แบบชีวประวัติของงูกลุ่มโฮมาลอปซิดในและนอกแอ่งโคราช ประเทศไทย

นายฉัตรพรรษ พงษ์เจริญ

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LIFE HISTORY PATTERNS OF HOMALOPSINE SNAKES INSIDE AND OUTSIDE THE KHORAT BASIN, THAILAND

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Zoology
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Thesis Title	LIFE HISTORY PATTERNS OF HOMALOPSID SNAKES INSIDE AND OUTSIDE THE KHORAT BASIN, THAILAND
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ฉัตรพรรษ พงษ์เจริญ: แบบชีวประวัติของงูกลุ่มโฮมาลอปซิดในและนอกแอ่งโคราช ประเทศไทย. (LIFE HISTORY PATTERNS OF HOMALOPSID SNAKES INSIDE AND OUTSIDE THE KHORAT BASIN, THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. กำธร ธีรคุปต์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: Dr. Harold K. Voris, 99 หน้า.

การศึกษาแบบแผนชีวประวัติของงูกลุ่มโฮมาลอปซิดระหว่างภายใน (บ้านมะต่าน อำเภอวังน้ำเขียว) และภายนอกแอ่งโคราช (บ้านบ่อทอง อำเภอกบินทร์บุรี) ประเทศไทย ได้ดำเนินการตั้งแต่เดือนเมษายน พ.ศ. 2548 จนถึงเดือนมีนาคม พ.ศ. 2549 พบชนิดของงูน้ำกลุ่มโฮมาลอปซิดจำนวน 5 ชนิดในพื้นที่ศึกษาแต่ละแห่ง โดยมีค่าดัชนีความคล้ายคลึงกันร้อยละ 86 งูสายรุ้งลายขีด (*Enhydris subtaeniata*) พบเฉพาะพื้นที่ศึกษาภายในแอ่งโคราชในขณะที่งูไซ (*E. bocourti*) พบเฉพาะพื้นที่ศึกษาภายนอกแอ่งโคราชเท่านั้น พื้นที่ศึกษาภายในแอ่งโคราชมีค่าดัชนีความหลากหลายทางชนิดมากกว่าแต่มีค่าความชุกชุมของงูน้ำน้อยกว่าพื้นที่ภายนอกแอ่งโคราช ชนิดของงูน้ำที่มีความโดดเด่นในพื้นที่ศึกษาทั้งสองแห่งได้แก่ งูสายรุ้งธรรมดา (*E. enhydris*) พบในอัตราส่วนร้อยละ 45.14 และร้อยละ 81.36 ภายในและภายนอกแอ่งโคราช ตามลำดับ ซึ่งอัตราส่วนของงูเพศผู้ต่องูเพศเมียทั้งสองพื้นที่ไม่มีความแตกต่างกันอย่างมีนัยสำคัญ งูน้ำจากพื้นที่ศึกษาทั้งสองแห่งมีความแตกต่างทางสัณฐานระหว่างเพศ โดยงูเพศเมียมีลักษณะทางสัณฐานเกือบทุกลักษณะใหญ่กว่างูเพศผู้ยกเว้นความยาวของหาง งูน้ำทั้งเพศผู้และเพศเมียจากพื้นที่ภายในแอ่งโคราชมีขนาดใหญ่กว่างูน้ำที่พบในพื้นที่นอกแอ่งโคราช จากการสำรวจภายในกระเพาะอาหารของงูน้ำ พบปลาขนาดเล็กบ่อยครั้งและพบปลาขนาดใหญ่เป็นครั้งคราว ปลาที่พบมากในกระเพาะของงูน้ำภายในและภายนอกแอ่งโคราช คือ ปลาในวงศ์ปลาตะเพียนและปลาในวงศ์ปลาสลิด ตามลำดับ ชนิดของเหยื่อที่พบในพื้นที่ศึกษาทั้งสองแห่งไม่ซ้อนทับกันอย่างสมบูรณ์ (Niche overlap มีค่าเท่ากับ 0.66) โดยงูน้ำภายในแอ่งโคราชมีแนวโน้มของเหยื่อที่มีความหลากหลายมากกว่า ในการศึกษาระบบสืบพันธุ์พบว่าลักษณะทางสัณฐานของงูสายรุ้งธรรมดา (*E. enhydris*) และงูสายรุ้งลายขีด (*E. subtaeniata*) เต็มวัยเพศเมียจากพื้นที่ศึกษาทั้งสองแห่งมีความสัมพันธ์กับจำนวนและน้ำหนักของตัวอ่อนในท่อนำไข่ จำนวนของงูเพศเมียเต็มวัยจากพื้นที่ศึกษาทั้งสองแห่งในแต่ละเดือนมีความสัมพันธ์กับปริมาณน้ำฝนอย่างมีนัยสำคัญ ในระบบสืบพันธุ์ของงูน้ำเพศเมียจากพื้นที่ศึกษาทั้งสองแห่งมีความแตกต่างกันอย่างมีนัยสำคัญเฉพาะลักษณะทางสัณฐานและวงรอบการสืบพันธุ์ งูน้ำที่พบภายในแอ่งโคราชมีแนวโน้มการสืบพันธุ์ตามฤดูกาลขณะที่งูน้ำที่พบนอกแอ่งโคราชมีแนวโน้มการสืบพันธุ์แบบต่อเนื่อง ปัจจัยทางกายภาพได้แก่ปริมาณน้ำฝนและอาหารที่มีอาจทำให้เกิดความแตกต่างทางด้านชนิด ความชุกชุม ลักษณะทางสัณฐาน และการสืบพันธุ์ของงูน้ำวงศ์โฮมาลอปซิดภายในและภายนอกแอ่งโคราช นอกจากนี้การศึกษาในครั้งนี้ยังระบุถึงข้อมูลทางด้านชีววิทยาของงูสายรุ้งลายขีด (*E. subtaeniata*) ที่ยังมีการศึกษาน้อย และงูกึ่งน้ำชนิดอื่นๆ ที่พบในพื้นที่อีกด้วย

ภาควิชา.......ชีววิทยา..... ลายมือชื่อนิสิต..

สาขาวิชา.....สัตววิทยา... ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก..........................

ปีการศึกษา...2551......... ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์ร่วม..........................

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KEYWORDS: LIFE HISTORY PATTERNS/ HOMALOPSIDAE/ KHORAT BASIN/ SPECIES DIVERSITY/ DIET/ FEMALE REPRODUCTION

CHATTRAPHAS PONGCHAROEN: LIFE HISTORY PATTERNS OF HOMALOPSID SNAKES INSIDE AND OUTSIDE THE KHORAT BASIN, THAILAND. ADVISOR: ASSOC. PROF. KUMTHORN THIRAKHUPT, Ph.D., THESIS CO-ADVISOR: HAROLD K. VORIS, Ph.D., 99 pp.

Life history patterns of homalopsid snakes were investigated between inside (Ban Badan, Wang Nam Kheaw District) and outside the Khorat basin (Ban Borthong, Kabin Buri District), Thailand from April 2006 to May 2007. Five species of homalopsid snakes were found at each study site. The similarity index of the snake assemblages from both study sites was 86%. *Enhydris subtaeniata* were found only inside the Khorat basin whereas *E. bocourti* were found only outside the Khorat basin. Species diversity inside the Khorat basin was higher than outside the Khorat basin but the abundance was less. *Enhydris enhydris* was the dominant species at 45.14% and 81.36% at inside and outside the Khorat basin, respectively and the sex ratio of this species was not different between study sites. Sexual size dimorphism was found in both study sites and most morphological characters of females were significantly larger than males, except for tail length. Both sexes of snakes from outside the Khorat basin were significantly larger than snakes from inside the Khorat basin. Small fish were usually found in homalopsid guts but larger fish were occasionally found. Fish in Family Cyprinidae and Family Belontiidae were dominant prey types inside and outside the Khorat basin, respectively. Prey types did not completely overlap between study sites (niche overlap = 0.66) and snakes from outside the Khorat basin tend to feed on various prey types. The size at first reproduction of females *E. enhydris* was 31.4 cm in SVL at both study sites. Many size characters of female *E. enhydris* and *E. subtaeniata* correlated with clutch size and clutch mass. The number of gravid females observed in each month were significantly correlated with total precipitation at both study sites. Significant differences in the reproductive condition of females between study sites were found in morphological characteristics and reproductive cycle. Seasonal and continuous reproduction tend to occur for homalopsid snakes inside and outside the Khorat basin, respectively. Environmental factors including total precipitation and food availability might bring about differences in abundance, morphological characteristics and reproduction of homalopsid snakes inside and outside the Khorat basin. Furthermore, morphological characters, diet and reproduction of a poorly known homalopsid snake, *E. subtaeniata,* and some other semi-aquatic snakes were documented.

Department: ....Biology... Student's Signature:..................................

Field of Study: ....Zoology... Advisor's Signature:..................................

Academic Year: ...2008...... Co-Advisor's Signature:..................................

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CHAPTER I

INTRODUCTION

1.1 Rationale

Fossorial ancestors of snakes appeared in the early Cretaceous period, since then snakes have shown impressive adaptations such as their anatomy, morphological characters, behavior, and etc. By this reason, they become the largest number of species of living reptiles, over 3,000 species under 19 families and occur on all continents on earth except New Zealand, Ireland, the polar region and in the deep oceanic level. Of the 19 living snake families, 6 families contain fresh water species; Family Acrochordidae, Family Boidae, Family Colubridae, Family Homalopsidae, Family Natricidae and Family Viperidae. (Alderton, 2007; Green, 1997; Mattison, 2007; Uetz, 2008; Stafford, 2000; Wikipedia, 2008).

Oriental - Australian rear fanged water snakes, homalopsid snakes, in Family Homalopsidae usually live in aquatic habitats, but are often found on land close to water. About 15 species of homalopsid snakes belonging to 8 genera have been reported in Thailand (Cox et al., 1998; Murphy, 2007; Murphy and Voris, 2005; Nabhitabhata, 2000; Taylor, 1965). Among these, ten species inhabit freshwater bodies and muddy substrates. Since freshwater resources are widespread in Thailand, the distribution of some species is very extensive.

Differences in environmental conditions among sites can lead to differences in life-history patterns among taxa resulting from ecological adaptation. Previous studies showed that many reptiles reproduce seasonally where climate is highly seasonal but continuously in equatorial climate (Berry and Linn, 1967; Colli, 1991; Mesquita and Colli, 2003; Vitt, 1981). In Thailand, the pioneer study by Karns et al. (2005) found some differences in the life-history patterns of semi-aquatic snake populations between inside and outside the Khorat Basin. They suggested that it could be because of the differences in geological features between these two locations and more detailed studies should be made.

The main propose of this research is to thoroughly study the life-history patterns of homalopsid snake populations living in water bodies inside the Khorat basin at Ban Badan, Wang Nam Kheaw District, Nakhon Ratchasima Province and outside the Khorat Basin at Ban Borthong, Kabin Buri District, Prachin Buri Province of Thailand. Although these two study areas are not far apart, approximately 80 km but there are several different features that may influence the adaptation of the life-history of homalopsid snakes.

Due to the lack of detailed information on the population ecology and life-history in terms of relative abundance, diet and reproductive biology of homalopsid snakes in Thailand the information on these snakes will provide a clear picture of homalopsid snakes and will allow us to be able to assess its environmental impact and can arrange proper conservation management in the future.

1.2 Objectives

To study homalopsid snakes in 4 aspects:

1.2.1 species composition and relative abundance in each study site.

1.2.2 morphological characters of males and females within and between study sites as well as size at sexual maturity and sex ratio in each study site.

1.2.3 diet, niche breadth and niche overlap within and between study sites.

1.2.4 reproductive biology and reproductive cycle of female snakes, and relationship between reproductive cycle and their environmental factors in each study site.

CHAPTER II

LITERATURE REVIEW

Homalopsid snakes

2.1 Classification and general description

2.1.1 Classification

Snakes are a magnificent group belonging to the class "Reptilia" (including turtles; Testudines, crocodiles; Crocodelia, Tuatara; Spenodontia, snakes and lizards; Squamata). They were considered to have been derived from lizards but many anatomical structures differ from other reptiles in size, shape and locomotion. All snakes are carnivorous and can be distinguished from legless lizards by their lack of eyelids, limbs, external ears, and vestiges of forelimbs. The 3,000 species in 19 families of snakes spread throughout the world, with the exception of polar regions, notable Ireland and New Zealand (Green, 1997; Stafford, 2000; Wikipedia, 2008). Homalopsid snakes used to be classified to a subfamily Homalopsinae of family Colubridae which contained a lot of varieties of snakes. For now, this group of snakes, approximately 35 species of aquatic to semi-aquatic snakes, was promoted to be a family Homalopsidae (Kelly, 2003; Lawson *et al.* , 2005; Vidal *et al.*, 2007). Ten genera of these snakes were classified in this family such as *Bitia, Cantoria, Cerberus, Enhydris, Erpeton, Fordinia, Gerarda, Herurnia, Homalopsis, Myron, Anoplohydrus* and *Brachyorrhos* (last 2 genera are still unclear). The genus *Enhydris* is the most specious (holding 22 species) which is widely distributed from northeast India and Myanmar eastward through to peninsular Indochina as far east as Sulawesi (Gyi, 1970; Mattison, 2007; Murphy, 2007; Murphy *et al.*, 2002; Murphy and Voris, 2005; Murphy *et al.*, 2005; Taylor, 1965). Murphy (2007) suggested that the total species discussed here, at this present time, may be only half of the species that exist. There is at least one undescribed genus at this time.

2.1.2 General description

External morphology of homalopsid snakes is described as a snake which the rostral scale has a shallow ventral notch with a right and left slit to allow the tongue to project downward. In most species the rostral scale is pentagonal and broader than tall, but in some it is more oval. Nostrils are crescent shaped slits and on the dorsal surface of the snout, usually located near the middle of the nasal scale. They can be opened and closed by a small pad of tissue present on the posterior edge of the opening. Presumably this pad is expanded and contracted by blood vessels allowing the nostril to be closed. Additionally, the opening of the glottis can be extended internally to cover the internal openings of the nostrils to ensure a complete mouth closure. The internasal scale may actually separate the nasals as in *Cantoria, Bitia*, *Heurnia*, *Myron*, *Fordonia* and *Gerarda* or they may lie behind the nasals as in *Cerberus*, *Enhydris, Erpeton,* or *Homalopsis*. The prefrontal is almost always paired and makes contact with the loreal. The loreal is absent in most *Fordonia* (also in *Brachyorrhus*) but present in other genera. In some species it may be divided and broken into smaller scales as in *Erpeton* and some populations of *Homalopsis*. In some genera there appear to be trends toward head scale fragmentation that usually involves the frontal and/or parietals in *Bitia*, *Cerberus*, and *Homalopsis*, but it involves many of the head scales in *Erpeton.* The eyes are small, usually the diameter is less than the distance between the bottom of the orbit and the bottom edge of the labial under the orbit (the eye - mouth distance). An exception to this is *Erpeton*. The supraocular scale is single in most, but divided in *Cerberus*; the preocular is usually single, but some have two; the postoculars can number 1 - 4, but usually there are two; suboculars are usually absent but a few species have as many as four, more often one or more upper labial enter the orbit. Upper labials can number 5 - 16, with eight being the most common. These scales are horizontally divided in some species and their pattern appears to have some systematic significance. The number contacting the loreal and the number entering the orbit are also useful characters. Lower labials number 5 – 21; the number in contact with the first pair of chin shields is a useful systematic character. Hypapophyses are present along the length of the vertebral column. The hemipenis is forked for about half its length, the distal end is finely calyculate. Spines near the end are fine and small and these become larger near the bifurcation point. Most have imbricate (overlapping) dorsal scales, *Bitia* does not. This group lacks apical pits on scales, but some have keeled scales, striated scales, tuberculate scales, or a combination of these. Dorsal scales in 17 - 47 rows. Ventrals number 91 - 284, and are keeled in *Bitia* and *Erpeton*. In *Erpeton* the ventral scales are exceptionally narrow for the length of the body; other species have narrow ventrals on the anterior and posterior body, with wider ventrals at midbody and narrow ventrals posteriorly. The anal plate is usually divided but it may be in three parts in some individuals, particularly some *Homalopsis*. Subcaudals are in 18 - 122 pairs. These snakes range between 0.4 - 1.3 m in length (Murphy, 2007). All homalopsid snakes are rear-fanged (Opisthoglyphous), grooved rear fangs are usually paired on the posterior of the maxillary bone (Figure 2.1a); these are usually longer than other maxillary teeth. Also, at least some species appear to have shallow grooves on the surface of other teeth. These snakes were considered mildly venomous, none are apparently dangerous to humans. Homalopsid snakes look the same as other kinds of snakes if play less intention but they have a variety of adaptations to aquatic and terrestrial life styles by abovementioned morphology as followes: valvular nostrils, shallow notch in rostral scale, and exhibit the ability to extend the glottis to the internal nares so the nostrils and mouth can form a watertight seal, small eyes and nares located dorsally so they can view the surface and ventilate their lungs without exposing their heads or their bodies, some species have slightly compressed tails for swimming, some species possibly have cutaneous gas exchange while submerged for extended periods in the water, species that live in saltwater habitats, *Cerberus rynchops*, have a small salt gland, which is not homologous to the salt gland in other groups of reptiles and it become non-functional when snakes lives in freshwater, many species have board ventral scales, round tails, and are capable of side-winding locomotion usually associated with a terrestrial life style (Dunson and Dunson, 1979; Green, 1997; Gyi, 1970; Murphy, 2007; Stuebing and Inger, 1999; Figure 2.1b).

Figure 2.1: (a) The position of the rear fangs on the posterior of the maxillary bone of *Enhydris enhydris.* (b) Some adaptations of homalopsid snakes, small eyes and nares located dorsally, in *Enhydris bocourti.*

2.1.3 Distribution and habitats

Homalopsid snakes are distributed from at least 33°N latitude to at least as far south as 20°S latitude. Therefore the distribution of the homalopsid snakes is decidedly tropical and subtropical, being mostly restricted between the Tropic of Cancer and the Tropic of Capricorn (Murphy, 2007). Pakistan's Indus River is the eastern edge of the family's distribution; thus the deep of the Gulf of Oman appears to be a formidable barrier to these shallow water snakes. On the western edge of their distribution they occur on Taiwan, Philippines, New Guinea and the west coast of Queensland which these points are deep waters (Areste and Cebrian, 2003; Cox, 1991; Greig, 1995; Gyi, 1970; Mattison, 1995; Mattison, 2002; Mattison, 2007; Karns *et al.*, 2000; Karns *et al.*, 2005; Murphy, 2007; Murphy and Voris, 1994;

Murphy and Voris, 2005; Whitaker and Captain, 2004; Figure 2.2).

Figure 2.2: Distribution of homalopsid snake (red area) [Robinson projection, 2003].

Fifteen species of homalopsid snakes have been found in Thailand. Ten species are freshwater snakes as follows *Enhydris enhydris, E. plumbea, E. subtaeniata, E. bocourti, E. chanardi, E. innominata, E. jagorii, Erpeton tentaculatus, Homalopsis buccata* and *H. nigroventralis* of which the first two species were found throughout the country. Five species are marine snakes which are *Bitia hydroides, Cantoria violacea, Cerberus rynchops, Fordonia leucobalia* and *Gerarda pravostiana* (Cox, 1991; Cox *et al.*, 1998; Karns and Voris, 1999; Nabhitabhata, 2000; Murphy, 2007; Murphy *et al.*, 1999; Taylor, 1965).

Jayne *et al.* (1988) and Murphy *et al.* (1999) suggested *Cerberus rynchops* may be one of the most abundant snakes on the planet. Murphy (2007) and Voris and Karns (1996) reported freshwater *Enhydris enhydris* and *Enhydris plumbea* are widespread and abundant species perhaps due to human agricultural practices. The widespread practice of agricultural area in Asia has provided increased habitat and food for these snakes and overfishing at many places may have simultaneously reduce large predatory fish and increase small prey fish of homalopsid snakes allowed snake population to explode (Stuart *et al.,* 2000). Although, many species of homalopsid snakes are appear to be endemic, or nearly endemic such as *Enhydris jagorii* and *Enhydris chanardi* live in habitats that are restricted to Thailand's Chao Praya's River (Murphy and Voris, 2005).

Homalopsid snakes seem to spend little of their time on land. Deep water seems to pose an effective barrier to their dispersal whereas shallow water, be it freshwater, brackish water or salt water is their habitat (Murphy, 2007). Habitats of homalopsid snakes were sorted out into two types. The former is six genera of homalopsis use saltwater or brackish water in marine coastal environment (mangrove forests, tidal mud-flats, shore coastal waters and estuaries) almost exclusively: *Bitia, Cantoria, Cerberus, Fordonia, Gerarda, Myron* and *Enhydris bennettii,* only know brackish water-saltwater *Enhydris.* Another type is freshwater habitats which are meadow pools, ponds, streams, lakes and dam. Both natural and artificial areas d tend to prefer slow moving or stagnate waters, giving an example; *Enhydris plumbea* was found to use buffalo wallows, *Enhydris enhydris* was found along town ditches. (Cox *et al.*, 1998; Murphy, 2007; Karns *et al.,* 2005; Voris and Karns, 1996; Voris and Murphy, 2002). Karns *et al.* (1999) studied spatial ecology of the water snakes at southern Thailand and reported that all snakes were closely associated with the mud-root-tangle found along aquatic edges and made heavy use of anthropogenic landscape elements; artificial fish bays, town ditches.

2.2 Diet

Literature on diet of homalopsid snakes is widely scattered and diet of some species are undocumented for a long time. Although, all reports suggested that most homalopsid snakes are piscivorous (feed mainly on fish) with exception in several species. Voris and Murphy (2002) reviewed the diet of homalopsid snakes and they placed diet into two groups of snakes. First, freshwater species with known diet feed primarily on fish, but some species feed on anurans and their larvae. Another group, brackish and marine species, tend to take either fish or crustaceans. Voris and

Murphy (2002) also reported on the size and number of prey items in snake guts. They reported that prey items tend to be small and stomachs often contained multiple prey items. Homalopsid snakes are reported to move and feed mostly at night. However, Voris and Karns (1996) monitored activities of *Enhydris plumbea* and found it to forage on the surface at night but also found occasional feeding during the day.

Homalopsid snakes feed in water. Murphy (2007) suggested the best way to observe feeding behavior is to use captive animals. Jayne *et al* (1988) examined the feeding behavior of *Cerberus rynchops* and found it to use a lateral strike from J-shape posture. Strikes appeared to have been initiated by mechanical stimulation; larger prey weas held longer and ariid catfish with sharp dorsal spines were swallowed head first.

Duvernoy's gland secretion was reported to be inefficient in subduing prey after observation of prey handling behavior by Mori (1998). Prey were swallowed head first and almost all prey remained alive while being ingested (Mori, 1998; Smith *et al.*, 2002). Murphy (2007) provided information of foraging behavior of *Enhydris enhydris* and many other homalopsid snakes that strikes and holds the prey in their mouth for several minutes presumably envenomating the prey and taking several more minutes to swallowed the prey. In contrast, Smith *et al.* (1998) reported distinct foraging behavior of *Erpeton tentaculatus,* the prey was secured on buccal teeth and quickly swallowed within less than a minute. This behavior is quite difference in species which feed on crustaceans. Jayne *et al.*, 2002 reported *Gerarda pravositiana* tears molted crabs, which are larger-size than its mouth, into pieces before swallowing prey bodies and this behavior is also found in *Gerarda*'s close relative, *Fordinia leucobalia* (Green, 1997; Murphy, 2007; Voris and Murphy, 2002).

Parasites of snakes were reported by many authors (Almeida *et al.*, 2006; Bauchot, 1994; De, 1998; Dusset *et al.*, 2000; Jone, 1980; Salakij, 2001), both of aquatic snake (such as *Laticauda colubrina*) and terrestrial snake (such as *Python* *reticulatus*). Likewise with homalopsid snakes, many reports mentioned parasites in the alimentary canal. Jone (1978, 1980) reported the nematode *Camallanides cerberi* (Spirunida: Camallanoides) from the esophagous and stomach of *Cerberus rynchops.* Schmidt (1927) reported *Enhydris chinensis* contained numerous of nematode worms in most of snake stomachs.

In addition, several types of predator of homalopsid snakes were documented. Sharks, large predatory fish, turtles, monitor lizards, crocodiles, birds of prey and mammals are known predators of these snakes (Lyle and Timms, 1987; Murphy, 2007; Voris and Murphy, 2002). Furthermore, Murphy (2007) suggested other snakes, such as *Bungarus fasciatus, B. multicinctus, Naja naja, Cylindrophis ruffus* and *Xenopeltis unicolor,* may be the most important predators on homalopsid snakes, because they can follow them into the mud-root tangle microhabitat.

2.3 Reproduction

2.3.1 Reproductive ecology

All animals have a basic urge to reproduce in order to pass their genes on to the next generation, and snakes are no exception. The more offspring they can produce, the more their genes their will proliferate. All aspects of reproductive behavior are directed towards this goal (Mattison, 2007).

Two modes of reproduction generally are recognized in reptiles. Most snakes, probably 70%, are oviparous, which means that some time after coupling, the females lay eggs that are protected by a hard shell. Although, others are viviparous, species share the property of retaining eggs in uterus for the entire period of embryonic development, so that fully developed youngs are produced at birth (Bauchot, 1994; Mattison, 1995; Mattison, 2002; Mattison, 2007; Shine, 1983; Strafford, 2000). Viviparity is very interesting phenomenon found in snakes which is basically an adaptation to the environment and also shows a surprising similarity to the most advanced group i.e. Mammalia. Shine and Bull (1979) explained the origins of live bearing in reptiles are an adaptation to cold environment and an adaptation to provide maternal care of the eggs inside the body. Seigel *et al.* (1978) suggested viviparity based on two possibilities: 1) females can regulate their body temperature and thus the temperature for the young, the total time of incubation should decrease, thus decreasing probability of mortality, 2) because temperature conditions are clinal, species invading colder areas might gradually increase retention time, and if retention does increase egg survivorship, the intermediate stages of viviparity can be seen as adaptive.

However, some authors reported viviparity in many groups of snake, such as Acrochordus, Boidae (Boinae), Elapidae (Hydrophiidae) and the most of Viperidae (Bauchot, 1994; Mattison, 1995; Mattison, 2002; Mattison, 2007, Stafford, 2000; Wangkulangkul, 2004). Homalopsid snakes also were reported viviparous, giving birth to young under water (Bauchot, 1994; Mattison, 2007; Murphy, 2007; Murphy *et al.*, 2002). Parameswaran (1954, 1963) found *Enhydris dussumieri* embryos have absorbed all of the yolk when the embryos are 17 cm long, but it continues to grow to 23 cm using nutrient obtained through a chorio-allantonic placenta. *Cerberus rynchops* were examined by Parameswaran (1943) and Samuel (1951). They considered the placenta structure of *Cerberus rynchops* less specialized than the sea snakes (Hydrophiinae) placenta.

Sexual maturity in male snakes was recognized by weight, spermatogenesis and testes size whereas in females, the presence of embryos or yolk follicles were used (Gibbon, 1972; Giron, 1982; Jorgensen and Nicholson, 2007; Seigel and Ford, 1987). The female body size also has an important influence on the reproductive traits of snakes. It is significantly correlated with clutch size and the number of offspring produced (Aubret *et al.*, 2002; Lemen and Voris, 1981 cited in Wangkulangkul, 2004; Seigel and Ford, 1987). Clutch size varies within snake species and among populations. The studies of *Acrochordus granulatus* by Lemen and Voris (1981), and Wangkulangkul (2004) and *A. arafurae* by Shine (1986) showed the correlation between relative clutch mass and female body size, larger females have larger clutch mass. Likewise, studies of *Crotalus viridis* by Jorgenson and Nicholson (2007) and *Dipsas albifons* by Hartmann *et al.* (2002) also showed the correlation between relative clutch size and female body size, larger females have larger clutch size.

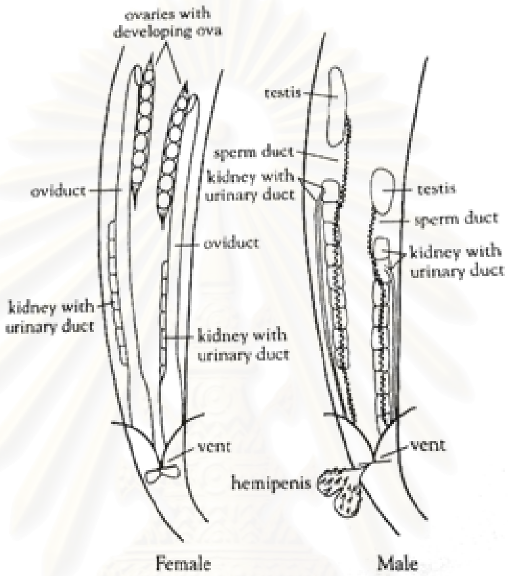
Recent studies about reproduction of homalopsid snakes show these correlations (between clutch mass or clutch size with female body size). A study of *Bitia hydroides* by Jayne *et al.*(1995) showed increasing significantly between clutch size and larger female SVL. Data from the study of *Enhydris alternans* suggested clutch size increases with female body size (Bergman, 1960 cited in Murphy, 2007). Female *Enhydris enhydris* from three populations (Cambodia, Myanmar and Thailand) were examined by Murphy *et al.* (2002) and female snakes from Kabin Buri, Thailand were examined by Karns *et al.* (2005). Both of them found clutch size was significantly correlated with female body size.

The reproductive biology of snakes is considerably less well understood than other reptilian groups. Especially, the reproduction of tropical snakes is still unknown, as well as little is known about the reproduction of homalopsid snakes (Mattison, 2007; Murphy, 2007; Seigel and Ford, 1987).

2.3.2 Sexual morphology

Males and females of all vertebrate species obviously differ in their reproductive organs. In snakes, female snakes normally have a pair of ovaries, staggered like the kidneys and the right ovary is situated anterior to the left one. The mesovarium supports each ovary. Swelling present in the ovaries are eggs. The oviduct on each side is supported by mesotubarium and it receives eggs through an anterior opening called the ostium or infundibulum. The anterior fallopian tube follows the infundibulum where the eggs pass to the uterus, where they remain to maturity

(Oldham *et al.*, 1970). Male snakes have paired testes staggered like ovaries and other paired organs. Each testis has a long slender convoluted tube; the ductus deferens, that connects to the cloaca. At the vent opening, male snakes have two copulatory organs namely hemipenes, each one conducts sperm from the gonads and ductus deferens. Each side is functionally complete and either may be used at a time,



but not both (Ernst and Zug, 1999; Mattison, 2000; Mattison, 2007, Figure 2.3).

Figure 2.3: Reproductive organs of female and male cottonmouth snakes (*Agkistrodon piscivorous*) [from Ernst and Zug, 1996].

But in many species, there are also marked differences in the secondary sex characteristics that are not directly associated with reproduction which is known in terms of sexual dimorphism. Sexual dimorphism is often visible in body size difference in which one sex is larger than opposite sex (Wangkulangkul, 2004). Homalopsid snakes were also reported sexual dimorphism by Ghodke and Andrews (2002), Karns *et al.* (2002), Karns *et al.* (2005). Female homalopsid snakes were reported larger than males in snout - vent length (SVL) and mass but shorter in tail length except *Fordonia leucobalia* and *Gerarda pravostiana* which were reported no differ significantly in SVL but differ significantly in tail length and mass, respectively.

2.3.3 Reproductive cycle

Mattison (2002, 2007) suggested that the timing of female reproductive cycle tends to be better defined than that in males and several stages can be recognized. The first stage is the formation of small, follicular eggs in the ovary. Maturation involves surrounding each egg with yolk, a process known as vitellogenesis and normally this takes place immediately before the breeding season. The production of yolk is depended on an adequate store of fat, however, tropical snakes form eggs directly from their food intake without relying on stored fat. Then, eggs are released from the ovary and they move into the body cavity and are then caught by the funnel-shaped opening, known as the infundibulum. A stimulus may be required before ovulation occurs and this varies from species to species. In temperate snakes, it seems that increasing temperature whereas in some tropical species is provided by cooler conditions. Eggs are fertilized in oviduct assuming sperm are present, if not, the females will lay infertile eggs or reabsorb them. Females of some species are able to store sperm for lengthy periods and so delayed fertilization. In species that produce more than one clutches in a single breeding season, sperm storage may be used to fertilizing the second clutch. Fertility from clutches produced from stored sperm is, however, usually lower than in clutches fertilized by fresh sperm. (Bauchot, 1994; Mattison, 2007)

St.Girons and Pfeffer (1971) assigned homalopsid snakes to be a monoestrous with seasonal reproduction; Spermatogenesis from July to February, matings in December or January, ovulation in January or February, give births in March to April at end of the dry season. Later researchers also reported reproduction of homalopsid snakes. Gorman *et al.* (1981) studied annual reproductive pattern of 3 marine snakes (*Acrochrodus granulatus, Laticauda colubrina* and *Cerberus rynchops*) at central Philippines. They suggested *Cerberus rynchops* at their study site appeared to be seasonally breeding population, vitellogenesis appeared from September to

March and pregnant females appeared from February to August. Martinez and Behler (1988) reported litters of *Erpeton tentaculatus* were born at New York Zoological Park; parturition occurred from early July to early October. Murphy *et al.* (2002) reported gravid females *Enhydris enhydris* from Cambodia in August and from Thailand in June and July. Murphy *et al.* (1999) reported gravid female *Enhydris enhydris* from Ban Tha Hin, Thailand was formed in July. Murphy (2007) reported examined specimen of *Fordonia leucobalia* gave birth on November. However, Berry and Lim (1967) reported no definite breeding season and juveniles were present at all times of the year in *Homalopsis buccata.* They found a statistically significant breeding peak existed from October to March and suggested that probably the rainfall or the accompanying high water level may exert a stimulus in initiating breeding.

Khorat basin

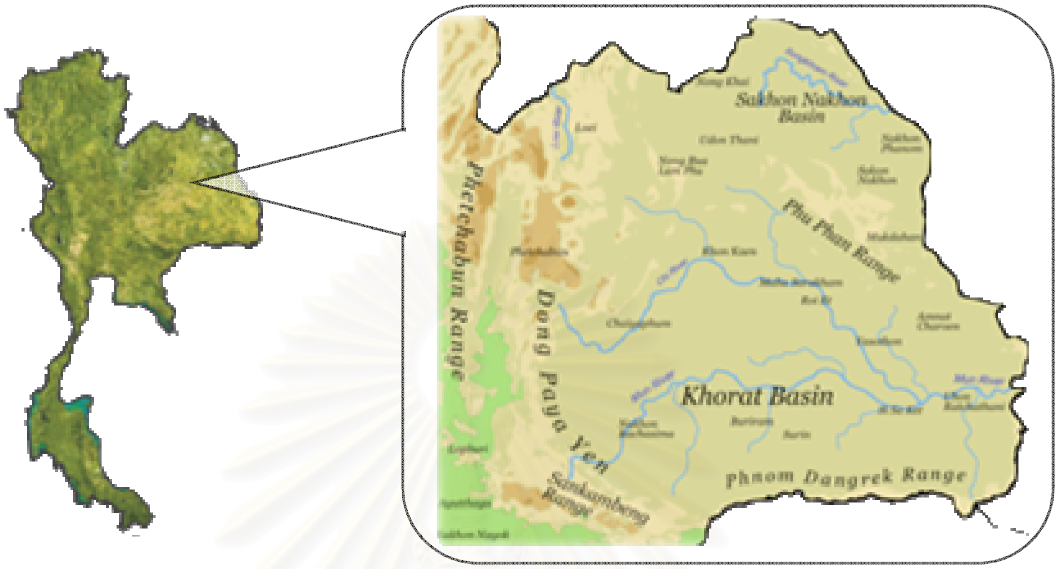
The Khorat Basin (Khorat plateau) is a prominent and ancient geographic feature in Indochina and its origin can be traced back to the early Mesozoic. Its morphology is due to the tectonic pressure along the margins in western and southern borders (Karns *et al*, 2005). Eastern Petchabun mountain range is a western border, straight in a north-south line with elevation ranged from 704 m to 1242 m. Panom Dongrak mountain range is a southern border, lie in east-west line with elevation range from 240 m to 740 m. These low mountain ranges together with the Truong Son Cordillera in the northeast create a relatively low elevation (200 - 1100 m above sea level) rim. The northern and eastern borders are formed by the Mekong River (Hutchinson, 1989 cited in Karns *et al.*, 2005).

Total area of the Khorat Basin is about 170,226 km2 (1 : 3 total area of Thailand) with elevation ranged from 150 – 250 m (Royal Institute, 2002). The basin tilts to the south and the east with the average elevation of approximately 200 m. The weaken of monsoon rains effected by mountainous rim making the Khorat basin the hottest, driest and most seasonal region of Thailand, rainfall is about 1,150 mm, compared with 1,500 mm in central region. (Karns et al., 2005, Wikipedia, 2008).

Royal Institute (2002) and Vidthayanon et al. (1997; cited in karns, 2005) recognized six major river drainages in Thailand. The Mekong drainage in the Khorat basin consists of four major river basins. The Mul and Chi are major rivers of the Khorat basin (765 km length, cover area about 69,700 km2 and 750 km length cover area about 49,477 km2, respectively) and water in the basin flows into the Mekong and then to the South China Sea. To the south and west of the Khorat basin are Southeastern drainage and Chao Phraya drainage, respectively, and two of them flow in to the Gulf of Thailand.

Karns et al. (2005) were interested in the geography and climate between inside and outside the Khorat basin which may influence the evolution and ecology of semi-aquatic snake assemblages; 1) The segregation of the Mekong drainage of the Khorat basin from the Chao Phraya and Southeastern drainages; 2) the mountainous southern an western rims of the Khorat basin; and 3) the hotter, drier and more seasonal climate of the Khorat basin coupled with infertile soils will affect the abiotic and biotic environment. They suggested that the separation of water, the mountainous rim barrier, the differences in habitat quality and prey availability can lead to genetic evolution that may promote isolation and speciation. The results from their study (compared community structure and population characteristics of semi-aquatic snakes) show higher diversity in the Khorat basin whereas snakes were over twice as abundant at sites located outside the Khorat basin, but there was a high degree of species overlap between assemblages found in and out of the basin. They also found sexual size dimorphism for Enhydris enhydris outside of the Khorat basin, but not in the basin, and female snakes (Enhydris enhydris and Enhydris plumbea) from outside the Khorat basin were larger and heavier in comparison to Khorat basin populations.

Figure 2.4: Khorat plateau on Northeastern Thailand (Wikipedia, 2008).



CHAPTER III

METHODOLOGY

3.1 Study sites

Outside the Khorat basin:
Ban Borthong (N13°59′17.01″ E101°44′43.21″, Figure 3.1)

Ban Borthong is a village in Kabin Buri District, Prachinburi Province, located on the east side of Thailand. Nong Pla Ka Yeang and surrounding ponds were chosen as a study site outside the Khorat basin. It is located on the west side of highway 33 from Prachantakam District to Kabin Buri District. In the past, this pond was a natural wetland and received water from small canals around the area. In 1983 a dam was built for holding water year-round. This pond has a total area of about 640,000 m^2 and contains about 1,920,000 m^3 of water (Pungrattana and Rattanamala, 2007). Nong Pla Ka Yeang is a freshwater pond with depths from 2 to 6 m and it is surrounded by rice-fields and a small town. This pond connects to Hanuman river on the east side and flows to the Bang Pa Kong river and to the gulf of Thailand.

There are many organisms in this pond. For flora, the middle area was covered by lotuses whereas weeds and sedges cover the surface at the rim. The fauna includes, mammals such as rats (*Rattus* sp.) and mice (*Mus* sp.), birds such as the little egret (*Egretta garzetta*), asian golden weaver (*Ploceus hypoxanthus*), white-breasted waterhen (*Amaurornis phoenicurus*) etc., amphibians such as the ricefield frog (*Fejervarya limnocharis*), green paddy frog (*Rana erythraea*), black-spined toad (*Bufo melanostictus*) etc., and reptiles such as the common sun skink (*Mabuya multifasciata*), lizards (*Calotes* spp.), burmese python (*Python morulus*), monocled

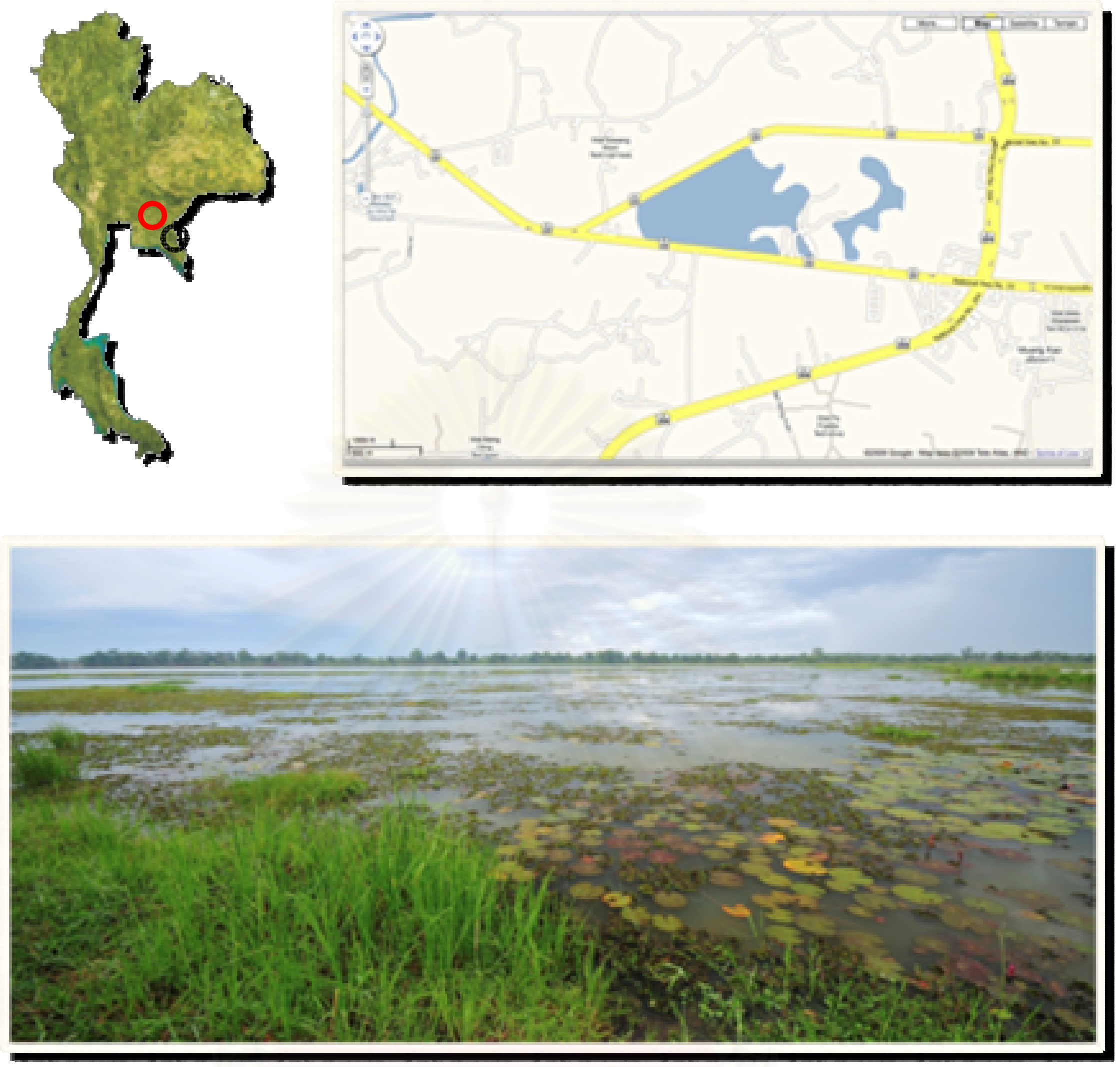


Figure 3.1: Map of Ban Borthong, Kabin Buri District, Prachinburi Province, Thailand (outside the Khorat basin) where snakes were captured (Tele Atlas, 2009).

cobra (*Naja kaouthia*) etc., dispersed over the area. There were also a lot of freshwater fish such as *Notopterus notopterus, Barbonymus gonionotus, B. schwanenfeldi, Cyclocheilichthys repasson, Pseudomystus siamensis. Mystus mysticetus, Macrognathus siamensis, Monopterus albus, Oxyeleotris marmolatus, Monopterus albus, Anabas testudineus, Trichogaster pectoralis, Trichogaster trichopterus, Channa striata, C. micropeltes, Monotreta fangi* etc.

Human activities have been increasing rapidly in this area. Fishing parks and recreation areas such as fitness park, playground, motorcross court, etc have been built along the side of the pond but most areas were used for fishery. The most popular fishing trap used by local people and fishermen is the gill net and they put gill nets in all areas of this pond.

Inside the Khorat basin:
Ban Badan (N14°30′56.36″ E101°57′40.43″, Figure 3.2)

Ban Badan is located in Wang Nam Kheaw District in Nakhon Ratchasima Province, northeastern Thailand. There are many small streams around this area that drain water from Panom Dongrak Mountain through Lam Ta kong river and Mul river and fuse with MeKong river at the east side of the basin.

Bong stream was selected as a study site. It is a small stream located near to the village and was blocked by a dam built by the Ministry of Agriculture and Cooperatives in 1996. The dam has a total area of about 1,600,000 m^2 (Royal Irrigation Department, 2007). This dam is surrounded by small ponds and rice fields. Disturbance from human activities is relatively low compared to Nong Pla Ka Yeang pond and mainly activities are fishery and cattle raising.

The use of gill net is also popular for trapping fish in this area. Local people and fishermen usually trap fish along the rim of the dam and northern part of the stream. Middle area of the dam has been used some for fish culture (Thai Red Tilapia, *Oreochromis niloticus x O. mossambicus*). The main flora of this area is grass at the rim of the dam but there is no water plant at the middle area of the dam. The northern part of the stream and surrounding ponds are covered by Cyperaceae such as sedge and rush. This area also has a lot of animals, mammals such as mice (*Mus* sp.), birds such as cattle egret (*Bubulcus ibis*), white-throated kingfisher (*Halcyon smyrnensis*), green bee-eater (*Merops viridis*) etc., amphibians such as ricefield frog (*Fejervarya limnocharis*), rugosed frog (*Hoplobatrachus rugulosus*), green paddy frog (*Rana erythraea*), black-spined toad (*Bufo melanostictus*), etc. and

reptiles such as blue crested lizard (*Calotes mystaceus*), northern butterfly lizard (*Leiolepis reevesii*), clouded monitor (*Varanus bengalensis*), banded krukri snake

(*Oligodon fasciolatus*), indochinese rat snake (*Ptyas korros*), etc are present. Many freshwater fish are found in Ban Badan dam such as *Notopterus notopterus, Osteochilus hasselti, Barbonymus altus, B. gonionotus, Hampala macrolepidota, Channa striata, C. lucius, Mytus mysticetus, Monopterus albus, Macrognathus siamensis, Parambassis siamensis, Anabas testudineus, Trichogaster pectoralis* and *T. trichopterus.*

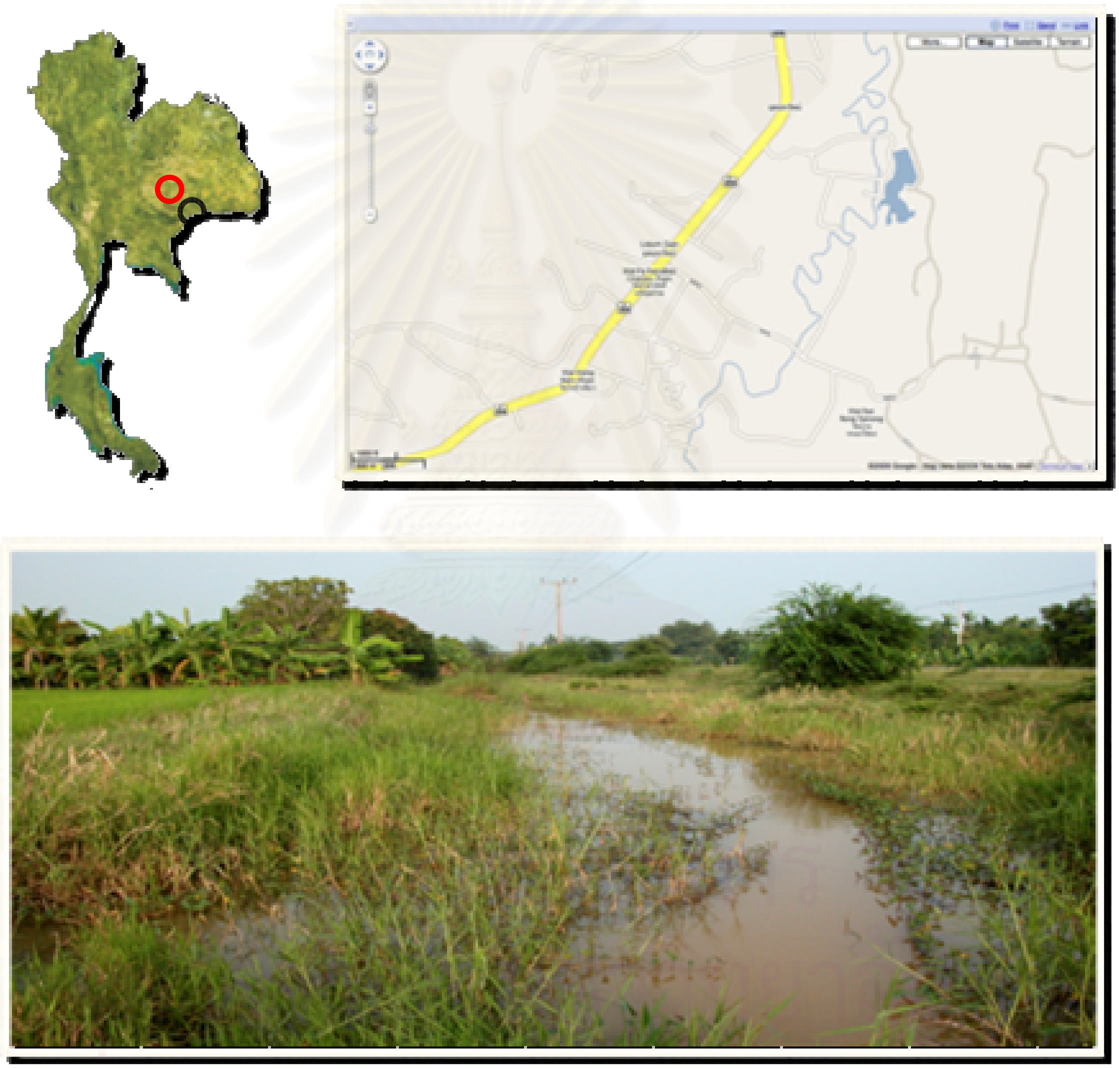


Figure 3.2: Map of Ban Badan, Wang Nam Kheaw District, Nakhon Ratchasima Province, Thailand (inside the Khorat basin) where snakes were captured (Tele Atlas, 2009).

3.2 Methods

Collection of samples:

Specimens of freshwater snakes, homalopsid snakes, in both study sites (inside and outside the Khorat basin) were collected from April 2006 to March 2007. Live and dead specimens were collected from fisherman's gill nets which were placed in the study sites. Fishermen placed their gill nets for trapping fish in late afternoon and take them back in the next morning. These traps were checked for homalopsid snakes regularly in the morning throughout the study period. Trapped snakes were kept in a styrofoam box for further measurements, diet and reproductive investigation before releasing at capture sites. Dead snakes were immediately placed in styrofoam boxes with ice and were moved to a refrigerator at the laboratory of Museum of Natural History Chulalongkorn University. Later on, snake specimens were deposited in the collection of Chulalongkorn University Museum of Natural History.

Species and numbers of each species were calculated for species composition, similarity, calculated by Sorensen coefficient and diversity, calculated by Evenness, at each site and were compared between sites. Trap sites were recorded for habitat investigation. Common species at each site were selected for population structure investigation.

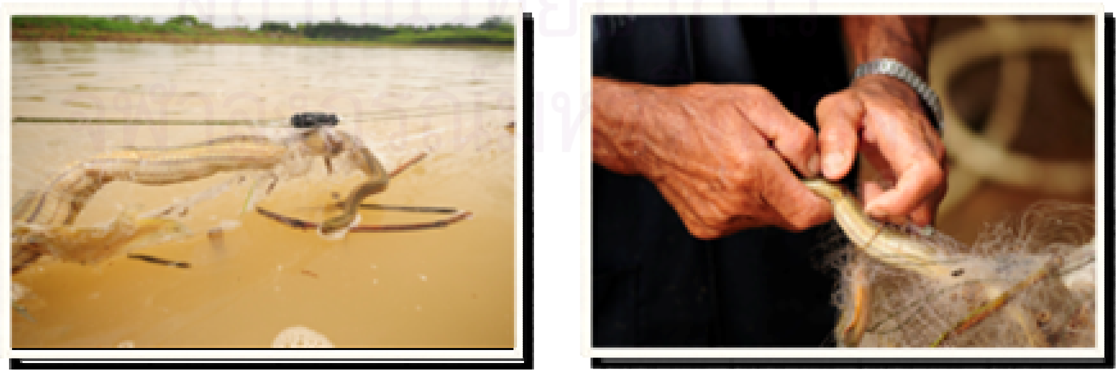


Figure 3.3: Snakes specimens were collected from local fisherman's gill nets which placed in the study sites.

Morphological measurements and sex identification:

Both live and dead homalopsid snakes were sexed and measured for 6 morphological characters as follows :

1. SEX: Snake sex was determined by checking for the presence of hemipenes. Hemipenes were checked by injecting water at the base of snake tail. In males, hemipenes would come out from the cloaca (ventral opening) but not in females.

2. Snout-vent length (SVL) was measured from the tip of nasal scale along the length of the body to the cloaca by measuring tape to the nearest 1 mm.

3. Tail length (TL) was measured from the cloaca to the tip of tail to the nearest 1 mm.

4. Neck girth (NG) was measured at the posterior end of the jaw by a measuring tape to the nearest 1 mm.

5. Body girth (BG) was measured at the middle of the body length by a measuring tape to the nearest 1 mm.

6. Weight: A digital balance was used for weighing snake specimens. The weight was recorded to nearest 1 g.

Morphological differences between sexes at each of the study sites and between the study sites within species were compared using the Man-Whitney U-test ($p<0.05$). The statistical analysis was performed on computer by SPSS 13.0 for Windows operating system.

Diet:

Live homalopsid snakes were forced to regurgitate their stomach contents by hand whereas stomach contents were removed from dead snake specimens by dissection. Prey items found were immediately preserved in 10% buffered formaldehyde, identified and weighed to nearest 1 g using a digital balance. The proportion between prey mass and snake mass for each species at each study site and the proportion of prey types found in homalopsid snake guts at each study site were investigated. Niche breadth and niche overlap at each site were calculated by Shannon-Weiner measure and Simplified Morisita Index, respectively. The proportion between prey mass and snake mass taken by different sexes among and between study sites were compared by Man-Whitney U-test ($p<0.05$). Simplified morishita's index of similarity were used to investigate similarity of diet of each species between study sites. The statistical analysis was performed on computer by SPSS 13.0 for Windows operating system.

Female reproductive biology:

The stage of reproduction, size and number of follicles, vitellogenesis and embryo of each female was recorded through the study period from dead specimens. Vernier calipers were used to measure to the nearest 0.01 mm and a digital balance was used for weighing to the nearest 1 g. The stages of embryos were identified following Zehr (1962). 10^{th} to 20^{th} stages were considered into early developing stage of embryo, 21^{st} to 29^{th} stages were considered into middle developing stage of embryo, 30^{th} to 36^{th} stages were considered into late developing stage of embryo and 37^{th} stage were considered full-term stage of embryo. Ova and embryos were removed from the carcasses, labeled and stored in 10% buffered formaldehyde. The relationships between female's SVL and mass with clutch size and clutch mass of each species at each study site were examined by Pearson's correlation. The relative clutch mass (RCM) was computed as the ratio of clutch mass to female mass. Correlations between physical factors and female reproduction were correlated by Pearson's test. The statistical analysis was performed on computer by SPSS 13.0 for Windows operating system.

Data Analysis:

Evenness (J') in Krebs (1989)

$$J' = \frac{H'}{\log n}$$

J' : Evenness measure of the Shannon - Weiner function
H' : Shannon-Weiner measure
n : Total number of possible resource states

Shannon - Weiner measure (H') in Krebs (1989)

$$H' = -\sum p_j \log p_j$$

H' : Shannon - Weiner measure of niche breadth
p_j : Proportion of individuals found in or using resource j
n : Total number of resource states

Sorensen similarity index (IS) in Krebs (1989)

$$IS = \frac{2W}{(A+B)} * 100$$

IS : value of Sorensen similarity index
W : number of species common to the both sites
A : the number of species in site A
B : the number of species in site B

Simplified morishita's index (C_H) in Kreb (1989)

$$C_H = \frac{2 \sum p_{ij} p_{ik}}{\sum p^2_{ij} + p^2_{ik}}$$

C_H : Simplified Morishita index of overlap
$p_{ij}\, p_{ik}$: Proportion resource i is of total resources used by the two species (i = 1, 2, 3, 4, ..., n)
n : Total number of resource states

Simplified morishita's index of similarity (C_H) in Krebs (1989)

$$C_H = \frac{2 \sum X_{ij} X_{ik}}{[(\sum X^2_{ij}/N^2_j) + (\sum X^2_{ij}/N^2_k)] N_j N_k}$$

C_H : Simplified Morishita index of similarity (Horn, 1966)
X_{ij}, X_{ik} : Number of individuals of species i in sample j and sample k
N_j : Total number of individuals in sample j
N_k : Total number of individuals in sample k

CHAPTER IV

RESULTS

4.1 Species composition

Outside the Khorat basin:
Ban Borthong, Kabin Buri District

From May 2006 to April 2007, 633 snakes were collected from local fisherman's gill nets. The collected snakes, consisting of 7 species, can be divided into two groups, snakes in the Family Homalopsidae and snakes in other families. The four species in the family Homalopsidae are *Enhydris enhydris, E. plumbea, E. bocourti* and *Homalopsis buccata,* and 3 species of other snake families are *Xenochrophis flavipunctatus* (Family Colubridae), *Xenopeltis unicolor* (Family Xenopeltidae) and *Cylindrophis ruffus* (Family Cylindrophiidae) (Figure 4.1). Of all the species, *E. enhydris* (81.36%) was the dominant species at this study site followed by *H. buccata* (5.85%), *X. flavipunctatus* (5.37%), *E. plumbea* (4.11%), *C. ruffus* (2.37%), *E. bocourti* (0.63%) and *X. unicolor* (0.32%), respectively. The number of each snake species separated by sexes is shown in Table 4.1.

For Homalopsidae, only *E. enhydris* were collected year-round with the highest number of 84 snakes in December followed by 75 snakes in February whereas the lowest number was 9 snakes in April. In contrast, three species such as *E. plumbea, H. buccata* and *E. bocourti* were not observed year-round. *E. plumbea* were not found from July to October and January, however the highest number of this species was 7 snakes in February. *H. buccata* were not observed in February, July and October, but the highest number of this species was 9 snakes

Figure 4.1: Photographs of snakes, 7 species, from Ban Borthong, Kabin Buri District (outside the Khorat basin).

in May. In addition, *E. bocourti* (4 snakes) were found only in December. For other snakes species, *Xenochrophis flavipunctatus* were not found in April and June, *Cylindrophis ruffus* were not observed in June, August, October and November, but the highest number of this species was 4 snakes in March, and *Xenopeltis unicolor* were found only in March and September (one snake in each month).

From Table 4.1, male specimens of *E. enhydris* were collected more often than female specimens. Males of *E. enhydris* were recorded as 52 snakes at highest number in February whereas those of females were 49 snakes in December. The lowest number of males was 4 snakes in April and August whereas those of female snakes was recorded in March and April (5 snakes in each month). In contrast, females of *E. plumbea* were found more often than male snakes. The highest number of female snakes was 5 in February whereas those of males was 2 snakes in February, March and May. The lowest number of females was 15 snakes in June and November. For *H. buccata*, female snakes were also found more often than male snakes. The highest number of female and male snakes was 7 snakes in December and May, respectively. The lowest number of female snakes was recorded in June, August and November (one snake in each month). Also the lowest number of male snakes was one in November and December. However, male and female of *E. bocourti* were observed in equal numbers (2 snakes) and only in December.

For other snake species, male snakes of *Xenochrophis flavipunctatus* were observed more than female snakes. The highest number of male was 3 snakes in January, July and September whereas those of female was 7 snakes in September. The lowest number of male and female snakes was one snake which were recorded in December for male, and in February, July, August and November for female. Male snakes of *C. ruffus* were found more than female. The highest number of male snakes was 2 in March and July, whilst the lowest number of one snake in January, February, April, May and September. Female snakes of *C. ruffus* were 2 snakes at the highest number in February and March, while the lowest number was one snake in

April and December. Beside, *Xenopeltis unicolor* were observed only two female snakes, one was found in March and another one was found in September.

Inside the Khorat basin:

Ban Badan, Wang Nam Kheaw District

In this study site, 350 snakes were collected from fisherman's gill nets. Four species of the Family Homalopsidae i.e., *Enhydris enhydris, E. plumbea, E. subtaeniata* and *Homalopsis buccata*, 3 species of other snakes i.e., *Xenochrophis flavipunctatus* (Family Colubridae) ,*Xenopeltis unicolor (*Family Xenopeltidae) and *Cylindrophis ruffus (*Family Cylindrophiidae) were found during the study period (Figure 4.2). From , the collected snakes, *E. enhydris* (45.14%) was a dominant species in this study site followed by *E. subtaeniata* (16.29%)*, Xenochrophis flavipunctatus* (13.43%)*, H. buccata* (11.14%)*, E. plumbea* (6.57%)*, Xenopeltis unicolor* (3.71%) and *C. ruffus* (3.71%). Number of each snake species separated by sex is shown in Table 4.1.

From the obtained data, two species of Family Homalopsidae, consisting of *E. enhydris and E. subtaeniata,* were found throughout the year. The highest number of *E. enhydris* was 22 snakes in February whereas the lowest number was recorded in March, July and August (5 snakes in each month). Whilst the highest number of *E. subtaeniata* was 14 snakes in July. The other two homalopsid snakes were not observed year-round. The first species was *E. plumbea* which was not found from February to May and August. The highest number of this species was 6 snakes in December whereas the lowest number was one snake in June and September. The later species was *H. buccata* which was not found in December. The highest number of this species was 10 snakes in February. For the other snake species, only *Xenochrophis flavipunctatus* was found all year. The highest number of this species was 9 snakes in November whereas the lowest number was recorded in February and March (one snake in each month). *Xenopeltis unicolor* was not observed in 6 scattered months; January, March, May, August, October and November. The highest number of this species was recorded in February and June (3 snakes in each month). For *C. ruffus*, none was observed in 8 months from July to February. The highest number of this species was 5 snakes in March whereas the lowest number was one snake in June.

From all collected Homalopsid snakes, male snakes of *E. enhydris* were found more than female snakes. The highest number of male snakes was 12 snakes in May and September whereas those of female snakes was 11 in February. The lowest number of male and female snakes was one in March and July, respectively. In contrast, female snakes of 3 homalopsid snakes consisting of *E. plumbea, E. subtaeniata and H. buccata*, were observed more than male snakes. The highest number of female snakes of *E. plumbea* was 6 snakes in December whereas those of male snakes was 2 snakes in January. The lowest number of these female snakes was one in January, June and September and those of male snake was also one snake in October. Like *E. plumbea*, female snakes of *H. buccata* were observed more than male snakes. The highest number of both sexes was 5 snakes in February. The lowest number of female snakes was one snake in 6 months (April, May, July, August, October and November) and those of males was also one snake in January and May to July. Besides, *E. subtaeniata*, female snakes were found more than male snakes also. The highest number of female snakes was 11 snakes in July while those of male snake was 4 snakes in January, June and August. The lowest number of females and males was one snake in September, and in February, April and September, respectively.

For other snake species, female snakes of *Xenochrophis flavipunctatus* were observed more than male snakes. Seven female snakes were recorded in December at the highest number while 6 male snakes were recorded in June. The lowest number of female snakes was one snake in March, May and August and those of male snakes was also one snake in February and August. In contrast, male snakes of

Xenopeltis unicolor were found more than female snakes. The highest number of male snakes was 2 snakes in February, April and June whereas those of female snakes was one snake in February, June, July and September. The lowest number of male snakes was one snake in July, September and December. Like *Xenopeltis unicolor,* male snakes of *C. ruffus* were observed more than female snakes. The highest number of male snakes was 4 snakes in March whereas those of female snakes was one snake from March to June. The lowest number of male snakes was 2 snakes in May.

Figure 4.2: Photographs of snakes, 7 species, from Ban Badan, Wang Nam Kheaw District (Inside the Khorat basin).

Comparison between study sites

Sites located outside (Ban Borthong, Kabin Buri District) and inside (Ban Badan, Wang Nam Kheaw District) the Khorat basin were dominated by *E. enhydris* (81.36% and 45.14%, respectively). By the way, snake assemblages which were collected from these two study sites were highly similar (Sorenson similarity index = 86%). The same families were collected from these two study sites (Family Colubridae, Family Cylindrophiidae, Family Xenopeltidae and Family Homalopsidae) but they have a different species composition in the Family Homalopsidae. *Enhydris bocourti* were collected only outside the Khorat basin study site whereas *E. subtaeniata* were collected only inside the Khorat basin study site.

Of the number of snake specimens collected per day, the number of collecting days and the emphasis on opportunity of collecting specimens among sites partly accounts for the differences in numbers of snakes collected among sites (Table 4.2). Ban Borthong exhibited the greatest abundance of snakes (21.07 snakes per day) while Ban Badan was much lower in abundance (6.14 snakes per day). Both study sites exhibited the same species richness, 7 species, of which 4 species were homalopsid snakes. Species diversity was different among sites. Species evenness indices for each site are shown in Table 4.2. Sites located inside the Khorat basin exhibited the greatest species evenness ($J' = 0.818$) compared with sites outside the Khorat basin ($J' = 0.399$).

Table 4.1 Numbers of snake specimens collected in both study sites, outside (Ban Borthong, Kabin Buri District) and inside (Ban Badan, Wang Nam Kheaw District) the Khorat basin, Thailand from April 2006 to May 2007. Data shown numbers of snake specimens collected each month and were separated by species and sexes.

Ban Borthong, Kabin Buri District														
		JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	Total
Enhydris enhydris	M	37	52	16	4	36	23	5	4	21	14	40	35	287
	F	16	23	5	5	20	25	14	20	10	22	19	49	228
Enhydris plumbea	M	0	2	2	1	2	0	0	0	0	0	0	1	8
	F	0	5	4	2	3	1	0	0	0	0	1	2	18
Enhydris bocourti	M	0	0	0	0	0	0	0	0	0	0	0	2	2
	F	0	0	0	0	0	0	0	0	0	0	0	2	2
Homalopsis buccata	M	2	0	0	0	7	4	0	0	2	0	1	1	17
	F	3	0	3	2	2	1	0	1	0	0	1	7	20
Xenochrophis flavipunctatus	M	3	2	2	0	2	0	3	0	3	2	0	1	18
	F	0	1	3	0	0	0	1	1	7	2	1	0	16
Xenopeltis unicolor	M	0	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	0	1	0	0	0	0	0	1	0	0	0	2
Cylindrophis ruffus	M	1	1	2	1	1	0	2	0	1	0	0	0	9
	F	0	2	2	1	0	0	0	0	0	0	0	1	6
													Total	633
Ban Badan, Wang Nam Kheaw District														
		JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	Total
Enhydris enhydris	M	8	11	1	5	12	7	4	0	12	8	10	5	83
	F	7	11	4	4	4	10	1	5	9	7	9	4	75
Enhydris plumbea	M	2	0	0	0	0	0	0	0	0	1	0	0	3
	F	1	0	0	0	0	1	4	0	1	2	5	6	20
Enhydris subtaeniata	M	4	1	0	1	2	4	3	4	1	0	2	2	24
	F	4	3	2	0	0	8	11	0	1	2	0	2	33
Homalopsis buccata	M	1	5	3	0	1	1	1	2	0	2	0	0	16
	F	3	5	3	1	1	4	1	1	2	1	1	0	23
Xenochrophis flavipunctatus	M	2	1	0	0	2	6	5	1	2	0	0	2	21
	F	2	0	1	2	1	2	0	1	2	2	6	7	26
Xenopeltis unicolor	M	0	2	0	2	0	2	1	0	1	0	0	1	9
	F	0	1	0	0	0	1	1	0	1	0	0	0	4
Cylindrophis ruffus	M	0	0	4	3	2	0	0	0	0	0	0	0	9
	F	0	0	1	1	1	1	0	0	0	0	0	0	4
													Total	350

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Table 4.2 Summary of snake specimens inside and outside the Khorat basin, Thailand, separated by species. Number in parentheses under locality names indicated the number of collecting days at that site. Species richness and evenness was also shown in the table.

Species	Outside (30 days)	Inside (57 days)	Total
Homalopsid snakes			
Enhydris enhydris	515	158	673
Enhydris plumbea	26	23	49
Enhydris subtaeniata	0	57	57
Enhydris bocourti	4	0	4
Homalopsis buccata	37	39	76
Other snakes			
Xenochrophis flavipunctatus	34	47	81
Xenopeltis unicolor	2	13	15
Cylindrophis ruffus	15	13	28
Total per site	633	350	983
No. of snake specimens per day	21.07	6.14	11.30
Species richness	7	7	8
Species evenness	0.399	0.818	-

4.2 Morphological characters

Outside the Khorat basin:
Ban Borthong, Kabin Buri District

Morphological characters (SVL, tail length, neck girth, body girth and mass) of male and female snakes of each species collected at this study site, are shown in Table 4.3. Mature snakes were considered as those with SVL equal to or larger than that of the smallest gravid female snake. Thus, a SVL of 31.4 cm or greater were considered as mature for both male and female of *Enhydris enhydris*. For *E. plumbea*, above 35.3 cm SVL were decided as the mature size for male and female snakes. By the way, the morphological characters of other snakes at maturity, such as *E. bocourti, Homalopsis buccata* and *Xenochrophis flavipunctatus* were not calculated because of the low numbers of snakes at mature size while gravid female snakes of *Xenopeltis unicolor* and *Cylindrophis ruffus* were not captured.

From Table 4.3, 282 female and 223 male snakes of *E. enhydris* were measured for morphological analysis. Mean values of SVL, neck girth, body girth and mass of female snakes (mean SVL: 54.1 ± 7.0 cm, mean neck girth: 2.9 ± 0.4 cm, mean body girth: 6.2 ± 1.2 cm and mean mass: 145.8 ± 60.9 grams) were significantly larger than male snakes (mean SVL: 47.4 ± 3.5 cm, mean neck girth: 2.3 ± 0.3 cm, mean body girth: 4.9 ± 0.5 cm and mean mass: 78.5 ± 17.2 grams, $p < 0.05$). In contrast, tail length of female snakes (mean value was 11.5 ± 1.5 cm) was significantly shorter than the tail length of male snakes (mean value was 12.2 ± 1.1 cm; $p < 0.05$). Six male and 15 female snakes of *E. plumbea* were selected for morphological analysis. Mean values of SVL, tail length, neck girth, body girth and mass of female snakes (mean SVL: 41.9 ± 2.4 cm, mean tail length : 6.0 ± 0.9 cm, mean neck girth: 4.2 ± 0.5 cm, mean body girth: 5.4 ± 1.1 cm and mean mass: 91.6 ± 23.1 grams) were not significantly different from male snakes (mean SVL: 41.6 ± 4.0 cm, mean tail length : 5.5 ± 1.4 cm, mean neck girth: 3.9 ± 0.4 cm, mean body girth: 4.8 ± 0.3 cm and mean mass: 70.5 ± 13.2 grams; $p > 0.05$).

Other homalopsid snakes, all collected snakes of *Homalopsis buccata* and *E. bocourti* were used for calculation. The smallest gravid female of *H. buccata* was 68.4 cm in SVL and the smallest gravid female of *E. bocourti* was 79.6 cm in SVL. Male and female snakes of *H. buccata* had significant differences in tail length (mean tail length was 17.4 ± 3.8 cm in female snakes and 19.5 ± 4.3 cm in male snakes, $p < 0.05$) but had no significant differences in SVL (mean SVL was 54.7 ± 12.2 cm in female snakes and 59.1 ± 12.5 cm in male snakes; $p > 0.05$), neck girth (mean neck girth: 4.2 ± 0.8 cm in female and 4.0 ± 0.6 cm in male), body girth (mean body girth: 5.5 ± 1.5 cm in female and 5.3 ± 1.0 cm in male) and mass (mean mass: 163.1 ± 127.7 grams in female and 127.5 ± 72.6 grams in male). For *E. bocourti* no significant differences in morphological characters were found between female (mean SVL: 75.3 ± 2.2 cm, mean tail length: 10.3 ± 0.3 cm, mean neck girth: 8.0 ± 0.1 cm, mean body girth: 11.1 ± 1.7 cm and mean mass: 635.0 ± 123.0 grams) and male snakes (mean SVL: 50.8 ± 15.8 cm, mean tail length: 9.5 ± 4.2 cm, mean neck girth: 5.4 ± 1.4 cm, mean body girth: 6.1 ± 1.4 cm and mean mass: 188.0 ± 123.0 grams; $p > 0.05$).

For other collected snakes, the smallest gravid female of *X. flavipunctatus* was 60.4 cm in SVL. *X. flavipunctatus* had significant differences in SVL and mass between sexes (mean SVL was 58.6 ± 7.0 cm and mean mass was 140.5 ± 50.9 grams in female snakes and mean SVL was 47.8 ± 8.2 cm and mean mass was 107.3 ± 41.6 grams in male snakes; $p < 0.05$). There were no significant differences in tail length, neck girth and body girth between sexes (mean tail length was 21.3 ± 3.0 cm, mean neck girth was 4.2 ± 0.6 cm and mean body girth was 5.4 ± 0.9 cm in female snakes and mean tail length was 20.5 ± 4.9 cm, mean neck girth was 3.8 ± 0.66 cm and mean body girth was 5.2 ± 0.8 cm in male snakes; $p > 0.05$).

Table 4.3 Morphological characters of homalopsid snakes and other snakes sampled from Ban Borthong, Kabin Buri District (outside the Khorat basin), male and female were separated. Each table shows the mean (± SE) values for 5 morphological characters. Statistical analysis using Man - Whitney U Test

Species	SEX	Morphological characters				
		SVL (cm)	TL (cm)	Neck girth (cm)	Body girth (cm)	Mass (grams)
Homalopsid snakes						
Enhydris enhydris	M (n=223)	47.4 ± 3.5 (55.6 - 36)	12.2 ± 1.1 (14.5 - 8)	2.3 ± 0.3 (4.2 - 1.6)	4.9 ± 0.5 (6.5 - 2.8)	78.5 ± 17.2 (126 - 26)
	F (n=282)	54.1 ± 7.0 (71 - 36)	11.5 ± 1.5 (15.3 - 7)	2.9 ± 0.4 (4.1 - 2)	6.2 ± 1.2 (8.8 - 2.5)	145.8 ± 60.9 (334 - 35)
	p - value	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Enhydris plumbea	M (n=6)	41.6 ± 4.0 (49.7 - 39)	5.5 ± 1.4 (7 - 3.5)	3.9 ± 0.4 (4.6 - 3.5)	4.8 ± 0.3 (5.1 - 4.3)	70.5 ± 13.2 (85 - 53)
	F (n=15)	41.9 ± 2.4 (46.5 - 38.7)	6.0 ± 0.9 (7 - 3.5)	4.2 ± 0.5 (4.9 - 3.3)	5.4 ± 1.1 (9.2 - 4.2)	91.6 ± 23.1 (128 - 55)
	p - value	0.39	0.76	0.09	0.07	0.07
Enhydris bocourti	M (n=2)	50.8 ± 15.8 (62 - 39.6)	9.5 ± 4.2 (12.5 - 6.5)	5.4 ± 1.4 (6.4 - 4.4)	6.1 ± 1.4 (7.1 - 5.1)	188.0 ± 123.0 (275 - 101)
	F (n=2)	75.3 ± 2.2 (76.9 - 73.77)	10.3 ± 0.3 (10.5 - 10.1)	8.0 ± 0.1 (8 - 7.9)	11.1 ± 1.7 (12.3 - 9.9)	635.0 ± 123.0 (722 - 548)
	p - value	-	-	-	-	-
Homalopsis buccata	M (n=17)	59.1 ± 12.5 (88.6 - 46.5)	19.5 ± 4.3 (30 - 15.6)	4.0 ± 0.6 (5.3 - 3.2)	5.3 ± 1.0 (8 - 3.9)	127.5 ± 72.6 (341 - 58)
	F (n=20)	54.7 ± 12.2 (76.6 - 43)	17.4 ± 3.8 (25.3 - 13.6)	4.2 ± 0.8 (6.2 - 2.8)	5.5 ± 1.5 (8.7 - 4.1)	163.1 ± 127.7 (495 - 57)
	p - value	0.19	0.02	0.53	0.98	0.92
Other snakes						
Xenochrophis flavipunctatus	M (n=18)	47.8 ± 8.2 (60 - 29.8)	20.5 ± 4.9 (29.5 - 12)	3.8 ± 0.66 (5 - 2.1)	5.2 ± 0.8 (6.2 - 3.7)	107.3 ± 41.6 (190 - 42)
	F (n=16)	58.6 ± 7.0 (66 - 39.5)	21.3 ± 3.0 (25 - 15.7)	4.2 ± 0.6 (5.4 - 2.8)	5.4 ± 0.9 (6.8 - 3.6)	140.5 ± 50.9 (227 - 39)
	p - value	0.00	0.80	0.12	0.33	0.04
Xenopeltis unicolor	M (n=0)	0	0	0	0	0
	F (n=2)	86.4 ± 14.1 (96.3 - 76.4)	9.0 ± 1.4 (10 - 8)	5.9 ± 1.0 (6.6 - 5.2)	7.1 ± 2.0 (8.5 - 5.7)	386.0 ± 212.1 (536 - 236)
	p - value	-	-	-	-	-
Cylindrophis ruffus	M (n=7)	57.8 ± 5.8 (67.2 - 48.2)	1.3 ± 0.1 (1.5 - 1.1)	4.5 ± 0.6 (5.5 - 3.8)	4.7 ± 0.7 (5.9 - 4)	106.9 ± 28.1 (142 - 66)
	F (n=7)	65.8 ± 5.9 (74 - 57.2)	1.3 ± 0.2 (1.6 - 1.2)	5.1 ± 0.7 (6 - 4.1)	5.7 ± 0.7 (6.8 - 4)	170.1 ± 61.6 (263 - 81)
	p - value	0.03	0.81	0.17	0.03	0.05

Cylindrophis ruffus had significant differences in SVL, body girth and mass between sexes. From obtained data, the female snakes (mean SVL: 65.8 ± 5.9 cm, mean body girth: 5.7 ± 0.7 cm and mean mass: 170.1 ± 61.6 grams) were significantly larger than male snakes (mean SVL: 57.8 ± 5.8 cm, mean body girth: 4.7 ± 0.7 cm and mean mass: 106.9 ± 28.1 grams; $p < 0.05$), but there were no significant differences in tail length and neck girth between sexes (mean tail length was 1.3 ± 0.2 cm and mean neck girth was 5.1 ± 0.7 cm in female snakes, and mean tail length was 1.3 ± 0.1 cm and mean neck girth was 4.5 ± 0.6 cm in male snakes; $p > 0.05$). However, *Xenopeltis unicolor* were not calculated for morphological differences between sexes because only female snakes were collected, and no gravid female was found in this study period.

Inside the Khorat basin:
Ban Badan, Wang Nam Kheaw District

Morphological characters (SVL, tail length, neck girth, body girth and mass) of male and female snakes of each species collected in this study site are shown in Table 4.4. Morphological characters of adult homalopsid snakes, *Enhydris enhydris* and *E. subtaeniata*, and other collected snakes, *Xenochrophis flavipunctatus,* were determined by SVL of the smallest gravid female of each collected species. From the obtained data, SVL from 31.4 cm, 39.5 cm and 48.7 cm were considered as the size of maturity of *Enhydris enhydris*, *E. subtaeniata* and *Xenochrophis flavipunctatus*, respectively. Other homalopsid snakes, *E. plumbea and Homalopsis buccata,* and other snakes, *Xenopeltis unicolor* and *Cylindrophis ruffus* were not calculated because of the low number of collected snakes at mature size.

From Table 4.4, 81 male and 73 female snakes of *E. enhydris* were selected at the mature size for morphological difference analysis between sexes. SVL, neck girth, body girth and mass of female snakes (mean SVL: 49.2 ± 6.6 cm, mean neck girth: 2.7 ± 0.4 cm, mean body girth: 5.7 ± 1.1 cm and mean mass: 116.5 ± 48.0 grams) were significantly larger than male snakes (mean SVL: 44.8 ± 3.1 cm, mean neck girth:

2.3 ± 0.2 cm, mean body girth: 4.9 ± 0.5 cm and mean mass: 76.3 ± 23.1 grams; $p < 0.05$). Moreover, significant difference in tail length was also found between male and female snakes.

Table 4.4 Morphological characters of homalopsid snakes and other snakes sampled from Ban Badan, Wang Nam Kheaw District (inside the Khorat basin), separated by male and female. Each table shows the mean (± SE) value for 5 morphological characters and the statistical test values (Man - Whitney U Test).

Species	SEX	Morphological characters				
		SVL (cm)	TL (cm)	Neck girth (cm)	Body girth (cm)	Mass (grams)
Homalopsid snakes						
Enhydris enhydris	M (n=81)	44.8 ± 3.1 (52.3 - 37.5)	11.9 ± 1.2 (14.2 - 8.3)	2.3 ± 0.2 (2.8 - 1.7)	4.9 ± 0.5 (6.1 - 3.8)	76.3 ± 23.1 (220 - 40)
	F (n=73)	49.2 ± 6.6 (62 - 31.4)	10.9 ± 1.5 (14 - 5.4)	2.7 ± 0.4 (3.5 - 2)	5.7 ± 1.1 (9.8 - 3.6)	116.5 ± 48.0 (226 - 40)
	p - value	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Enhydris plumbea	M (n=2)	44.0 ± 5.7 (48 - 40)	5.6 ± 3.4 (8 - 3.2)	3.6 ± 0.3 (3.8 - 3.4)	4.8 ± 0.2 (4.9 - 4.6)	80.0 ± 7.1 (85 - 75)
	F (n=17)	39.6 ± 2.6 (43.5 - 35.3)	5.2 ± 1.0 (6.3 - 3.2)	3.8 ± 0.6 (4.5 - 3)	5.2 ± 1.0 (7.6 - 4)	85.8 ± 31.2 (153 - 41)
	p - value	-	-	-	-	-
Enhydris subtaeniata	M (n=12)	43.1 ± 2.9 (48.5 - 39.5)	10.8 ± 3.3 (19.8 - 8.8)	2.8 ± 0.2 (3 - 2.4)	4.9 ± 0.4 (5.4 - 4.3)	79.4 ± 13.2 (105 - 68)
	F (n=28)	46.4 ± 5.1 (57.5 - 39.5)	8.6 ± 1.3 (13.8 - 6.7)	3.2 ± 0.3 (3.7 - 2.5)	6.7 ± 0.9 (8.3 - 4.9)	136.8 ± 49.5 (250 - 45)
	p - value	0.07	< 0.05	< 0.05	< 0.05	< 0.05
Homalopsis buccata	M (n=18)	57.3 ± 3.6 (78 - 41.6)	18.6 ± 3.6 (25.3 - 13.5)	4.1 ± 0.6 (5.3 - 3)	5.8 ± 1.1 (8 - 4.4)	148.8 ± 83.7 (376 - 62)
	F (n=20)	46.1 ± 9.0 (69 - 31)	13.8 ± 2.4 (19.4 - 9.6)	3.6 ± 0.5 (4.9 - 2.4)	4.7 ± 0.9 (6.2 - 2.5)	88.7 ± 41.1 (182 - 23)
	p - value	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Other snakes						
Xenochrophis flavipunctatus	M (n=16)	52.9 ± 4.7 (65 - 48.7)	22.0 ± 3.1 (28 - 17.5)	4.1 ± 0.3 (4.6 - 3.7)	5.5 ± 0.6 (6.5 - 4.3)	131.3 ± 17.0 (163 - 107)
	F (n=26)	56.1 ± 7.8 (76 - 48.7)	21.7 ± 3.3 (29.2 - 17.2)	4.2 ± 0.5 (5.6 - 3.2)	5.6 ± 1.1 (8.8 - 4)	143.1 ± 69.9 (381 - 65)
	p - value	0.13	0.64	0.56	0.71	0.53
Xenopeltis unicolor	M (n=9)	75.3 ± 10.6 (90.3 - 50.1)	6.1 ± 2.8 (8.6 - 1.3)	5.4 ± 0.6 (6.3 - 4.5)	6.2 ± 0.9 (7.6 - 5.3)	250.2 ± 85.3 (358 - 150)
	F (n=4)	66.4 ± 11.9 (78.6 - 53)	4.5 ± 3.8 (8.5 - 1)	5.1 ± 0.1 (5.2 - 5)	6.8 ± 1.2 (8.4 - 5.6)	254.0 ± 98.7 (386 - 147)
	p - value	0.26	0.60	0.33	0.41	0.94
Cylindrophis ruffus	M (n=9)	59.3 ± 4.5 (65.5 - 50.5)	1.4 ± 0.2 (1.7 - 1)	4.7 ± 0.4 (5.4 - 4.3)	5.2 ± 0.5 (6 - 4.3)	130.8 ± 32.0 (185 - 84)
	F (n=4)	58.3 ± 4.3 (63.5 - 54)	1.2 ± 0.1 (1.4 - 1.1)	4.6 ± 0.4 (5.2 - 4.4)	5.3 ± 0.4 (5.7 - 4.9)	127.0 ± 23.2 (161 - 84)
	p - value	0.60	0.15	0.83	0.94	0.94

The tail length of male snakes were significantly larger than female snakes (mean tail length was 11.9 ± 1.2 cm in male snakes and 10.9 ± 1.5 cm in female snakes; $p < 0.05$). For *E. subtaeniata*, 28 female and 12 male snakes were selected for morphological study. Four characters showed significant differences between sexes. Neck girth, body girth and mass of female snakes (mean neck girth: 3.2 ± 0.3 cm, mean body girth: 6.7 ± 0.9 cm and mean mass: 136.8 ± 49.5 grams) were larger than male snakes (mean neck girth: 2.8 ± 0.2 cm, mean body girth: 4.9 ± 0.4 cm and mean mass: 79.4 ± 13.2 grams) whereas tail length of female snakes (mean tail length was 8.6 ± 1.3 cm) was shorter than male snakes (mean tail length 10.8 ± 3.3 cm).

For other homalopsid snakes, all collected *Homalopsis buccata* were used for calculation. However, the smallest gravid female of *H. buccata* was not found in this study. There were significant differences in all morphological characters between female and male snakes. Means of SVL, tail length, neck girth, body girth and mass of female snakes (mean SVL: 46.1 ± 9.0 cm, mean tail length: 13.8 ± 2.4 cm, mean neck girth: 3.6 ± 0.5 cm, mean body girth: 4.7 ± 0.9 cm and mean mass: 88.7 ± 41.1 grams) were significantly smaller than male snakes (mean SVL: 57.3 ± 3.6 cm, mean tail length: 18.6 ± 3.6 cm, mean neck girth: 4.1 ± 0.6 cm, mean body girth: 5.8 ± 1.1 cm and mean mass: 148.8 ± 83.7 grams; $p < 0.05$). Characters of *E. plumbea* were not calculated for morphological differences between sexes because of the low numbers of male snakes at the size maturity (2 male snakes). However, the smallest gravid female of *E. plumbea* collected in this study was 35.3 cm in SVL.

Twenty six female and sixteen male snakes of *Xenochrophis flavipunctatus* were selected for morphological analysis. There were no significant differences between sexes (mean SVL was 56.1 ± 7.8 cm, mean tail length was 21.7 ± 3.3 cm, mean neck girth was 4.2 ± 0.5 cm, mean body girth was 5.6 ± 1.1 cm and mean mass was 143.1 ± 69.9 grams in female snakes, and mean SVL was 52.9 ± 4.7 cm, mean tail length was 22.0 ± 3.1 cm, mean neck girth was 4.1 ± 0.3 cm, mean body girth was 5.5 ± 0.7 cm and mean mass was 131.3 ± 17.0 grams in male snakes, $p > 0.05$). For other snakes, *Xenopeltis unicolor*, any significant differences in morphological characters between female and male snakes were not found (mean SVL was 66.4 ± 11.9 cm, mean tail length was 4.5 ± 3.8 cm, mean neck girth was 5.1 ± 0.1 cm, mean body girth was 6.8 ± 1.2 cm and mean mass was 254.0 ± 98.7 grams in female snakes, and mean SVL was 75.3 ± 10.6 cm, mean tail length was 6.1 ± 2.8 cm, mean neck girth was 5.4 ± 0.6 cm, mean body girth was 6.2 ± 0.9 cm and mean mass was 250.2 ± 85.3 grams in male snakes, $p> 0.05$). Like *X. unicolor*, all characters of *Cylindrophis ruffus* were not significantly different between sexes(mean SVL was 58.3 ± 4.3 cm, mean tail length was 1.2 ± 0.1 cm, mean neck girth was 4.6 ± 0.4 cm, mean body girth was 5.30 ± 0.4 cm and mean mass was 127.0 ± 23.2 grams in female snakes, and mean SVL was 59.3 ± 4.5 cm, mean tail length was 1.4 ± 0.2 cm, mean neck girth was 4.7 ± 0.4 cm, mean body girth was 5.2 ± 0.5 cm and mean mass was 130.8 ± 32.0 grams in male snakes, $p > 0.05$).

Comparison between study sites

Three species of homalopsid snakes, *Enhydris enhydris, E. plumbea* and *Homalopsis buccata*, and one species of other snakes, *Xenochrophis flavipunctatus* were analyzed for morphological differences between study sites. Morphological differences of each snake species separated by sexes are shown in Table 4.5.

For female and male snakes of *E. enhydris,* significant differences in morphological characters were found. All morphological characters of female snakes from Ban Borthong, outside the Khorat basin (mean SVL: 54.1 ± 7.0 cm, mean tail length: 11.5 ± 1.5 cm, mean neck girth: 2.9 ± 0.4 cm, mean body girth: 6.2 ± 1.2 cm and mean mass: 145.8 ± 60.9 grams) were significantly larger than female snakes from Ban Badan, inside the Khorat basin (mean SVL: 49.2 ± 6.6 cm, mean tail length: 10.9 ± 1.5 cm, mean neck girth: 2.7 ± 0.4 cm, mean body girth: 5.7 ± 1.1 cm and mean mass: 166.5 ± 48.0 grams; $p < 0.05$). Male snakes from Ban Borthong, outside the Khorat basin were also significantly larger than male snakes from Ban Badan, inside the Khorat basin in SVL and mass (male snakes were 47.5 ± 3.5 cm in mean SVL and 78.5 ± 17.2 grams in mean mass at outside the Khorat basin, and were 44.8 ± 3.1 cm in mean SVL and 76.3 ± 23.1 grams in mean mass at inside the Khorat basin; $p < 0.05$) but were not significantly different in tail length, neck girth and body girth ($p > 0.05$).

Morphological differences between study sites of *E. plumbea* were also calculated but the comparison was only performed on female snakes because of the low numbers of collected male snakes (three male snakes at Ban Badan, inside the Khorat basin and 6 male snakes at Ban Borthong, outside the Khorat basin). Morphological differences were found significantly in SVL, tail length and neck girth of female snakes between two study sites. The female snakes from Ban Borthong, outside the Khorat basin (mean SVL: 41.9 ± 2.4 cm, mean tail length: 6.0 ± 0.9 cm and mean neck girth: 4.2 ± 0.5 cm) were larger than female snakes from Ban Badan, inside the Khorat basin (mean SVL: 39.6 ± 2.6 cm, mean tail length: 5.2 ± 1.0 cm and mean neck girth: 3.8 ± 0.6 cm; $p < 0.05$), but not found significant differences in body girth and mass were not found ($p > 0.05$).

The morphological characters of another homalopsid snake, *Homalopsis buccata,* were not calculated because of the low number of collected snakes at maturity size. Significant differences in 3 morphological characters; SVL, tail length and neck girth were found only in female snakes between two study sites. The female snakes from Ban Borthong, outside the Khorat basin (mean SVL: 54.7 ± 12.2 cm, mean tail length: 17.4 ± 3.8 cm and mean neck girth: 4.2 ± 0.8 cm) were larger than female snakes from

Ban Badan, inside the Khorat basin (mean SVL: 46.1 ± 9.0 cm, mean tail length: 13.8 ± 2.4 cm and mean neck girth: 3.6 ± 0.5 cm; $p < 0.05$).

For *Xenochrophis flavipunctatus,* only SVL were significantly different between two study sites. Female snakes from Ban Borthong, outside the Khorat basin (mean SVL: 58.6 ± 7.0 cm) were significantly larger than female snakes from Ban Badan, inside the Khorat basin (mean SVL: 56.1 ± 7.8 cm; $p = 0.05$).

Table 4.5 Morphological differences of 3 homalopsid snakes, *Enhydris enhydris, E. plumbea* and *Homalopsis buccata*, and one other snake, *Xenochrophis flavipunctatus*. Data were separated by snake species and sexes and p - value from Man - Whitney U Test were shown.

Species	Sex	Morphological differences (*p* - value)				
		SVL (cm)	Tail length (cm)	Neck girth (cm)	Body girth (cm)	Mass (grams)
Homalopsid snake						
Enhydris enhydris	M	0.00	0.11	0.24	0.25	0.02
	F	0.00	0.00	0.00	0.01	0.00
Enhydris plumbea	M	-	-	-	-	-
	F	0.03	0.01	0.02	0.53	0.43
Homalopsis buccata	M	0.90	0.71	0.38	0.20	0.36
	F	0.04	0.00	0.01	0.13	0.07
Other snake						
Xenochrophis flavipunctatus*	M	0.17	0.78	0.13	0.21	0.07
	F	0.05	0.95	0.98	1.00	0.60

4.3 Diet

Outside the Khorat basin:
Ban Borthong, Kabin Buri District

Two of four species of homalopsid snakes had contents in their stomachs. *Enhydris enhydris* (56 snakes) had the highest number of stomachs with contents and followed by *Homalopsis buccata* (4 snakes). For other species, four snakes of *Xenochrophis flavipunctatus* and one snake of *Cylindrophis ruffus* had an item in their stomachs. However, the diets of two species of homalopsid snakes, *E. plumbea* and *E. bocourti*, and one species of other snakes, *Xenopeltis unicolor*, were not found. Stomach contents data of each species were shown in Table 4.6. The largest prey item in proportion to body mass occurred in *X. flavipunctatus* guts (average proportion of prey mass and body mass 17.51 ± 12.57%, n = 4, ranged from 2.56% to 30.95%) followed by *C. ruffus* (proportion of prey mass and body mass was 6.79%, n = 1), *E. enhydris* (average proportion of prey mass and body mass 5.14 ± 4.76%, n = 56, ranged from 0.70% to 18.18%) and *H. buccata* (average proportion of prey mass and body mass 1.89 ± 0.40%, n = 4, ranged from 1.37% to 1.89%), respectively.

Of the 513 *Enhydris enhydris* collected, diet items were found in the guts of fifty six snakes (10.92%, 35 female snakes and 21 male snakes) , of which fifty snakes (89.29%) contained identifiable items (Table 4.7). *E. enhydris* totally fed on six families of fish. Family Belontiidae (41%) was the dominant group of prey types followed by Family Cyprinidae (34%), Family Anabantidae (9%), Family Channidae (2%), Family Eleotridae (2%) and Family Pristolepidae (2%), respectively. Nevertheless, 10.47% of prey items in snake guts were unidentified but some fin rays were observed. Family Belontiidae composed of *Trichogaster trichopterus*, *T. pectoralis* and *Trichopis vittatus* where as Family Anabantidae was *Anabas testudineus,* Family Channidae was *Channa striata,* Family Eleotridae was *Oxyeleotris marmoratus* and Family Pristolepidae was

Pristolepis fasciatus. However, the fish species in Family Cyprinidae was unidentified. The largest prey item was found in a male snake (18.18% of snake mass) and the smallest prey item was found in a female snake (0.70% of snake mass). A significant difference was found between sexes. The proportion of prey mass to snake mass of male snakes (proportion averaged 8.05 ± 5.52%, n = 21, ranged from 1.23 to 18.18%) was significantly larger ($p < 0.05$) than female snakes (proportion averaged 3.39 ± 3.21%, n = 35, ranged from 0.70 to 17.99%). A significant difference in prey types between male and female snakes was not found.

Four male snakes (14.8%) of thirty seven collected *Homalopsis buccata* had diet items in their guts and all of them were identifiable items. *H. buccata* also fed on fish. Two kinds of prey types were fish in Family Belontiidae (*Trichogaster trichopterus*) and family Cyprinidae (unidentifiable species). They were found in equivalent proportion. The largest and smallest prey items were found in male snakes (2.27% and 1.37% of snake mass).

In addition, diets of four snakes (11.77%, one female snake and 3 male snakes) from thirty four snakes of *Xenochrophis flavipunctatus* were found and all of them were identifiable items. The prey items found in snake guts were fish in Family Cyprinidae and frogs in Family Dicroglossidae and Family Ranidae. The main type of prey items was frogs in Family Dicroglossidae, *Fejervayar limnocharis* (50%) followed by frogs in Family Ranidae, *Hylarana erythrae* (25%) and fish in Family Cyprinidae, unidentifiable species (25%). The largest prey item was found in a male snake (30.95% of snake mass) and the smallest prey item was found in a female snake (2.56% of snake mass). The sexes of *X. flavipunctatus* had no significant differences in prey type and the proportion between prey mass and snake mass ($p > 0.05$). However, only one prey item, *Fejervayar limnocharis* in family Dicroglossidae, was found in a male *Cylindrophis ruffus* gut.

As presented in Figure 4.3, the main prey item of homalopsid snakes at Ban Borthong, outside the Khorat basin, was fish in Family Belontiidae (41.67%) whereas fish in Family Channidae, Eleotridae and Pristolepidae were the lowest proportion (1.67%). Niche breadth of *E. enhydris* at Ban Borthong (outside the Khorat basin) were shown in Table 4.7.

Figure 4.3 Proportion of prey types found in homalopsid snake guts at Ban Borthong, Kabin Buri District (outside the Khorat basin).

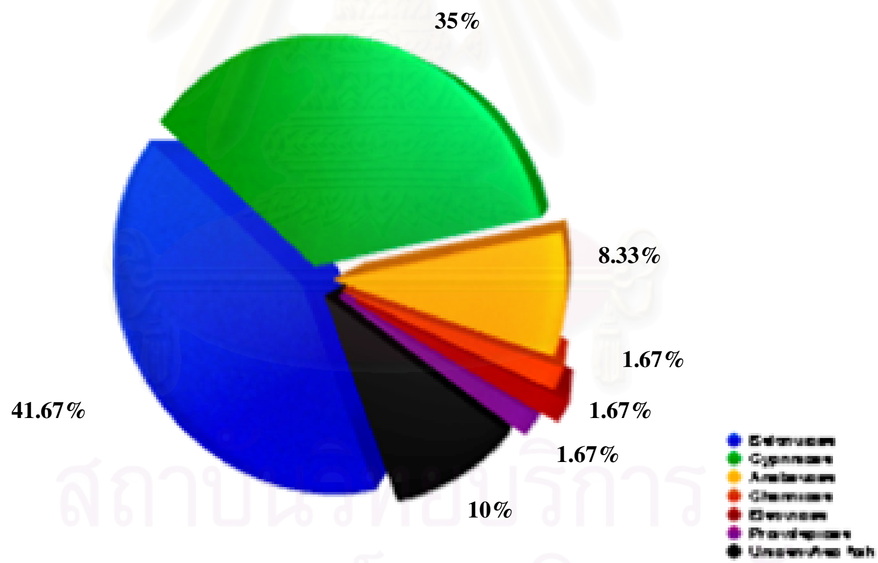


Table 4.6 Diet of homalopsid snakes and other snakes at Ban Borthong, Kabin Buri District (outside the Khorat basin).

SPECIES	SEX	MASS (g)	PREY TYPES	PREY MASS (grams)	% weight
Homalopsid snakes					
Enhydris enhydris	F	146	Anabantidae *(Anabas testudineus)*	4	2.74
Enhydris enhydris	F	166	Anabantidae *(Anabas testudineus)*	4	2.41
Enhydris enhydris	F	243	Anabantidae *(Anabas testudineus)*	5	2.06
Enhydris enhydris	F	127	Belontiidae *(Trichogaster trichopterus)*	4	3.15
Enhydris enhydris	F	133	Belontiidae *(Trichogaster trichopterus)*	5	3.76
Enhydris enhydris	F	146	Belontiidae *(Trichogaster trichopterus)*	11	7.53
Enhydris enhydris	F	157	Belontiidae *(Trichogaster trichopterus)*	5	3.18
Enhydris enhydris	F	170	Belontiidae *(Trichogaster trichopterus)*	12	7.06
Enhydris enhydris	F	175	Belontiidae *(Trichogaster trichopterus)*	2	1.14
Enhydris enhydris	F	175	Belontiidae *(Trichogaster trichopterus)*	5	2.86
Enhydris enhydris	F	176	Belontiidae *(Trichogaster trichopterus)*	3	1.70
Enhydris enhydris	F	185	Belontiidae *(Trichogaster trichopterus)*	10	5.41
Enhydris enhydris	F	242	Belontiidae *(Trichogaster trichopterus)*	2	0.83
Enhydris enhydris	F	97	Belontiidae *(Trichogaster pectoralis)*	2	2.06
Enhydris enhydris	F	121	Belontiidae *(Trichogaster pectoralis)*	4	3.31
Enhydris enhydris	F	139	Channidae *(Channa striata)*	25	17.99
Enhydris enhydris	F	87	Cyprinidae	4	4.60
Enhydris enhydris	F	98	Cyprinidae	2	2.04
Enhydris enhydris	F	106	Cyprinidae	3	2.83
Enhydris enhydris	F	107	Cyprinidae	1	0.93
Enhydris enhydris	F	123	Cyprinidae	1	0.81
Enhydris enhydris	F	130	Cyprinidae	9	6.92
Enhydris enhydris	F	131	Cyprinidae	5	3.82
Enhydris enhydris	F	139	Cyprinidae	1	0.72
Enhydris enhydris	F	142	Cyprinidae	1	0.70
Enhydris enhydris	F	245	Cyprinidae	5	2.04
Enhydris enhydris	F	275	Cyprinidae	7	2.55
Enhydris enhydris	F	278	Cyprinidae	5	1.80
Enhydris enhydris	F	282	Cyprinidae	11	3.90
Enhydris enhydris	F	64	Unknown fish	1	1.56
Enhydris enhydris	F	107	Unknown fish	1	0.93
Enhydris enhydris	F	120	Unknown fish	4	3.33
Enhydris enhydris	F	172	Unknown fish	3	1.74
Enhydris enhydris	F	250	Eleotridae (*Oxyeleotris marmoratus*)	20	8.00
Enhydris enhydris	F	175	Pristolepidae *(Pristolepis fasciatus)*	4	2.29
Enhydris enhydris	M	75	Anabantidae *(Anabas testudineus)*	11	14.67
Enhydris enhydris	M	89	Anabantidae *(Anabas testudineus)*	16	17.98
Enhydris enhydris	M	90	Belontiidae *(Trichogaster trichopterus)*	8	8.89
Enhydris enhydris	M	98	Belontiidae *(Trichogaster trichopterus)*	5	5.10
Enhydris enhydris	M	52	Belontiidae *(Trichopis vittatus)*	2	3.85
Enhydris enhydris	M	70	Belontiidae *(Trichopis vittatus)*	4	5.71
Enhydris enhydris	M	72	Belontiidae *(Trichopis vittatus)*	3	4.17
Enhydris enhydris	M	77	Belontiidae *(Trichopis vittatus)*	1	1.30
Enhydris enhydris	M	44	Belontiidae *(Trichogaster pectoralis)*	8	18.18
Enhydris enhydris	M	70	Belontiidae *(Trichogaster pectoralis)*	5	7.14
Enhydris enhydris	M	73	Belontiidae *(Trichogaster pectoralis)*	5	6.85
Enhydris enhydris	M	93	Belontiidae *(Trichogaster pectoralis)*	12	12.90
Enhydris enhydris	M	95	Belontiidae *(Trichogaster pectoralis)*	14	14.74
Enhydris enhydris	M	69	Cyprinidae	4	5.80
Enhydris enhydris	M	75	Cyprinidae	12	16.00
Enhydris enhydris	M	76	Cyprinidae	2	2.63
Enhydris enhydris	M	91	Cyprinidae	6	6.59
Enhydris enhydris	M	94	Cyprinidae	4	4.26
Enhydris enhydris	M	109	Cyprinidae	10	9.17
Enhydris enhydris	M	54	Unknown fish	1	1.85
Enhydris enhydris	M	81	Unknown fish	1	1.23
Homalopsis buccata	M	94	Belontiidae *(Trichogaster trichopterus)*	2	2.13
Homalopsis buccata	M	282	Belontiidae *(Trichogaster trichopterus)*	5	1.77
Homalopsis buccata	M	73	Cyprinidae	1	1.37
Homalopsis buccata	M	132	Cyprinidae	3	2.27
Other snakes					
Xenochrophis flavipunctatus	F	39	Cyprinidae	1	2.56
Xenochrophis flavipunctatus	M	121	Dicroglossidae *(Fejervayar limnocharis)*	15	12.40
Xenochrophis flavipunctatus	M	42	Ranidae *(Hylarana erythrae)*	13	30.95
Xenochrophis flavipunctatus	M	58	Ranidae *(Hylarana erythrae)*	14	24.14
Cylindrophis ruffus	M	201	Dicroglossidae *(Fejervayar limnocharis)*	14	6.97

Table 4.7 Proportion of prey types, niche breadth and niche overlap of *Enhydris enhydris* at Ban Borthong, Kabin Buri District (outside the Khorat basin).

Family of prey types	*Enhydris enhydris*	
	Number	%
Belontiidae	23	41.07
Cyprinidae	19	33.93
Anabantidae	5	8.93
Channidae	1	1.79
Eleotridae	1	1.79
Pristolepidae	1	1.79
Unidentified fish	6	10.71
Total	56	100
Niche breadth	1.5	

Inside the Khorat basin:
Ban Badan, Wang Nam Kheaw District

In this study site, stomach contents were found in 4 species of homalopsid snakes; *Enhydris enhydris, E. plumbea, E, subtaeniata* and *Homalopsis buccata.* The highest number of stomachs containing food was *E. enhydris* (19 specimens) followed by *E. subtaeniata* (12 specimens) *, H. buccata* (6 specimens) and *E. plumbea* (4 specimens), respectively. Other snakes, *Xenochrophis flavipunctatus* and *Xenopeltis unicolor,* prey items were found in their stomachs. Only *Cylindrophis ruffus* lacked prey items in their stomachs in this study period. Stomach contents of each species were shown in Table 4.8. The largest prey items were found in *Xenopeltis unicolor* guts (proportion averaged 21.39 ± 19.21%, n = 2, ranged from 7.81% to 34.97%) followed by *E. plumbea* (proportion averaged 16.43 ± 10.57%, n = 4, ranged from 9.09% to 31.91%), *Xenochrophis unicolor* (proportion averaged 9.79 ± 7.55%, n = 10, ranged from 2.69% to 29.20%), *H. buccata* (proportion averaged 5.13 ± 4.03%, n = 6, ranged from 1.95% to 9.52%), *E. enhydris* (proportion averaged 2.77 ± 2.52%, n = 19, ranged from 0.47% to 8.70%) and *E. subtaeniata* (proportion averaged 2.47 ± 2.62%, n = 12, ranged from 0.61% to 7.69%), respectively.

From Table 4.9, diets of nineteen snakes (12.03%, 12 female snakes and 7 male snakes) of collected *Enhydris enhydris* were found, of which 15 snake (78.95%) contained identifiable items. Identifiable items were fish in 4 families composed of Family Belontiidae (*Trichopis vittatus*), Family Channidae (*Channa striata*), Family Bagridae (*Mystus mysticetus*) and Family Cyprinidae (unidentified species). However, 21.05% of prey items in snake guts were unidentified fish. The dominant prey item was fish in Family Cyprinidae (63.16%). The largest prey item was found in male snakes (8.70% of snake mass) whereas the smallest prey item was found in female snakes (0.47% of snake mass). Both sexes of *E. enhydris* had no significant differences in prey type or the proportion between prey mass and snake mass ($p > 0.05$).

Of twenty three collected *E. plumbea*, four female snakes (17.39%) contained stomach contents. Two kinds of prey items were found in their guts in the equivalent proportion. One kind were fish in 2 families, Symbranchidae (*Monopterus albus*) and Cyprinidae (unidentified species), and another one was frog in Family Microhylidae (*Kaloula pulchra*). The largest and smallest prey items were 31.19% and 9.09% of snake mass, respectively.

Six snakes (15.38%, 4 female snakes and 2 male snakes) of *H. buccata* had contents in their guts and 5 snakes (83.33%) contained identifiable items. All prey items were fish in 3 families composing of Family Cyprinidae, Family Belontiidae and Family Anabantidae. Family Cyprinidae (50%) was the dominant prey type followed by Family Belontiidae (16.67%) and Family Anabantidae (16.67%) and 16.67% of prey items were unidentified fish. Both of the largest and smallest prey items were found in male snakes (9.52% and 1.25% of snake mass, respectively). Significant differences of prey types and proportion of prey mass and snake mass were not found between male and female snakes ($p > 0.05$).

Twelve *E. subtaeniata* (21.05%, 9 female snakes and 3 male snakes) had food in their guts, of which 11 snakes (91.67%) contained identifiable items. Prey items were fish in 2 families composed of Family Cyprinidae and Family Belontiidae. The dominant prey type was fish in Family Cyprinidae (75%, unidentified species) followed by Family Belontiidae (16.67%, *Trichopis vittatus*). However, 8.33% of prey items were unidentified fish. Significant differences were found between sexes. Prey types were significantly different between female and male snakes ($p < 0.05$). Female snakes only fed fish in Family Belontiidae whereas male snakes fed only fish in Family Cyprinidae. The largest prey item was found in a male snake (7.69% of snake mass) whereas the smallest prey item was found in a female snake (0.61% of snake mass). Significant differences between sexes were also found in proportion of prey mass and snakes mass. Proportions of prey mass and snake mass of male snakes (proportion averaged 5.97 ± 2.52%, n = 3, ranged from 3.08% to 7.69%) were significantly larger than female snakes (proportion averaged 1.31 ± 1.30%, n = 9, ranged from 0.61% to 4.76%, $p < 0.05$).

In addition, ten *Xenochrophis flavipunctatus* (21.28%, 5 female snakes and 5 male snakes) had stomach contents in their guts. Prey types were 3 families of fish composed of Family Anabantidae (*Anabas testudineus*), Family Channidae (*Channa striata*) and Family Mastacembelidae (*Macrognathus siamensis*), and 2 families of frogs consisting of Family Ranidae (*Hylarana erythrae*) and Family Dicroglossidae (*Fejervayar limnocharis* and *Hoplobatrachus chinensis*). The dominant prey type was Family Dicroglossidae (30%) followed by Family Ranidae (30%), Family Mastacembelidae

(20%), Family Anabantidae (10%) and Family Channidae (10%). Both of the largest and smallest prey items were found in female snakes (29.20% and 2.62% of snake mass, respectively). Both sexes of *X. flavipunctatus* had no significant differences in prey types and the proportion between prey mass and snake mass ($p > 0.05$).

Two *Xenopeltis unicolor* (23.08%, one female snake and one male snake) had stomach contents in their guts. Two types of prey items were identified. One prey item was a snake in Family Homalopsidae (*Enhydris subtaeniata*) which was found in a female snake gut and another prey item was a mouse in Family Muridae (*Mus* sp.) in a male snake gut. The largest prey item was found in female snake (34.97% of snake mass) whereas the smallest prey item was found in male snake (7.81% of snake mass). Both sexes of *X. unicolor* were significantly different in prey types and the proportion of prey mass and snake mass ($p < 0.05$).

From Figure 4.4, the main prey item of homalopsid snakes at Ban Badan, inside the Khorat basin was fish in Family Cyprinidae (60.98%) followed by Family Belontiidae (9.76%) and Family Anabantidae (4.88%) whereas Family Bagridae (2.44%), Family Channidae (2.44%), Family Symbranchidae (2.44%) and frog in Family Microhylidae (2.44%) were the lowest proportion of prey types. Niche breadth of homalopsid snakes at Ban Badan (inside the Khorat basin) is shown in Table 4.9. Niche breadth of *E. plumbea* was highest (H' = 1.64), followed by *H. buccata* (H' = 1.12), *E. enhydris* (H' = 0.85) and *E. subtaeniata* (H' = 0.56), respectively. The highest niche overlap occurred between *E. enhydris* and *E. subtaeniata* (C' = 0.98) whereas the lowest niche overlap occurred between *E. plumbea* and *E. subtaeniata* (C' = 0.43). Niche overlap of homalopsid snakes at Ban Badan (inside the Khorat basin) is presented in Table 4.10.

Table 4.8. Diets of homalopsid snakes and other snakes at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin).

SPECIES	SEX	MASS (g)	PREY TYPES	PREY MASS (grams)	% weight
Homalopsid snakes					
E. enhydris	F	83	Bagridae (*Mystus mysticetus*)	6	7.23
E. enhydris	F	92	Channidae (*Channa striata*)	2	2.17
E. enhydris	F	69	Cyprinidae	2	2.90
E. enhydris	F	120	Cyprinidae	2	1.67
E. enhydris	F	135	Cyprinidae	4	2.96
E. enhydris	F	201	Cyprinidae	6	2.99
E. enhydris	F	201	Cyprinidae	3	1.49
E. enhydris	F	138	Cyprinidae	1	0.72
E. enhydris	F	184	Cyprinidae	1	0.54
E. enhydris	F	215	Cyprinidae	1	0.47
E. enhydris	F	60	Unidentified fish	1	1.67
E. enhydris	F	119	Unidentified fish	1	0.84
E. enhydris	M	76	Belontiidae (*Trichopis vittatus*)	6	7.89
E. enhydris	M	54	Cyprinidae	1	1.85
E. enhydris	M	69	Cyprinidae	6	8.70
E. enhydris	M	71	Cyprinidae	1	1.41
E. enhydris	M	93	Cyprinidae	4	4.30
E. enhydris	M	67	Unidentified fish	1	1.49
E. enhydris	M	77	Unidentified fish	1	1.30
E. plumbea	F	58	Anabantidae (*Anabas testudineus*)	6	10.34
E. plumbea	F	55	Cyprinidae	5	9.09
E. plumbea	F	94	Microhylidae (*Kaloula pulchra*)	30	31.91
E. plumbea	F	153	Symbranchidae (*Monopterus albus*)	22	14.38
E. subtaeniata	F	84	Cyprinidae	4	4.76
E. subtaeniata	F	191	Cyprinidae	2	1.05
E. subtaeniata	F	92	Cyprinidae	1	1.09
E. subtaeniata	F	106	Cyprinidae	1	0.94
E. subtaeniata	F	108	Cyprinidae	1	0.93
E. subtaeniata	F	117	Cyprinidae	1	0.85
E. subtaeniata	F	119	Cyprinidae	1	0.84
E. subtaeniata	F	144	Cyprinidae	1	0.69
E. subtaeniata	F	163	Cyprinidae	1	0.61
E. subtaeniata	M	65	Belontiidae (*Trichopis vittatus*)	2	3.08
E. subtaeniata	M	70	Belontiidae (*Trichopis vittatus*)	5	7.14
E. subtaeniata	M	65	Unidentified fish	5	7.69
H. buccata	F	65	Anabantidae (*Anabas testudineus*)	6	9.23
H. buccata	F	63	Belontiidae (*Trichopis vittatus*)	1	1.59
H. buccata	F	40	Cyprinidae	3	7.50
H. buccata	F	117	Cyprinidae	2	1.71
H. buccata	M	21	Cyprinidae	2	9.52
H. buccata	M	240	Unidentified fish	3	1.25
Other snakes					
X. flavipunctatus	F	111	Anabantidae (Anabas testudineus)	5	4.50
X. flavipunctatus	F	381	Dicroglossidae (*Hoplobatrachus chinensis*)	10	2.62
X. flavipunctatus	F	137	Mastacembelidae (*Macrognathus siamensis)*	40	29.20
X. flavipunctatus	F	281	Mastacembelidae (*Macrognathus siamensis)*	15	5.34
X. flavipunctatus	F	112	Ranidae *(Hylarana erythrae)*	11	9.82
X. flavipunctatus	M	94	Channidae (*Channa striata*)	8	8.51
X. flavipunctatus	M	122	Dicroglossidae (*Fejervayar limnocharis*)	12	9.84
X. flavipunctatus	M	150	Dicroglossidae (*Hoplobatrachus chinensis*)	13	8.67
X. flavipunctatus	M	72	Ranidae *(Hylarana erythrae)*	10	13.89
X. flavipunctatus	M	145	Ranidae *(Hylarana erythrae)*	8	5.52
X. unicolor	F	386	*Enhydris subtaeniata*	135	34.97
X. unicolor	M	256	Muridae (*Mus* sp.)	20	7.81

Figure 4.4. Proportion of prey types found in homalopsid snake guts at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin).

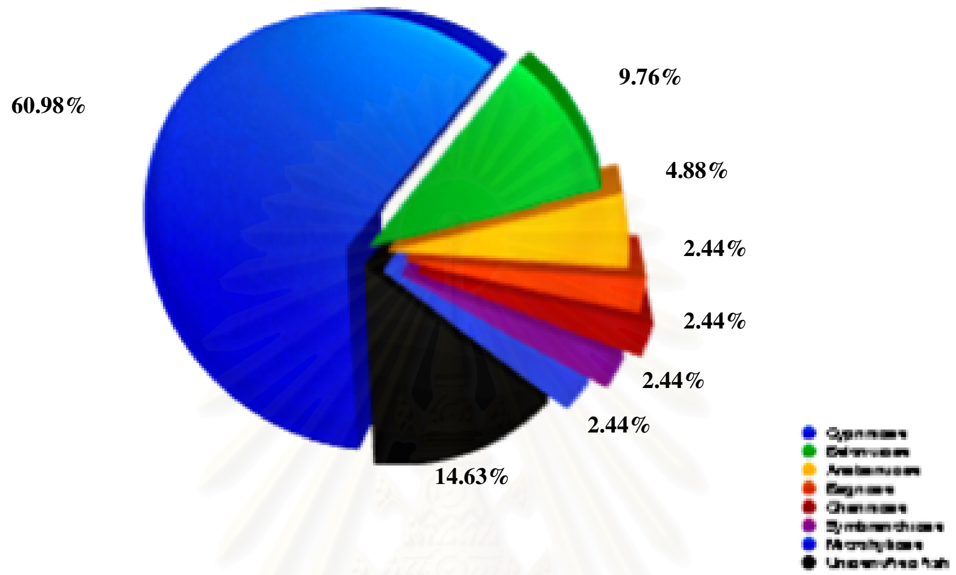


Table 4.9. Proportion of prey types and niche breadth of homalopsid snakes at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin).

Prey types	*Enhydris enhydris* Number	*Enhydris enhydris* %	*Enhydris plumbea* Number	*Enhydris plumbea* %	*Enhydris subtaeniata* Number	*Enhydris subtaeniata* %	*Homalopsis buccata* Number	*Homalopsis buccata* %	Total
Cyprinidae	12	63.16	1	25.00	9	75.00	3	50.00	25
Belontiidae	1	5.26	0	0	2	16.67	1	16.67	4
Anabantidae	0	0	1	25.00	0	0	1	16.67	2
Bagridae	1	5.26	0	0	0	0	0	0	1
Channidae	1	5.26	0	0	0	0	0	0	1
Symbranchidae	0	0	1	25.00	0	0	0	0	1
Microhylidae	0	0	1	25.00	0	0	0	0	1
Unidentified fish	4	21.05	0	0	1	8.33	1	16.67	6
Total	19		4		12		6		41
Niche breadth	0.85		1.64		0.56		1.12		

Table 4.10. Food overlap matrix between four species of homalopsid snakes according to the Simplified Morisita Index (Krebs, 1989) at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin).

	E. enhydris	***E. plumbea***	***E. subtaeniata***	***H. buccata***
E. enhydris	1.00			
E. plumbea	0.44	1.00		
E. subtaeniata	0.98	0.43	1.00	
H. buccata	0.90	0.58	0.92	1.00

Comparison between study sites

Comparison of diets of homalopsid snakes between Ban Borthong, Kabin Buri District (outside the Khorat basin) and Ban Badan, Wang Nam Kheaw (inside the Khorat basin) were performed in 2 species, *Enhydris enhydris* and *Homalopsis buccata*. Because of a lack of stomach contents in male snake guts at Ban Borthong (outside the Khorat basin), comparison was performed only on female snakes of *H. buccata*. Other homalopsid snakes were not considered because of a lack of stomach contents in *E. plumbea guts* at Ban Borthong (outside the Khorat basin) and the appearance of a few snakes in each study site. Besides, *E. subtaeniata* were found only at Ban Badan (inside the Khorat basin) and *E. bocourti* were found only at Ban Borthong (outside the Khorat basin).

A significant difference in proportion between prey mass and snake mass between male and female snakes of *Enhydris enhydris* from two study sites, Ban Borthong (outside the Khorat basin) and Ban Badan (Inside the Khorat basin) was not found. Prey types were not completely overlapping between study sites (niche overlap, *C'* = 0.66). Significant differences in prey types were found between female snakes from these two study sites ($p < 0.05$) but not found in male snakes between these two study sites ($p > 0.05$). Female snakes at Ban Borthong fed primarily on fish in Family Belontiidae whereas female snakes from Ban Badan fed primarily on fish in Family Cyprinidae. Moreover, Niche breadth of *E. enhydris* at Ban Borthong, outside the Khorat basin ($H' = 1.5$) was higher than *E. enhydris* at Ban Badan, inside the Khorat basin ($H' = 0.85$).

Female snakes of *Homalopsis buccata* from Ban Borthong (outside the Khorat basin) and Ban Badan (inside the Khorat basin) had no significant differences in prey types and proportion between prey mass and snake mass ($p > 0.05$). Prey items of *H. buccata* females from both study sites were quite similar (niche overlap, $C' = 0.85$).

4.4 Reproduction of female snakes

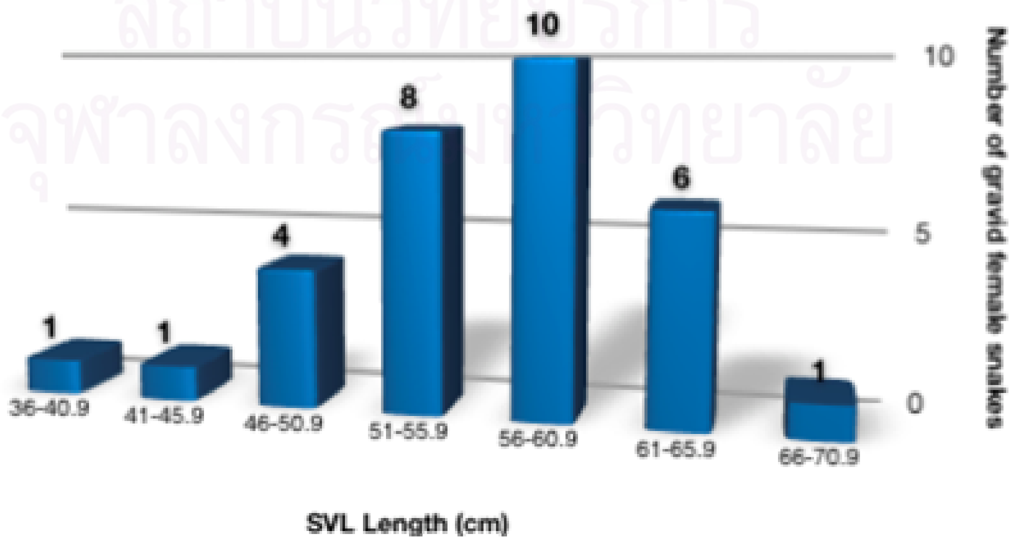
4.4.1 Reproductive biology

Outside the Khorat basin:
Ban Borthong, Kabin Buri District

Gravid female snakes of *Enhydris enhydris, E. plumbea* and *Homalopsis buccata* were collected at this study site. Thirty one gravid females of *E. enhydris* was the highest number followed by 3 *H. buccata*, 2 *E. plumbea* and 2 *E. bocourti*. Only gravid female snakes of *E. enhydris* were used for the reproductive biology study because of the highest number mentioned above. Nevertheless, gravid female snakes of other species, *Xenochrophis flavipunctatus, Xenopeltis unicolor* and *Cylindrophis ruffus* were not found in this site during study period.

From two hundred and eighty two collected female snakes, thirty one (11.0%) were gravid females (Figure 4.5). Mean SVL of gravid females was 55.9 ± 5.9 cm (ranged from 36.0 to 66.0 cm), mean tail length was 11.8 ± 1.1 cm (ranged from 7.8 to 13.5 cm), mean neck girth was 3.1 ± 0.4 cm (ranged from 2.1 to 4.0 cm), mean body girth was 6.5 ± 1.1 cm (ranged from 3.6 to 8.7 cm) and mean mass was 132.2 ± 36.8 grams (ranged from 61 to 223 grams).

Figure 4.5. The number of gravid females *E. enhydris* captured at Ban Borthong, Kabinburi District (outside the Khorat basin), separated by SVL class size.



In ovaries of female *E. enhydris*, the number of follicles (small follicles and oocytes, follicles with yolk in ovary) was 17 ± 6 follicles. Average size of small follicles was 0.3 ± 0.1 cm (ranged from 0.1 to 0.7 cm in length).

In oviduct, the average clutch size was 13 ± 5 embryos (n = 31), of which the smallest clutch size was 6 embryos whereas the largest clutch size was 25 embryos. The average clutch mass was 32.6 ± 17.9 grams (n = 31), of which the smallest clutch mass was 10 grams whereas the largest clutch mass was 82 grams. The mean relative clutch mass (RCM) of this species was 0.3 ± 0.2 (ranged from 0.4 to 1.3, n = 31). Significant relationship between female mass and clutch size (Figure 4.6: r = 0.500, p = 0.005), and between female fat body and clutch mass were found (Figure 4.7: r = 0.458, p = 0.011).

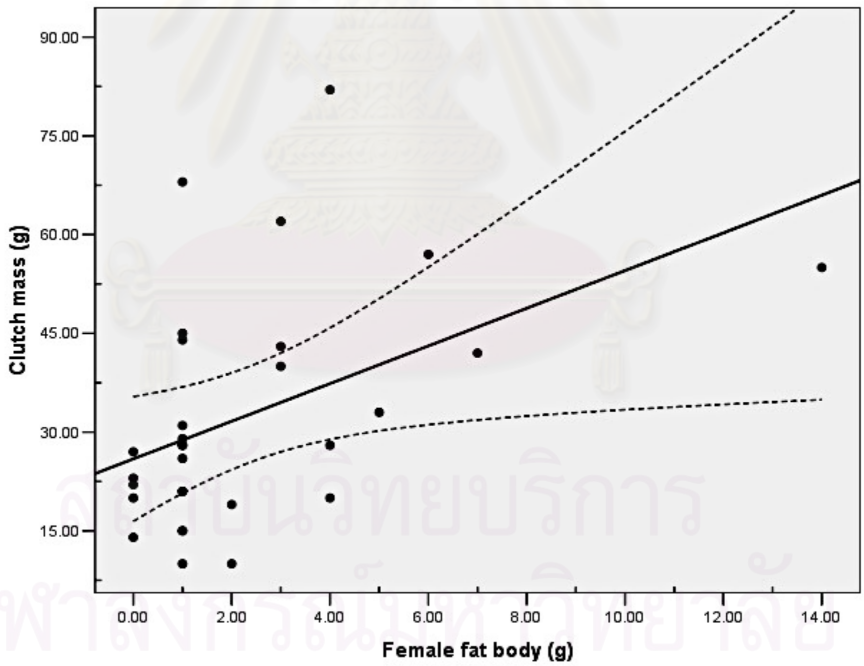
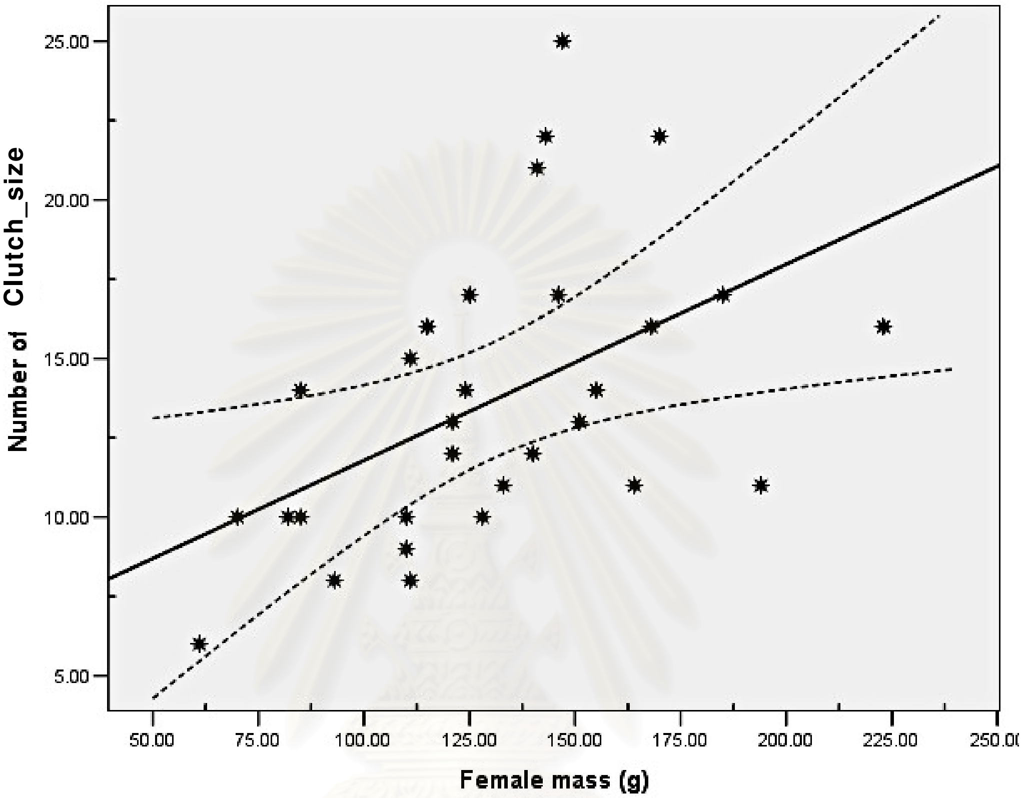


Figure 4.6. Regression and 95% confidence limits of female fat body of 31 females *E. enhydris* from Ban Borthong, Kabinburi District (outside the Khorat basin) versus the clutch mass. The correlation is significant (r = 0.458, p = 0.011). The mean clutch mass was 32.6 ± 17.9 grams.

Figure 4.7. Regression and 95% confidence limits of female mass of 31 females *E. enhydris* from Ban Borthong, Kabinburi District (outside the Khorat basin) versus the clutch size. The correlation is significant (r = 0.500, p = 0.005). The mean clutch size was 13 ± 5 embryos.



Ninety five full-term embryos (stage 37th) which were removed from dead gravid females of *E. enhydris*, had 15.6 ± 0.5 cm in mean SVL (ranged from 14.7 cm to 16.8 cm), 3.9 ± 0.3 cm in mean TL (ranged from 3.4 cm to 4.6 cm) and 3.1 ± 0.3 grams in mean mass (ranged from 2 grams to 4 grams).

In addition, gravid females of *E. plumbea* (2 specimens), *H. buccata* (3 specimens) and *E. bocourti* (2 specimens) were also collected at this study site. The two gravid females of *E. plumbea* were 41.9 ± 26.9 cm in mean SVL (ranged from 40.0 cm to 43.8 cm), 4.8 ± 1.8 cm in mean TL (ranged from 3.5 cm to 6.3 cm) and 111.5 ± 7.8 grams in mean mass (ranged from 106 grams to 117 grams). The mean clutch size and the mean clutch mass of this species was 17 ± 1 embryos (ranged from 16 embryos to

18 embryos) and 14.5 ± 5.0 grams (ranged from 11 grams to 18 grams), respectively. The mean RCM was 0.1 ± 0.1 (ranged from 0.1 to 0.2). The three gravid female of *H. buccata* were 71.8 ± 3.3 cm in mean SVL (ranged from 68.4 cm to 75.0 cm), 23.6 ± 1.7 cm in mean TL (ranged from 22.0 cm to 25.3 cm) and 322.7 ± 100.1 grams in mean mass (ranged from 306 grams to 430 grams). The mean clutch size and the mean clutch mass of this species were 9 ± 2 embryos (ranged from 8 embryos to 11 embryos) and 74.7 ± 9.1 grams (ranged from 65 grams to 83 grams), respectively. The mean RCM was 0.3 ± 0.1 (ranged from 0.2 to 0.4). The two gravid female *E. bocourti* were 75.3 ± 2.2 cm in mean SVL (ranged from 73.8 cm to 76.9 cm), 10.3 ± 0.3 cm in mean TL (ranged from 10.1 cm to 10.5 cm) and 510.0 ± 190.9 grams in mean mass (ranged from 375 grams to 645 grams). The mean clutch size and the mean clutch mass of this species were 6 ± 3 embryos (ranged from 4 embryos to 8 embryos) and 125.0 ± 67.9 grams (ranged from 77 grams to 173 grams), respectively. The mean RCM was 0.3 ± 0.2 (ranged from 0.1 to 0.5).

Inside the Khorat basin:
Ban Badan, Wang Nam Kheaw District

Three species of gravid female homalopsids were found at this study site. Fifteen gravid females of *Enhydris subtaeniata* were the highest followed by twelve gravid females of *E. enhydris* and four gravid females of *E. plumbea*. In addition, three gravid females of another semi-aquatic snake, *Xenochrophis flavipunctatus* were also collected. According to the number of gravid female snakes, *E. subtaeniata* and *E. enhydris* were considered for the reproduction study. Nevertheless, gravid females of *Homalopsis buccata*, *Xenopeltis unicolor* and *Cylindrophis ruffus* were not found in this study site during the study period.

Fifteen from thirty two female snakes (46.9%) of *E. subtaeniata* were gravid females (Figure 4.8). Mean SVL of these snakes was 46.9 ± 5.2 cm (ranged from 39.5 cm to 57.5 cm), mean tail length was 8.9 ± 1.6 cm (ranged from 7.0 cm to 13.8 cm), mean neck girth was 3.2 ± 0.3 cm (ranged from 2.5 cm to 3.6 cm), mean body girth was 7.0 ± 0.7 cm (ranged from 6.0 cm to 8.3 cm) and mean mass was 144.7 ± 46.4 grams (ranged from 57 grams to 235 grams). For *E. enhydris,* twelve female snakes (16.7%) from seventy six female were gravid females (Figure 4.8). Mean SVL of gravid female snakes was 50.2 ± 8.9 cm (ranged from 31.4 cm to 62.0 cm), mean tail length was 11.5 ± 1.3 cm (ranged from 9.8 cm to 13.6 cm), mean neck girth was 2.7 ± 0.4 cm (ranged from 2.1 cm to 3.3 cm), mean body girth was 6.4 ± 1.3 cm (ranged from 4.7 cm to 9.8 cm) and mean mass was 133.4 ± 46.4 grams (ranged from 67 grams to 215 grams).

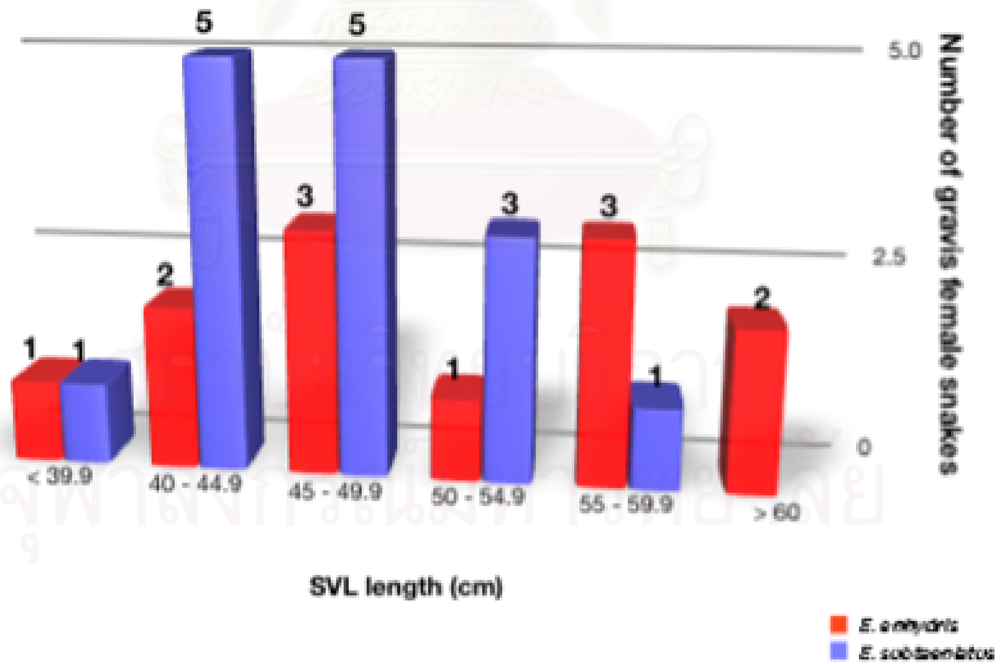


Figure 4.8. The number of gravid females of *E. enhydris* and *E. subtaeniata* captured at Ban Borthong, Kabinburi District (outside the Khorat basin), separated by SVL class size.

In ovaries of *E. enhydris* females, the mean number of follicles was 19 ± 10 follicles (ranged from 2 follicles to 34 follicles) and the average size of follicles was 0.3 ± 0.2 cm (ranged from 0.1 cm to 0.8 cm) in length. In the oviducts, the average clutch size was 11 ± 4 embryos (n = 11), of which the smallest clutch size was 8 embryos whereas the largest clutch size was 20 embryos. The average clutch mass was 33.9 ± 14.8 grams (n = 11), of which the smallest clutch mass was 19 grams whereas the largest clutch mass was 72 grams. The mean relative clutch mass of this species was 0.4 ± 0.3 (ranged from 0.2 to 1.4, n = 11). Significant relationships between female SVL and clutch size (Figure 4.9: r = 0.404, p = 0.005), and between female mass and relative clutch mass (Figure 4.10: r = -0.662, p = 0.026) of *E.* enhydris were found.

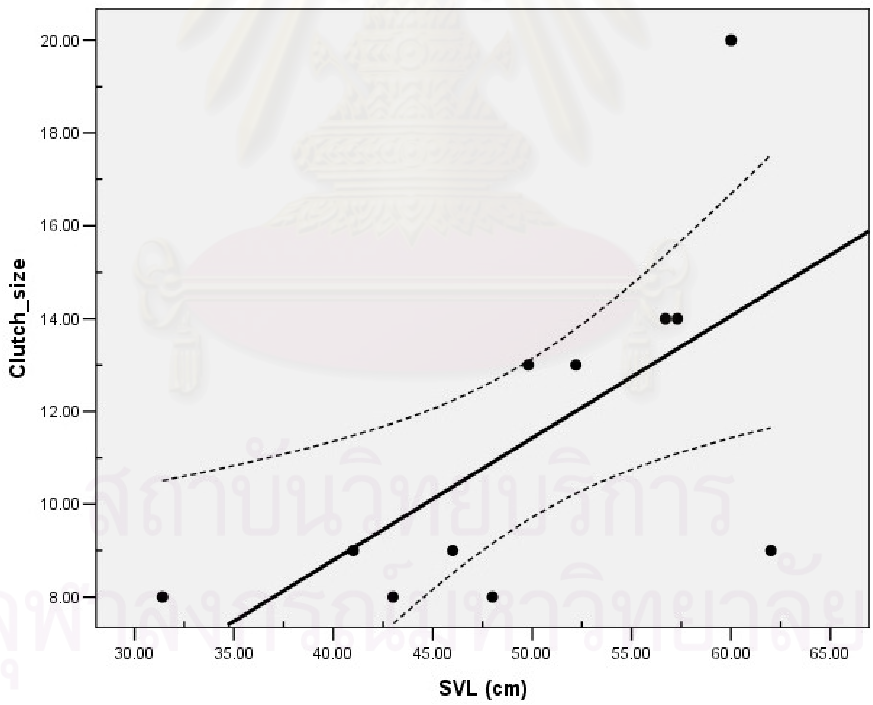


Figure 4.9. Regression and 95% confidence limits of female SVL of 11 *E. enhydris* from Ban Badan, Wang Nam Kheaw District (inside the Khorat basin) versus the clutch size. The correlation is significant (r = 0.404, p = 0.005). The mean clutch size was 11 ± 4 embryos.

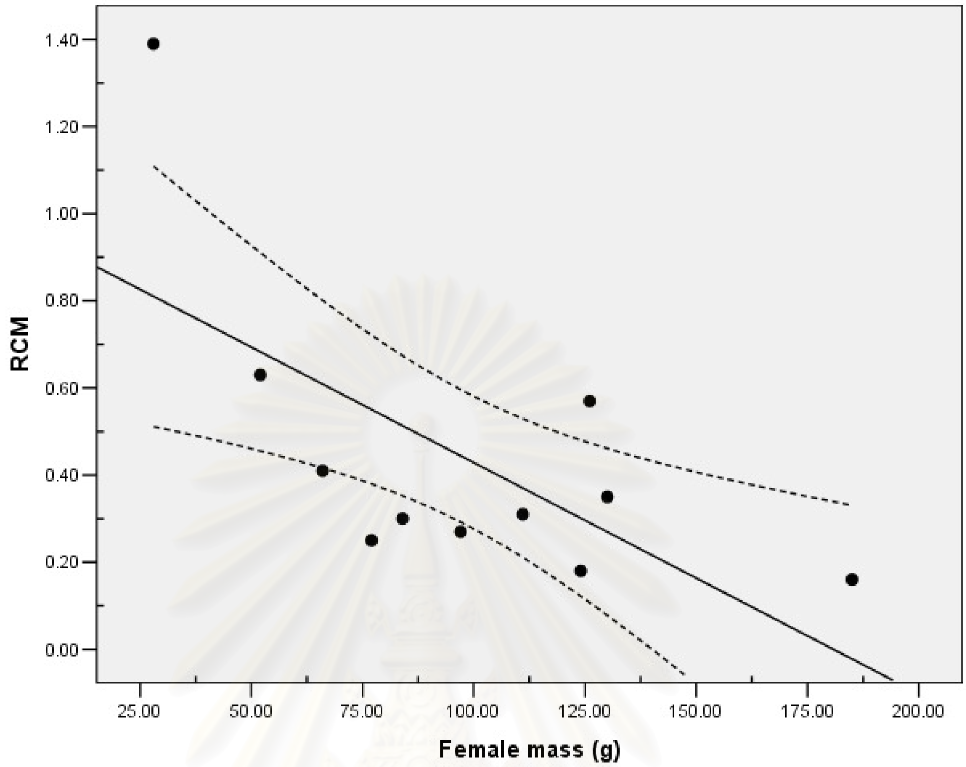


Figure 4.10. Regression and 95% confidence limits of female mass of 11 *E. enhydris* from Ban Badan, Wang Nam Kheaw District (inside the Khorat basin) versus relative clutch mass. The correlation is significant (r = -0.662, p = 0.026). The mean relative clutch mass was 0.4 ± 0.3.

For *E. subtaeniata* females, the number of follicles in ovaries was 21 ± 10 follicles (ranged from 11 follicles to 42 follicles) and the average size of follicles was 0.3 ± 0.1 cm (ranged from 0.1 cm to 0.5 cm) in length. In oviducts, the average clutch size was 12 ± 6 embryos (n = 13), of which the smallest clutch size was 7 embryos whereas the largest clutch size was 29 embryos. The average clutch mass was 22.2 ± 7.0 grams (n = 13), of which the smallest clutch mass was 15 grams whereas the largest clutch mass was 36 grams. The mean relative clutch mass of this species was 0.2 ± 0.1 (ranged from 0.1 to 0.8, n = 13). Significant relationships between female mass and clutch size (Figure 4.11: r = 0.635, p = 0.020), and between female mass and relative clutch mass (Figure 4.12: r = -0.665, p = 0.013) of *E. subtaeniata* were found.

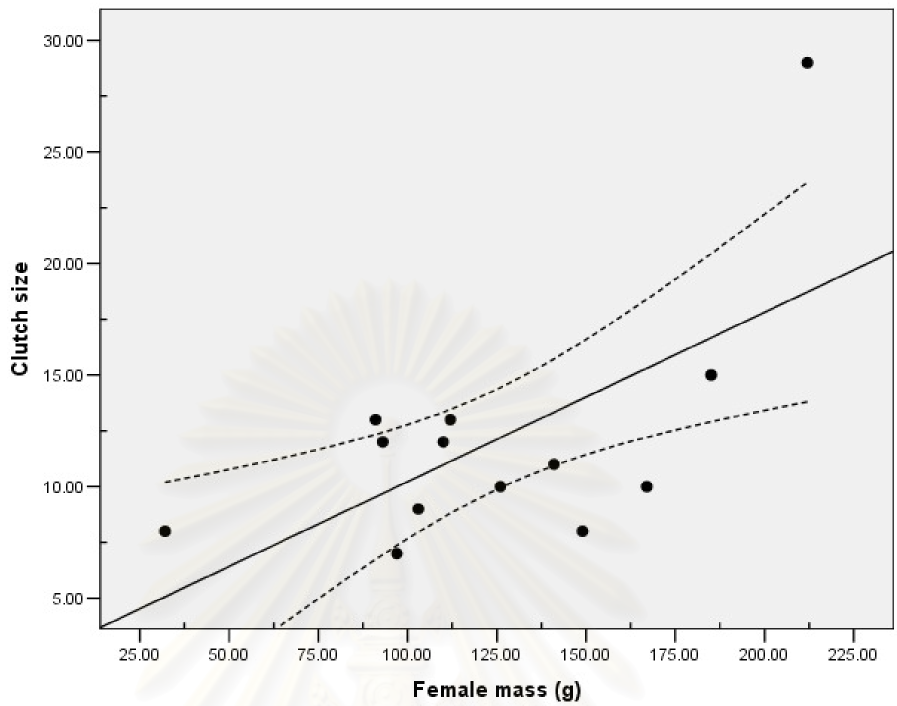


Figure 4.11. Regression and 95% confidence limits of female mass of 13 *E. subtaeniata* from Ban Badan, Wang Nam Kheaw District (inside the Khorat basin) versus clutch size. The correlation is significant (r = 0.635, p = 0.020). The mean clutch size was 12 ± 6 embryos.

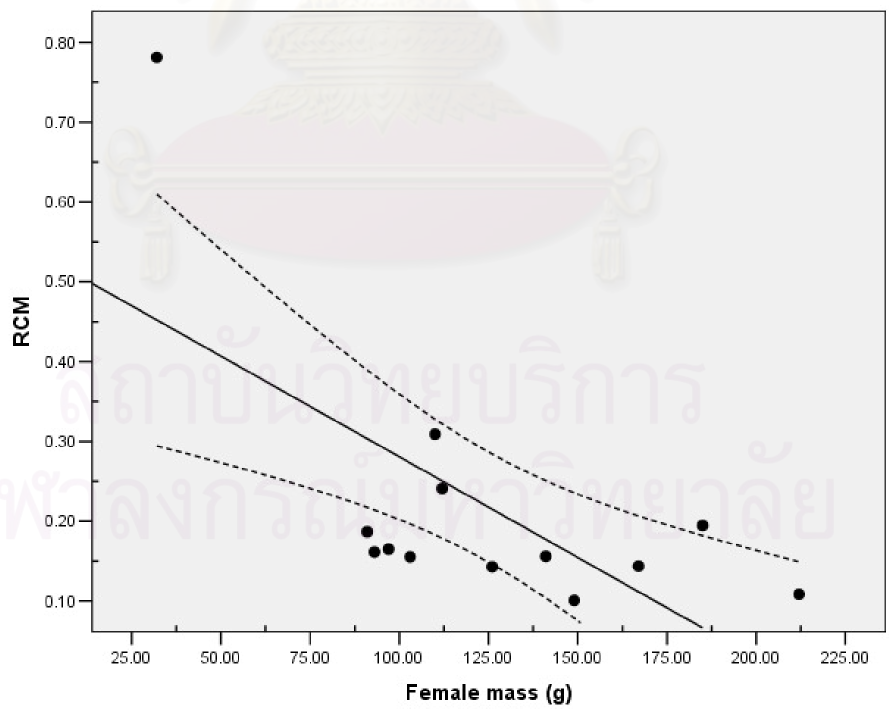


Figure 4.12. Regression and 95% confidence limits of female mass of 13 *E. subtaeniata* from Ban Badan, Wang Nam Kheaw District (inside the Khorat basin) versus the relative clutch mass. The correlation is significant (r = -0.665, p = 0.013). The mean relative clutch mass was 0.2 ± 0.1.

In addition, gravid females of *E. plumbea* (4 specimens) were also collected. This species had 39.0 ± 1.5 cm in mean SVL (ranged from 37.0 cm to 40.4 cm), 4.7 ± 1.3 cm in mean tail length (ranged from 3.2 cm to 6.3 cm), 3.7 ± 0.6 cm in mean neck girth (ranged from 3.0 cm to 4.4 cm), 5.1 ± 0.1 cm in mean body girth (ranged from 4.9 cm to 5.2 cm) and 79.5 ± 16.7 grams in mean mass (ranged from 67 grams to 103 grams). The mean clutch size and the mean clutch mass were 17 ± 7 embryos (ranged from 12 embryos to 27 embryos) and 13.0 ± 7.0 grams (ranged from 5 grams to 21 grams), respectively. The mean RCM was 0.2 ± 0.1 (ranged form 0.1 to 0.4).

For semi-aquatic snake species, 3 gravid females of *Xenochrophis flavipunctatus* were collected in this study site. The mean SVL was 52.0 ± 1.8 cm (ranged from 50.5 cm to 54.0 cm), the mean tail length was 19.7 ± 2.3 cm (ranged from 18.0 cm to 21.3 cm), the mean neck girth was 4.0 ± 0.3 cm (ranged from 3.8 cm to 4.3 cm), the mean body girth was 5.9 ± 0.7 cm (ranged from 5.5 cm to 6.7 cm), and the mean mass was 135.0 ± 45.1 grams (ranged from 106 grams to 187 grams). The mean clutch size was 23 ± 8 embryos (ranged from 18 embryos to 32 embryos) and the mean clutch mass was 34.3 ± 4.0 grams (ranged from 30 grams to 38 grams). The mean RCM was 0.4 ± 0.1 (ranged from 0.3 to 0.5).

4.4.2 Reproductive cycle

Outside the Khorat basin:
Ban Borthong, Kabin Buri District

The reproductive cycle of gravid female snakes was classified to 3 periods, follicles, oocytes and embryos. Ovaries of adult female *E. enhydris* from Ban Borthong, Kabin Buri District (inside the Khorat basin) contained small follicles (follicle period) throughout the year. The highest number of female snakes contained follicles was 21 snakes in October. Females contained oocytes were found in 7 months, separated into 2 periods from May to August and November to January. The highest number of female snakes contained oocytes was 26 snakes in December. Female snakes contained embryos (embryo period) were found during 8 months from February to September, of which the highest number was 8 snakes in August. The number of female snakes in each month was shown in Table 4.11.

Table 4.11. The number of female *E. enhydris* in 3 reproductive conditions in each month at Ban Borthong, Kabin Buri District (outside the Khorat basin).

Reproductive condition	Month											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Follicles	1	5	1	2	1	15	5	9	8	21	7	2
Oocytes	9	0	0	0	5	1	2	1	0	0	15	26
Embryos	0	4	3	4	3 (1)*	4 (4)*	3	8	2 (1)*	0	0	0

(n)* = number of gravid females which contained full-term embryos

The embryo development was classified into 4 stages. The early developing stage of embryo was found in 4 months which separated into 2 periods, February to March (lower than 10th stage) and July to August (lower than 10th to 20th stage). The middle developing stage of embryos was found in 3 months which separated into 2 periods, August (21st stage) and April to May (25th to 28th stage). The last developing stage of embryos was found in 3 months and also separated into 2 periods, April to May (30th to 35th stage) and September (30th stage). The full-term stage of embryo, 37th stage, was found in 3 months, May, June and September. The stages of embryos in each month were shown in Table 4.12.

Table 4.12. The stages of embryos found in *E. enhydris* females in each month at Ban Borthong, Kabin Buri District (outside the Khorat basin).

Embryos developing stage	**Month**											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
The early developing stage		Lower 10th	Lower 10th			Lower 10th	Lower 10th	20th				
The middle developing stage				25th	28th			21st				
The last developing stage				30th	35th				30th			
Full-term stage					37th	37th			37th			

For other homalopsid snakes, two gravid females with embryos in oviducts of *E. plumbea* were collected in March and December. All embryos of both gravid females were recorded as lower than 10th stage since embryos in yolk sacs were invisible. Two gravid females of *E. bocourti* were collected in December. Embryos of these females were considered as 32nd to 35th stage since well-developing embryos and some yolk sacs were observed. Three gravid females of *H. buccata* were also collected in March and May. Embryos in March were recorded as lower than 10th stage since embryos in yolk sacs were invisible, whereas embryos in May were considered as 36th stage by their well-developing embryos and little yolk sacs were observed. However, full-term oviducal embryos, 37th stage, of these three homalopsid species were not found during the study period.

Inside the Khorat basin:
Ban Badan, Wang Nam Kheaw District

Follicles in ovaries of female snakes of *E. enhydris* at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin) were found throughout the year. The highest number of female snakes which contained follicles was 7 snakes in June. Female snakes containing oocytes were found in 8 months which separated into 2 periods, April to June and October to February. The highest number of female snakes which contained oocytes was 10 snakes in February. Female snakes contained embryos were found in 6 months which separated into 2 periods, March to May and August to October. The number of female snakes in 3 reproductive periods in each month was shown in Table 4.13.

Table 4.13. The number of *E. enhydris* females in 3 reproductive conditions in each month at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin).

Reproductive condition	Month											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Follicles	5	1	2	2	1	7	1	4	5	4	3	3
Oocytes	3	10	0	1	1	3	0	0	0	1	5	1
Embryos	0	0	2	1	2	0	0	1	4 (1)*	2 (1)*	0	0

(n)* = number of gravid females which contained full-term embryos

The early developing stage of embryo was found in March (lower than 10th stage). The middle developing stage of embryo was not found in this study site during the study period. The last developing stage of embryo was found in 3 months, May (30^{th} stage), August (34^{th} stage) and September (30^{th} to 32^{nd} stage), whereas the full-term stage of embryo, 37^{th} stage, was found in September and October. The stages of embryos in each month were shown in Table 4.14.

Table 4.14. The stages of embryos found in *E. enhydris* females in each month at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin).

Embryos developing stage	**Month**											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
The early developing stage			Lower 10^{th}									
The middle developing stage	-	-	-	-	-	-	-	-	-	-	-	-
The last developing stage					30^{th}			34^{th}		30^{th} ,32^{nd}		
Full-term stage									37^{th}	37^{th}		

Gravid females of *E. subtaeniata* were collected in 8 months during the study period. Follicles in ovaries of female snakes were found every month. Female snakes contained oocytes were found in 5 months; January, March, June, October and December. The highest number of female snakes which contained oocytes was 2 snakes in January, June and October. Females contained embryos were collected in 5 months; January, February, March, June and July. The number of female snakes in 3 reproductive periods in each month was shown in Table 4.15.

Table 4.15. The number of female *E. subtaeniata* in 3 reproductive periods in each month at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin).

Reproductive condition	Month											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Follicles	1	0	0	0	0	5	1	0	1	0	0	0
Oocytes	2	0	1	0	0	2	0	0	0	2	0	1
Embryos	1	3	1	0	0	2	8 (1)*	0	0	0	0	0

(n)* = number of gravid females which contained full-term embryos

The early developing stage of embryo was found in 3 months, January (lower than 10th stage), February (lower than 10th stage) and July (lower than 10th stage). The middle developing stage embryos was found only in March (28th stage). The last developing stage of embryo was found in July (30th stage) whereas the full-term stage of embryo, 37th stage, was found only in July. The stages of embryos in each month were shown in Table 4.16.

Table 4.16. The stages of embryos found in *E. subtaeniata* females in each month at Ban Badan, Wang Nam Kheaw District (inside the Khorat basin).

Embryos developing stage	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
The early developing stage	Lower 10th	Lower 10th					Lower 10th					
The middle developing stage			28th									
The last developing stage							30th					
Full-term stage							37th					

For other homalopsid snakes, four gravid females with embryos in oviducts of *E. plumbea* were collected in 3 months. Embryos in oviducts of two gravid female snakes in October were lower than 10th stage since embryos in yolk sac were invisible. Other two gravid female snakes were collected in December and January and were recorded as 30th stage since well-developing embryos and some yolk sacs were observed. Another semi-aquatic snake, three gravid female snakes with embryos in oviducts of *X. flavipunctatus* were recorded as 24th and 28th stage since moderate developing embryos and amount volume of yolk sacs were observed. However, full-term embryos, 37th stage, of these three snakes species were not found during the study period.

4.4.3 The relationship between female reproductive cycle and environmental factors

Outside the Khorat basin:
Ban Borthong, Kabin Buri District

Three environmental factors; precipitation, humidity and air temperature of Ban Borthong, Kabin Buri District (Outside the Khorat Basin) were collected from Kabin Buri Meteorological Station at Kabin Buri District. Total precipitation was used for determining wet and dry season at this study site. The rainy season is from April to October (7 months) and dry season is from November to March (5 months). During the study period, the highest precipitation was recorded in July (470.5 mm) followed by September (337.8 mm) and May (266.6 mm), respectively. However, there was no precipitation recorded in January. The average relative humidity in this study site ranged from 64% to 86%, the higher level started from May to October (6 months) and the lower level started from November to April (6 months). The highest average relative humidity of this study site was recorded in July and September (85%) and lowest average relative humidity was recorded in January (64%). The air temperature of this study site ranged from 25.8 ºC to 29.8 ºC, of which the lowest temperature was recorded in January whereas the highest temperature was recorded in May. These three environmental factors at this study site were shown in Figure 4.13.

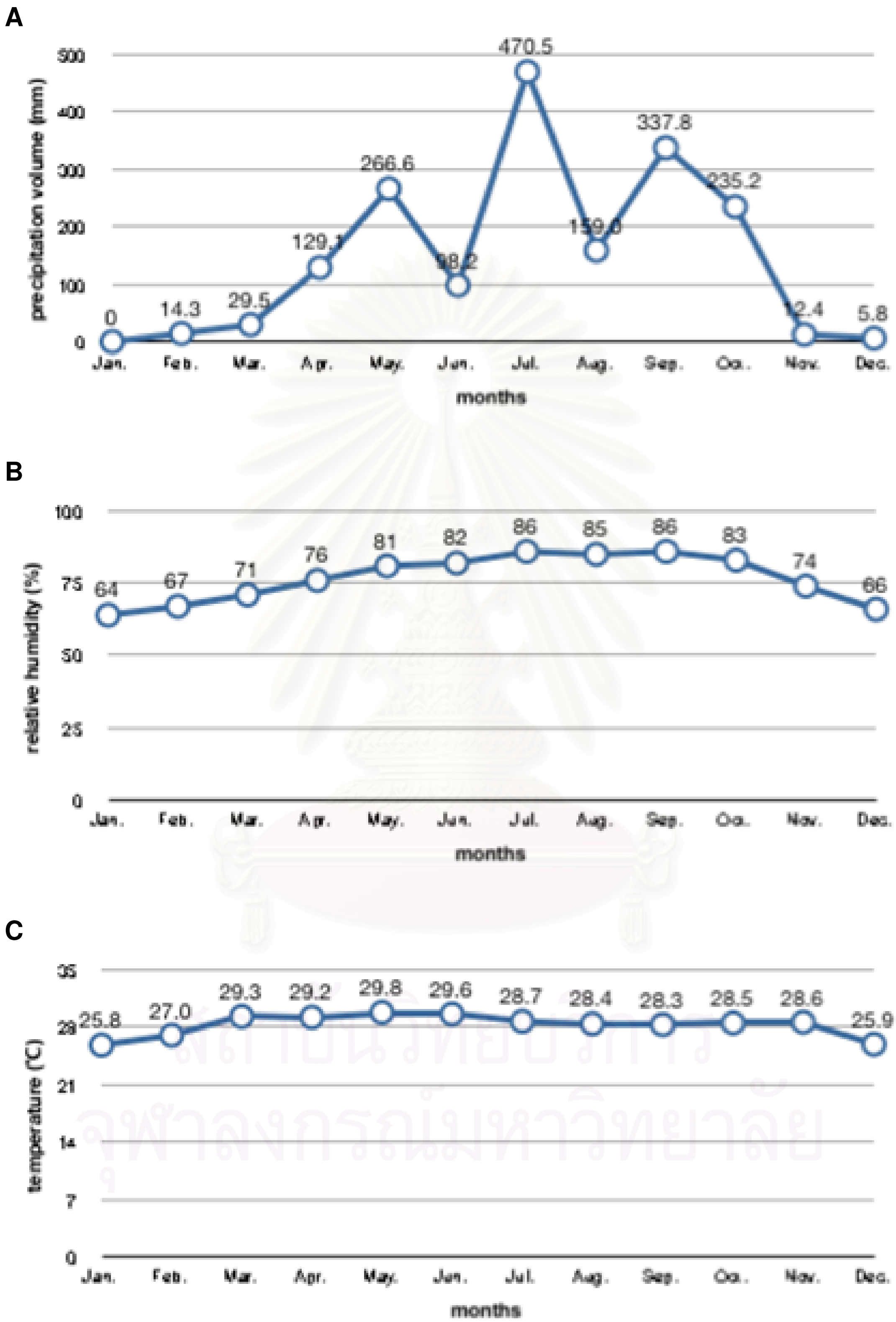


Figure 4.13. Three environmental factors in each month at Ban Borthong, Kabin Buri District, Prachinburi Province (Outside the Khorat basin). A - total precipitation (mm), B - average relative humidity (%) and C - mean air temperature (ºC)

Significant correlation between the number of gravid female snakes and environmental factors was not found in this study area (r^2 = 0.247, p = 0.440 with total precipitation; r^2 = 0.569, p = 0.053 with average relative humidity; r^2 = 0.341, p = 0.279 with mean air temperature).

Inside the Khorat basin:
Ban Badan, Wang Nam Kheaw District

Three environmental factors; precipitation, humidity and air temperature of Ban Badan, Wang Nam kheaw District (inside the Khorat Basin) were collected from Chok Chai Meteorological Station at Chok Chai District. The season of this study site was determined by the total precipitation. The rainy season started from March to October (8 months) and the dry season started from November to February (4 months). The highest precipitation was recorded in October (271.5 mm) followed by September (160.8 mm) and April (144.6 mm), but there was no precipitation recorded in January. The average relative humidity of this study site ranged from 61% to 81%, the higher level started from April to November (8 months) and the lower level started from December to March (4 months). The highest average relative humidity was recorded in September (81%) and the lowest average relative humidity was recorded in February (61%). The air temperature of this study site ranged from 24.2 °C to 29.8 °C, of which the lowest temperature was recorded in January whereas the highest temperature was recorded in March. These environmental factors at this study site were shown in Figure 4.14.

Significant correlation between the environmental factors and the number of gravid female snakes was found with the total precipitation (r^2 = 0.637, p = 0.027). The average relative humidity and the mean air temperature had no significant correlation with the number of gravid female snakes (r^2 = 0.556, p = 0.060 and r^2 = 0.370, p = 0.236, respectively).

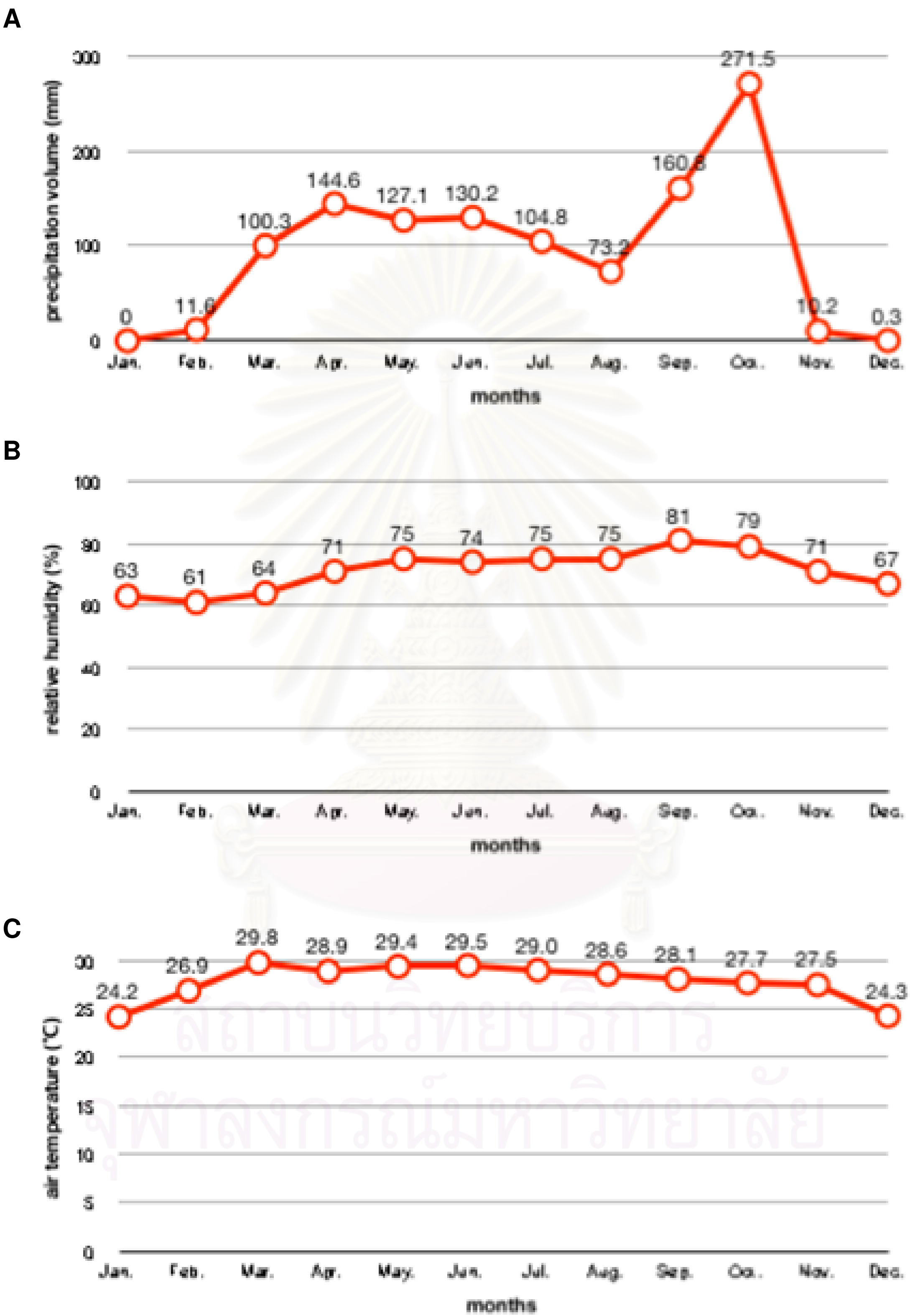


Figure 4.14. Three environmental factors in each month at Ban Badan, Wang Nam Kheaw District, Prachinburi Province (Outside the Khorat basin). A - total precipitation (mm), B - average relative humidity (%) and C - mean air temperature (°C)

Comparison between study sites

Comparison of reproduction of female homalopsid snakes between Ban Borthong, Kabin Buri District (outside the Khorat basin) and Ban Badan, Wang Nam Kheaw District (inside the Khorat basin) were performed for only one species, *E. enhydris*, For other homalopsid snakes, *E. plumbea*, *E. bocourti* and *H. buccata*, analyses were not performed because of the low number of gravid female snakes. Moreover, gravid females of *E. subtaeniata* were found only at Ban Badan (inside the Khorat basin).

From 5 morphological characters; SVL, tail length, neck girth, body girth and body mass which were recorded from *E. enhydris* females, 2 morphological characters were significantly different. SVL of females from Ban Borthong (outside the Khorat basin, SVL = 55.9 ± 5.9 cm) were significantly larger than females from Ban Badan (inside the Khorat basin, SVL = 50.2 ± 8.9 cm, $p = 0.046$). Likewise, neck girth of females from Ban Borthong (outside the Khorat basin, neck girth = 3.1 ± 0.4 cm) were significantly larger than females from Ban Badan (inside the Khorat basin, neck girth = 2.7 ± 0.4 cm, $p = 0.01$). Significant differences were not found in other 3 morphological characters; tail length, body girth and body mass ($p > 0.05$). Moreover, the number of follicles, clutch size, clutch mass and relative clutch mass (RCM) of females from these two study sites had no significant differences ($p > 0.05$).

Females from both study sites were found to have follicles in ovaries throughout the year. Oocytes were found in 7 months, May to August and November to January at Ban Borthong (outside the Khorat basin) whereas at Ban Badan (inside the Khorat basin), Oocytes were found in 8 months, April to June and October to February. At Ban Borthong (outside the Khorat basin), embryos were found in 8 months from February to September of which the full term stages of embryo, 37^{th} stage, were found in 3 months separated into 2 periods; May to June and September. However, embryos at

Ban Badan (inside the Khorat basin) were found in 6 months separated into 2 periods; March to May and August to October, of which the full term stages of embryos, 37^{th} stage, was found in September to October.

Gravid female snakes at Ban Borthong (outside the Khorat basin) had no significant correlation with three environmental factors, total precipitation (r^2 = 0.247, p = 0.44), average relative humidity (r^2 = 0.569, p = 0.053) and mean air temperature (r^2 = 0.341, p = 0.279). In contrast, number of gravid females at Ban Badan had significant correlation with total precipitation (r^2 = 0.637, p = 0.0027) but had no significant correlation with other environmental factors, average relative humidity (r^2 = 0.556, p = 0.060) and mean air temperature (r^2 = 0.370, p = 0.236).

CHAPTER V

DISCUSSION & CONCLUSION

5.1 Species composition

Five of fifteen homalopsid snake species found in Thailand were recorded inside and outside the Khorat basin, comprising *Enhydris enhydris, E. plumbea, E. bocourti, E. subtaeniata* and *Homalopsis buccata.* Four species of homalopsid snakes were found in each study site, of which *E. subtaeniata* was absent outside the Khorat basin whereas *E. bocourti* was absent inside the Khorat basin. Other semi aquatic snakes including *Xenochrophis flavipunctatus, Xenopeltis unicolor* and *Cylindrophis ruffus* were found at both study sites. Species richness of snakes (7 species) inside the Khorat basin was comparable to that of outside the Khorat basin. A high degree of species overlap between inside and outside the Khorat basin (0.85) was similar to the previous study by Karns *et al.* (2005), in which 8 species were found in and outside the Khorat basin, and species overlap was 0.89 between the study sites. Like the pervious study (Karns *et al.,* 2005), species evenness (0.818) inside the Khorat basin was higher than outside the Khorat basin (0.399). *Enhydris enhydris* was the dominant species in snake assemblages at both study sites, 81.36% outside the Khorat basin and 45.14% inside the Khorat basin. *H. buccata* (5.85%) was the subdominant species of homalopsid snake outside the Khorat basin, whereas *E. subtaeniata* (16.92%) was the subdominant species inside the Khorat basin. In contrast with a previous study by Karns *et al.* (2005), *E. bocourti* was absent from inside the Khorat basin and *Erpeton tentaculatum* was absent from outside the Khorat basin in this study. The total number of snakes at Ban Borthong (outside the Khorat basin) was higher than the number of snakes at Ban badan (inside the Khorat basin) except for *X. unicolor*. The number of homalopsid snakes outside the Khorat basin site was 2.09 times higher than that inside the Khorat basin site. Moreover, the number of homalopsid snakes was 11.35 times higher than other snakes outside the Khorat basin and was about 3.79 times Ban Badan, and the overall number of homalopsid snakes in this study was more than 6.9 times other snakes. Comparison with the previous study of homalopsid snakes at Lake Songkhla in southern Thailand by Murphy *et al.* (1999) and Karns *et al.* (1999-2000), three species (*E. enhydris, E. plumbea* and *H. buccata*) found inside and outside the Khorat basin were similar to those found at Lake Songkhla as well as the dominant species (*E. enhydris*). In contrast with the previous study in Sabah, Malaysia, Voris and Karns (1996) reported the snake assemblage consisted almost exclusively of *E. plumbea* at the study sites (rice paddy and buffalo wallow environments). However, the differences in homalopsid snakes observed between inside and outside the Khorat basin in this study might be affected by many historical and biological factors, the age and stability of ancient an feature (Khorat basin), the separation of the Mekong drainage in the Khorat basin from Chao Phraya drainage and Southeastern drainage, and also with waterfalls, rocky and fast-flowing streams which are barriers at the mountain rims of the Khorat basin (Karns *et al.,* 2005).

5.2 Morphological characters

Females larger and heavier than males in snakes is well known and has been reported by many authors (Jayne *et al.*, 1995; Pearson *et al.*, 2002; Shine, 1986; Wankulangkul, 2004;. Karns *et al.* 2005).In this study snakes from Kabin Buri exhibited sexual size dimorphism but not at Ban Badan. In this study, sexual differences in morphological characters (SVL, Tail length, neck girth, body girth and body mass) of homalopsid snakes were found both inside and outside the Khorat basin. Female *E.*

enhydris from both inside and outside the Khorat basin were larger and heavier than males in most morphological characters except tail length (Figure 4.15). All morphological characters of *H. buccata* males from inside the Khorat basin were larger and heavier than females but only SVL and tail length of males from outside the Khorat basin were larger than females.

Figure 4.15. Morphological differences between males and females of *E. enhydris* inside and outside the Khorat basin

For other homalopsid snakes, morphological characters between males and females of *E. bocourti* and *E. plumbea* were not significantly different at both study sites. Sexual differences in morphological characters of other snakes were found in *X. flavipunctatus* and *C. ruffus* from outside the Khorat basin. SVL and mass of *X. flavipunctatus* females were larger than males and *C. ruffus* females were larger than males in SVL, body girth and mass.

In a previous study, morphological differences were found only in females of *E. enhydris* and *E. plumbea* between inside and outside the Khorat basin. Females from outside the Khorat basin were lager and heavier than females from inside the Khorat basin (Karns *et al.,* 2005). In this study, three species of homalopsid snakes; *E.*

enhydris, E. plumbea and *H. buccata* showed morphological differences between inside and outside the Khorat basin. Both sexes of *E. enhydris* from outside the Khorat basin were larger and heavier than snakes from inside the Khorat basin. Significant differences in morphological characters of *E. plumbea* and *H. buccata* between study sites were found only in males, SVL and mass of males from outside the Khorat basin were larger than males from inside the Khorat basin. In addition, only females of *X. flavipunctatus* showed significant difference in SVL between study sites. Females from outside the Khorat basin were significantly larger than females from inside the Khorat basin. Karns *et al.* (2005) suggested that differences in morphological characters were the result of the differences in the quality of habitat and prey availability influenced by abiotic and biotic differences between inside and outside the Khorat basin. Moreover, they suggested that these causes also influence the differences in density and diversity of homalopsid snakes observed inside and outside the Khorat basin.

5.3 Diets

Freshwater homalopsid snakes have been reported to primarily feed on fish (piscivorous) in the literature (Karns *et al.,* 2005; Murphy, 2007; Murphy *et al.,* 1999; Taylor, 1965; Voris and Murphy, 2002). They also reported the size and number of prey in homalopsid snake guts. A few small fish were often found as prey items and a large prey item was also occasionally found. Amphibian eggs, tadpoles and adults were also reported as prey types of homalopsid snakes such as *E. plumbea, E. subtaeniata* and *H. buccata* (Karns *et al.,* 2005; Voris and Karns, 1996; Voris and Murphy, 2002). Voris and Karns (1996) reported that these prey types were the diet examined in stomachs of the majority of snakes. In this study, fish were often found in homalopsid snake guts at both study sites. Fish in Family Cyprinidae (inside the Khorat basin) and Belontiidae (outside the Khorat basin) were found in a high proportion. The dominant proportion of Belontid and Cyprinid prey types might be explained by the abundance of these fish in freshwater habitats at both study sites. Prey types were not completely overlaping between inside and outside the Khorat basin and significant differences in prey types were found in females. Furthermore, homalopsid snakes outside the Khorat basin fed on various prey types more than snakes inside the Khorat basin. Prey items in snake guts from both study sites were small in proportion between prey mass and snake mass which were about 5 to 10 % of snake mass. However, a large prey item was found in a few, such as fish in Family Belontiidae, in *E. enhydris* gut from Ban Borthong (18.18 % of snake mass) and fish in Family Symbranchidae, in *E. plumbea* gut from Ban Badan (14.38 % of snake mass). The proportion between prey mass and snake mass was not significantly different between study sites. The larger snakes found outside the Khorat basin can be explained by the larger prey items in this area. Amphibians (*Kaloula pulchra,* Family Microhylidae) were found being swallowed by *E. plumbea* once during the day beside the stream inside the Khorat basin but not found outside the Khorat basin. This result might help to explain the difference in habitat utilization of *E. plumbea* with other species in genus *Enhydris.* For the poorly known homalopsid snake, *E. subtaeniata,* small fish in family Cyprinidae were found in their guts in a high proportion and males fed on significantly larger fish.

Another semi-aquatic snake, *X. flavipunctatus,* was reported to eat fish, frogs and mice (e.g. Cox, 1991; Cox *et al.,* 1998; Alderton *et al.,* 2007 and Taylor, 1965). Likewise, *X. flavipunctatus* from both study sites had fish and frogs in their stomachs. Various species of frogs were found as large prey items and in a high proportion of stomach contents. Rodents, birds, lizards and other snakes were documented as prey items of *X. unicolor* (Cox, 1991; Cox *et al.,* 1998; Karns *et al.,* 2005) and it was also reported to feed on a freshwater homalopsid snake, *E. enhydris*, in captivity (Voris and Murphy, 2002). In this study, mice (*Mus* sp.) and a homalopsid snake (*E. subtaeniata*) were found in male and female stomachs of *X. unicolor* inside the Khorat basin. The diet of *C. ruffus* has been reported to by many authors to include small rodents, fish, amphibians and some reptiles, e.g. Cox (1991), Cox *et al.* (1998), Alderton *et al.* (2007), Areste and Cebrain (2003), Karns *et al.* (2005), Malkmus *et al.* (2002), Taylor (1965) and Whitaker and captain (2004). In this study, only one frog (*Fejervayar limnocharis*) was documented as a prey item of a male *C. ruffus* outside the Khorat basin.

5.4 Reproduction

Geographic variation in reptile reproduction has often been reported (Colli, 1991; Mesquita and Colli, 2003; Pearson *et al,* 2002; Shine, 1986; Vitt, 1981). Karns *et al.* (2005), Murphy *et al.* (2002) and Murphy (2007) reported the variation in reproductive characteristics including litter size, frequency of reproduction and size at first reproduction, of *E. enhydris* among Myanmar, Cambodia and Thailand and found that the reproduction of Cambodian samples is proximately twice as large as other sites. In this study, the size of female *E. enhydris* at first reproduction from inside and outside the Khorat basin were similar (31.4 cm in SVL), but they were smaller when compared with a previous study by Murphy (2002) and Karns *et al.* (2005), which reported that *E. enhydris* females were matured at 37.5 cm and 43.6 cm in SVL at Lake Songkhla and Kabin Buri District, respectively. Mean SVLs of gravid female *E. enhydris* found inside and outside the Khorat basin, 50.2 ± 8.9 cm and 56.0 ± 5.9 cm, respectively, were larger than those at Lake Songkhla, Thailand and Myanmar, 42.6 ± 3.5 cm and 42.8 ± 2.6 cm, respectively (Murphy *et al*., 2002). The average clutch size of female *E. enhydris* was 11 ± 4 embryos inside and 13 ± 5 embryos outside the Khorat basin. This average clutch size was larger than those studied by Karns, et al. (2005) and Murphy et al. (2002) which reported that the clutch sizes were 11 ± 5 and 8 ± 3 embryos at Lake Songkhla and Myanmar, respectively, but smaller than the clutch size of a Cambodian population, 20 ± 7 embryos. Stuart *et al.* (2002) suggested that the relatively large reproduction for the Cambodian homalopsid population was caused by the increase in the small fish due to human removal of the larger species and Seigel and Ford (1987) cited in Karns *et al.* (2005) suggested that local environmental conditions and food availability can be the cause for this type of variation. In contrast, differences in reproduction of *E. enhydris* between inside and outside the Khorat basin in this study were found only in female morphological characters including SVL and neck girth but not in tail length, body girth and mass (females from outside the Khorat were significantly larger than females from inside the Khorat basin) whereas clutch size, clutch mass and RCM were not significantly different between study sites. From both study sites, larger females reproduced larger clutch sizes (Figure 4.7, 4.9 and 4.11). It was also found that larger females with larger clutch sizes at inside the Khorat basin such as *E. enhydris* and *E. subtaeniata* reproduced smaller embryos (Figure 4.10 and 4.12). However, these negative correlations were not found among the snakes outside the Khorat basin.

The average relative humidity and mean air temperature were not different but the total precipitation was different between study sites during the study period. This is also true from the 10 years data shown in figure 4.14. The mean precipitation outside the Khorat basin was higher than inside the Khorat basin. However, the relationship between total precipitation and the amount of water throughout the year in each study area should be studies because the availability of water could related to the amount of diet and reproductive pattern.

The significant correlation between total precipitation and number of gravid females, and an appearance of the last developing stage and full term stage of embryos suggested that a seasonal reproduction occurred inside the Khorat basin and continuous reproduction could possibly occur outside the Khorat basin. It is possible that the gravid females with full term stage of embryos were not captured during the dry season at outside the Khorat basin.

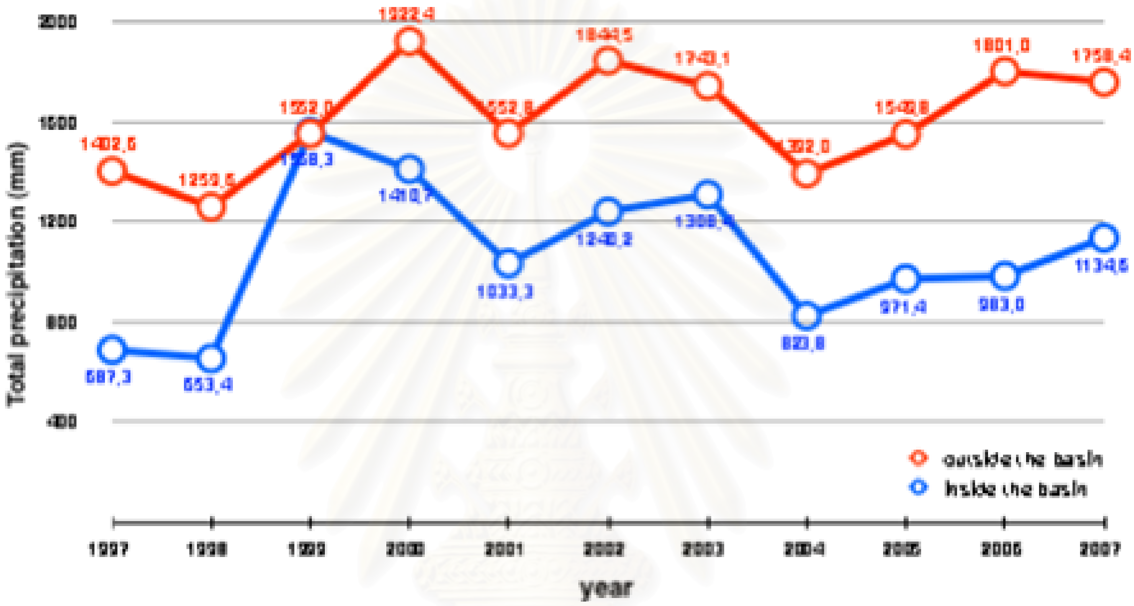


Figure 4.16 Total precipitation from 1997 to 2007 inside and outside the Khorat basin, Thailand

From these results, differences in environmental factors such as total precipitation, and food availability might bring about differences in life history patterns of homalopsid snakes, including species composition, abundance, morphological characteristics, diet and reproductive cycle between inside and outside the Khorat basin. Likewise, the previous study by Karns *et al.* (2005) found some differences in the life-history patterns of semi-aquatic snake populations between inside and outside the Khorat basin. They suggested that it could be because of the differences in geological features and food availability and these causes could lead to speciation in the future.

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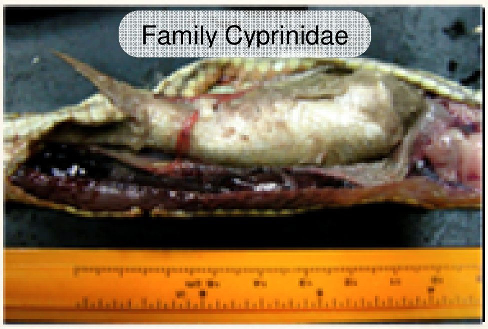
Appendices

Appendix I:

Stomach contents of homalopsid snakes from Ban Badan,

Wang Nam Kheaw District (inside the Khorat basin)


Family Cyprinidae


Family Belontiidae


Family Anabantidae


Family Channidae


Family Symbranchidae


Family Bagridae

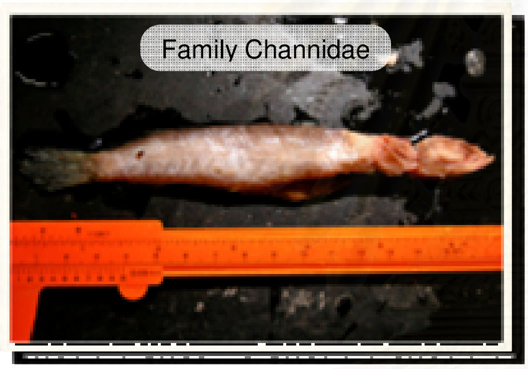

Koloula pulchra was being eaten by *Enhydris plumbea*

Appendix II:

Stomach contents of homalopsid snakes from Ban Borthong, Kabin Buri District (outside the Khorat basin)


Family Pristolepidae


Family Anabantidae


Family Channidae

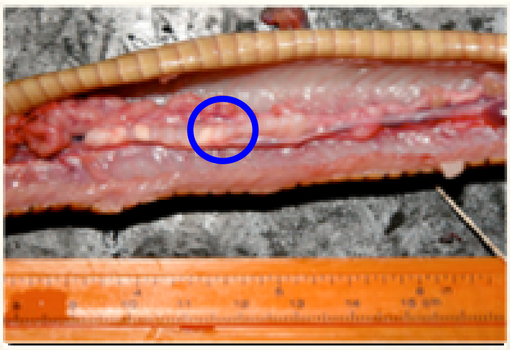

Family Belontiidae


Family Eleotridae


Family Cyprinidae

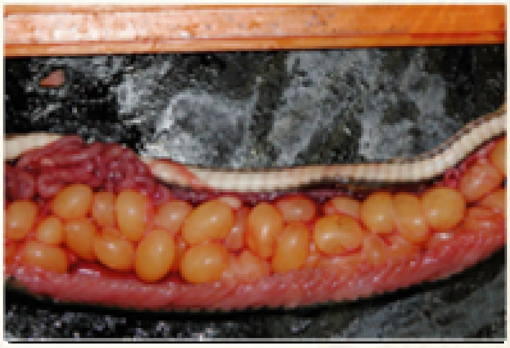
Appendix III:

Reproductive conditions of Homalopsid snakes



Follicles in ovary of female homalopsid snakes

Oocytes in ovary of female homalopsid snakes



The early developing stage of embryos,
less than 10th to 20th stage

The middle developing stage of embryos,
21st to 29th stage

The late developing stage of embryos,
30th to 36th stage

The full term stage of embryos, 37th stage

BIOGRAPHY

Chattraphas Pongcharoen, male, was born on April 26, 1983 in Thailand. He received Bachelor of Science degree, Forestry from the Department of Forest Biology, Faculty of Forestry, Kasetsart University in 2005. His interest in Amphibians and reptiles was happened during his study in herpetology class at Kasetsart University. He decided to start his master degree by an advice from his beloved and respected teacher. In 2005, he furthered his education in Zoology in the Department of Biology, Faculty of Science, Chulalongkorn University.