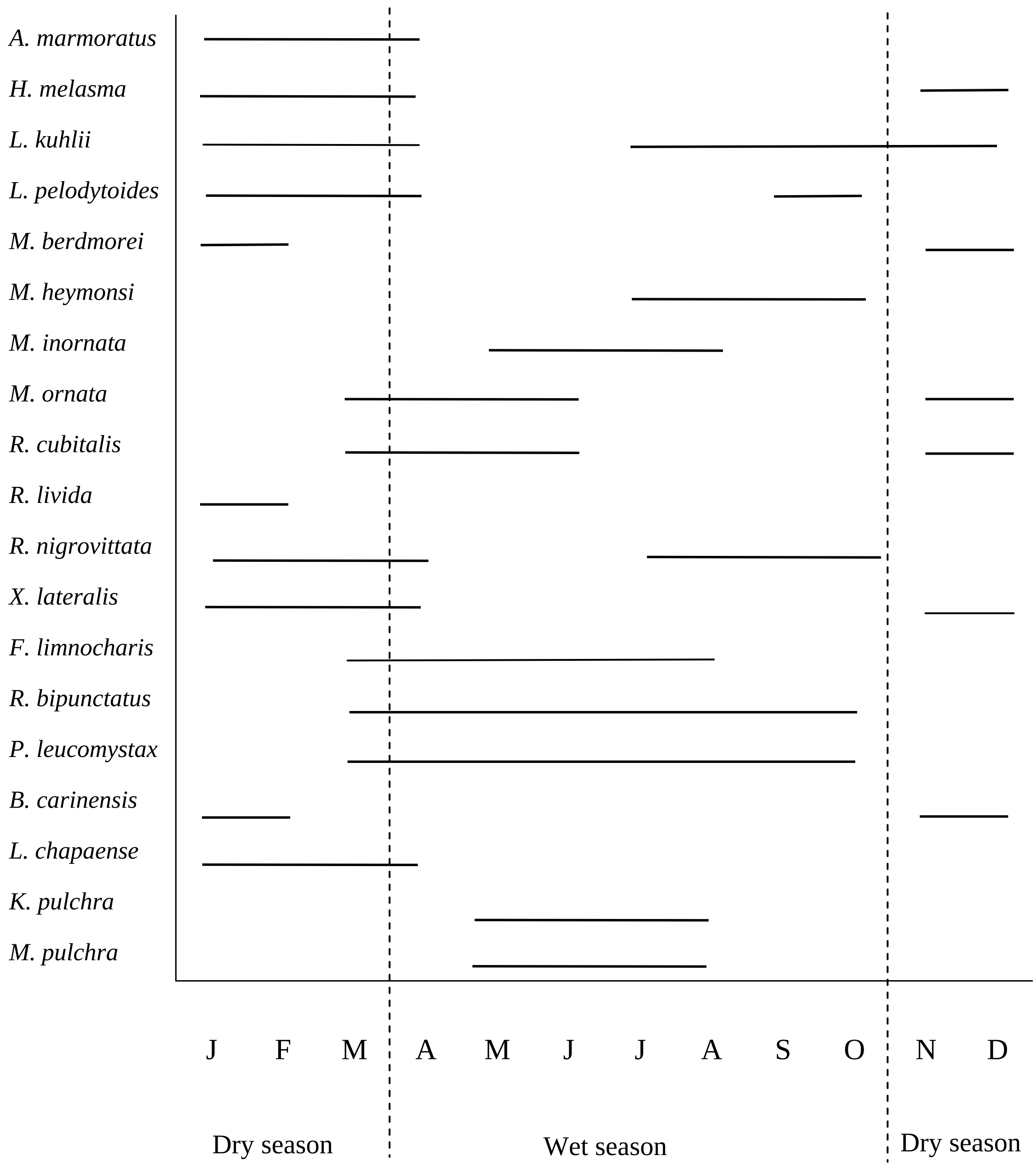


Figure 6 Tadpole species appearance

Morphological Hierarchy Clustering

The result from cluster analysis can be categorized in five groups based on 21 external morphological characters and this studied did not cover feeding behaviour (Appendix Table 2). A horizontal of dendrogram at 62.5 percent (Figure 5) showed group A in below hierarchical tree which consisted of two member of microhylids (*Microhyla ornata* and *M. heymonsii*) and the other four Microhylidae (*Kaloula pulchra, M. inornata, M. berdmorei, M. pulchra,*) also were member of group B on above of dendrogram. Group C was a large group moreover, built up of ten members in eight genera, and next leptobrachids is only one species in group D. The last group on the top of dendrogram was group E and consisted of two members. There were *Huia melasma.* and *Amolops mamoratus*. In comparison of some results in this study had different from Inthara *et al.* (2005) who described the microhabitat character of tadpole by some relationship between mouth part structure and feeding behaviour in five groups. *M. heymonsi* had been differed from *M. ornata* and they were classified in different group. Because *M. heymonsi* and *M. ornata* had a filament in the end of the tail tip.

Group A, *M. ornata* and *M. heymonsii* were obviously different from all members because of their tails extended into filament. As the other microhylids appeared only sharp-tail tips which they were body slight and lacked keratin mouth part. Group C has the most members and they were rather different in cluster group. Cluster analysis can be separated in five sub-clusters at 82.5 percent in group C. First sub-cluster consisted of four species. *L. pelodytoide, R. cubitalis* and *R. bipunctatus* and *P. luecomystac* were close relationship among them. Second sub-cluster was *B. carinensi* and *X. lateralis* their mouth are bi-triangular oral disc with finesse shape stretch on water surface and without denticle in mouth cavity. Third sub-cluster quite a few differents by using 21 external morphological characters especially *R. nigrovittata* and *F. limnocharis* but they were differed from *R. livida*. Forth sub-cluster was only one species, *L. khulii* which was most differed in group C. In addition, *L. chapaense* was only one member in group D because it has large body size. The last cluster group, *A. mamoratus* and *H. melasma*. were special mouthpart and papilla extended adaptation to be suckers.

Some tadpole, *M. ornata, P.leucomystrax*, *M. heymosii* and *F. limnocharis* in side of highway pond has contrasting black tail tips. This result according to Heyer (1974) studied niche measurements of frog larvae in a tropical location in Thailand. The contrasting black tail tips are adaptability serving to attract from dragonfly larvae predators. The adaptation is probably phenotypic responses but this implies that genetic base allows phenotypic plasticity.

The cluster result follows with morphological taxonomic in each species. For example, *Amolops* groups have sucker cling their habitat which different from other *Rana*, *Megophrys* groups have their special mouth for supporting and feeding. Microhylids' body structures are fragile and absolutely differed from other species.

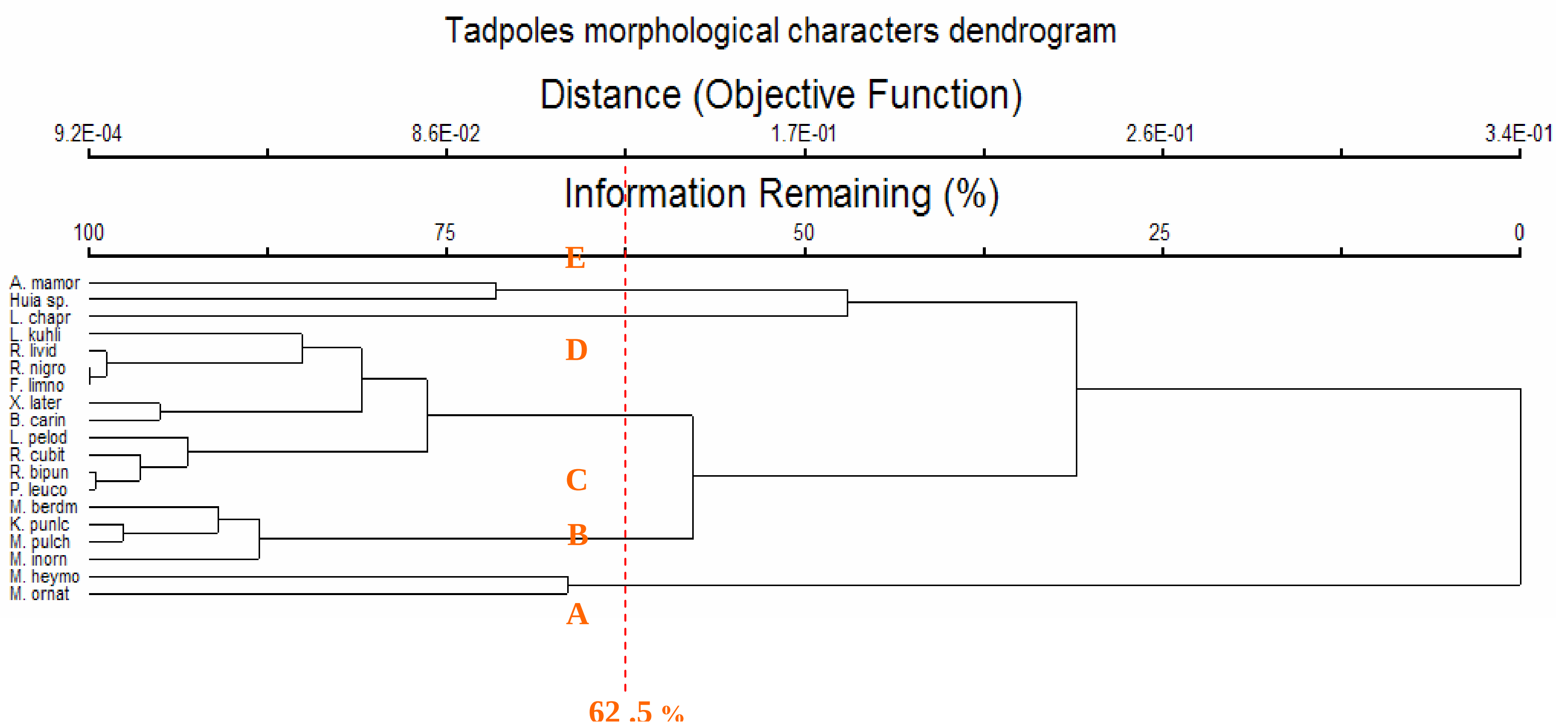


Figure 7 Tadpoles among external morphological characters dendrogram

Ecological relationships

Total of 61 sample points were sampled from Chiang Dao district for one year. The ordination technique showed the relationship among tadpoles appearance and 7 abiotic factors in 3 axes and the constrained canonical correspondence analysis (CCA) is shown in Figure 8. They were certainly appeared relationship in three abiotic factors (water current, dissolved oxygen and temperature) with tadpoles occurred in the plots.

The percentages of variance explained by Axis 1, Axis 2 and Axis 3 were 24.3 %, 3.5 % and 10.8 %, respectively, while its cumulative percentages explained were 24.3 %, 28.6 % and 35.1 %, respectively. Eigenvalues to explain variation in community showed 0.066, 0.010 and 0.029 respectively. Also, Pearson correlation is the correlation coefficient between sample scores for axis derived the linear combinations of the environment variable. The most value of correlation was in Axis 3 (0.729, 0.518 and 0.768) (Table 1).

Table 1 The axis summary of total variance (“inertia”) in the species data

	Axis 1	**Axis 2**	**Axis 3**
Eigenvalues	0.066	0.010	0.029
Variance in species data			
% of variance explained	24.3	3.5	10.8
Cumulative % plained	24.3	38.6	35.1
Pearson Correlation. Spp=Envt	0.729	0.518	0.768
Kendall (Rank) Corr.Spp-Envt	0.427	0.462	0.626

In addition, correlation among environmental variables and axes presented strong positive of water current with Axis 3. Other variables, Temperature was most positively correlated to Axis 3, dissolved oxygen was also most positively correlated to Axis 3. All of variable, current water was the strongest effect to species appearance (Table2).

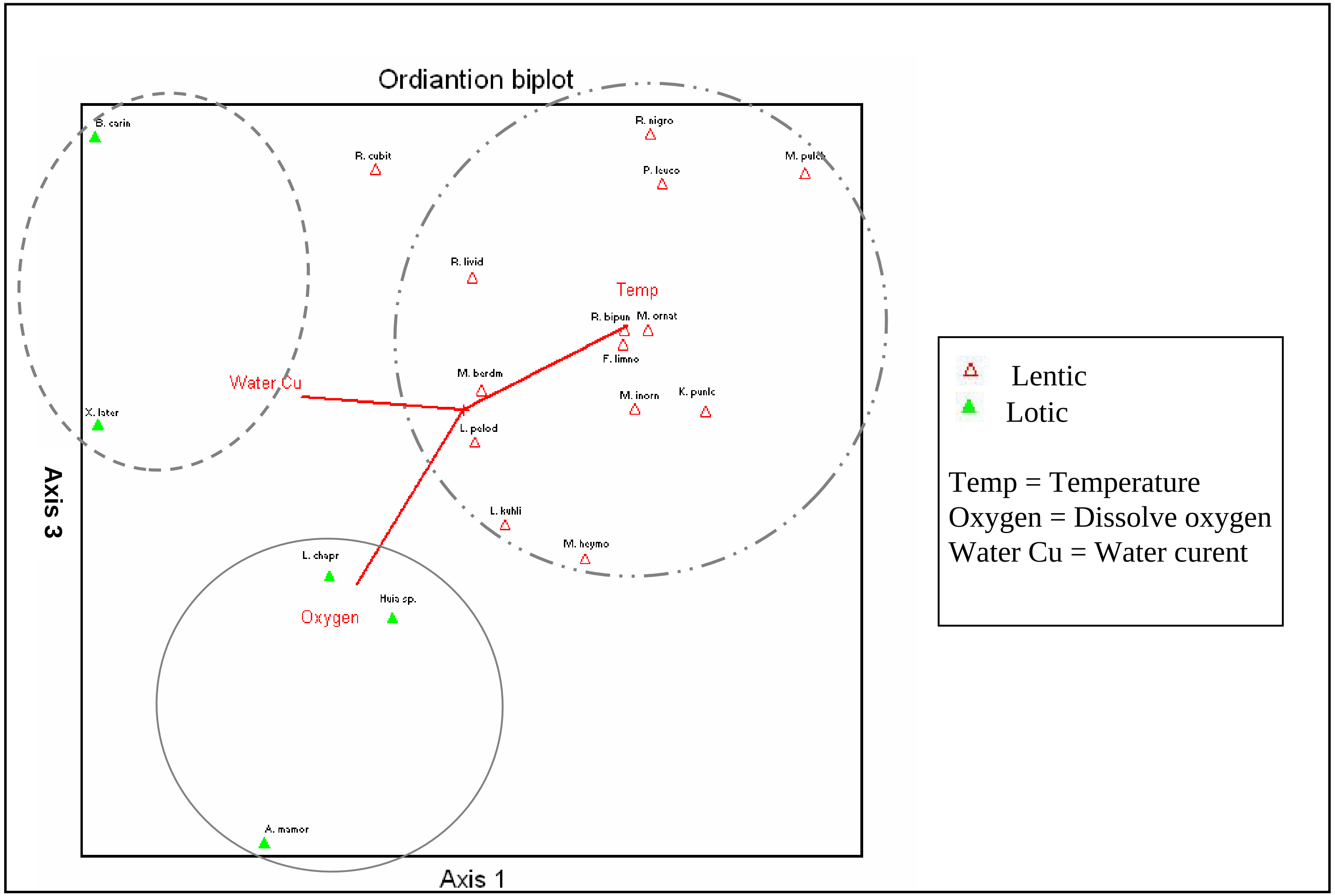
Table 2 The correlation among variables and axes

Variable	Correlation		
	Axis 1	**Axis2**	**Axis3**
Temperature	-0.336	-0.258	0.565
Dissolved oxygen	0.631	-0.235	0.163
Water current	-0.002	-0.185	0.718

In CCA ordination graphs, the species-environmental biplot was presented. The triangles represented individual species and grouping by water body factor with each color, plus signs representing each plot sampling and a red line was representing each environmental variable was plotted pointing in the direction of maximum change of the environmental variable across the diagram. In addition, the angles between the red vectors reflected the intercorrelation between variable.

Constrain CCA, the diagrams was able to distinguish in habitat selection preferences which were suggested both between species occurrence constituents and abiotic factors. The three of environment factors affected tadpole species appearance. The environmental gradients and the relative importance and intercorrelation of the environmental variable were showed obviously by the red vector in figure 8.

The biplot for this data in figure 8 showed the species and community distribution and three variable vectors appeared on Axis 1 and Axis 3. Both of two axes have strongly relation in three variables. The length of dissolved oxygen vector was similar value to those of temperature vector and they were the longest most significant.



Figur 8 Represent the constrained CCA of tadpole data between Axis 1 and Axis 3

Considering figure 8, grouping can be used to explained species occurrence constituents which depended on abiotic factors. Three groups and the individual species were shown the relation to the red factors representing environment factors. The first group was *B. carinensis, X. lateralis* and showed strong correlation with current water. They found in surface of slow current water and both of them used bi-triangular oral disc with finesse shape stretch or support. Sometime they put their mouth on the leaves for floating on the water surface. In addition, some individuals of *R. cubitalis* and *L. kuhlii* able to live in running water but they normally live in lentic water.

Second group, three individual species association were emerged and related to dissolved oxygen. Species of this community occurred to the below of the diagram, they were *L. chapaense, H.melasma* and *A. mamoratus*. Pochjananapasriri (1980) that in winter season of Chiang Dao it has highest of dissolve oxygen and the low temperature. In addition, timing of frog reproduction determines the temporal distribution of tadpoles in each site (McDiarmid and Altig, 1999). Therefore, this group of tadpoles was often found in winter season.

Third group, they were consisted of thirteen species association with temperature factors. Almost of them found in lentic water. Temperature was high value in third group and more impacted to lentic species. The influence temperature dramatically affects the time taken to reach metamorphosis (McDiarmid and Altig, 1999). The influence determines larval body size and length of the larval period (Reques and Tejedo, 1995). In addition, the temperature was influence to tadpoles which live in still water (temporary) and the microhylids have fast rates development before dry.

In this study, it was not possible to test all possible relationships between independent variables and tadpoles species because the number of possible test exceeded the total degree of freedom, which was limited by the external characters of tadpoles studied. Each species has different strongly relation to each environment factor.

External Morphology of Tadpoles

1. *Leptobrachium chapaense* (Bourret, 1937)

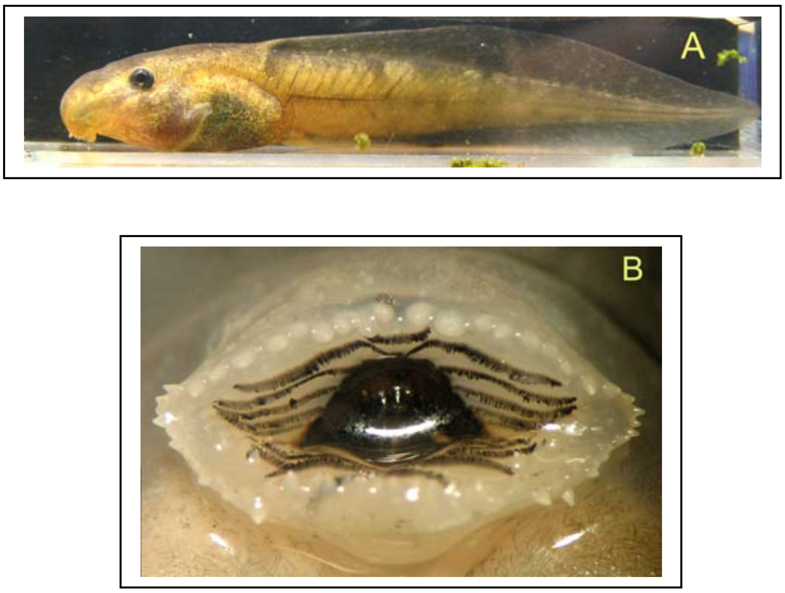


Figure 9 *Leptobrachium chapaense* (Bourret, 1937)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a large tadpole, the longest larva had a total length of 73.15 mm at 37stages (Gosner, 1960). Thirty tadpoles form local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body oval broadly rounded at snout, flat below, BL 9.95-12.76 mm; eye near lateral, not visible from below; nostril open on dorsal; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal fin convex, fin deeper than muscle beyond middle of the tail, margin of ventral fin weakly convex, tail tapering to point tip (Figure 9).

Color/Markings; in life, dorsum and flanks of body brownish, body and tail eruption with dark brown on the skin, white granular dispersed under body skin and appearing on the bridge of upper and lower of tails. In preservative, body becomes a light shade of brown.

Oral disc; mouth ventral, subtermal, oral disc width 3.82-7.02 mm of ODW; marginal disc with single row of papillae; upper and lower jaw sheath serrated and massive, edge with black, upper jaw and lower sheath V-shaped but lower jaw sheath smaller than upper.

LTRF I:5+5/4+4:I

Larval microhabitat; found in well moderate current water and tadpole moved on the bottom gravel of stream of type of locality using ventral body; water clear, current water, shadow water, the gravel is cover with thallophytic or algae. Larval observed to be active at night and have been found associate with *H. melasma* (Figure 10).

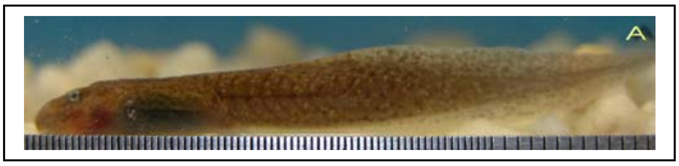
Figure 10 Habitat of *Leptobrachium chapaense* tadpole

When considering the relative of external morphologies of *L. chapaense* which lives in fast current water. The regression model showed the relationship between the dependent factor (current water, Z) and those independent factors. It can be created in a multiple linear regression model as follow;

$$Z = 5.8817 + 1.8635(BL) + 0.7406(MTH) - 2.4664(BD) + 1.1726(BW) - 2.9687(IND) - 1.5891(SS)$$

The model used specific factors for *L. chapaense* in Chiang Dao only. The regression's F-value is 3.139 (6, 23 df, $p<0.05$). The multiple linear regression model could explain 30.68 percent (R^2= 0.3068) of the relationship between current water affected to six external features. The relationship result was low because found this species just only two sample points, they have been dwell in high-mountain. Three features (BL, MTH and BW) related positively, they might be expected increasing as more as the water current higher that mean the water flowing slower while body length, maximum tail high and body width were bigger. Other negative relationship (BD, IND and SS), they were smaller when dwell in fast-flowing water. The most of features affected to water current because flexible for moving among fast water although they have big body size. The body of tadpole quite round and body depth useful for moving control by belly (Inthara, 2000).

2. *Leptolalax pelodytoides* (Boulenger, 1893)



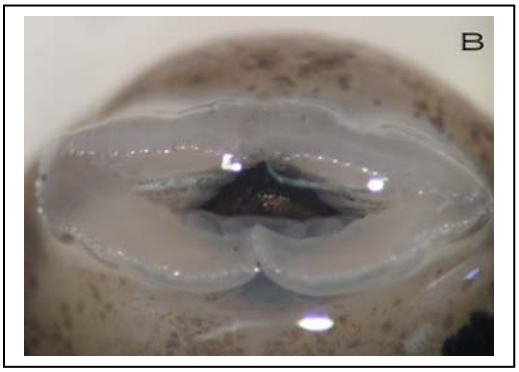


Figure 11 *Leptolalex pelodytoides* (Boulenger, 1893)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva had a total length of 52.22 mm at 28 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Elongated oval body , BL 13.48-16.01 mm; eye leteral, not visible from below; nostril open on dorsal; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal and ventral fin parallel, crests rather low, ventral fin quite small, fin tapering to point tip (Figure11).

Color/Markings; in life, dorsum and tail muscle dark brownish, body and tail muscle scattered with small dark. In preservative, body becomes a light shad of brown.

Oral disc; mouth near ventral, oral disc width 2.69-4.34 mm of ODW; papilla expanded around mouth, marginal papilla serrated and upper separated two parts; upper and lower jaw sheathes massive and serrated, edge with black, short teeth row.

LTRF I:4+4/3+3:I

Larval microhabitat; found in well side stream or side pools of small stream banks, water clear and shadow. Often have been found they live under the pebble (Figure 12).

Figure 12 Habitat of *Leptolalax pelodytoides* tadpole

When considering the relative of external morphologies of *L. pelodytoides* which lives in slow current water. The regression model showed the relationship between the dependent factor (Z= temperature) and those independent factors can be created in a multiple linear regression models as follow;

$$Z = 19.4199 - 0.4605(TL) + 1.0013(BL) - 2.3893(TMH) - 0.8512(MTH) + 1.9270(IND) + 2.191(IOS) + 2.6136(IOD)$$

The model used specific factor for *L. pelodyt*oides in Chiang Dao only. The regression's F-value is 6.091 (7, 7 df, $p<0.05$). The multiple linear regression model could explain 71.79 percent (R^2= 0.7179) of the relationship between temperature and three external features.

The model showed that the probability of temperature was higher when BL, IND, IOS and IOD increase and the tendency of relationship affected positively. On the other hand TL, TMH and MTH were negative decreasing. This lotic species found in winter season as the temperature is low and high dissolved oxygen. The body quite slender accelerated relative to metamorphosis at that time temperature higher.

3. *Brachytarsophrys carinensis* (Boulenger, 1899)

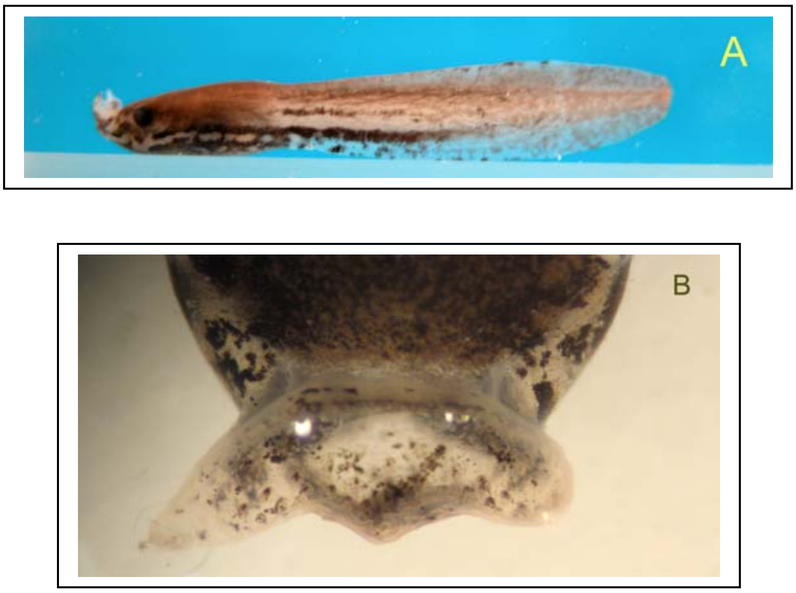


Figure 13 *Brachytarsophrys carinensis* (Boulenger, 1899)

A: Body shape of tadpole

B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva attained a total length of 40.58 mm at 35 stages (Gosner, 1960). Twenty tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body ellipsoidal, flat below, BL 9.95-12.7 mm; eye lateral visible from below; nostril open on lateral; spiracle sinistral; vent tube median, unattached to ventral fin; tail muscle strong, deeper than caudal fin except near tip, caudal fin slender, fins originating at root of tail, margin sub-parallel, tip point (Figure 13).

Color/Markings; in life, dorsum of body brownish and flanks of ventral with black and white strips, appearing white trait scattered on the ventral. In preservative, body becomes a light shade of brown, but all scatters pattern retained.

Oral disc; mouth terminal, lips expanded into funnel, the lower labium commonly is larger than upper labium, month width 3.58-6.87 mm of LW, without denticle and papillae, jaw sheath weak.

Larval microhabitat; found in well stream of moderate current.
They live in water surface and supports by floating litters or aquatic plants. They are associated with *X. lateralis* (Figure 14).

Figure 14 Habitat of *Brachytarsophrys carinensis* tadpole

When considering the relative of external morphologies of *B. carinensis* which live in fast current water. The regression model showed relationship between the dependent factor (Z = Current water) and those independent factors can be created in a multiple linear regression model as follow;

$$Z = 8.0378 + 0.2437(TL) + 0.3283(BL) - 0.3887(MTH) + 1.7211(BW) -1.6195(IND) - 0.8826(IOS) -2.2923(IOD) + 0.3652(LM)$$

The model used specific factor for *B. carinensis* in Chiang Dao only. The regression's F-value is 6.091 (7, 7 df, $p<0.05$). The multiple linear regression model could explain 49.76 percent (R^2= 0.4976) of the relationship between current water. The model showed positive the probability of water current was higher when four external features increased (TL, MTH, BW and LM) and five features (BL, IND, IOS and IOD) negative relationship. The positive features supposed big body size for dwell in slower flowing- water. Length of bi-tri angular mouth (LM) obviously showed the relationship with current water because the oral disc specialized feeding on film surface water.

4. *Xenophrys lateralis* (Anderson, 1871)

Figure 15 *Xenophrys lateralis* (Anderson, 1871)

A: Body shape of tadpole

B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva attained a total length of 39.98 mm at 26 stages (Gosner, 1960). Twenty tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body ellipsoidal, flat below, BL 7.84-11.86 mm; eye lateral visible from below; nostril open on lateral; spiracle sinistral; vent tube median, unattached to ventral fin; tail muscle strong, deeper than caudal fin except near tip, caudal fin slender, fins originating at root of tail, tip point (Figure 15).

Color/Markings; in life, head-body and tail muscle overall dark brown, some individual have thin yellow or cream band running above dorsal body; tail scattered with dark spots on posterior half of tail. In preservative, body becomes a light shade of brown, but all scatters pattern retained.

Oral disc; mouth terminal, lips expanded into funnel, the lower labium commonly is larger than upper labium, month width 1.22-2.67 mm of LW, lips without marginal papillae but inside lips with row radiating from center, without denticles and jaw sheath weak.

Larval microhabitat; found in well stream of moderate current. Often found they live in surface water and support by floating litters or aquatic plants. They live associate with *B. carinensis* (Figure 16).

Figure 16 Habitat of *Xenophrys lateralis* tadpole

When considering the relative of external morphologies of *X. lateralis* which live in fast current water. The regression model showed the relationship between the dependent factor (Z = Current water) and those independent factors can be created in a multiple linear regression model as follow;

$$Z = -19.586 + 4.233(TMH) + 5.972(BD) - 2.154(BW) - 11.387(IOS) + 6.075(LM)$$

The model used specific factors for *X. lateralis* in Chiang Dao only. The regression's F-value is 6.228 (5, 14 df, $p<0.05$). The multiple linear regression model could explain 57.91 percent (R^2= 0.5791) of the relationship between current water effected to external features. The model shown positive the probability of water current was higher when (TMH, BD and LM) increase and other negative relationship (BW and IOS). Suspicion of tadpole different stages is possibly affect to this model because of the stages of specimen differed and *X. lateralis* was younger than *B.carinensis*. Some individuals of *X. lateralis* dwelled in the side of stream with aquatic plants were existed.

5. *Amolops mamoratus* (Blyth, 1855)

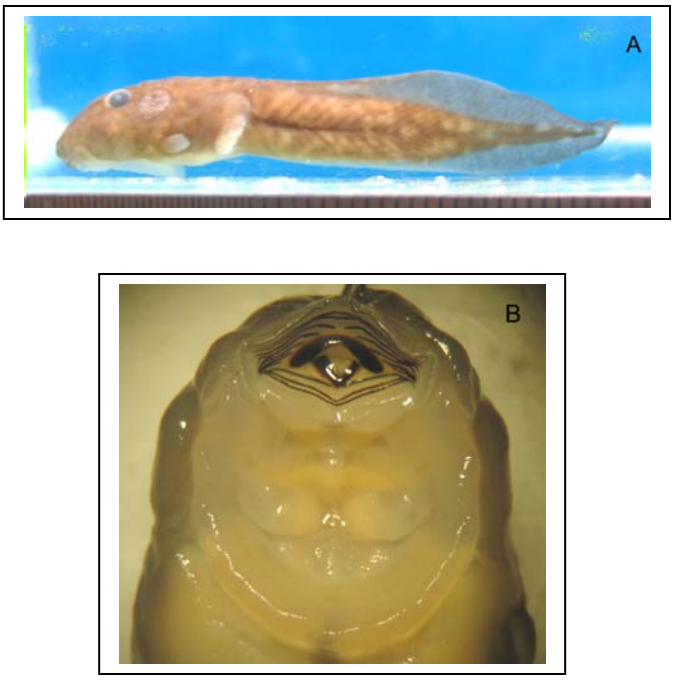


Figure 17 *Amolops mamoratus* (Blyth,1855)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva had a total length of 62 mm at 40 stages (Gosner, 1960). Seventeen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body oval broadly rounded at snout, flat below, body and tail slightly scatters with small, BL 13.66-22.50 mm, eye dorsal, not visible from below; nostril open on dorsal; postorbital glands appearing; spiracle sinistral; vent tube dextral; the middle of tail on the dorsal fin is expanded and slight smaller on the tip, ventral fin starting at the end of the body, dorsal fin slightly deeper than ventral fin, tip point (Figure 17).

Color/Markings; in life, dorsum and flanks of body is dark green, ventral unpigmented and beige. In preservative, body becomes a light shade of green brown, but all scatters pattern retained.

Oral disc; mouth ventral, oral disc width 5.36-8.86 mm of ODW, upper lip with papillae expand to be sucker, upper and lower jaw sheath serrated and massiveness; edge with black, upper and lower jaw sheath V-shaped.

LTRF III:5+5/1+1:II

Larval microhabitat**;** found in well speech waterfall and caught with the rock of type of locality; water clear, fast water, the rock is cover with thallophytic or algae. Larval observed to be active at night (Figure 18).

Figure 18 Habitat of *Amolops mamoratus* tadpole

When considering the relative of external morphologies of *A. mamoratus* which live in fast current water. The regression model showed the relationship between the dependent factor (Current water, Z) and those independent factors can be created in a multiple linear regression model as follow;

$$Z = 4.1114 + 0.0575(TAL) + 0.0197(TMH) - 0.2659(BD) - 0.3133(BW) + 0.3103(IND) - 0.0774(IOS) - 0.1221(SS) - 0.0850(ODW) + 0.1949(IOD) - 0.4090(WS) + 0.7402(WTF) + 0.8552(WLF)$$

The model used specific factor for *A. mamoratus* in Chiang Dao only. The regression's F-value is 24.62 (3, 13 df, $p<0.05$). The multiple linear regression model could explain 95.05 percent ($R^2= 0.9505$) of the relationship between current water effected to twelve external features. The model showed positive the probability of water current was higher when TAL, TMH, IND, IOD, WTF and WLF increase and seven negative relationship (BD, BW, IOS, SS, ODW and WS). The oral dice is specialize width of sucker muscle (WS) was showed negative correlation with fast-flowing water, size of WS larger when rate of current water decreasing. In addition, tadpole bodies depressed withstand the fast-flowing water.

6. *Huia melasma* Stuart and Chan-ard, 2005

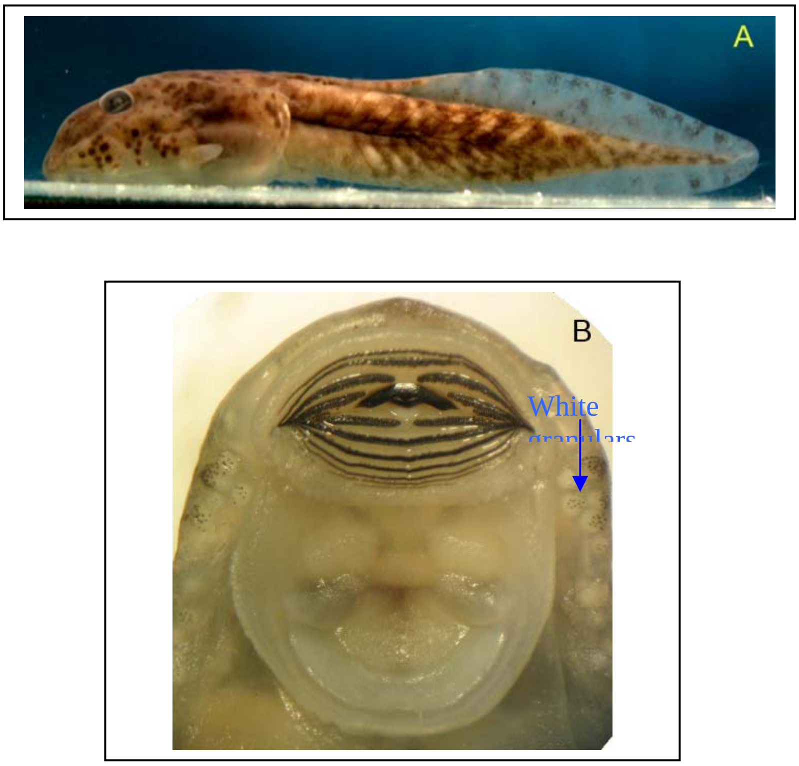


Figure 19 *Huia melasma* Stuart and Chan-ard, 2005

A: Body shape of tadpole

B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva had a total length of 48.45 mm at 39 stages (Gosner, 1960). Nineteen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body oval broadly rounded at snout, flat below, body and tail slightly scatters with small, BL 9.49-16.28 mm, eye dorsal, not visible from below; nostril open on dorsal; postorbital gland disappearing; spiracle sinistral; vent tube dextral; the middle of tail on the dorsal fin is expanded and slight smaller on the tip, ventral fin starting at the end of the body, dorsal fin slightly deeper than ventral fin, tip point (Figure19).

Color/Markings; in life, dorsum and flanks of body dark green and brown, ventral unpigmented and beige, white granular dispersed under body skin and appearing on the bridge of upper and lower of tails (Figure 8-B). In preservative, body becomes a light shade of brown, but all scatters pattern retained.

Oral disc; mouth ventral, oral disc width 4.20-7.46 mm of ODW, upper lip with papillae expand to be sucker, upper and lower jaw sheath smoothed; edge with black, upper jaw sheath massive and M-shaped but lower jaw sheath small and slight V-shaped.

LTRF II:3+3/1+1:VIII

Larval microhabitat; found in well current water and caught with the bottom gravel of stream of type of locality; water clear, current water, shadow water, the gravel is cover with thallophytic or algae. Larvae observed to be active at night and have been found associate with *L. chapaense* (Figure 20).

Figure 20 Habitat of *Huia melasma* tadpole

When considering the relative of external morphologies of *Huia melasma* which live in fast current water. The regression model showed the relationship between the dependent factor (Current water, Z) and those independent factors can be created in a multiple linear regression model as follow;

$$Z = -1.2248 + 0.5287(BW) - 0.8713(IOS) - 0.3785(ODW) + 0.4109(IOD) + 0.7230(WLF)$$

The model used specific factors for *H. melasma* in Chiang Dao only. The regression's F-value is 19.99 (5, 13 df, $p<0.05$). The multiple linear regression model could explain 0.8406 percent (R^2= 0.8406) of the relationship between current water effected to five external features. The model showed the positive probability of water current was higher when BW, IOD and WLF) increased and two negative relationship (IOS and ODW). The tail fin, It was only WLF was affected to this model but different from *A. mamoratus*. Because of *H. melasma* lived among steam and tend to the lower tail fin more positive value than WTD moving plan direction.

7. *Fejervarya limnocharis* (Boie, 1835)

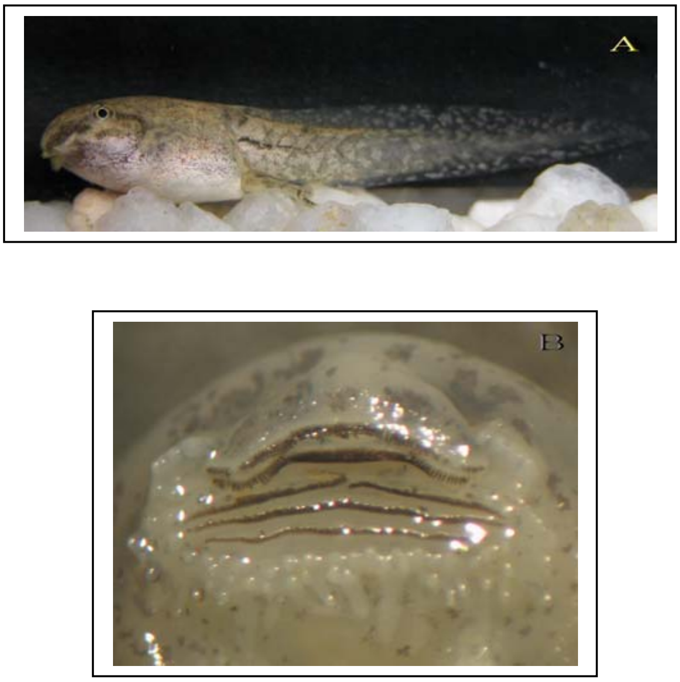


Figure 21 *Fejervarya limnocharis* (Boie, 1835)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva had a total length of 29.44 mm at 38 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body oval broadly rounded at snout, slight flattened above, BL 9.11-10.66 mm; eye dorsal, not visible from below; nostril open on dorsal; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal and ventral fin convex, fin deeper than muscle beyond middle of the tail, fin tapering to point tip (Figure 21).

Color/Markings; in life, dorsum and flanks of body brownish or olive, body and tail scattered with yellow spots. In preservative, body becomes a light shade of brown and the spots darken.

Oral disc; mouth antero-ventral, oral disc width 1.94-2.23 mm of ODW; marginal disc with 3 rows of lower papillae, outer papilla expanded to longer than inner ; upper and lower jaw sheathes shadow and smooth, edge with black.

LTRF I :1+1/III

Larval microhabitat; found in well pool, where there are accumulated litters or sediment on the bottom and often found in agriculture area. Larvae observed to be active at night and tadpoles is very similar *R.nigrovittata* (Figure 29).

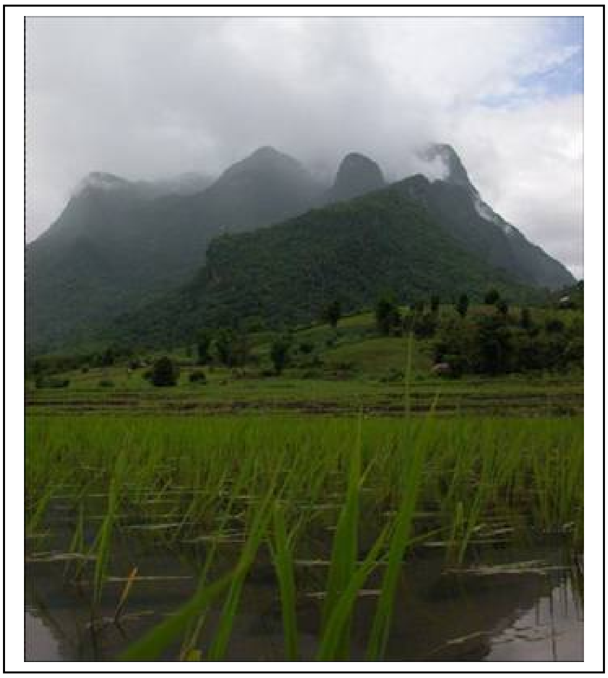


Figure 22 Habitat of *Fejervarya limnocharis* tadpole

When considering the relative of external morphologies of *F. limnocharis* which lives depend on dependent factor (Z= rainfall). The regression model showed the relationship between dependent factors and independent factors can be created a multiple linear regression models as follow;

Z = 1935.07 + 32.38(TL) + 185.53(BL) + 121.81(TMH) + 200.05(BD)
+ 236.88(BW) + 518.92(IND) + 176(IOS) - 783.16(ODW) - 721.39(IOD)

The model used specific factors for *F. limnocharis* in Chiang Dao only. The regression's F-value is 6.652 (5, 9 df, $p<0.05$). The multiple linear regression model could explain 78.42 percent (R^2= 0.7842) of the relationship between rainfall affected to external features.

The model showed positive the probability of rainfall was higher when seven features (TL, BL, TMH, BD, BW, IND, IOS, LS and TMH) increase and two negative relationships (ODW and IOD). Tadpoles found in wet season in temporal aquatic and high rainfall. They are bentic tadpole, rasp food from submerged surface and sometime found in black-waters lentic site.

8. *Limnonectes kuhlii* (Tschudi, 1838)

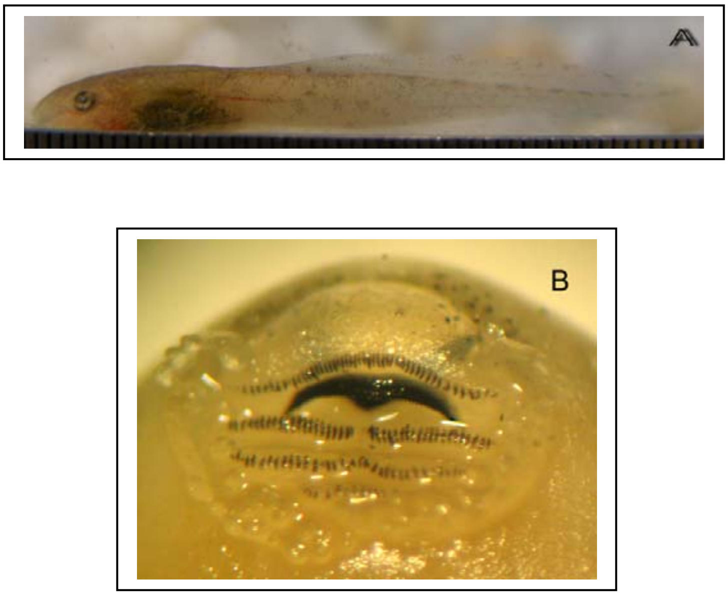


Figure 23 *Limnonectes kuhlii* (Tschudi, 1838)

A: Body shape of tadpole

B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva had a total length of 37.53 mm at 38 stages (Gosner, 1960). Thirty tadpoles form local area were examined and data of minimum and maximum of each feature was shown in appendix table 3.

Head-body oval rounded at snout, slight flattened above, BL 7.54-12.98 mm; eye dorsal, not visible from below; nostril open on dorsal; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal and ventral fin parallel, crests rather low, fin tapering to point tip (Figure 23).

Color/Markings; in life, dorsum and flanks of body brownish, body and tail scattered with small black on the skin. In preservative, body becomes a light shade of brown.

Oral disc; mouth anterior, oral disc width 1.62-2.61 mm of ODW; marginal disc with 2 rows of lower papillae, 2-4 sub-marginal papillae ; upper and lower jaw sheathes shadow and smooth, edge with black: teeth row short and small.

LTRF I :1+1/1+1 :II

Larval microhabitat; found in well side pools of small stream banks, where there are accumulated litters or sediment on the bottom. Larvae observed to be active at night (Figure 24).

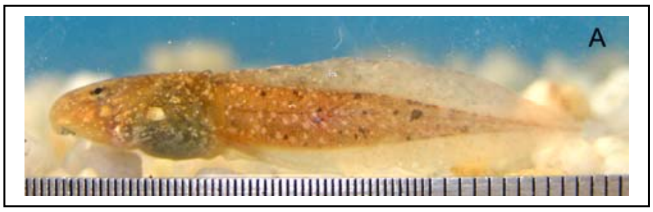
Figure 24 Habitat of *Limnonectes kuhlii* tadpole

When considering the relative of external morphologies of *L. kuhlii* which lives depend on dependent factor (Z= rainfall). The regression model showed the relationship between dependent factors and independent factors can be created in three multiple linear regression models as follow;

$$Z_1 = 603.07 - 57.40(BL) - 27.43(TAL) - 56.59(MTH) + 54.71(BD) + 22.82(IOS) + 134.51(ODW) + 93.79(IOD)$$

The model used specific factors for *L. kuhlii* in Chiang Dao only. The regression's F-value is 10.9 (7, 22 df, $p<0.05$). The multiple linear regression model could explain 70.49 percent (R^2= 0.7049) of the relationship between rainfall affected to external features. The model showed positive the probability of rainfall was higher when three features (MTH, BD, IOS, ODW and IOD) increased and two negative relationships (BL and TAL). Tadpoles can be found in both of lentic and lotic water. The most tadpoles occurrence in tropical depend on breeding season and breeding activity of adult anurans may be strongly dependent on rainfall (Crump, 1974). *L. kuhlii* breeds though out the year and more activity in early and late rainy season.

9. *Rana cubitalis* Smith, 1917



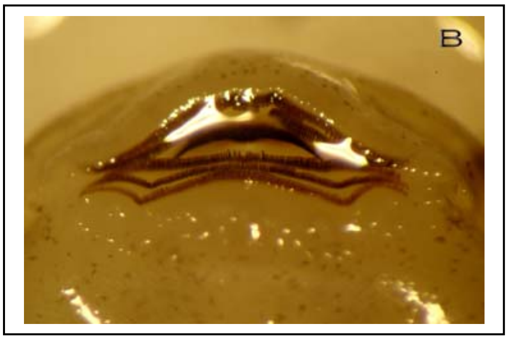


Figure 25 *Rana cubitalis* Smith, 1917
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva had a total length of 38.31 mm at 39 stages (Gosner, 1960). Seventeen tadpoles from local area were examined and data of minimum and maximum of each feature was showed in appendix table 3. Head-body oval broadly rounded at snout, slight flattened above, BL 10.35-13.41 mm; eye dorsal, not visible from below; nostril open on dorsal; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal and ventral fin convex, fin deeper than muscle beyond middle of the tail, fin tapering to point tip (Figure 25).

Color/Markings; in life, dorsum and flanks of body brownish or olivaceous, body and tail scattered with black and yellow reflex on the skin. In preservative, body becomes a light shade of brown and the spots darken.

Oral disc; mouth terminal, oral disc width 3.11-4.34 mm of ODW; marginal disc with 2 rows of lower papillae; upper and lower jaw sheathes shadow and smooth, edge with black.

LTRF I:1+1/III

Larval microhabitat; found in well side pools of small stream banks, where there are accumulated litters or sediment on the bottom. Larvae observed to be active at night and tadpoles is very similar *R. nigrovittata* but that is larger and stouter (Figure 26).

Figure 26 Habitat of *Rana cubitalis* tadpole

When considering the relative of external morphologies of *R. cubitalis* which live in stream. The regression model showed relationship between the dependent factor (Oxygen, Z) and those independent factors can be created in a multiple linear regression model as follow;

$$Z = 0.2378 - 2.6818(BL) + 0.9250(TAL) - 2.1825(MTH) + 4.5845(IOS) + 3.1905(SS) - 2.3070(IOD)$$

The model used specific factors for *R. cubitalis* in Chiang Dao only. The regression's F-value is 25.23 (8, 22 df, $p<0.05$). The multiple linear regression model could explain 83.58 percent ($R^2 = 0.83.58$) of the relationship between dissolved oxygen effected to external features. The model showed positive the probability of dissolved oxygen was higher when three features (TAL, IOS and SS) increase and four negative relationships (MTH and IOD). Although tadpoles have been found in side pool but sometime they live in the side of stream that slow-flowing water. Tadpoles have a large maximum tail length for moving among column water however, shape of body similar *R. nigrovittata*.

10. *Rana livida*, (Blyth, 1856)

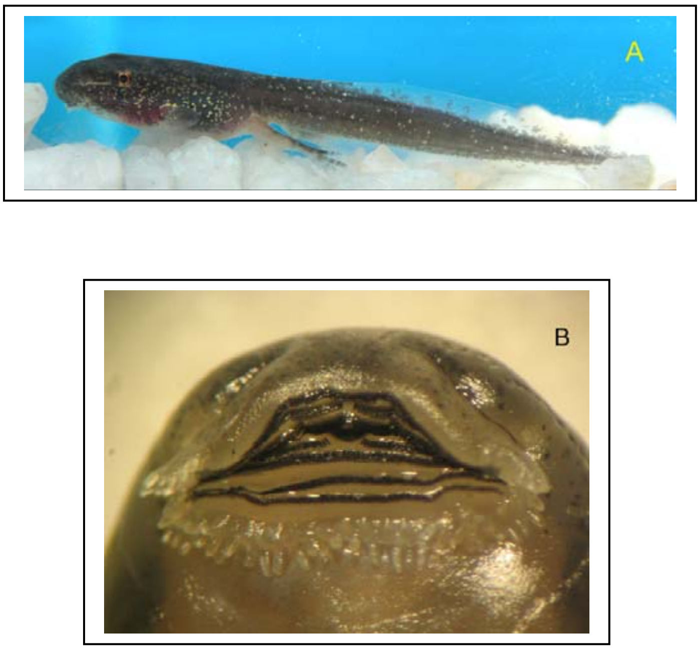


Figure 27 *Rana livida* (Blyth, 1856)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology**;** a medium tadpole, the longest larva had a total length of 33.25 mm. at 35 stages (Gosner, 1960). Twelve tadpoles form local area were examined and data of minimum and maximum of each feature was showed in appendix table 3. Head-body slender , BL 8.39-11.56 mm; eye dorsal, not visible from below; nostril open on lateral; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal and ventral fin parallel, crests rather low, ventral fin quite small, fin tapering to point tip (Figure 27).

Color/Markings; in life, dorsum and tail muscle gray or dark, body and tail muscle scattered with small gold or yellow reflex; tail is transparent and scattered some dark spots; belly of tadpoles scarlet. In preservative, body becomes dark.

Oral disc; mouth anterior, oral disc width 1.81-3.66 mm of ODW; marginal disc with 2 rows of lower papillae, marginal papilla fine; upper and lower jaw sheathes shadow and serrated, edge with black.

LTRF I:4+4/1+1:III

Larval microhabitat; found in well side pools of small stream banks, where there are accumulated litters or sediment on the bottom Figure 28).

In field work collected only twelve tadpole specimens in this area. It was not enough for creating regression model because of the period occurred flood

Figure 28 Habitat of *Rana livida* tadpole

11. *Rana nigrovittata* (Blyth, 1856)

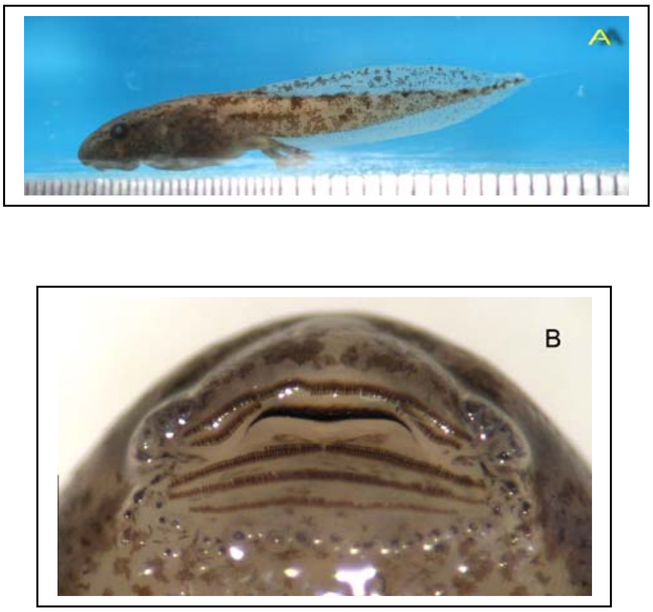


Figure 29 *Rana nigrovittata* (Blyth, 1856)

A: Body shape of tadpole

B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva had a total length of 29.06 mm at 39 stages (Gosner, 1960). Sixteen tadpoles from local area were examined and data of minimum and maximum of each feature was showed in appendix table 3. Head-body oval broadly rounded at snout, slight flattened above, BL 8.89-10.29 mm; eye dorsal, not visible from below; nostril open on leteral; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal and ventral fin convex, fin deeper than muscle beyond middle of the tail, fin tapering to point tip (Figure 29).

Color/Markings; in life, dorsum and flanks of body brownish or dark, body and tail scattered with dark spots. In preservative, body becomes a light shade of brown and the spots darken.

Oral disc; mouth anteroventral, oral disc width 2.40-3.33 mm of ODW; marginal disc with 3 rows of lower papillae, outer papilla expanded to longer than inner ; upper and lower jaw sheathes shadow and smooth, edge with black.

LTRF I:1+1/1+1:II

Larval microhabitat; found in well side pools of small stream banks, where there are accumulated litters or sediment on the bottom. Larvae observed to be active at night and tadpoles is very similar *R. cubitalis* but that is smaller and slender (Figure 30).

Figure 30 Habitat *Rana nigrovittata* tadpole

When considering the relative of external morphologies of *R.nigrovittata* which lives depend on dependent factor (Z= dissolved oxygen).The regression model showed the relationship between dependent factors and independent factors can be created in three multiple linear regression models as follow:

$$Z = 3.9603 + 0.4682(BL) + 2.2643 (TMH) + 0.8557(BD) - 1.6608(SS) - 2.2473(ODW) + 1.4141(IOD)$$

The model used specific factors for *R.nigrovittata* in Chiang Dao only. The regression's F-value is 4.641 (6, 19 df, $p<0.05$). The multiple linear regression model could explain 59.29 percent (R^2= 0.5929) of the relationship between dissolve oxygen affected to external features.

The model showed positive the probability of dissolved oxygen was higher when four features (BL, BD, TMH and IOD) increased and two negative relationships (SS and ODW). But the result of dissolved oxygen inverted because of the study sit is high rainfall all year and also affected to high oxygen dissolved in this period.

12. *Rhacophorus bipunctatus* Ahl, 1927

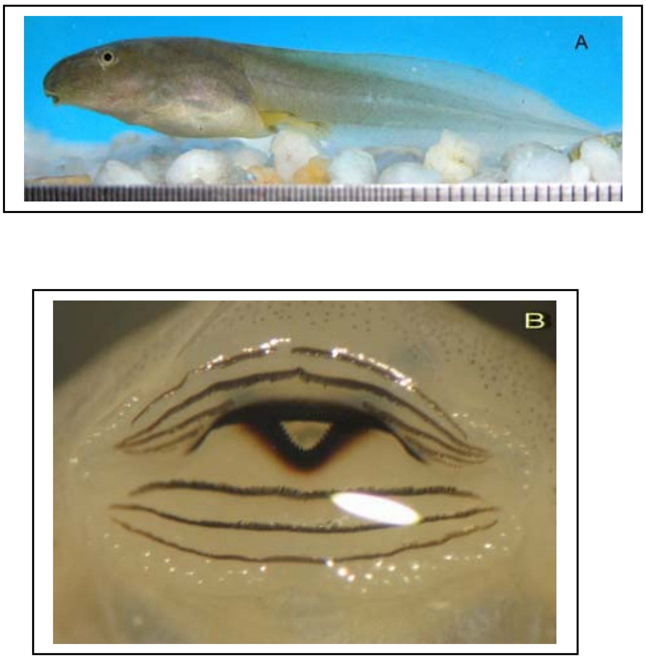


Figure 31 *Rhacophorus bipunctatus* Ahl, 1927
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a large tadpole, the longest larva had a total length of 47.39 mm at 35 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was showed in appendix table 3. Head-body oval broadly rounded at snout, fleshy body, BL 18.28-20.26 mm; eye dorsal, not visible from below; nostril open on dorsal; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal and ventral fin convex, fin deeper than muscle beyond middle of the tail, fin tapering to point tip (Figure 31).

Color/Markings; in life, dorsum and flanks of body were grayish or olive. In preservative, body becomes a light shade of gray.

Oral disc; mouth anteroventral, oral disc width 3.1-4.91 mm of ODW; marginal disc with a row of lower papillae; upper and lower jaw sheathes medium and serrated, edge with black.

LTRF II:3+3/1+1:II, II:2+2/III, I:3+3/III, I:4+4/1+1:I

Larval microhabitat; found in well pool, where there are accumulated litters or sediment on the bottom. Larvae observed to be active at night and associated with microhylids (Figure 32).

Figure 32 Habitat of *Rhacophorus bipunctatus* tadpole

When considering the relative of external morphologies of *R. bipunctatus* which lives depend on dependent factor (Z= rainfall). The regression model showed the relationship between dependent factor and independent factors can be created in three multiple linear regression models as follow;

$$Z = -251.240 + 25.083(TL) - 45.377(BL) + 43.669(BD) - 75.095(BW) + 11.041(IND) + 64.674(ODW)$$

The model used specific factors for *R. bipunctatus* in Chiang Dao only. The regression's F-value is 8.202 (5, 18 df, $p<0.05$).The multiple linear regression model could explain 60.30 percent (R^2= 0.603) of the relationship between rainfall affected to external features.

The model showed positive the probability of rainfall was higher when four features (TL, BL, IND and ODW) increased and two negative relationships (BL and BW). The pattern of *R. bipunctatus*'s net initiation and proportion of successful net were greatly influence by corresponding seasonal pattern of rainfall. Therefore, the rainfall more important and specify tadpoles body became to be large and fleshy.

13. *Polypedates leucomystax* (Gravenhorst, 1829)

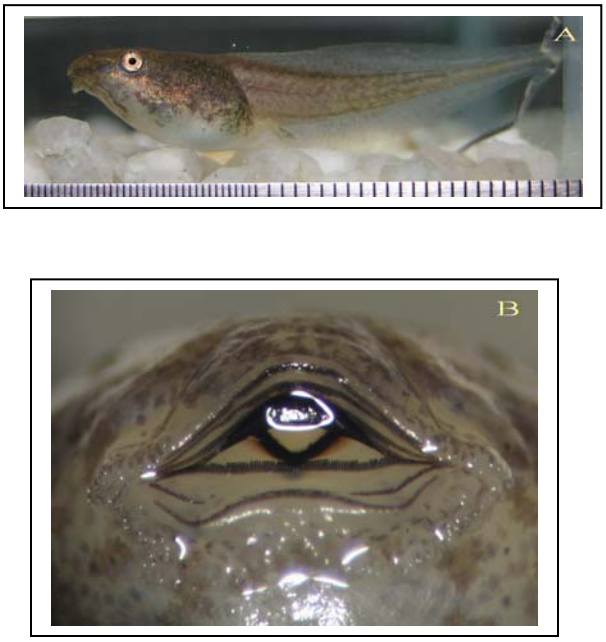


Figure 33 *Polypedates leucomystax* (Gravenhorst, 1829)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a medium tadpole, the longest larva had a total length of 48.52 mm at 40 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body avoid in plan view, rounded at snout, dorsal surface flatted, BL

10.44-16.28 mm; eye lateral; nostril open on lateral; spiracle sinistral; vent tube dextral; tail muscle strong, fin beginning at root of tail, margin of dorsal fin convex, fin deeper than muscle beyond middle of the tail, ventral fin parallel along caudal fin, fin tapering to point tip (Figure 33).

Color/Markings; in life, dorsum and flanks of body is grayish or olive. Over body is green pattern but belly is white. In preservative, body becomes a light shade of gray

Oral disc; mouth anteroventral, oral disc width 3.21-4.81 mm of ODW; marginal disc with a row of lower papillae; upper and lower jaw sheathes medium and serrated, edge with black.

LTRF I:3+3/1+1:II, I:4+4/1+1:II

Larval microhabitat; found in well pool, where there are accumulated litters or sediment on the bottom. Water may be clear or turbid. Larvae observed to be active at night (Figure 34).

Figure 34 Habitat of *Polypedates leucomystax* tadpole

When considering the relative of external morphologies of *P. luecomystac* which lives depend on dependent factor (Z_1= rainfall). The regression model showed the relationship between dependent factors and independent factors can be created in three multiple linear regression models as follow:

$$Z = 6.8134 - 0.0361(TAL) + 0.1749(TMH) + 0.3883(MTH) -0.6500(BD) +0.2284(IND) + 0.5228(SS) - 0.3455 (IOD)$$

The model used specific factors for *P. luecomystac* in Chiang Dao only. The regression's F-value is 20.94 (7, 18 df, $p<0.05$). The multiple linear regression model could explain 90.89 percent (R^2= 0.9089) of the relationship between rainfall affected to external features.

The model showed positive the probability of rainfall was higher when three features (TMH, MTH, IND and SS) increased and three negative relationships (TAL, BD and IOD). *P. luecomystac* also built net foam before tadpole move to the lentic water.

14. *Kaloula punlchra* Gray, 1831

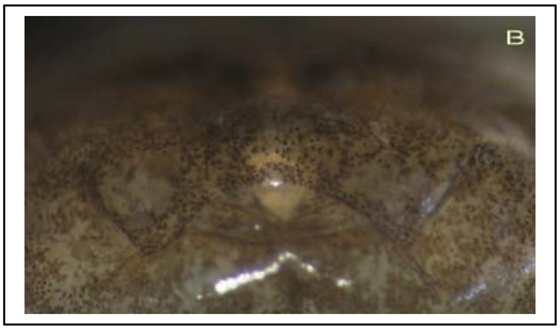


Figure 35 *Kaloula pulchra* Gray, 1831
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a small tadpole, the longest larva had a total length of 30.61 mm at 38 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was showed in appendix table 3. Head-body oval, flattened above and below, wider than high, BL 7.07-9.65 mm; snout broad and truncate ; eye lateral, equidistant between their eyes; nostril close at stages 38; spiracle medial; vent median and vent tube curving downwards and backward, fin beginning at root of tail, fin marginal subequal, no terminal filament (Figure 35).

Color/Markings; in life, head-body from olive-brown to black above, occasionally with golden speckles, ventral lighter, caudal fin dark and a white small strip. In preservative, body becomes to grayish and fin slightly clear.

Oral disc Mouth; terminal, small oral disc width 1.52-2.30 mm of ODW; oral papillae, labial teeth and jaw sheaths absent; consisting of a straight upper lip and contractile lower one.

Larval microhabitat**;** found in well in pools and still water in roadsides where there are some aquatic plants and sediment. Sometimes found they associated with other microhylids (Figure 36).

Figure 36 Habitat of *Kaloula pulchra* tadpole

When considering the relative of external morphologies of *K. pulchra* which lives depend on dependent factor (Z= rainfall). The regression model showed the relationship between dependent factors and independent factors can be created in three multiple linear regression models as follow;

$$Z = - 22.076 - 11.0200(BL) + 2.360(TAL) + 2.360(MTH) -4.er399(BD) + 3.353(BW) + 48.957(IND) + 9.561(ODW)$$

The model used specific factors for *K. pulchra* in Chiang Dao only. The regression's F-value is 4.682 (7, 19 df, $p<0.05$). The multiple linear regression model could explain 64.80 percent (R^2= 0.6480) of the relationship between rainfall affected to external features.

The model showed positive the probability of rainfall was higher when five features (TAL, MTH, BW, IND and ODW) increased and two negative relationships (BL and BD). Suspension feeder tadpoles almost entirely by sitting quiescently in the water column and pumping water though out buccalpharangeal structures. Normally, have been found in the critical first rain therefore the tail muscle and fin tail more important for moving in water column.

15. *Microhyla berdmorei* (Blyth, 1856)

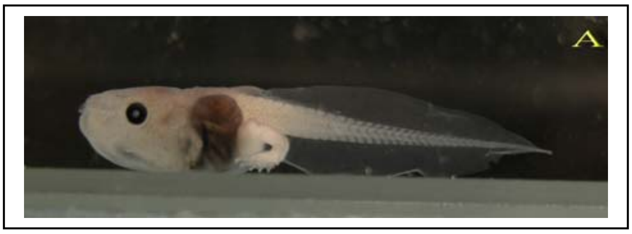


Figure 37 *Microhyla berdmorei* (Blyth, 1856)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a small tadpole, the longest larva had a total length of 29.33 mm at 36 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body oval, flattened above and below, wider than high, BL 7.07-9.65 mm; snout broadly rounded; eye lateral, equidistant between their eyes; nostril close at stages 36; spiracle medial; vent tube running vertically to edge of ventral fin; tail muscle weak, fin beginning at root of tail, margin of dorsal and ventral fin convex, fin deeper than muscle beyond middle of the tail, fin tapering to point tip (Figure 37).

Color/Markings; in life, head-body and tail were grayish, scattered small black pigment on the skin; fin tails clearly. In preservative, body becomes to faded and tail clearly.

Oral disc; mouth terminal, oral disc width 1.70-2.47 mm of ODW; oral papillae, labial teeth and jaw sheaths absent; lower lip about equal to upper, not produced into funnel.

Larval microhabitat; found in well in pools, potholes, side pools in the stream and still water in sides of stream where there are some accumulated litter and sediment. Sometime they have been showed schooling behavior and active in day and night (Figure 38).

Figure 38 Habitat of *Microhyla berdmorei* tadpole

When considering the relative of external morphologies of *M. berdmorei* which lives depend on dependent factor (Z= temperature). The regression model showed the relationship between dependent factors and independent factors can be created in three multiple linear regression models as follow;

$$Z = 19.4111 - 0.9320(BL) - 2.863(TAL) - 1.9478(TMH) + 0.8195(BD) + 0.0183(BW) - 0.9782(SS) + 1.6915(ODW) + 1.1388(IOD)$$

The model used specific factors for *M. berdmorei* in Chiang Dao only. The regression's F-value is 4.345 (9, 19 df, $p<0.05$). The multiple linear regression model could explain 68.25 percent ($R^2 = 0.6825$) of the relationship between temperature affected to external features. The length of larval period related to temperature in temporal habitat. *M. berdmorei* are special species their breeding in winter season that low temperature and are accelerated metamorphosis in early summer. Generally, microhylids lives in still water but sometime this species can be dwell in the side stream.

16. *Microhyla heymonsi* Vogt, 1911

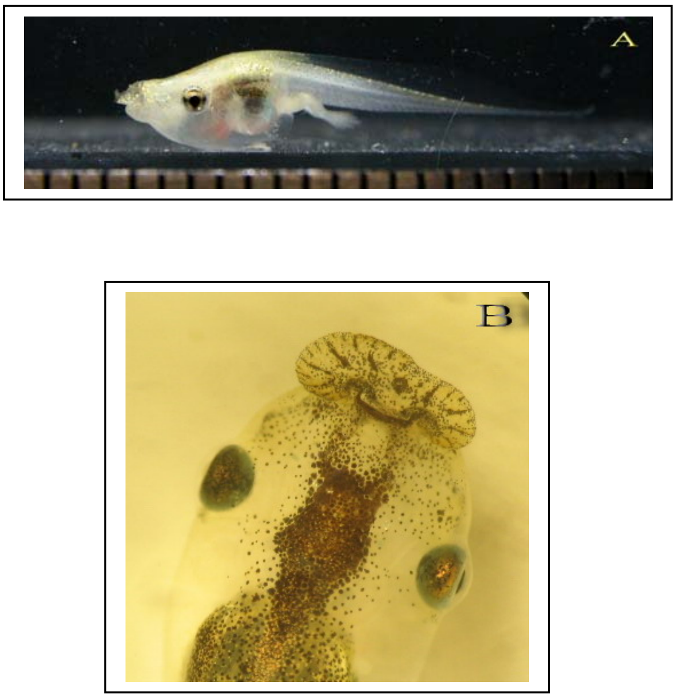


Figure 39 *Microhyla heymonsi* Vogt, 1911

A: Body shape of tadpole

B: Mouthparts of tadpole

Larval morphology; a small tadpole, the longest larva had a total length of 19.46 mm at 36 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body ovoid, moderately flattened dorsally at the head region, BL 5.23-6.43 mm; snout bluntly round ; eye lateral; nostril close at stages 36; spiracle medial; vent median and vent tube opening below center of gut, fin dorsal fin slightly, ventral fin subequal; tail possessing a terminal filament (Figure 39).

Color/Markings; in life, head-body and tail muscle pale white, above cover with pale buff to yellow brown. In preservative, scattering dark spot pigments on the skin, both of fin usually clear.

Oral disc; mouth dorso-terminal, lower lip expanded into abroad funnel surrounding the mouth, oral disc width 5.23-6.43 mm of ODW, upper lip hours-shoe shaped; oral papillae, labial teeth and jaw sheaths absent.

Larval microhabitat; found in well in pools and still water in roadsides where there are some aquatic plants and sediment. Sometimes found they associated with other microhylids and some of rhacophorid (Figure 40).

Figure 40 Habitat *Microhyla heymonsi* tadpole

When considering the relative of external morphologies of *M. heymonsii* which lives depend on dependent factor (Z_1= rainfall). The regression model showed the relationship between dependent factors and independent factors can be created in three multiple linear regression models as follow;

$$Z = -54.04 – 186.89(BL) + 29.19(TAL) + 218(SS)$$

The model used specific factors for *M. heymonsii* in Chiang Dao only. The regression's F-value is 8.131 (3, 11 df, $p<0.05$).The multiple linear regression model could explain 60.45 percent (R^2= 0.6045) of the relationship between rainfall affected to external features.

The model showed positive the probability of rainfall was higher when two features (TAL and SS) increase and BL negative relationships. Microhylids tadpoles have special spiracle different from other family. Their spiracles are not sinistral but are mid-ventral on belly or near vent.

17. *Microhyla pulchra* (Hallowell, 1861)

Figure 41 *Microhyla pulchra* (Hallowell, 1861).
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a small tadpole, the longest larva had a total length of 30.61 mm. at 38 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body ovoid, moderately flattened dorsally at the head region, BL 7.16-9.97 mm; snout bluntly round ; eye lateral; nostril close at stages 38; spiracle medial; vent median and vent tube opening below center of gut, fin dorsal fin slightly, ventral fin subequal; no terminal filament (Figure 41).

Color/Markings; in life, head-body and tail muscle pale white, above cover with pale buff to yellow brown. In preservative, scattering dark spot pigments on the skin, both of fin usually clear.

Oral disc; mouth dorso-terminal, oral disc width 1.52-2.30 mm of ODW, upper lip hours-shoe shaped; oral papillae, labial teeth and jaw sheaths absent.

Larval microhabitat; found in well in pools and still water in roadsides where there are some aquatic plants and sediment. Sometimes found they associated with other microhylids and some of rhacophorid (Figure 42).

Figure 42 Habitat of *Microhyla pulchra* tadpole

When considering the relative of external morphologies of *M. pulchra* which lives depend on dependent factor (Z = temperature). The regression model showed the relationship between dependent factor and independent factors can be created in three multiple linear regression models as follow;

$$Z = 6.0243 + 2.1455(BL) + 5.8430(TMH) - 1.6354(MTH) - 0.4092(BD) -0.3370(BW) + 1.5609(IND) + 1.1936(ODW) - 0.6662(IOD)$$

The model used specific factors for *M. pulchra* in Chiang Dao only. The regression's F-value is 31.99 (8, 13 df, $p<0.05$). The multiple linear regression model could explain 88.73 percent (R^2= 0.8873) of the relationship between rainfall affected to external features.

The model showed positive the probability of temperature was higher when four features (BL, TMH, IND and ODW) increased and three negative relationships (MTH, BD, BW and IOD). The temperature affected to growing as body larger before metamorphosis.

18. *Microhyla ornata* (Dumeril and Bibro, 1841)

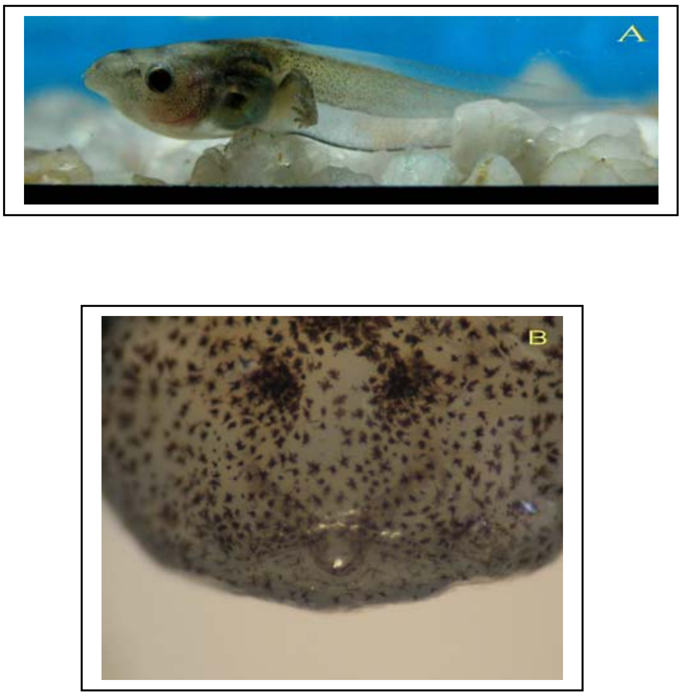


Figure 43 *Microhyla ornata* (Dumeril and Bibro, 1841)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a small tadpole, the longest larva attained a total length of 13.29 mm at 30 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was showed in appendix table 3. Head-body oval, moderately flattened dorsally at the head region, spheroidal ventral, BL 5.23-6.43 mm; snout bluntly round; eye lateral; nostril close at stages 30; spiracle medial; vent median and vent tube running between body and ventral fin, fin dorsal fin slightly and parallel caudal muscle, ventral fin subequal; tail possessing a terminal filament (Figure 43).

Color/Markings; in life, head-body and tail muscle pale white, margin of ventral fin darken. In preservative, scattering dark spot pigments on the skin, both of fin usually clear.

Oral disc; mouth terminal, oral disc width 0.95-1.13 mm of ODW; oral papillae, labial teeth and jaw sheaths absent; lower lip about equal to upper, not produced into funnel.

Larval microhabitat; found in well in pools and still water in roadsides where there are some aquatic plants and sediment. Sometimes found they associated with other microhylids and some of rhacophorid (Figure 44).

Figure 44 Habitat of *Microhyla ornata* tadpole

When considering the relative of external morphologies of *M. ornata* which lives depend on dependent factor (Z = dissolved oxygen). The regression model showed the relationship between dependent factor and independent factors can be created in three multiple linear regression models as follow;

$$Z = 44.619 – 8.913(TAL) – 20.992(TMH) + 16.978(IOD)$$

The model used specific factors for *M. ornata* in Chiang Dao only. The regression's F-value is 4.679 (3, 11 df, $p < 0.05$). The multiple linear regression model could explain 44.09 percent ($R^2 = 0.4409$) of the relationship between rainfall affected to external features.

The model showed positive the probability of rainfall was higher when IOD increase and two negative relationships (TAL). Tadpole found in wet season and high rainfall. They are wide tolerance and able to live in low levels of dissolved oxygen.

19. *Micryletta inornata* (Boulenger, 1890)

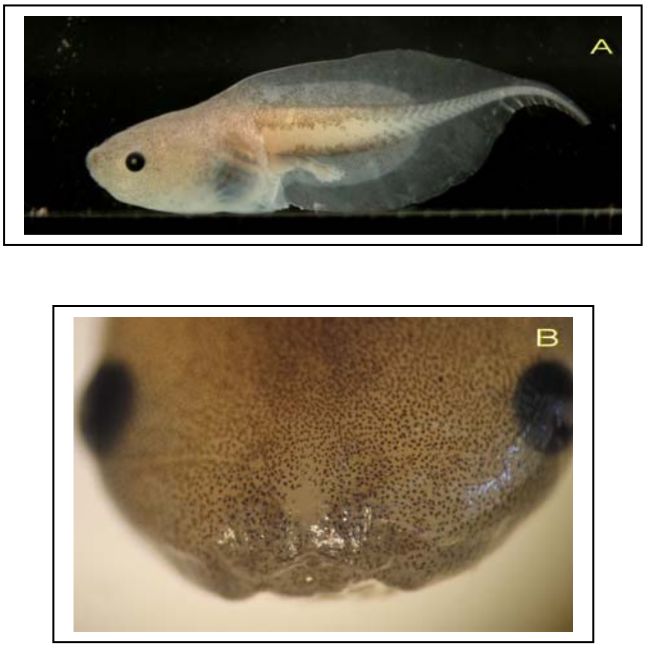


Figure 45 *Micryletta inornata* (Boulenger, 1890)
A: Body shape of tadpole
B: Mouthparts of tadpole

Larval morphology; a small tadpole, the longest larva had a total length of 22.82 mm at 35 stages (Gosner, 1960). Fifteen tadpoles from local area were examined and data of minimum and maximum of each feature was shown in appendix table 3. Head-body oval, moderately flattened dorsally at the head region, spheroidal ventral, BL 6.58-7.61 mm; snout round; eye lateral; nostril close at stages 35; spiracle medial; vent median and vent tube running between body and ventral fin, dorsal and ventral fin depth; tail possessing a terminal filament (Figure 45).

Color/Markings; in life, head-body brownish and belly yellowish, tail muscle and both of fins cross by yellow strip. In preservative, scattering dark spot pigments on the pale brown skin, both of fin usually clear.

Oral disc; mouth terminal, oral disc width 1.37-2.20 mm of ODW; oral papillae, labial teeth and jaw sheaths absent; lower lip about protruded to upper, not produced into funnel.

Larval microhabitat; found in well in pools and still water in roadsides where there are some aquatic plants and sediment. Sometimes found they associated with other microhylids and some of rhacophorid (Figure 46).

Figure 46 Habitat of *Micryletta inornata* tadpole

When considering the relative of external morphologies of *M. inornata* which lives depend on dependent factor (Z= temperature). The regression model showed the relationship between dependent factor and independent factors can be created in multiple linear regression models as follow;

$$Z_3 = 47.518 - 5.321(BL) - 2.576(MTH) + 2.405(BD) - 4.244(BW) + 8.893(IOD) - 3.205(ODW)$$

The model used specific factors for *M. inornata* in Chiang Dao only. The regression's F-value is 3.506 (6, 18 df, $p<0.05$). The multiple linear regression model could explain 51.79 percent ($R^2= 0.5179$) of the relationship between temperature affected to external features.

The model showed positive the probability of temperature was higher when two features (BD and IOD) increased and five negative relationships (BL, MTH, BW and ODW). The small microhylids also dwell in low levels of dissolved oxygen.

CONCLUSIONS AND RECOMMENDATION

Conclusion

Nineteen tadpole species belong to fourteen genera and in four families were found in the study site. Four species were recorded only in permanent water, three species only found in temporary pools and twelve species occurred in both kinds of water body. *R. bipunctatus* occurred in several sites more than other species

Seven species only found in dry season. Seven species only found in wet season, and five found in both of season. The late dry season, transition to wet season found twelve species overlapped.

Using the cluster analysis could be categorized in five groups based on 21 external morphological characters when considering a horizontal of dendrogram at 62.5 percent. Group A consisted of two members of *Microhyla ornata* and *M. heymonsii* and four of Microhylidae; *Kaoulal punlchra, M. inornata, M. berdmorei and M. pulchra* were a member of group B. Group C is a large group consisted of ten species; *Polypedates leucomystrax, Rhacophorus bipunctatus, Rana cubitalis, Leucomystax polydytoides, Brachytrasophrys carinensis*, *Xenophrys lateralis*, *Fejervarya limnocharis*, *R. nigrovittata*, *R. livida*, *Limnonectes kuhlii*. Group D has only one species; *Leptobrachium chapaense* and group E is the last group which consisted of two members; *Amolops marmoratus* and *Huia melasma*.

The result of ordination technique showed the relationship among tadpoles present and three abiotic factors on three axes. The percentages of variance explained by Axis 1, Axis 2 and Axis 3 were 24.3 %, 3.5 % and 10.8 %, respectively, while the cumulative percentages explained were 24.3 %, 28.6 % and 35.1 %, respectively. Eigenvalues to explain variation in community showed in three axes were 0.066, 0.010 and 0.029 respectively. The value of correlation was most in Axis 2 (0.729, 0.518 and 0.768).

The biplot of ordination technique showed greatest correlation on Axis 1 and Axis 2 and was appeared three variables. Dissolved oxygen was also the strongest value. The biplot was used grouping to explain species occurrence constituents which depended on abiotic factors. Three groups were a result, first group was *B. carinensis, X. lateralis* occurring depended on current water. Second group; *L. chapaense, H.melasma* and *A. marmoratus* found the highest of dissolved oxygen. Last group, they were consisted of thirteen species association with temperature factors. Almost of them found in lentic water.

Each individual could be created the regression model among environment factor by refer to ordination technique with their external morphology. *L. chapaense* related to current water and the morphological modal could be explained 30.68 percent (R^2= 0.3068). *L. pelodytoides* related to current water variable. The morphological modal could be explained 71.79 percent (R^2= 0.7179) of water current variable. *B. carinensis* related to current water. The multiple linear regression model could explain 49.76 percent (R^2= 0.4976) of the relationship between current water. *X. lateralis* related to current water and the morphological modal could be explained 57.91 percent (R^2= 0.5791). *A. marmoratus* related to current water and the morphological modal could be greatest explained 95.05 percent (R^2= 0.9505). *H. melasma* related to current water and the morphological modal could be also greatest explained 0.8406 percent (R^2= 0.8406). *F. limnocharis* related to rainfall variable. The morphological modal could be explained 78.42 percent (R^2= 0.7842) of the relationship between humidity. *L. kuhlii* related to rainfall variable. The morphological modal could be explained 70.49 percent (R^2= 0.7049). *R. cubitalis* related to dissolved oxygen and the morphological modal could be explained 83.58 percent (R^2= 0.9237).

R. livida could collect only twelve tadpole specimens in this area. It is not enough for creating regression model because of the period had flood. *R. nigrovittata* related to dissolved oxygen variable. The morphological modal could be explained 59.29 percent (R^2= 0.5929) of the relationship between dissolved oxygen.

R. bipunctatus related to rainfall variable. The morphological modal could be explained 60.30 percent (R^2= 0.603) of the relationship between rainfall. *P. leucomystax* related to rainfall variable. The morphological modal could be explained 90.89 percent (R^2= 0.9089). *K. pulchra* related to rainfall variable. The morphological modal could be explained 64.80 percent (R^2= 0.648) of the relationship between rainfall variable. *M. berdmorei* related to temperature variable. The morphological modal could be explained 68.25 percent (R^2= 0.6825). *M. heymonsi* related to rainfall variable. *M. pulchra* related to temperature variable. The morphological modal could be explained 88.73 percent (R^2= 0.8873) of the relationship between the variable. *M. ornata* related to temperature variable. The morphological modal could be explained 44.09 percent (R^2= 0.4409). *M. inornata* related to temperature variable. The morphological modal could be explained 51.79 percent (R^2= 0.5179).

Each tadpole species had different way responses of external morphotypes to the environmeantal factors. Certain shapes and other morphological modification are clearly associated with particular environmental condition. There are several clear examples, one of them being larval *A. marmoratus* and *H.melasma* have abdominal suckers enabling them to cling to rocks and maintain position in fast water current. Some species have indirect correlation with morphological such as *P. leucomystrax* larvae having big body and large fin for dwelling in still water after breeding in rainy.

Recommendation

In this research, there are apply the regression model to explained relationship between external morphology and environmental factors in their habitat. The specimen in some species was not enough to provide the model, should be gain more time and sampling plot for collected the specimen in every month. Moreover, record and analyze have to increase some the environmental factors such as pH, predators, competition, percentage of water surface cover, percentage of sediment, width and depth of the water resource. Climate data such as temperature, amount of rainfall and percent of humidity might be record high exhaustive way. What’s the character we should be selected to create the good and be valuable model for prediction? Some feature appears after live in stress and some result of genetic feature. Otherwise the model will gain more residual. In addition, *R. nigrovittata* and *F. limnocharis* showed the same result in cluster technique, may be the external features were not enough sufficient difference. In the future, should be using some technique to show the result obviously such as buccal cavity or DNA analysis.

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APPENDIXES

Appendix Table1 List of tadpoles in Chiang Dao, Chiang Mai

Family	Genus	Species
MEGOPHRYDAE	*Leptobrachium* Tschudi,1838	*Leptobrachium chapaense* (Bourret, 1937)
	Leptolalex Dubois, 1980	*Leptolalax pelodytoides* (Boulenger, 1893)
	Brachytarsophrys Tian and Hu,1983	*Brachytarsophrys carinensis* (Boulenger, 1899)
	Megophrys Kuhl and Van Hasselt	*Xenophrys lateralis* (Anderson, 1871)
RANIDAE	*Amolops* Cope, 1865	*Amolops marmoratus* (Blyth,1855)
	Huia Yang, 1991	*Huia melasma* Stuart and Chan-ard, 2005
	Fejervaya Bolkay, 1915	*Fejervarya limnocharis* (Boie, 1835)
	Limnonectes Fitzinger, 1843	*Limnonectes kuhlii* (Tschudi, 1838)
	Rana Linnaeus,1758	*Rana cubitalis* Smith, 1917
		Rana livida, (Blyth, 1856)
		Rana nigrovittata (Blyth, 1856)
RHACOPHORIDAE	*Rhacophorus* Kukl and Van Hasselt, 1822	*Rhacophorus bipunctatus* Ahl, 1927
	Polypedates Tschudi, 1838	*Polypedates leucomystax* (Gravenhorst, 1829)
MICROHYLIDAE	*Kaloula* Gray, 1831	*Kaloula punlchra* Gray, 1831
	Microhyla Tschudi, 1838	*Microhyla berdmorei* (Blyth, 1856)
		Microhyla heymonsi Vogt, 1911
		Microhyla pulchra (Hallowell, 1861)
		Microhyla ornate (Dumeril and Bibro, 1841)
	Mycryletta Dubois, 1987	*Micryletta inornata* (Boulenger, 1890)

Appendix Table 2. External morphologicals average measuresment of tadpoles (mm)

	TL		BL		TAL		TMH		MTH		BD		BW		IND	
Species	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**
A. marmoratus	50.95	8.05	18.05	2.18	32.90	6.24	5.99	1.43	2.84	0.46	8.76	1.62	12.17	1.58	3.09	0.44
H. melasma	33.65	6.35	12.00	1.98	21.66	4.42	4.70	0.70	2.41	0.63	5.96	1.18	8.41	1.50	2.78	0.36
L. kuhlii	27.73	3.74	9.44	1.29	18.29	2.75	3.03	0.57	4.55	0.77	3.66	0.57	5.60	0.73	2.20	0.91
L. pelodytoides	48.00	2.41	14.73	0.84	33.27	2.08	5.02	0.56	7.09	0.70	4.95	0.55	6.95	0.53	3.52	0.43
M. berdmorei	24.41	2.11	8.73	0.72	15.68	1.87	1.68	0.22	3.80	0.71	4.85	0.64	9.42	12.73	0.00	0.00
M. heymonsi	15.03	4.04	5.86	0.38	9.16	4.04	1.32	0.21	3.30	0.32	3.59	0.35	3.52	0.27	0.00	0.00
M. inornata	20.84	1.35	7.10	0.32	13.74	1.15	1.91	0.27	5.46	0.49	4.69	0.39	5.05	0.35	0.00	0.00
M. ornata	11.88	0.71	4.39	0.33	7.49	0.50	0.91	0.11	2.46	0.26	2.61	0.27	3.22	0.19	0.00	0.00
R. cubitalis	33.58	2.60	11.63	1.04	21.96	1.75	4.42	0.44	6.19	1.03	5.44	0.56	7.77	0.56	3.41	0.26
R. livida	30.42	1.93	9.64	0.98	20.78	1.96	3.34	0.33	4.76	0.34	3.73	0.36	5.48	0.44	2.53	0.26
R. nigrovittata	27.26	1.12	9.64	0.45	17.62	0.86	2.50	0.16	4.41	0.16	4.27	0.25	6.00	0.38	2.15	0.37
X. lateralis	32.27	4.03	9.68	1.27	22.60	2.96	3.87	0.66	5.09	0.80	3.90	0.57	4.56	0.82	2.71	0.25
F. limnocharis	27.20	1.40	10.15	0.41	17.05	1.18	2.96	0.22	4.87	0.27	5.05	0.30	6.69	0.24	1.37	0.13
R. bipunctatus	40.89	4.24	15.06	1.82	25.83	2.72	5.03	1.01	8.02	1.26	7.32	1.16	9.62	0.68	2.96	0.27
P. leucomystax	38.14	6.53	13.38	1.64	24.76	5.59	5.32	0.82	8.53	0.99	6.65	0.93	7.34	1.22	3.49	0.58
B. carinensis	37.59	2.18	11.74	0.57	25.84	1.76	3.87	0.78	5.54	0.58	4.61	0.81	5.69	0.75	3.34	0.38
L. chapaense	62.05	8.87	21.40	3.09	40.66	6.77	8.97	1.01	14.03	2.34	11.95	1.80	13.14	2.95	5.36	0.64
K. punlchra	23.94	1.70	9.04	0.70	14.89	1.39	2.53	0.40	5.11	0.66	4.40	0.58	6.48	0.73	1.14	0.10
M. pulchra	28.20	1.91	8.41	0.81	19.79	1.86	2.61	0.18	5.37	0.85	5.15	0.44	5.82	0.64	2.20	0.39

Appendix Table 2 (Continued)

	IOS		SS		ODW		IOD		FIL		WS	
spcies	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**
A. marmoratus	3.97	0.56	13.19	1.33	7.21	0.97	6.77	0.98	0.00	0.00	8.27	0.84
H. melasma	2.70	0.48	9.66	1.18	5.35	0.85	5.57	0.77	0.00	0.00	5.85	0.90
L. kuhlii	1.71	1.12	5.95	0.96	2.00	0.25	4.02	0.56	0.00	0.00	0.00	0.00
L. pelodytoides	2.54	0.41	7.39	0.74	3.43	0.40	5.04	0.45	0.00	0.00	0.00	0.00
M. berdmorei	0.00	0.00	6.12	0.75	2.11	0.24	5.52	0.48	0.00	0.00	0.00	0.00
M. heymonsi	0.00	0.00	4.94	0.50	3.72	5.20	3.46	0.28	3.41	0.88	0.00	0.00
M. inornata	0.00	0.00	0.00	0.00	1.86	0.22	5.04	0.32	3.70	0.47	0.00	0.00
M. ornata	0.00	0.00	0.00	0.00	1.26	0.20	2.99	0.30	1.51	0.37	0.00	0.00
R. cubitalis	2.49	0.30	8.40	0.34	3.89	0.33	5.48	0.28	0.00	0.00	0.00	0.00
R. livida	2.20	0.23	7.42	0.41	3.18	0.25	3.45	0.23	0.00	0.00	0.00	0.00
R. nigrovittata	1.86	0.26	7.28	0.35	2.72	0.22	4.19	0.23	0.00	0.00	0.00	0.00
X. lateralis	0.99	0.15	5.72	0.73	0.00	0.00	4.03	0.61	0.00	0.00	0.00	0.00
F. limnocharis	1.89	0.21	6.30	0.36	2.05	0.09	4.35	0.18	0.00	0.00	0.00	0.00
R. bipunctatus	3.07	0.40	10.32	0.89	3.69	0.85	7.26	0.64	0.00	0.00	0.00	0.00
P. leucomystax	3.40	0.54	8.61	0.98	3.99	0.45	7.64	0.71	0.00	0.00	0.00	0.00
B. carinensis	1.48	0.39	6.75	0.36	0.00	0.00	4.86	0.50	0.00	0.00	0.00	0.00
L. chapaense	4.38	0.68	13.90	2.00	5.80	0.84	9.62	1.25	0.00	0.00	0.00	0.00
K. punlchra	1.25	0.13	0.00	0.00	2.41	0.20	6.02	0.56	0.00	0.00	0.00	0.00
M. pulchra	0.00	0.00	0.00	0.00	1.98	0.18	6.08	0.55	0.00	0.00	0.00	0.00

Appendix Table 2 (Continued)

Species	WTF		WLF		WM		LM		NO	EO	Jaw
	X	SD	X	SD	X	SD	X	SD			
A. marmoratus	12.18	1.48	2.84	0.46	0.00	0.00	0.00	0.00	Dorsal	Dorsal	Massive
H..melasma	7.71	1.15	1.84	0.45	0.00	0.00	0.00	0.00	Dorsal	Dorsal	Massive
L. kuhlii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Dorsal	Dorsal	Shallow
L. pelodytoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Dorsal	Lateral	Massive
M. berdmorei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	None	Lateral	None
M. heymonsi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	None	Lateral	None
M. inornata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	None	Lateral	None
M. ornata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	None	Lateral	None
R. cubitalis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Dorsal	Dorsal	Shallow
R. livida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Lateral	Dorsal	Shallow
R. nigrovittata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Lateral	Dorsal	Shallow
X. lateralis	0.00	0.00	0.00	0.00	0.12	0.32	5.35	0.98	Lateral	Lateral	None
F. limnocharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Dorsal	Dorsal	Medium
R. bipunctatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Dorsal	Dorsal	Shallow
P. leucomystax	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Lateral	Lateral	Massive
B. carinensis	0.00	0.00	0.00	0.00	2.51	0.40	0.18	0.65	Lateral	Lateral	None
L. chapaense	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Dorsal	Dorsal	Massive
K. punlchra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	None	Lateral	None
M. pulchra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	None	Lateral	None

Appendix Table 3 Measurement of external tadpole morphologies

		TL		BL		TAL		TMH		MTH		BD		BW	
Species	No.	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
A. marmoratus	17	35.21	62.00	13.66	22.50	21.06	40.62	3.90	8.80	2.12	3.66	5.86	12.43	9.23	14.78
H. melasma	19	27.86	48.45	9.49	16.28	17.16	32.17	3.80	7.33	1.22	3.77	4.38	9.00	6.44	12.43
L. kuhlii	30	23.53	37.53	7.54	12.98	14.76	24.55	2.24	4.74	3.40	6.77	2.76	5.41	4.23	7.18
L. pelodytoides	15	43.88	52.22	13.48	16.01	30.40	37.05	3.94	5.71	5.86	8.23	3.93	5.89	6.25	7.92
M. berdmorei	15	21.22	29.33	7.07	9.65	12.43	20.48	0.99	2.02	2.03	4.85	3.41	5.63	4.99	55.38
M. heymonsi	15	1.86	19.46	5.23	6.43	4.27	13.03	0.99	1.63	2.74	3.79	3.14	4.49	3.05	4.11
M. inornata	15	18.14	22.82	6.58	7.61	11.47	15.60	1.53	2.74	4.76	6.30	3.89	5.22	4.33	5.48
M. ornata	15	10.29	13.29	3.66	5.16	6.63	8.13	0.61	1.07	2.08	2.92	2.140	3.05	2.86	3.52
R. cubitalis	17	30.44	38.31	10.35	13.41	19.61	25.52	3.51	5.00	5.04	8.23	4.13	6.39	6.76	8.80
R. livida	12	27.02	33.25	8.39	11.56	17.65	24.86	2.74	3.94	4.28	5.23	3.12	4.42	4.90	6.16
R. nigrovittata	16	25.41	29.06	8.89	10.29	16.16	19.52	2.25	2.88	4.02	4.60	3.89	4.84	5.38	2.54
X. lateralis	20	27.10	39.98	7.84	11.86	18.51	28.76	2.13	4.82	3.47	6.23	3.21	5.23	2.48	5.98
F. limnocharis	15	24.16	29.44	9.11	10.66	15.05	18.86	2.62	3.48	4.28	5.38	4.42	5.41	6.14	6.97
R. bipunctatus	24	31.59	47.39	18.28	20.26	20.26	29.81	1.24	6.53	4.10	10..39	2.84	9.01	8.56	10.91
P. leucomystax	15	28.54	48.52	10.44	16.28	17.22	34.31	4.43	6.66	6.39	10..35	5.18	8.60	5.11	9.25
B. carinensis	20	32.44	40.58	9.95	12.76	19.68	28.73	2.08	5.14	4.09	6.36	3.33	6.04	4.00	7.06
L. chapaense	30	45.35	73.15	14.97	25.36	30.16	50.79	6.49	11.15	11.27	18.78	8.06	14.79	9.70	16.81
K. punlchra	15	20.03	26.73	8.15	10.86	11.82	17.78	2.16	3.52	4.00	5.98	3.17	5.36	5.31	7.48
B. carinensis	20	32.44	40.58	9.95	12.76	19.68	28.73	2.08	5.14	4.09	6.36	3.33	6.04	4.00	7.06

Appendix Table 3 (Continued)

Species	No.	TL		BL		TAL		TMH		MTH		BD		BW	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
A. marmoratus	17	2.44	4.06	2,98	4.95	11.20	16.32	5.36	8.86	5.42	8.46	0.00	0.00	7.01	10.00
H. melasma	19	2.26	3.700	1.89	3.78	8.34	12.16	4.20	7.46	4.09	7.21	0.00	0.00	4.34	7.90
L. kuhlii	30	1.58	5.53	0.97	7.40	4.23	7.93	1.62	2.61	3.05	5.53	0.00	0.00	0.00	0.00
L. pelodytoides	15	3.01	4.56	1.93	3.39	6.50	9.52	2.69	4.34	4.26	5.66	0.00	0.00	0.00	0.00
M. berdmorei	15	0.00	0.00	0.00	0.00	4.30	7.05	1.70	2.47	5.01	2.66	0.00	0.00	0.00	0.00
M. heymonsi	15	0.00	0.00	0.00	0.00	4.04	5.54	2.15	2.56	3.03	3.86	2.08	4.67	0.00	0.00
M. inornata	15	0.00	0.00	0.00	0.00	0.00	0.00	1.37	2.20	4.29	5.54	2.83	4.80	0.00	0.00
M. ornata	15	0.00	0.00	0.00	0.00	0.00	0.00	0.95	1.73	2.37	3.69	0.96	2.14	0.00	0.00
R. cubitalis	17	2.81	3.90	1.90	3.09	7.92	9.26	3.11	4.34	4.98	5.90	0.00	0.00	0.00	0.00
R. livida	12	2.14	2.95	1.77	2.55	6.79	8.16	2.81	3.66	3.11	3.84	0.00	0.00	0.00	0.00
R. nigrovittata	16	1.17	2.54	1.40	2.46	6.56	7.82	2.40	3.33	3.69	4.50	0.00	0.00	0.00	0.00
X. lateralis	20	2.30	3.27	0.75	1.30	4.70	7.24	0.00	0.00	3.00	5.21	0.00	0.00	0.00	0.00
F. limnocharis	15	1.15	1.57	1.47	2.20	5.54	6.93	1.94	2.23	4.04	4.68	0.00	0.00	0.00	0.00
R. bipunctatus	24	2.31	3.42	2.35	3.82	9.02	11.94	0.40	4.91	6.46	8.61	0.00	0.00	0.00	0.00
P. leucomystax	15	2.32	4.34	2.66	4.59	6.51	10.27	3.21	4.81	6.10	8.74	0.00	0.00	0.00	0.00
B. carinensis	20	2.54	4.00	1.01	2.69	6.02	7.55	0.00	0.00	4.22	5.79	0.00	0.00	0.00	0.00
L. chapaense	30	4.00	6.45	3.20	5.55	10.42	17.07	3.82	7.02	7.13	11.44	0.00	0.00	0.00	0.00
K. punlchra	15	1.02	1.36	1.01	1.59	0.00	0.00	2.06	2.68	5.14	6.74	0.00	0.00	0.00	0.00
M. pulchra	15	1.45	2.86	0.00	0.00	0.00	0.00	1.52	2.30	5.10	6.89	0.00	0.00	0.00	0.00

Appendix Table 3 (Continued)

		WTF		WLF		WM		LM	
Species	No.	Min	Max	Min	Max	Min	Max	Min	Max
A. marmoratus	17	2.12	3.66	1.76	2.98	0.00	0.00	0.00	0.00
H. melasma	19	1.22	3.20	1.26	3.90	0.00	0.00	0.00	0.00
L. kuhlii	30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. pelodytoides	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M. berdmorei	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M. heymonsi	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M. inornata	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M. ornata	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R. cubitalis	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R. livida	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R. nigrovittata	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
X. lateralis	20	0.00	0.00	0.00	0.00	3.70	6.60	1.22	2.67
F. limnocharis	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R. bipunctatus	24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. leucomystax	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. carinensis	20	0.00	0.00	2.04	3.55	3.58	6.87	0.00	0.00
L. chapaense	30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K .punlchra	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M. pulchra	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table 4 Relative tadpole external morphologies of *Leptobrachium chapaense* related to dissolve oxygen

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	5.8817	3.2941	1.786	0.0874.
BL	1.8635	0.5718	3.259	0.0035**
MTH	0.7406	0.4187	1.769	0.0902 .
BD	-2.4664	0.9039	-2.729	0.0120 *
BW	1.1726	0.6097	1.923	0.0669 .
IND	-2.9687	1.4098	-2.106	0.0464 *
SS	-1.5891	0.8191	-1.940	0.0647 .

Signif, codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Appendix Table 5 Relative tadpole external morphologies of *Leptolalax pelodytoides* related to temperature

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	19.4199	5.2233	3.718	0.0075 **
TL	-0.4605	0.2433	-1.893	0.1002
BL	1.0013	0.4902	2.043	0.0804 .
TMH	-2.3893	0.6165	-3.875	0.0061 **
MTH	-0.8512	0.5099	-1.669	0.1390
IND	1.9270	1.1683	1.649	0.1430
IOS	2.1987	0.7604	2.891	0.0233 *
IOD	2.6136	0.7650	3.416	0.0112 *

Appendix Table 6 Relative tadpole external morphologies of *Brachytarsophrys carinensis* related to current water

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	8.0378	3.3752	2.3810	0.0364 *
TL	0.2437	0.0990	2.4620	0.0315 *
BL	0.3283	0.2569	1.2780	0.2277
MTH	-0.3887	0.3383	-1.1490	0.2750
BW	1.7211	0.4730	3.6380	0.0039**
IND	-1.6195	0.6059	-2.6730	0.0217 *
IOS	-0.8826	0.6748	-1.3080	0.2176
IOD	-2.2923	0.7019	-3.2660	0.0075 **
LM	0.3652	0.2065	1.7680	0.1047

Appendix Table 7 Relative tadpole external morphologies of *Xenophrys lateralis* Related to current water

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	-19.586	6.028	-3.249	0.0058 **
TMH	4.233	1.523	2.780	0.0148 *
BD	5.972	2.219	2.692	0.0175 *
BW	-2.154	1.455	-1.481	0.1609
IOS	-11.387	7.758	-1.468	0.1643
LM	6.075	2.354	2.581	0.0218 *

Appendix Table 8 Relative tadpole external morphologies of *Amolops mamoratus* related to current water

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	4.1114	0.2168	18.961	0.0003 ***
BL	0.1245	0.0312	3.990	0.0282 *
TAL	0.0575	0.0067	8.588	0.0033 **
TMH	0.0197	0.0219	0.902	0.4334
BD	-0.2659	0.0282	-9.418	0.0025 **
BW	-0.3133	0.0329	-9.519	0.0025 **
IND	0.3103	0.0635	4.888	0.0164 *
IOS	-0.0774	0.0395	-1.959	0.1450
SS	-0.1221	0.0252	-4.846	0.0168 *
ODW	-0.085	0.0430	1.975	0.1428
IOD	0.1949	0.0301	6.470	0.0075 **
WS	-0.4090	0.0653	-6.266	0.0082 **
WTF	0.7402	0.1266	5.845	0.0098 **
WLF	0.8552	0.1217	7.027	0.0059 **

Appendix Table 9 Relative tadpole external morphologies of *Huia melasma* related to current water

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	-1.2248	0.9095	-1.347	0.2011
BW	0.5287	0.2542	2.080	0.0579 .
IOS	-0.8713	0.6279	-1.388	0.1886
ODW	-0.3785	0.1891	-2.002	0.0666 .
IOD	0.4109	0.2875	1.429	0.1766
WLF	0.7230	0.3547	2.039	0.0624 .

Appendix Table 10 Relative tadpole external morphologies of *Fejervaya limnocharis* related to rainfall

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	1935.07	515.15	3.756	0.0132 *
TL	32.38	19.12	1.693	0.1512
BL	185.53	78.81 .	2.354	0.0652
TMH	121.81	71.83	1.696	0.1507
BD	200.05	85.98	2.327	0.0675 .
BW	236.88	142.92	1.657	0.1583
IND	518.92	153.37	3.384	0.0196 *
IOS	176.50	134.29	1.314	0.2458
ODW	-783.16	205.92	-3.803	0.0126 *
IOD	-721.39	159.33	-4.527	0.0062 **

Appendix Table 11 Relative tadpole external morphologies of *Limnonectes kuhlii* related to rainfall

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	603.07	146.65	4.112	0.0005 ***
BL	-57.40	29.12	-1.971	0.0614 .
TAL	-27.43	9.66	-2.839	0.0095 **
MTH	-56.59	42.63	-1.327	0.1980
BD	54.71	36.02	1.519	0.1430
IOS	22.82	13.29	1.717	0.0995 .
ODW	134.51	96.65	1.392	0.1779
IOD	93.79	66.05	1.420	0.1696

Appendix Table 12 Relative tadpole external morphologies of *Rana cubitalis* related to dissolved oxygen

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	0.2378	5.5955	0.042	0.9671
BL	-2.6818	0.4653	-5.764	0.0004 ***
TAL	0.9250	0.2093	4.419	0.0022 **
MTH	-2.1825	0.4547	-4.800	0.0014 **
BD	4.5845	0.6963	6.584	0.0002 ***
IND	1.2089	0.9057	1.335	0.2187
IOS	-4.0435	0.9349	-4.325	0.0025 **
SS	3.1905	0.6553	4.868	0.0012 **
IOD	-2.3070	0.9028	-2.555	0.0339 *

Appendix Table 13 Relative tadpole external morphologies of *Rana nigrovittata* releted to dissolved oxygen

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	3.9603	2.4657	1.606	0.1427
BL	0.4682	0.3429	1.365	0.2053
TMH	2.2643	0.7767	2.915	0.0172 *
BD	0.8557	0.5629	1.520	0.1628
SS	-1.6608	0.4271	-3.888	0.0037 **
ODW	-2.2473	0.5655	-3.974	0.0032 **
IOD	1.4141	0.6569	2.153	0.0598 .

Appendix Table 14 Relative tadpole external morphologies of *Rhacophorus bipunctatus* related to rainfall

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	-251.240	229.285	1.096	0.2885
TL	25.083	8.745	2.868	0.0107 *
BL	-45.377	31.289	-1.450	0.1652
BD	43.669	29.216	1.495	0.1533
BW	-75.095	34.083	-2.203	0.0417 *
IND	111.041	65.520	1.695	0.1084
ODW	64.674	20.842	3.103	0.0065 **

Appendix Table 15 Relative tadpole external morphologies of *Polypedates leucomystax* related to rainfall

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	6.8134	0.4395	15.503	1.12e-06 ***
TAL	-0.0361	0.0222	-1.627	0.1478
TMH	0.1749	0.0705	2.480	0.0422 *
MTH	0.3883	0.1139	3.410	0.0113 *
BD	-0.6500	0.0896	-7.253	0.0002 ***
IND	0.2284	0.1063	2.149	0.0687 .
SS	0.5228	0.1810	2.889	0.0233 *
IOD	-0.3455	0.2231	-1.549	0.1654

Appendix Table 16 Relative tadpole external morphologies of *Kaloula pulchra* related to rainfall

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	-22.076	32.225	-0.685	0.5153
BL	-11.690	2.817	-4.150	0.0043 **
TAL	2.360	1.249	1.890	0.1007
MTH	4.736	2.944	1.609	0.1517
BD	-4.399	3.590	-1.225	0.2601
BW	3.353	3.018	1.111	0.3033
IND	48.957	21.984	2.227	0.0613 .
ODW	9.561	9.022	1.060	0.3245

Appendix Table 17 Relative tadpole external morphologies of *Microhyla berdmorei* related to temperature

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	19.4111	4.3924	4.419	0.0069 **
BL	-0.9320	0.3933	-2.370	0.0640 .
TAL	-0.2863	0.2449	-1.169	0.2951
TMH	-1.9478	1.9349	-1.007	0.3603
MTH	0.8195	0.4968	1.649	0.1600
BD	1.8151	0.6096	2.978	0.0309 *
BW	0.0183	0.0199	0.919	0.4002
SS	-0.9782	0.5524	-1.771	0.1368
ODW	1.6915	1.6563	1.021	0.3540
IOD	1.1388	0.7449	1.529	0.1869

Appendix Table 18 Relative tadpole external morphologies of *Microhyla heymonsi* related to rainfall

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	-54.04	327.37	-0.165	0.8719
BL	-186.89	98.12	-1.905	0.0833 .
TAL	29.19	8.72	3.348	0.0065 **
SS	218.98	74.76	2.929	0.0137 *

Appendix Table 19 Relative tadpole external morphologies of *Microhy pulchra* related to temperature

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	6.0243	3.9379	1.530	0.1770
BL	2.1455	0.1789	11.994	2.04e-05 ***
TMH	5.8430	0.9072	6.440	0.0007 ***
MTH	-1.6354	0.1949	-8.392	0.0002***
BD	-0.4092	0.3209	-1.275	0.2493
BW	-0.3370	0.2100	-1.605	0.1597
IND	1.5609	0.4390	3.556	0.0120 *
ODW	1.1936	0.7015	1.702	0.1397
IOD	-0.6662	0.2026	-3.288	0.0167 *

Appendix Table 20 Relative tadpole external morphologies of *Microhyla ornata* related to dissolved oxygen

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	44.619	17.364	2.570	0.0261 *
TAL	-8.913	2.698	-3.304	0.0070 **
TMH	-20.992	10.311	-2.036	0.0666 .
IOD	16.978	4.862	3.492	0.0050 **

Appendix Table 21 Relative tadpole external morphologies of *Micryletta inornata* related to temperature

External Morphology	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	47.518	9.830	4.834	0.0013 **
BL	-5.321	2.086	-2.551	0.0341 *
MTH	-2.576	1.252	-2.058	0.0736 .
BD	2.405	1.784	1.348	0.2145
BW	-4.244	2.366	-1.794	0.1106
ODW	-3.205	2.832	-1.132	0.2905
IOD	8.893	3.152	2.821	0.0225 *