# นิเวศวิทยาประชากรและชีววิทยาการสืบพันธุ์ของงูสายรุ้งดำ *Enhydris jagorii* (Peters, 1863) ณ บึงกะโล่ จังหวัดอุตรดิตถ์ ประเทศไทย

นายฉัตรพรรษ พงษ์เจริญ





วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาวิทยาศาสตร์ชีวภาพ
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2558

# POPULATION ECOLOGY AND REPRODUCTIVE BIOLOGY OF JAGOR'S WATER SNAKE, *Enhydris jagorii* (Peters, 1863) AT BUNG KA LOH, UTTARADIT PROVINCE, THAILAND

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A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Biological Sciences
Faculty of Science
Chulalongkorn University
Academic Year 2015

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|---|---|
| Thesis Title | POPULATION ECOLOGY AND REPRODUCTIVE BIOLOGY OF JAGOR'S WATER SNAKE, *Enhydris jagorii* (Peters, 1863) AT BUNG KA LOH, UTTARADIT PROVINCE, THAILAND |
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| Field of Study | Biological Sciences |
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ฉัตรพรรษ พงษ์เจริญ : นิเวศวิทยาประชากรและชีววิทยาการสืบพันธุ์ของงูสายรุ้งดำ *Enhydris jagorii* (Peters, 1863) ณ บึงกะโล่ จังหวัดอุตรดิตถ์ ประเทศไทย (POPULATION ECOLOGY AND REPRODUCTIVE BIOLOGY OF JAGOR'S WATER SNAKE, *Enhydris jagorii* (Peters, 1863) AT BUNG KA LOH, UTTARADIT PROVINCE, THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร.กำธร ธีรคุปต์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ดร.ฮาโรลด์ เค. วอริส, หน้า.

งูสายรุ้งดำ *Enhydris jagorii* เป็นงูน้ำจืดที่จัดเป็นชนิดพันธุ์เฉพาะถิ่นของประเทศไทย พบได้เฉพาะพื้นที่ราบลุ่มแม่น้ำเจ้าพระยา-ท่าจีนเท่านั้น งูชนิดนี้ถูกพบและตั้งชื่อเป็นครั้งแรกจากตัวอย่างที่จับได้จากพื้นที่ใกล้เคียงกับกรุงเทพมหานครในปี พ.ศ. 2406 และไม่มีรายงานการพบที่แน่นอนอีกจวบจนกระทั่งในปี พ.ศ. 2553 Karns, et al. (2010) ได้ระบุพื้นที่การแพร่กระจายใหม่ซึ่งได้แก่ บึงกะโล่ บึงน้ำสารธารณะใกล้ตัวเมืองจังหวัดอุตรดิตถ์ ปัจจุบันงูชนิดนี้กำลังเผชิญหน้ากับปัญหาถิ่นที่อยู่อาศัยถูกทำลายและจำนวนประชากรที่กำลังถูกคุกคามอย่างหนักจากกิจกรรมต่าง ๆ ของมนุษย์ในพื้นที่บึงกะโล่ เช่น การประมงที่ไม่มีการควบคุม การขยายตัวอย่างรวดเร็วของพื้นที่เกษตรกรรมและการพัฒนาพื้นที่ของหน่วยงานต่าง ๆ จากทั้งภาครัฐและเอกชน ดังนั้นเพื่อเป็นการเริ่มต้นการอนุรักษ์อย่างถูกต้อง การศึกษาข้อมูลเบื้องต้นของงูน้ำชนิดนี้จึงเป็นสิ่งที่จำเป็นและเร่งด่วน การศึกษางูน้ำชนิดนี้ ได้ทำการศึกษา ณ บึงกะโล่ ใช้ระยะเวลารวมทั้งสิ้น 23เดือน โดยเริ่มตั้งแต่เดือนตุลาคม พ.ศ. 2553 ถึงเดือนสิงหาคม พ.ศ. 2555 ได้ผลการศึกษาดังนี้ ในเรื่องของลักษณะทางสัณฐาน จากลักษณะที่ทำการตรวจสอบทั้งหมด 11 ลักษณะ แบ่งออกเป็นข้อมูลที่ได้จากการวัดขนาด 6 ลักษณะและข้อมูลที่ได้จากการนับจำนวนเกล็ด 3 ลักษณะพบว่า งูน้ำชนิดนี้มีลักษณะทางสัณฐานที่แตกต่างกันอย่างมีนัยสำคัญระหว่างเพศผู้และเพศเมีย ($p < 0.05$) โดยที่งูเต็มวัยเพศเมียจะมีขนาดลำตัวใหญ่และน้ำหนักมากกว่างูเพศผู้อย่างชัดเจน ยกเว้นความยาวของหางโดยที่งูเพศผู้จะมีความยาวของหางมากกว่างูเพศเมียที่มีขนาดความยาวลำตัวเท่ากัน งูน้ำชนิดนี้กินเฉพาะปลาเป็นอาหาร การศึกษาจากทั้งตัวอย่างที่ตายและมีชีวิตพบว่า สัดส่วนของปลาที่พบมากที่สุดได้แก่ ปลาในวงศ์ปลาตะเพียน (Family Cyprinidae, 31.28%) และเหยื่อที่พบนั้นมีขนาดเล็กเมื่อเทียบกับสัดส่วนของงู (ประมาณ 10% ของน้ำหนักตัว) สำหรับการศึกษาในครั้งนี้ไม่พบความแตกต่างกันในเรื่องของอาหารระหว่างงูเพศผู้และงูเพศเมีย จากการศึกษาเรื่องระบบสืบพันธุ์ของงูเพศเมียพบว่า ในการศึกษาครั้งนี้ขนาดความยาวลำตัวที่เล็กที่สุดของงูเพศเมียที่พบการตั้งท้องคือ 34.0 เซนติเมตร จำนวนเอ็มบริโอเฉลี่ยในการตั้งท้องแต่ละครอกคือ 11 ±9 ตัว (พบจำนวนเอ็มบริโอได้ตั้งแต่ 1-28 ตัว) และมีน้ำหนักเฉลี่ยแต่ละครอกเท่ากับ 56.43 ±50.56 กรัม (น้ำหนักพบได้ตั้งแต่ 3.1-123..0 กรัม) และพบว่าขนาดลำตัวและน้ำหนักของงูเพศเมียมีความสัมพันธ์กับจำนวนเอ็มบริโอและน้ำหนักของเอ็มบริโอในแต่ละครอกอย่างมีนัยสำคัญ ($p < 0.05$) และงูเพศเมียที่มีขนาดลำตัวและน้ำหนักใหญ่กว่าจะสามารถผลิตเอ็มบริโอได้จำนวนและน้ำหนักที่มากกว่างูเพศเมียที่มีขนาดเล็กกว่า วงรอบการสืบพันธุ์ในเพศเมียของงูน้ำชนิดนี้มีความเป็นไปได้ที่จะมีวงรอบการสืบพันธุ์แบบเป็นฤดูกาลและมีการออกลูกในฤดูฝน โดยพิจารณาจากจำนวนงูเพศเมียที่ตั้งท้องและออกลูกที่สำรวจพบเป็นจำนวนมากในช่วงฤดูฝนทั้ง 2 ช่วงระหว่างทำการศึกษา คือ เดือนมีนาคมถึงเดือนตุลาคม ปี พ.ศ. 2554 และเดือนพฤษภาคมถึงเดือนสิงหาคม ปี พ.ศ. 2555 และความสัมพันธ์กันอย่างมีนัยสำคัญระหว่างจำนวนงูเพศเมียที่ตั้งท้องและออกลูกที่สำรวจพบได้กับข้อมูลปัจจัยสิ่งแวดล้อมของพื้นที่ในแต่ละเดือน ($p < 0.05$) ในการศึกษาครั้งนี้ยังได้มีการบันทึกและรายงานเป็นครั้งแรกเกี่ยวกับลักษณะทางสัณฐานของงูในวัยอ่อน และผู้ล่าตามธรรมชาติของงูน้ำชนิดพันธุ์นี้อีกด้วย อย่างไรก็ตามสถานภาพในการอนุรักษ์ทั้งระดับชาติและระดับนานาชาติของงูน้ำชนิดนี้นั้นยังคงมีการประเมินค่าที่คลาดเคลื่อนและต่ำกว่าความเป็นจริงอยู่มาก ดังนั้นการศึกษานี้จึงเป็นประโยชน์ต่อการปรับปรุงสถานภาพในการอนุรักษ์ทั้งระดับชาติและระดับนานาชาติ อีกทั้งยังให้ข้อมูลพื้นฐานที่มีความสำคัญยิ่งสำหรับใช้ในการจัดทำแนวทางในการอนุรักษ์งูสายรุ้งดำอีกด้วย

สาขาวิชา วิทยาศาสตร์ชีวภาพ ลายมือชื่อนิสิต .....

ปีการศึกษา 2558 ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

# # 5273911323 : MAJOR BIOLOGICAL SCIENCES
KEYWORDS: HOMALOPSIDAE / MORPHOLOGY / SCALATION / SEXUAL DIMORPHISM / FRESHWATER SNAKE / ENHYDRIS JAGOORII / NEONATE / DIET / REPRODUCTION / CONSERVATION

CHATTRAPHAS PONGCHAROEN: POPULATION ECOLOGY AND REPRODUCTIVE BIOLOGY OF JAGOR'S WATER SNAKE, *Enhydris jagorii* (Peters, 1863) AT BUNG KA LOH, UTTARADIT PROVINCE, THAILAND. ADVISOR: ASSOC. PROF. KUMTHORN THIRAKHUPT, Ph.D., CO-ADVISOR: HAROLD K. VORIS, Ph.D., pp.

Jagor's water snake, *Enhydris jagorii* is an endemic species restricted to the Chao Phraya - Ta Chin basin in the central plain of Thailand. Holotype of this freshwater snake was collected from the vicinity of Bangkok and was firstly described by Peters in 1863. Since then, there is no other information regarding this species of snake until Karns, et al. (2010) reported the new area of distribution of this snake in Bung Ka Loh wetland, Uttaradit Province, Thailand. In modern time, the snake has faced a major threat due to habitat loss and human disturbance. A large area of the wetland has been rapidly developed into urban and agricultural areas. Moreover, the population of this snake has been seriously threatened by uncontrolled fishing around the wetland. In order to protect this endemic species, basic information on natural history is certainly needed. This study was conducted at Bung Ka Loh wetland located close to Nan River, Uttaradit Province during October, 2010 to August, 2012. In this study, 6 morphological characters were measured and 3 types of scale rows were counted and calculated from male and female specimens collected from this wetland. The data of sexual dimorphism recorded was the first report of this freshwater homalopsid species. The results indicated that females exhibited larger and heavier than males in term of overall body size and weight, but not tail length. Males showed the significantly longer tail than female at the same size of SVL. Furthermore, morphological measurements were first reported on neonates. Results from the study of both live and dead specimens indicated that this snake is piscivorous, feeding only on fish. The dominant prey belongs to fish in Family Cyprinidae (31.28%). Observed prey items were small in weight, usually less than 10% of snake body mass and multiple prey items were occasionally found inside their stomachs. Significant difference on diet between sexes of this snake was not found. Additional to this, predation on this snake was firstly recorded in this study. The smallest gravid female specimen that was collected from the site during the period of study was 34.0 cm in SVL. Average clutch size and mass were 11 ±9 embryos (1-28 embryos, n=18) and 56.43 ±50.56 grams (3.1-123.0 grams, n=14), respectively. Significant relationships were found between female morphological characteristics (SVL, TL and body mass) and their clutches, being larger females reproduced larger clutch size and clutch mass ($p < 0.05$). Females possibly has a seasonal reproduction according to the number of gravid females collected during the two periods of rainy season (March to October in 2011 and May to August in 2012). Seasonal reproduction of these female snakes which is related to the rainy season was supported by significant correlations between the number of collected gravid females and physical factors data collected from the wetland ($p < 0.05$). However, the conservation status, both international and national levels, of this freshwater snake are underestimated. Hence, the proper status and conservation implication of this freshwater snake are proposed in this study.

Field of Study: Biological Sciences
Academic Year: 2015

Student's Signature .....
Advisor's Signature .....
Co-Advisor's Signature .....

# ACKNOWLEDGEMENTS

It is a genuine pleasure to express deep sense of my thankful and gratitude to my advisor, Assoc. Prof. Dr. Kumthorn Thirakhupt, and my Co-advisor, Dr. Harold K. Voris. Their dedication and keen interest to help their advisee had been solely and mainly responsible for completing my work. Their timely advice, meticulous scrutiny and scholarly advice have helped me to a very great extent to accomplish this work.

I would like to thanks all of local fishermen from each wetland for their assistance in field work during the period of study, especially to the local fishermen at Bung Ka Loh wetland.

I also wish to express my sincere thanks to Mr. Merel J. Cox, Assit. Prof. Dr. Duangkae Sitthicharoenchai and Dr. Thongchai Ngamprasetwong for their useful comments and suggestions on my thesis and presentation.

I thanks to all members of Thai Turtle Lab for their kind help throughout my study period, especially during the procedure of CU E-Thesis.

It is my privilege to thank my family and all of my forester friends for their constant encouragement throughout my research period.

This study is dedicated to the memory of Dr. Daryl Ralph Karns who discovered the Jagor's water snake, Enhydris jagorii at Bung Ka Loh wetland in 2007. Dr. Daryl Ralph Karns was a biologist and specialist on Oriental-Australian rear-fanged water snakes in Family Homalopsidae whom passed away in 2011.

Field equipments in the early period of this study were provided by MacAuthur Foundtion. This study was supported by the 90th Anniversary of Chulalongkorn University Fund (Ratchadaphiseksomphot Endowment Fund) (16/2011) and the Center of Excellence in Biodiversity under the Research Program on Conservation and Utilization of Biodiversity (CEB_D_27_2011), Department of Biology, Faculty of Science, Chulalongkorn University.

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# Chapter I

# Introduction

## 1.1 Rational

Since the widespread of aquatic resources existed in this country, high biodiversity of aquatic fauna and flora occurs throughout Thailand, especially at the Chao Phraya - Ta Chin basin. Human and metropolises located inside the central plain of Thailand have been supported by these natural resources for a long time (Murphy, 2007a; Royal Institue, 2002). Nevertheless, aquatic habitats such as pond, streams and rivers have been substantially disturbed according to numerous kinds of human activities. Uncontrolled fishery, extended of agricultural areas and rapid urbanization are mainly negative effects to the population of aquatic lifeforms. Therefore, various kinds of aquatic plants and animals, especially freshwater snakes, are facing the population decline (Brooks et al., 2007; Karns et al., 2010; Murphy, 2007a; Stuart et al., 2000).



Of the 3,500 species from 19 living families, 6 families contain species of snake lived in freshwater habitats; Family Acrochordidae, Family Boidae, Family Colubridae, Family Homalopsidae, Family Natricidae and Family Viperidae (Alderton, 2007; Gower et al., 2012; Greene, 1997; Mattison, 2007; Stafford, 2000). Freshwater snakes in Family Homalopsidae live in the aquatic habitats throughout Thailand. These piscivorous snakes spend most of their life time in freshwater habitats such as buffalo wallows, ponds, canals, small streams and rivers. Aquatic snakes are recognized as an important predator in maintaining biodiversity of the wetlands. Fifty three species in 18 genera of homalopsid snakes have been reported throughout their distribution, of

which 18 species in 8 genera were discovered in this country. From those, 12 species are freshwater species lived in freshwater habitats (Cox, 1991; Cox et al., 2012; Gyi, 1970; Karns et al., 2010; Karns et al., 2005; Murphy, 2007a; Murphy and Voris, 2005; Pongcharoen et al., 2008a). With no exception, these freshwater snakes also have the negative effects caused by human activities. Murphy (2007a) reported that these freshwater species have received little attention and are the critically threatened snakes by urbanization and increasing of agro-ecosystem.

From all freshwater homalopsid snakes, the Jagor's water snake, *Enhydris jagorii* is one of the excellent example for threatened freshwater homalopsid snakes in this country (Murphy, 2007a). This species is an endemic species found only in the Chao Phraya - Ta Chin basin inside the central plain of Thailand. Karns et al. (2010) updated the new localities of this freshwater homalopsid snake at the Bung Ka Loh wetland at Uttaradit Province. Nevertheless, large area of this wetland is seriously disturbed by habitat change and destruction. Hence, this freshwater homalopsid snake is in need of immediate protection due to its status and threats. The conservation and management on both of procedure and policy are very urgent not only for this freshwater homalopsid snake but for other aquatic lifeforms lived inside this wetland, as well. To be able to conduct the conservation and management procedures, basic information is absolutely needed. However, the basic information of this freshwater snakes is lacking in details. More researches of this freshwater homalopsid snake ought to be conducted. Therefore, the main propose of this study is to thoroughly study the basic information of the Jagor's water snake, *Enhydris jagorii* living inside the Bung Ka Loh wetland located at Uttaradit Province in the central plain of Thailand.

1.2 Objectives

To study:

1.2.1 freshwater snake community at the Bung Ka Loh wetland, Uttaradit Province, Thailand

1.2.2 morphology and sexual dimorphism of the Jagor's water snake, *Enhydris jagorii* at Bung Ka Loh wetland, Uttaradit Province, Thailand

1.2.3 diets from stomach contents of the Jagor's water snake, *Enhydris jagorii* at Bung Ka Loh wetland, Uttaradit Province, Thailand

1.2.4 female reproductive biology and the relationship between reproductive activities and the environmental factors at Bung Ka Loh wetland, Uttaradit Province, Thailand

1.2.5 distribution and the status of the Jagor's water snake, *Enhydris jagorii* at the Chao Phraya - Ta Chin basin, Thailand

# Chapter II

# Literature review

## 2.1 Family Homalopsidae

Snakes, more than 3,000 species in 19 families, have been classified into Suborder Ophidia of the Class Reptilia. This class consists of 4 orders; Testudines (turtles), Crocodelia (crocodiles), Spenodontia (Tuatara) and Squamata (snakes and lizards). Lacking of eyelids, limbs, external ears, and vestiges of forelimbs are characters that separated snakes from legless lizards. Exception of polar region, Ireland and New Zealand, snakes were found anywhere throughout the world in many kinds of habitat types (Greene, 1997; Stafford, 2000). Oriental Australian rear-fanged water snakes or mud snakes were classified into Family Homalopsidae. Members of this family used to be arranged in Subfamily Homalopsinae, Family Colubridae but molecular phylogenetic analysis supported that it is monophyletic and recover the Homalopsid as a sister group of Family Colubridae and Elapidae (Kelly et al., 2003; Lawson et al., 2005; Vidal et al., 2007).

Homalopsid snakes were found in a wide range of distribution. They 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, 2007a). Pakistan's Indus River is the western edge of the family distribution; thus the deep of the Gulf of Oman appears to be a formidable barrier to these shallow water snakes. On mainland, homalopsid snakes were found in aquatic

habitats from India throughout Southeast Asia and some parts of China. On the eastern 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; Cox et al., 2012; Gyi, 1970; Karns et al., 2005; Karns, 1999-2000; Mattison, 1995, 2002, 2007; Murphy, 2007a; Murphy, 2007b; Murphy and Voris, 1994; Murphy and Voris, 2005; Pongcharoen et al., 2008a, 2008b; Whitaker and Captain, 2004) (Figure 2.1).

**Figure 2.1**: Distribution of homalopsid snakes (red area) [Robinson projection, 2003]

Approximately 53 species in 18 genera of homalopsid snakes live in both freshwater (such as ponds, ditches, buffalo's wallows, lakes, water reservoirs, canals, small streams, rivers, Figure 2.2a,b) and brackish or marine habitats (mangrove forests, tidal-mudflats, estuaries, seashores and coastlines, Figure 2.2c), and exhibit great adaptation for aquatic life around the world (Cox, 1991; Cox et al., 2012; Gyi, 1970; Karns et al., 2005; Karns, 1999-2000; Mattison, 1995, 2002, 2007; Murphy, 2007a; Murphy, 2007b; Murphy et al., 2012a; Murphy and Voris, 1994; Murphy and Voris, 2005, 2013; Murphy et al., 2005; Murphy et al., 2012b; Murphy et al., 2012c; Whitaker and Captain, 2004). Recent species of water snakes in Family Homalopsidae were shown in

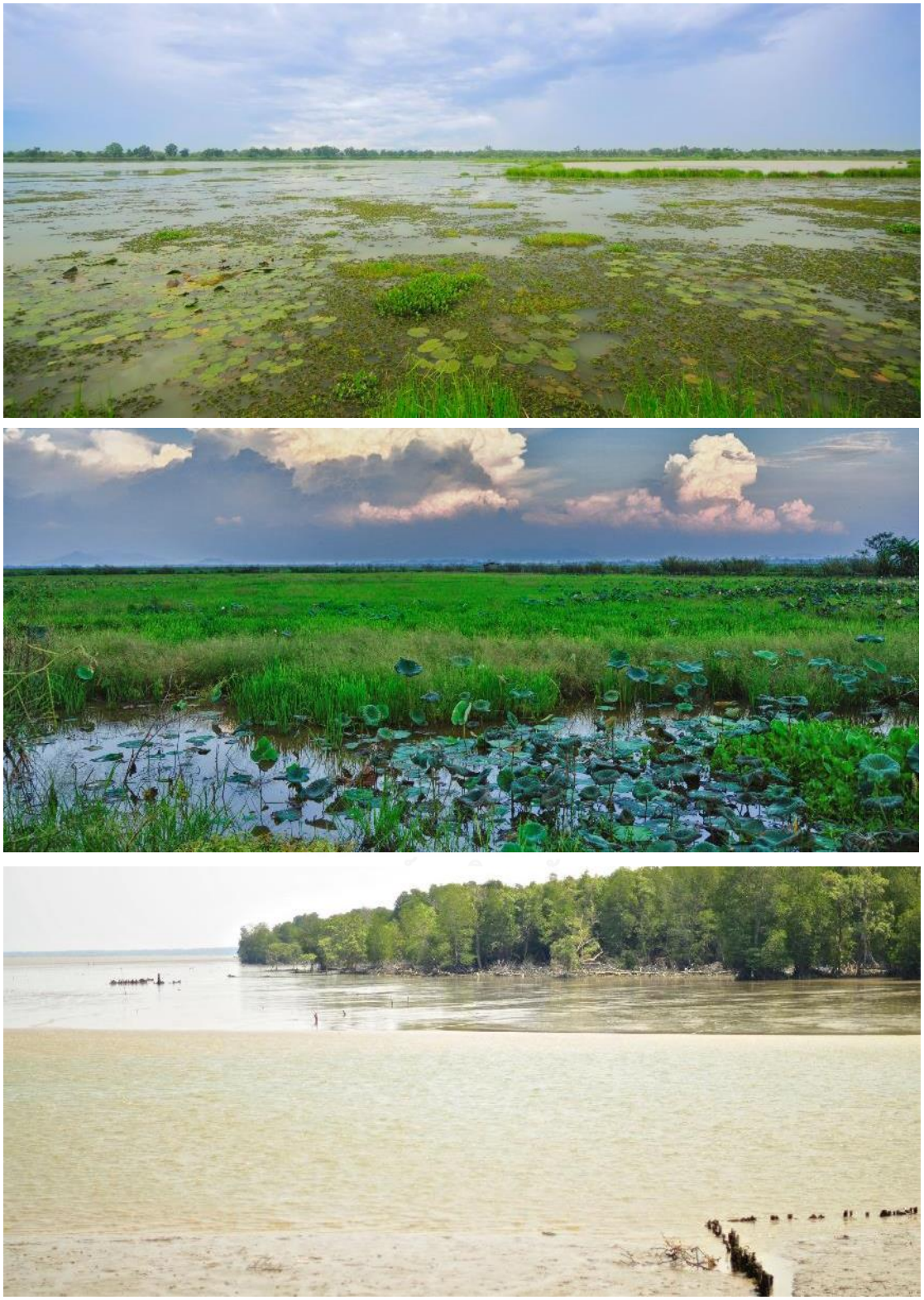

**Figure 2.2**: Aquatic habitats of water snakes in Family Homalopsidae; (a, b) freshwater habitats and (c) brackish or marine habitat.

Appendix 1. However, some homalopsids were reported as a terrestrial species and stick to the Indonesian and Papua New Guinea islands. Such homalopsids are in genus Brachyorrhos and genus Calamophis (Murphy, 2012; Murphy et al., 2012a).

All homalopsid snakes are opisthoglyphous. Their grooved rear fangs are usually paired on the posterior of the maxillary bone and these are usually longer than other maxillary teeth. Homalopsid snakes look the same as other kinds of snakes if less intention was done but they have a variety of adaptations to aquatic and terrestrial habitats and life styles. They have valvular nostrils and exhibit the ability to extend the glottis to the internal nares so that the nostrils and mouth can form a watertight seal. Their small eyes and nares located dorsally enable them to view the surface and ventilate their lungs without exposing their heads or bodies. Some species have slightly compressed tails for swimming and some species possibly have cutaneous gas exchange while submerged for extended periods in the water. Species that live in saltwater habitats, such as the dog-faced water snake, *Cerberus rynchops* has a small salt gland which is not homologous to the salt gland in other groups of reptiles and it becomes non-functional when the snake 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; Greene, 1997; Gyi, 1970; Murphy, 2007a; Stuebing and Inger, 1999). The grooved rear fangs and some adaptations to live in aquatic habitats of homalopsid snakes were shown in Figure 2.3.




**Figure 2.3**: (a) The position of the rear fangs on the posterior of the maxillary bone of *Enhydris enhydris*. (b , c) Some adaptations of homalopsid snakes, small eyes and nares located dorsally. Thus, they can view the surface and ventilate their lungs without exposing their bodies.

Water snakes in Family Homalopsidae were reported as a viviparous species (Figure 2.4a), and their embryos were nourished during development through a placenta via the female circulatory system (Figure 2.4b). Females, such as *Enhydris enhydris, E. subtaeniata, Hypsiscopus plumbea* and *Homalopsis buccata,* give birth in the rainy season and their offspring can immediately feed on by themselves (Bauchrot, 1994; Mattison, 2007; Murphy, 2007a; Murphy et al., 2002; Pongcharoen et al., 2008b). Geographic variations in reproduction were also found among populations of water snakes. Females of *Enhydris enhydris* found in the central plain of Thailand reproduced continuously throughout the year whereas females in the northeast reproduced more seasonally. Clutch mass and clutch size have a strong correlation with female body size by larger females could reproduce larger clutch mass and size. The largest clutch size of 39 offspring was reported in a female of *Enhydris enhydris* captured in the central plain of Thailand with full-term stage ($37^{th}$ stage) of development (Karns et al., 2010; Karns et al., 2005; Murphy et al., 2002; Pongcharoen et al., 2008a, 2008b).

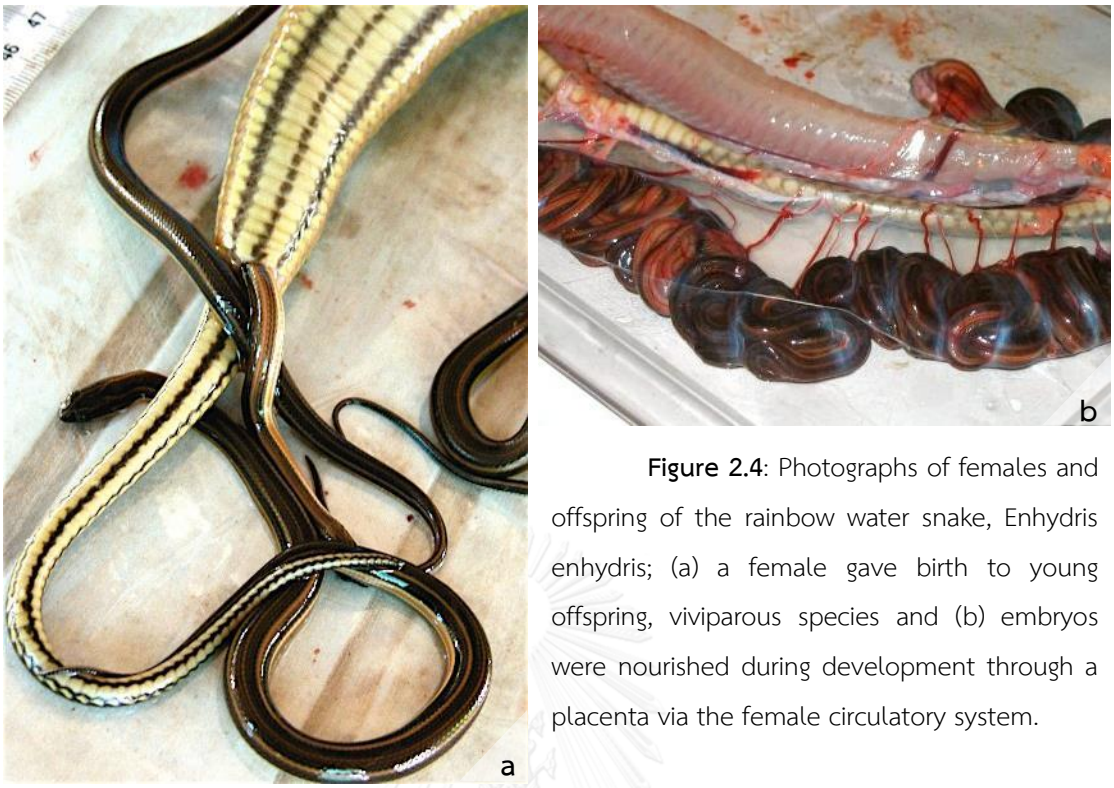


**Figure 2.4**: Photographs of females and offspring of the rainbow water snake, Enhydris enhydris; (a) a female gave birth to young offspring, viviparous species and (b) embryos were nourished during development through a placenta via the female circulatory system.

Moreover, Voris et al. (2008) reported multiple paternity in the Oriental-Australian rear-fanged water snakes, Family Homalopsidae found in Thailand. Thus, this might be the reason why this kind of snake can easily generate a new population in new locations, and supported that homalopsid snakes may be one of the most abundant snakes on this planet (Jayne et al., 1988; Murphy et al., 1999). Murphy et al. (2012b) reported the abundance of dog-faced water snake, *Cerberus rynchops*, that more than 40 individuals were collected by one man during 2 hours of surveying period at Pak Panang Peninsular, Thailand. Study on population of rainbow water snake, *Enhydris enhydris,* by Murphy et al. (1999) in Lake Songkhla at Ban Tha Hin, Sa Thing Phra District, Songkhla Province, Thailand, suggested that this area contained about 406-567 individuals and estimated a density of one snake for about every 6 feet of shoreline. More than 250 individuals of freshwater snake in Family Homalopsidae were collected in one night using 5 gill net traps (10 meters per trap) during study period in

rainy season at Ban Borthong, Kabin Buri District, Prachinburi Province, Thailand (Pongcharoen et al., 2008a, 2008b) (Figure 2.5).

**Figure 2.5:** Photograph of a container with more than 250 individuals of homalopsids, such as rainbow water snake, *Enhydris enhydris*, plumbeous water snake, *Hypsiscopus plumbea*, Bocourt's water snake, *Subcessor bocourti* and Cox's mask water snake, *Homalopsis mereljcoxi*, which were collected from Ban Borthong, Kabin Buri District, Prachinburi Province, Thailand in only one night using gill nets (Pongcharoen et al., 2008a, 2008b).



Homalopsid snakes were considered as a piscivorous (Figure 2.6a, b), feed mainly or only on fish, with exception in several species such as plumbeous water snake, *Hypsiscopus plumbea*, feed mainly on small mammals and frogs (Figure 2.6c), Cantor's water snake, *Cantoria violacea*, and Gerard's water snake, *Gerarda pravositiana* feed mainly on crustaceans. *G. prevostiana* has a very distinctive behavior by ripping the large prey into chunks before swallowing them. Prey items were usually found in small size when compared to snake body (about less than 10% of snake body mass) and multiple prey (usually 2 or 3 prey items) items were found in their stomachs. (Cox, 1991; Cox et al., 2012; Jayne et al., 2002; Mori, 1998; Murphy, 2007a; Pongcharoen


**Figure 2.6**: Photographs of stomach contents and diets of freshwater snakes; (a) climbing perch, *Anabas testudineus* in Family Anabantidae found in Cox's mask water snake, *Homalopsis mereljcoxi* digestive system, (b) tentacled snake, *Erpeton tentaculatum* feeding on red-tailed tinfoil barb, *Barbonymus altus* in Family Cyprinidae and (c) plumbeous water snake, *Hypsiscopus plumbea* feeding on Asian painted frog, *Kaloula pulchra* in Family Microhylidae.

et al., 2008a, 2008b; Smith et al., 2002; Voris and Karns, 1996; Voris and Murphy, 2002). Karns et al. (2005), Karns et al. (2010), Pongcharoen et al. (2008a) and Pongcharoen et al. (2008b) reported that small fish in Families Cyprinidae, Belontiidae, and Channidae are mainly prey types of water snakes in freshwater ecosystem in Thailand. In addition, predators of homalopsid snakes were observed and reported. Sharks, large predatory fish, turtles, monitor lizards, crocodiles, birds of prey and mammals, as well as invertebrates, are known predators of this snakes (Lyle and Timms, 1987; Murphy, 2007a; Voris and Murphy, 2002). Crustaceans, such as the crabs, were also reported as a predator of Asian Bockadam or dog-faced water snake, *Cerberus rhynchops* at Pak Panang Peninsular, Thailand. Furthermore, Murphy (2007a), Pongcharoen et al. (2008a) and Pongcharoen et al. (2008b) reported that other kinds of snakes such as the banded

krait, *Bungarus fasciatus,* many-banded krait, *Bungarus multicinctus,* indian cobra, *Naja naja,* red-tailed pipe snake, *Cylindrophis ruffus* and sunbeam snake, *Xenopeltis unicolor* are also predators of homalopsid snakes (Figure 2.7).

**Figure 2.7:** A female of the Mekong water snake, *Enhydris subtaeniata* was found in a male sunbeam snake, *Xenopeltis unicolor* gut during stomach content investigation at Ban Badan in Khorat basin, northeastern Thailand (Pongcharoen et al., 2008a).

Since aquatic resources are widespread in Thailand, 18 species (33.96%) in 8 genera of water snakes in Family Homalopsidae were reported from aquatic ecosystems in this country (Appendix 2). In 3 genera; *Enhydris* (8 species), *Homalopsis* (3 species) and *Erpeton* (1 species), and the other are 6 marine species in 5 genera; *Bitia, Cantoria, Fordonia, Gerarda* and *Cerberus* (each genus was only one species contained except Genus *Cerberus* with 2 species contained). Among them, Genus *Enhydris* contains freshwater species which has a widest distribution, especially the rainbow water snake, *Enhydris enhydris* as well as Genus *Hypsiscopus*, plumbeous

water snake, *H. plumbea* (Figure 2.8). These 2 species could be found throughout the country in freshwater habitats such as small streams, rivers, ponds, canals, rice fields, paddy fields, shallow wallows and water reservoirs (Cox, 1991; Cox et al., 2012; Gyi, 1970; Karns et al., 2005; Karns, 1999-2000; Murphy, 2007a; Murphy, 2007b; Murphy et al., 2012b; Murphy et al., 2012c; Pongcharoen et al., 2008a, 2008b). Consequently, most studies on freshwater homalopsid snakes were mostly based on *Enhydris enhydris* and *Hypsiscopus plumbea* (Karns et al., 2005; Karns, 1999-2000; Murphy et al., 2005; Murphy et al., 2002; Voris and Murphy, 2002). Nevertheless, there is another


**Figure 2.8:** Photographs of 2 widespread homalopsid species found in Thailand; (a) rainbow water snake, *Enhydris enhydris* (a freshwater species) and (b) plumbeous water snake, *Hypsiscopus plumbea* (terrestrial-freshwater species).



mysterious and interesting freshwater homalopsid species in the Genus *Enhydris*, the Jagor's water snake, *Enhydris jagorii* which is an endemic species found only in Chao Phraya Basin, the central plain of Thailand. Natural history, habitat, diet and reproduction of this species still unclear. Moreover, photographs of some species of homalopsid snakes which were found in Thailand were shown in Figure 2.9.


**Figure 2.9**: Photographs of some water snake species, Family Homalopsidae, found in Thailand. Freshwater species; (a) Mekong water snake, *Enhydris subtaeniata,* (b) Cox's mask water snake, *Homalopsis mereljcoxi* and (c) tentacled snake, *Erpeton tentaculatum* and marine species; (d) dog-faced water snake, *Cerberus rynchops,* (e) crab-eating water snake, *Fordonia leucobalia* and (f) Gerard's water snake, *Gerarda pervostiana*. Pictures c to d were come from discus-hinas.nl and reptile-database.com.

2.2 The Jagor's water snake, *Enhydris jagorii* (Peters, 1863)

**Classification**

Kingdom; **Animalia**

Phylum; **Chordata**

Class; **Reptilia**

Order; **Squamata**

Suborder; **Ophidia**

Family; **Homalopsidae**

Genus; ***Enhydris***

Species; ***Enhydris jagorii* (Peters, 1863)**

Nineteen species (35.84%) of homalopsid snakes belong to Genus *Enhydris* are widely distributed from India throughout Southeast Asia and eastward to Australia. This group of snakes is a freshwater species living in various kinds of freshwater habitats such as ponds, ditches, wallows, canals, small streams, lakes and water reservoirs with a dense of root-tangled or mud-substrate. Despite a broad distribution of some species such as the rainbow water snake, *Enhydris enhydris*, some species are very restrictive species such as the kapuas water snake, *Enhydris gyii* was reported only from Sungai Kapuas at Putussibau in west Kalimantan, Indonesia, Voris's water snake, *Enhydris vorisi,* was reported only from vicinity of Maubin, Ayeyarwady Division in Myanmar, and the sand river water snake, *Enhydris pakistanica* was reported only from lower Indust River in Pakistan (Cox, 1991; Cox et al., 2012; Gyi, 1970; Mattison, 2007; Murphy, 2007a; Murphy, 2007b; Murphy and Voris, 2005; Murphy et al., 2005; Murphy et al., 2002; Reptile Database, 1995; Taylor, 1965). In Thailand, *Enhydris* is the largest genus of water snake in Family Homalopsidae. This genus consists of 8 freshwater species (44.44%) from 18 species of homalopsid species found in this

country. Most freshwater species in this genus are quite common and could be easily found in freshwater habitats. Other 2 species, Chanard's water snakes, *Enhydris chanardi* and Jagor's water snake, *E. jagorii* were reported only from the central plain of Thailand and restricted to the Chao Phraya Basin. Thus, they were considered as endemic species found only in Thailand (Cox, 1991; Cox et al., 2012; Gyi, 1970; IUCN Red List of Threatened Species, 2014; Karns et al., 2010; Murphy, 2007a; Murphy and Voris, 2005; Murphy et al., 2005; Reptile Database, 1995). According to this reason, one of these species becomes a primary focus in this study, the Jagor's water snake, *Enhydris jagorii* (figure 2.10).

The Jagor's water snake was first described by Peters in 1863 as *Hypsirhina* (*Eurostus*) *jagorii* which, nowadays, has been changed to *Enhydris jagorii.* The exact location of holotype was not documented but was reported that type specimen was collected from the vicinity near Bangkok, Thailand. This species was decided to be an endemic species at Chao Phraya Basin, the major basin in the central plain of Thailand. Generic name of this species, *Enhydris*, probably derived from Greek which the meaning is "water snake", and specific epithet was named to be honor to F. Jagor Ph.D., who made the collection of reptiles in Thailand for the Zoology Museum in Berlin, Germany. Since then, the last record of this species occurred in 1970s by Saint Giron and was reported as *Enhydris innominata smithi* (Cox et al., 2012; Gyi, 1970; Murphy, 2007a). Murphy (2007a) suggested that this snake habitat may have been greatly reduced in the last century with the urban sprawl of Bangkok consuming much of its known distribution, thus this species may be in danger.




**Figure 2.10**: Photographs of endemic freshwater homalopsid species, the Jagor's water snake, *Enhydris jagorii*, found only in the Chao Phraya Basin, the major basin in central plain of Thailand; (a) whole body picture of the species and (b) close-up picture of the species head.

External morphology of the Jagor's water snake provided here follows Murphy (2007a). Their head is modestly long, wider than neck, and appears intermediate in width between *E. innominata* (narrow head) and *E. longicaudata* (wide head). The head is not depressed as in either of the other two species. Eyes are dorsal and their diameter is about 80% of eye-nostril distance.

**On the head;** the rostral scale is pentagonal and twice as broad as tall (Figure 2.11a). The nasal scales are semi-divided with the nasal cleft touching the first labial (Figure 2.11b). The broad internasal can be single or divided and connects to the loreal scales (Figure 2.11c). The prefrontals touch the loreal, preocular, and supraocular. The frontal is slightly longer than the parietals. The supraoculars are rectangular which the posterior edge is wider than the anterior edge. The loreal is in contact with first and third upper labials (Figure 2.11d). It is usually single but one specimen has a divided loreal. The preocular is single and tall which dorsal edge is narrower than the ventral edge. There are two postocular scales and the upper scale is taller than the bottom scale. The temporal formula is 1+2 which primary temporal is taller than broad. This scale is very similar in size to the occipital scales but barely distinguishable from them. There are eight or nine upper labial scales. Sixth or seventh upper labial is the tallest upper labial scale. The fourth upper labial which is a large scale enters the orbit. Sometimes, the fifth upper labial enter the orbit but rare.

**On the chin;** there are 10-11 lower labial scales which the largest is sixth or seventh scale. First to fourth, sometimes first to fifth, lower labial scales contact an anterior chin shields. Anterior chin shields are longer than the posterior shields and they are flared or petal-shaped scales (Figure 2.11e). A small pair of scales separates the posterior chin shields from each other. There are 9-10 gular scales.

**On the body;** there are 23-25 anterior scale rows on the neck. Scale rows at the midbody are 21 rows. Scale rows at the posterior body are reduced to 19-20 rows. There are no scale ornaments and the scales become more ovate posteriorly particularly in the further ventral rows (Figure 2.11f). Dorsal scales in the first row are larger than those in the second row. The tail is slightly compressed about the same

degree as occur in *Enhydris innominata.* Ventral scales are 117-122 rows from the three females examined whereas males have 117-127 ventral rows. The ventrals are rounded and wide about three times of the height of a nearly dorsal scale. The anal plate is divided and slightly longer than a ventral scales.

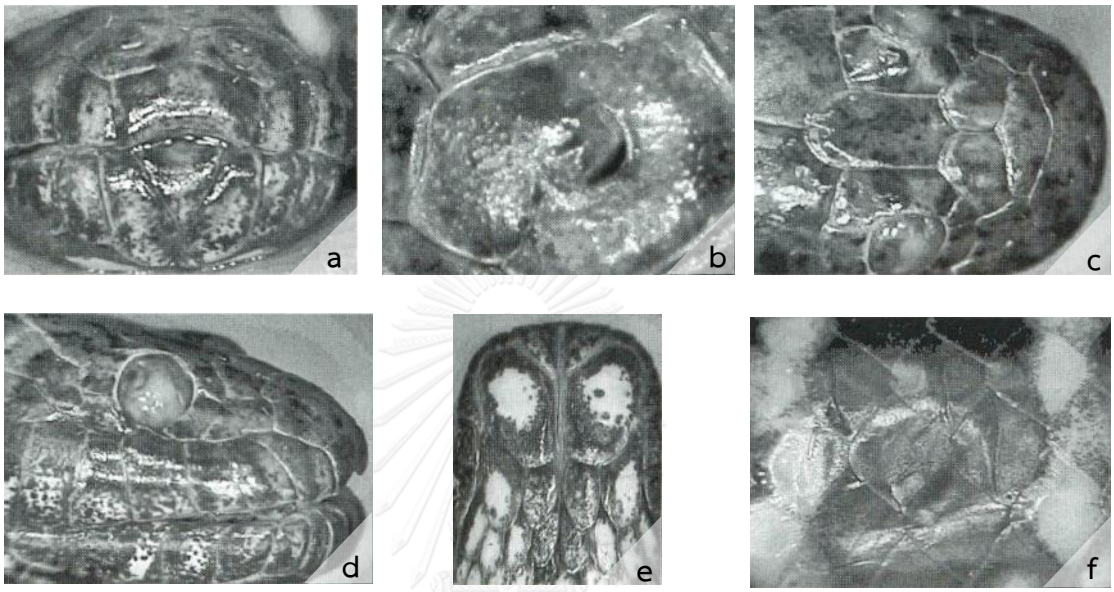


**Figure 2.11**: Photographs of the Jagor's water snake, *Enhydris jagorii*, scalation in some parts of snake's body, type specimen No.ZMB 4746 (male) at Zoologisches Museum, Universität Humboldt, Berlin; (a) rostral view, (b) nostril view, (c) crown view, (d) profile view, (e) chin shields view and (f) first three dorsal scale rows view, photographs from Murphy (2007a).

**On the tail;** the subcaudal scales are divided. There are 48-54 pairs of subcaudal scales in females whereas 53-68 pairs in males. Thus, subcaudal counts are sexually dimorphic. Formula of dorsal scales at the tail base is 12-12 rows. These scales are smooth and ovate. At the base of the snake tail, the tail width is 83% of the tail height based upon one snake specimen.

**Color and pattern;** the head is uniform. Labials may have some yellow spots or mottling. Vertebral spots are about 38 spots and occur on 10-14 scale rows.

Spots on 1-8 and 1-9 scale rows form a series of large lateral blotches that are 2-3 scale rows wide. Sometimes the vertebral row fuses with the spots on 8-9 rows and form a small bars. Large dark blotches are about 38 blotches which each 2-3 scale rows wide can be counted on the lateral side of snake body. The lateral blotches are separated by the thin yellow or white bars. These white or yellow cross bars intrude onto the venter so that they completely encircle the body and forming a pattern of white or yellow rings.

Since 1864, the Jagor's water snake, *Enhydris jagorii,* has been confused with other species, especially Mekong water snake, *E. subtaeniata* (Figure 2.12a), and Chanard's water snake, *E. chanardi* (Figure 2.12b), due to specimens in museum collection (Murphy, 2007a). This situation caused a lot of misidentification to herpetologist in the field survey. However, Murphy (2007a) provided a re-description of Holotype of this species as follows; Male holotype of *Hypsirhina jagorii* total length 463 mm, tail 118 mm (25.5%). Head small, slightly depressed, body cylindrical anteriorly, laterally compressed. Rostral scale 2.3 time broader than all. Nasal scale large, semi-divided, nasal cleft contacts the first labial. Internasal single, contacts the loreal on each side. Two prefrontal each equal to eye diameter. Frontal length slightly less than interocular distance. Parietals entire, and equal in length to the frontal. Loreal single, contacts first three upper labials. Ocular ring contains one supraocular; one preocular; two postoculars, fourth upper labial enters the orbit. Temporal 1+2+3 on both sides, secondary temporal scales each larger than the primary temporal. Upper labials 8/8; lower labial 10/11. Two pairs of chin shields; anterior pair longer than flared (almost circular), contact first four lower labials. Dorsal scale rows 24-21-21 (neck, midbody, posterior body); first three rows at mid- and posterior body are ovate, forming almost a perfect half circle; toward the midline become quadrangular. Rounded

ventrals 127, about four times width of adjacent dorsal scale at midbody; 86 pair subcaudals. Crown dark brown with darker spots on each shield; labials mottled with brown, black and yellow pigment; anterior chin shields have perimeter of dark brown pigment with a central yellow spot. Color pattern of 39 lateral dark brown blotches separated by 39 narrow yellow bars. Dark brown blotches extend from scale row one through scale row nine and area 2-3 scale rows wide. Lateral blotches do not all extend to the vertebral line, area between them filled with 14 spots, most located on anterior body. Yellow bands 14 on dorsal and lateral tail surface; ventral tail surface has irregular yellow cross bands on dark brown ground color.

Obscuring was not found only between *Enhydris jagorii* and its close relatives. Confusion in classification also found with other two species of freshwater snake which very resemble in morphological characters such as the Tay ninh water snake, *E. innominata* (Figure 2.12c), and long-tailed water snake, *E. longicauda* (Figure 2.12d). Murphy (2007) suggested the diagnosis among these water snake species as follows; flared or petal-shaped anterior chin shields can distinguished these snakes with 21 dorsal scale rows at midbody from other *Enhydris* with 21 dorsal scale rows. Ventral scales number 117-127, usually separated *E. jagorii* from *E. innominata* which has 108-117 ventral scales with which it shares a pattern of scalloped black blotches that arise from ventral side and extend onto the dorsum. *E. longicaudata* also has similar body color pattern (but slightly darker) with *E. jagorii* and *E. innominata* but ventral scales number 124-135 and subcaudals 64-73 pairs of males and 53-76 pairs of females are greater than both species (subcaudals 68 pairs in males and 50 pairs in females of *E. jagorii,* and 51-56 pairs of males and 42-49 pairs in females of *E. innominata*). For *E. chanardi*, 21 scale rows on the neck differ from 23 to 25 scale rows on the neck of *E. jagorii* and secondary pair of chin shield as long as or longer than

anterior pair. Black scalloped pattern was not found in *E. jagorii* but has a wide, bold zigzag strip on the edge of ventral scales and first scale row, clusters of scales with dark pigment that form lateral spots. *E. subtaeniata* also has 21 body scale rows, but elongated chin shields (two or three pairs), a striped pattern on scale rows 1-3, dark lateral spots on the scale rows above stripe, and a ventral count of 136-153 which is greater than *E. jagorii.*


**Figure 2.12:** Photographs of 4 homalopsid species which are related to the Jagor's water snake, *Enhydris jagorii*; (a) Mekong water snake, *Enhydris subtaeniata* (Ban Badan, Nakhon Ratchasima Province, Thailand), (b) Chanard's water snake, *Enhydris chanardi* (Pichai district, Uttaradit province, Thailand), (c) Tay ninh water snake, *Enhydris innominata* (Mekong Delta, Vietnam, photo courtesy of Alex Krohn), and (d) long-tailed water snake, *Enhydris longicauda* (Tonle Sap Lake, Cambodia, photo courtesy of John C. Murphy).

Due to the lack of specimens or records since 1970s, the knowledge of this species is meagerness (Murphy, 2007a). Anatomy, taxonomy and geographic distribution of the Jagor's water snake, *Enhydris jagorii*, have been studied in some length (Das, 2010; Karns et al., 2010; Murphy, 2007a), their natural history remain largely

anecdotal and scattered. Fortunately, (Karns et al., 2010) reported that they found the Jagor's water snake, *Enhydris jagorii* during the field survey of freshwater snakes in July, 2007 at Bung Ka Loh, located close to Nan River, in Pa Sao subdistrict, Muang district, Uttaradit Province, Thailand, which is the only location of this species reported in recent time. Some information on ecology of this species were reported. However, there is no information on predator, as well as reproduction of the species were reported from their study. Due to the short period of studying time and they did not focus on this species, basic information of the Jagor's water snake, *Enhydris jagorii* at Bung Ka Loh wetland, Uttaradit Province, Thailand is still unclear.

Unfortunately from the field survey during the study period, this wetland is now under habitat destruction caused by land developments, human activities and etc. Local authority of Uttaradit Province have been applying areas in the north of this wetland to be an agricultural areas such as rice fields, water reservoirs, fishery and livestock areas. A new campus of Uttaradit University has already opened up the areas and constructed a large building resulting in the negative effects to this endemic freshwater species. Fishery is also one of the major threat to *Enhydris jagorii* population. Lots of snakes, males, females and juveniles, have been killed by many kinds of fish traps, such as multiple-sized gill nets and funnel traps. Besides, dead snakes were abandoned with these fish traps and the traps have caused a lot of dangers to other lives in this freshwater wetland. A combination of these problems with lacking of knowledge of Bung Ka Loh wetland, the study on biology, ecology and population of the Jagor's water snake, *Enhydris jagorii* is needed to prepare a management program for this species. Moreover, this program will not be benefit only for this freshwater snake species but will be benefit to all organisms in this freshwater ecosystem.

# Chapter III

## Study area: Bung Ka Loh wetland

The central plain, an area of about 177,900 square kilometers (34.61% of total area of Thailand) is one of the major regions of Thailand. This alluvial plain had been formed by sediments from the eastern, northern and western mountains around the central plain. This place is flooded every year during the rainy season. Rainy season is about 6 months long, lasting from May to October dominated by the southwest monsoon, and the rain fall is about 1,500 millimeters per year. Average temperature is about 28.5°C, ranged between 21.0°C to 35.8°C. The elevation of the central plain is between 2.5-60.0 meters AMSL (height above mean sea level). This plain located inside the Chao Phraya - Tha Chin basin, the greatest basin covered an area about 157,925 square kilometers (30.75% of total area of Thailand). The area in the northern part of this basin is a highland and mountainous area, which provide most of the water resource for this basin, whereas lower plain area is in the southern part. This basin consists of 70 sub-basins which are gathered into 8 main basins such as Ping, Wang, Yom, Nan, Sakae Krang, Pa Sak, Tha Chin and Chao Phraya basin. From these basins, Chao Phraya basin is a major basin of this plain combined from 4 major rivers (Ping, Wang, Yom and Nan River) in northern Thailand. Much more than benefits of the great resources on agriculture, aquaculture, fishery and transportation, this basin has been provided. Chao Phraya - Tha Chin basin also produces plenty of freshwater habitats that lead to a very high biodiversity of aquatic life, both in this basin and the central plain of Thailand (Hygro and Agro Informatics Institute, 1998; Pollution Control Department, 2004; Royal Institue, 2002; Royal Irrigation Department, 2009; Thai Meteorological Department, 2014) (Figure 3.1).


a

**Figure 2.3:** The central plain of Thailand and 8 major basins; Ping, Wang, Yom, Nan, Sakae Krang, Pa Sak, Tha Chin and Chao Phraya basin.

Bung Ka Loh, as known as Bung Thung Ka Loh (Figure 3.2), is the wetland located close to downtown of Meuang District, Uttaradit Province in lower part of northern Thailand (about 500 kilometers from Bangkok). This wetland is also situated close to Nan River and connected to the Chao Phraya basin (47P 622245.886E 1944102.878N). This public use area has been managed and controlled by 2 local

b

government organizations, Pa Sao and Khung Taphao Subdistrict Administrative Organization (SAO). There is a small village at the east side of this wetland, Ban Mai Bung Wang Ngew, the 7$^{th}$ village of Pa Sao subdistrict. An area is about 10.5 square kilometers (~1050 hectares) with 2-3 meters of water depth around the center, and about 5-6 meters of water depth of canal surrounding this wetland. Land transportation is the easiest way to access this wetland, 2 kilometers in distance from 11$^{th}$ state highway and connected to many local roads, dirt and asphalt roads. In contrast, boat is the best transportation inside this wetland but in some areas during


**Figure 3.1**: Photographs of Bung Ka Loh wetland, Pa Sao and Khung Taphao Subdistrict, Meuang District, Uttaradit Province, Thailand; (a) arial view of Bung Ka Loh wetland, located close to the 11$^{th}$ highway, Nan River and downtown of Meuang Uttaradit (Arial Photo from Google Earth Program) and (b) wetland during preliminary survey in 2008.

dry season walking by feet is better than other methods. This wetland was a natural freshwater wetland which water level increase by running surface water inflow from Nan River in rainy season and water were stored for multi-proposes. Fishermen, both local and outsider, collect fish, crabs and prawns using lawns and fish traps, multiple

size of gill nets and types of funnel traps. Local farmers use stored water for rice field or paddy field, both inside and outside the wetland during dry season, as well as surrounding agricultural areas such as kitchen gardens, plantations, and orchards. Livestock and aquaculture, especially cows, chickens, ducks and Nile tilapias, are also occurred in some part of this wetland. Furthermore, animal hunting is found in this wetland, most for avocation. Small mammals and avian such as rice-field rat, *Rattus argentiventer* and Asian open-billed, *Anastomus oscitans* are often hunted by local people using traps and muskets, respectively (Figure 3.3).

In this wetland, the biodiversity is very rich as high numbers of plant and animal species have been found. One hundred and forty five species of 128 genera in 66 families of plant have been reported (Biological Diversity Division, 2009). Most of plant species, in the area, are aquatic plants in Family Cyperaceae (sedge), Nelumbonaceae (lotus), Nymphaeaceae (water lilly), Mimosaceas (water mimosa), Convolvulaceae (water morning glory) and more. These aquatic plants species disperse around the center and some parts along the edge of this wetland, and are harvested, especially seeds of sacred lotus, *Nelumbo nucifera.* There are many kinds of fruits and vegetables planted inside and outside this wetland by local people such as papaya, *Carica papaya,* mango, *Mangifera indica,* jack fruit, *Artocarpus heterophyllus,* watermelon*, Citrullus lanatus,* cucumber*, Cucumis savitus, yardlong* bean*, Vigna unguiculata,* tomato*, Solanum lycopersicum,* and many more. For plantation, river red gum, *Eucalyptus camaldulensis,* and Black wattle, *Acacia mangium, are* common logging species which are also planted along the edge of canal and surrounding the wetland.


**Figure 3.2**: Photographs of human activities occurred in Bung Ka Loh wetland, Uttaradit Province, Thailand; (a, b) rice fields, (c, d) fishery by gill nets and funnel traps, (e, f) livestocks such as cows and ducks, and (g, h) hunting of rice field rats and pond heron.

Vertebrate animals of this wetland compose of fish in Family Cyprinidae (barb, carp, minnow, etc.), Clariidae (walking catfish), Channidae (snake-headed fish), Belontiidae (gourami and fighting fish), Mastacembelidae (spinyeel), Bagridae (naked and bagrid catfish), Siluridae (sheatfish), Notopteridae (featherback and knifefish) and more; mammals such as rodents in Family Muridae (rat and mice), treeshrew in Family Tupaiidae, and mongoose in Family Herpestidae; amphibians such as frogs in Family Ranidae (frog, paddy frog, etc.), Microhylidae (chubby frog or painted frog), Rhacophoridae (tree frog), and Bufonidae (toad); and reptiles in Family Agamidae (lizard), Scincidae (skink), Bataguridae (turtle), Pythonidae (python), Cylindrophiidae (pipe snake), Xenopeltidae (sunbeam snake), Elapidae (cobra and krait), Homalopsidae (freshwater snake) and Colubridae (rat snake, tree snake, kukri snake, and etc.). Among those animals, avian is the only kind of animal which biodiversity has been reported Biological Diversity Division (2009), 93 species in 41 families, such as birds in Family Halcyonidae (kingfisher), Ardeidae (heron, egret and white egret), Pelicanidae (pelican), Ciconiidae (stork and their adjacent), Anatidae (duck), Podicipedidae (grebe), Accipitridae (eagle, hawk and etc.), Glareolidae (pratincole), Turnicidae (quail), Corvidae (crow, drongo, etc.), and Passeridae (sparrow, myna, fly-catcher, robin and etc.). Photographs of plants and animals found in Bung Ka Loh wetland are shown in Figure 3.4.

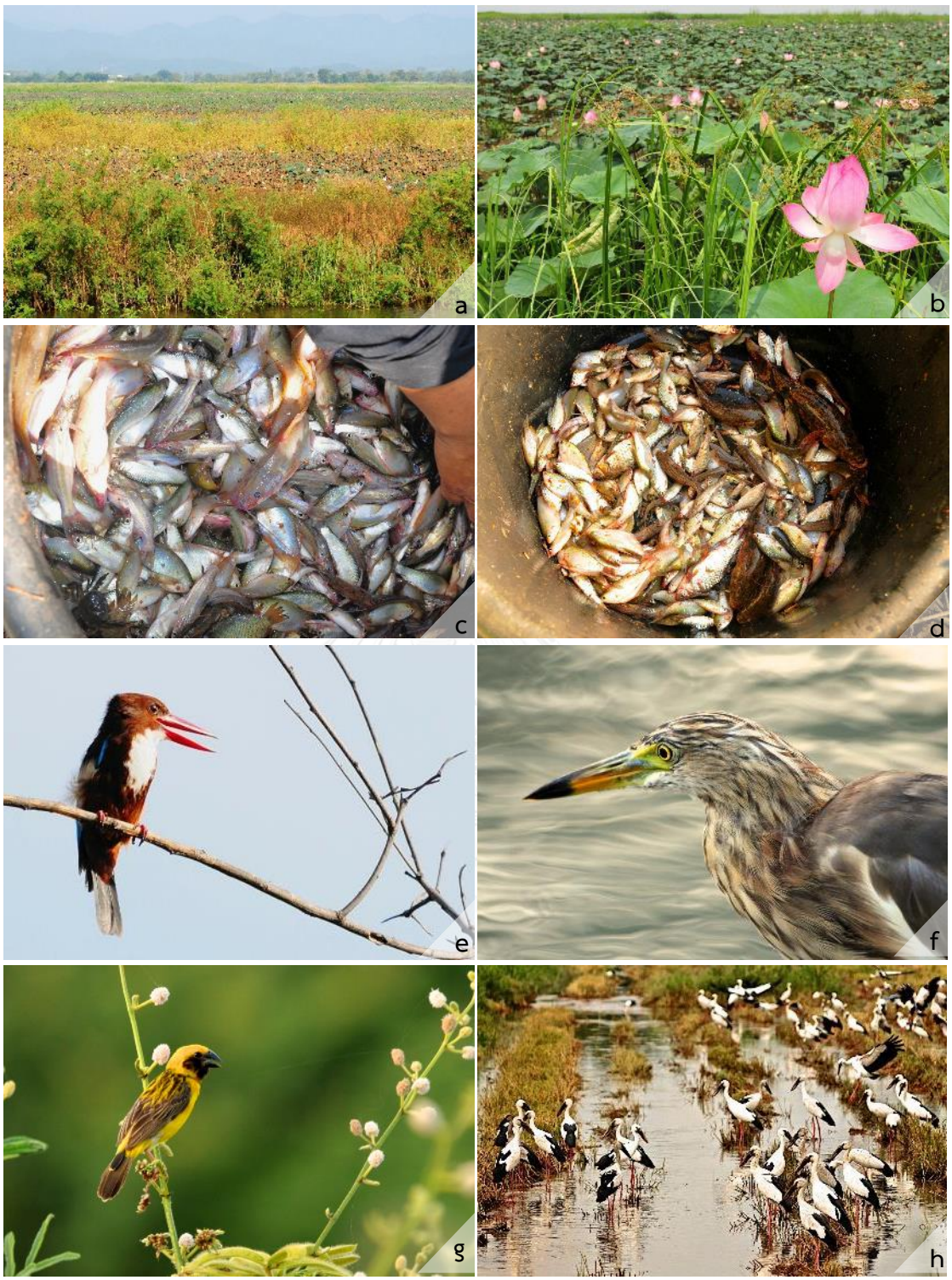


**Figure 3.3:** Plants and animals found in Bung Ka Loh, Meuang District, Uttaradit Province, Thailand; (a, b) aquatic plants species such as sedges and lotus, (c) native fish species in Family Cyprinidae, Bagridae and Belontiidae, (d) native fish species in Family Bagridae, Cyprinidae and Eleotridae, introduced species, *Hypostomus plecostomus*, was also found and (e to h) are birds in Family Halcyonidae, Ardeidae, Passeridae, Ciconiidae respectively.


**Figure 3.4 (continued):** Animals found in Bung Ka Loh, Meuang District, Uttaradit Province, Thailand; (a) treeshrew in Family Tupaiidae, (b) amphibian in Family Ranidae, (c to f) reptiles, such as turtle in Family Bataguridae and snakes in Family Xenopeltidae and Colubridae, respectively. For invertebrates, (g, h) freshwater crabs in Family Parathelphusidae and tiny freshwater shrimp in Family Palaemonidae.

Previous study by Karns et al. (2010) also reported that there are at least four species of freshwater snake in Family Homalopsidae, such as the rainbow water snake (*Enhydris enhydris*), Bocourt's water snake (*Subcessor bocourti*), the Jagor's water snake (*Enhydris jagorii*) and the puff-faced water snake (*Homalopsis buccata*), found inside this wetland. For other snake species, the common keelback (*Xenochrophis flavipunctatus*) in Family Colubridae and the sunbeam snake (*Xenopeltis unicolor*) in Family Xenopeltidae also occurred at Bung Ka Loh wetland. However, the recent revision on taxonomy and distribution of *Homalopsis buccata* complex in 2012 reformed our knowledge that the puff-faced water snake (*H. buccata*) which has been identified from the central plain of Thailand, is the new species (Murphy et al., 2012b). Hence, specimens of *H. buccata* found in this wetland by Karns et al. (2010) would be changed to the Cox's mask water snake, *Homalopsis mereljcoxi* (Figure 3.5).


**Figure 3.4**: Photographs of freshwater snake species in Family Homalopsidae which are found by Karns et al. (2010) during the survey at Bung Ka Loh, Meuang District, Uttaradit Province, Thailand; (a) rainbow water snake, *Enhydris enhydris*, (b) Bocourt's water snake, *Subcessor bocourti*, (c) Jagor's water snake, *Enhydris jagorii*, and (d) Cox's masked water snake, *Homalopsis mereljcoxi*.

Unfortunately, exotic species, both plants and animals, have been invading Bung Ka Loh wetland. Plant species such as the narrow-leaved cat-tail (*Typha angustifolia*), hydrilla (*Hydrilla verticillata*) and giant thorny sensitive plant (*Mimosa pigra*) have invaded throughout the area, especially in the southern part whereas water hyacinth (*Eichhornia crassipes*) has invaded along the edge of canal surrounding this wetland. For exotic animals, 4 species were found in this wetland, of which 3 species are vertebrates and another one species is invertebrate. Three species of vertebrates consist of 2 fish species such as nilotica or Nile tilapia (*Oreochromis niloticus*) in Family Cichlidae and common sucker or common pleco (*Hypostomus plecostomus*) in Family Loricariidae, and one mammal species such as house rat or sewer rat (*Rattus Norvegicus*) in Family Muridae whereas the golden apple snail (*Pomacea canaliculata*) in Family Ampullariidae is the only invertebrate species found in this wetland (Figure 3.6).


**Figure 3.5:** Photographs of exotic freshwater species occurred in Bung Kha Loh wetland; (a, b) exotic freshwater plants; giant thorny sensitive plant, *Mimosa pigra* and water hyacinth, *Eichhornia crassipes,* respectively and (c, d) exotic animals; common sucker or common pleco, *Hypostomus plecostomus* and golden apple snail, *Pomacea canaliculata,* respectively.

Nowadays, Bung Ka Loh wetland is transformed by many development projects from local government organizations (both of Pa Sao and Kung Taphao SAO.) such as increasing agriculture, fishery and livestock areas, increasing volume of water reservoir for more water drainage, and more. Owing to the flooding crisis in 2006 at Uttaradit Province, there was flooded all over the left side of Nan River and caused a lot of damages. However the right side of Nan River, Bung Ka Loh wetland and surrounding areas, there was no flood. Therefore, government sectors and business quarters in downtown of Uttaradit Province also attempt to construct and allocate this wetland to be a new public services and business areas (Bloggang, 2008; Prachathai, 2011; Public Relations office Region 4 Phitsanulok, 2006; Sanook, 2006). This wetland was a natural wetland until surrounding ridge with water gates were built to get more water storage for agriculture during dry season. These conversions have caused a shallow water in the middle of the area (about 1-2 meters of water depth) whereas water depth at the edge is deeper (about 5-6 meters). This deep canal combined with the ridge along the edge has been the barrier around the wetland prevented a lot of aquatic animal migration, food and reproductive area during flooding in rainy season. This construction has also performed a dirt road, leading to more human activities, such as modern agriculture (using insecticide, pesticide, fertilizer, machinery, etc.), overfishing, hunting and more.

Moreover, Bung Ka Loh wetland has been confronted to habitat changes and habitat destruction crisis from constructions of new Rajabhat Uttaradit University's campus and a new power plant in the area of the northern part, and deserted OTOP buildings which were constructed by Baromarajonani College of Nursing, Uttaradit, Thailand in the western part of this wetland. The construction of these buildings and infrastructures already changed and destroyed these areas by

digging and clearing out the surface area in large-scale since 2006, about 360 hectares or 3.6 square kilometers (Bloggang, 2008; Prachatham, 2012; Public Relations office Region 4 Phitsanulok, 2006; Sanook, 2006). Not only human activities that affected to Bung Ka Loh wetland but also during the dry season of 2011, El Niño gathered with draining out lots of water brought a very long drought period, over 4 months, in this wetland. All of these past and recent occurrences (over-hunting, pollution, habitat loss and climate change) have caused negative effects to all organisms, both plants and animals in this freshwater ecosystem. The study on these effects on plants and animals in this wetland, which is an important for conservation and management program, still has been unconcerned. Photographs of habitat changes around and inside the Bung Ka Loh wetland were shown in Figure 3.7.


**Figure 3.6**: Photographs of habitat changes and destructions occurred at Bung Ka Loh wetland; (a, b) surrounding ridge with water gates along the edge of the wetland, caused a wide and deep canal, which has formed a barrier and dirt road around the wetland and (c to f) construction areas of a new campus of Rajabhat Uttaradit University and power plant at the northern part of the wetland.

# Chapter IV

# Freshwater snake community at Bung Ka Loh wetland, Uttaradit Province, Thailand

## 4.1 Introduction

Freshwater snake communities inside the central plain of Thailand were reported by Karns et al. (2010). Four wetlands: Bung Boraphet, Bung Cho, Petchabun wetland and Bung Ka Loh, were observed during summer 2007. Six species of freshwater homalopsid snake were recorded such as the rainbow water snake, *Enhydris enhydris*, the Mekong water snake, *Enhydris subtaeniata*, the Jagor's water snake, *Enhydris jagorii*, the Cox's masked water snake, *Homalopsis mereljcoxi*, the Bocourt's water snake, *Subcessor bocourti* and the tentacle snake, *Erpeton tentaculatum*. Results showed that *Enhydris enhydris* was the dominant species. Surprisingly, the Jagor's water snake, *Enhydris jagorii* was collected only at Bung Ka Loh, Uttaradit Province Thailand. This was the latest report on specimen collection of this species since 1863 with twenty six specimens were collected. However, information on freshwater snake community at Bung Ka Loh was collected in a very short period of time (3 days of specimen collection). Hence, this study aims to collect information on freshwater snake community at this wetland in detail.

4.2 Methodology

Snake specimens were collected from Bung Ka Loh wetland, Pa Sao and Kung Taphap subdistrict, Meuang district, Uttaradit Province, Thailand during the period from October 2010 to August 2012. Snake specimens in this study were obtained from local fishermen due to snakes were usually caught by fisherman's fish traps (Figure 4.1). For this reason, local fishermen living around the wetland were contacted to collect the snake specimens from their fish traps monthly, throughout the study period, at least 15 days per month. Multiple mesh size of gill nets and many kinds of funnel traps were used for trapping fish every day.

**Figure 4.1:** Photographs showed snakes were accidentally caught by local fisherman's fish traps which were set for trapping fish inside the Bung Ka Loh wetland at Uttaradit Province, Thailand.

Gill nets which were used for trapping fish are usually about 1.5 meters in height and about 10 meters in length. Mesh size between 2.5 to 5.0 centimeters of gill nets were commonly used in this wetland (Figure 4.2a, b). About funnel traps, many kinds of these traps in multiple size were used by local fishermen. These traps were made from many kinds of materials such as plastic, metal and bamboo (Figure 4.2c, d). Fish traps were set in various locations inside this wetland up to each fisherman experiences. Funnel traps were usually set along the side and the edge of the wetland

whereas gill nets were set in all places over the wetland. Nevertheless, these fish traps were set mostly at shallow water with dense of vegetation, aquatic and riparian plants (Figure 4.3).


**Figure 4.2**: Photographs of some fish traps used for trapping fish by local fishermen inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. Gill nets of 2.5 to 5.0 centimeters in mesh size were commonly used (a, b) and (c, d) showed various kinds of funnel traps.


**Figure 4.3:** Photographs of various locations where fish traps were set by local fishermen inside the Bung Ka Loh wetland, Uttaradit Province, Thailand; (a to c) the funnel traps were set with line defenders along the side of the wetland, (d) another kind of funnel trap was set without line defender in lotus zone near the edge of the wetland and (e, f) gill nets are one kind of fish traps that can be found in all places over the wetland.

Many fish traps, both gill nets and funnel traps, were placed in the late afternoon and checked for fish in the early morning. Despite propose of these traps, freshwater and some other snake species were occasionally captured by fish traps inside this wetland. Captured snakes were brought to the base camp closed to the

wetland. Hence, snake specimens were separated from fish and classified to species before preparing for other investigations (Figure 4.4).


**Figure 4.4**: Snakes were captured by local fisherman's fish trap at Bung Ka Loh wetland, Uttaradit Province, Thailand; (a, b) snakes were captured by funnel trap and gill net, respectively and (c) collected fish and snakes were brought to the base camp and separated before study.



Live snake specimens were kept in styrofoam boxes filled with water and some aquatic plants to keep them alive for investigations. Afterwards, live specimens were released at their site of collection inside the wetland. For dead snakes, specimens were immediately kept in styrofoam boxes filled with ice and were moved to a refrigerator at Chulalongkorn University laboratory for further study on sexual dimorphism, diets and reproduction. Later on, snake specimens were kept in 95% alcohol for preservation and were deposited in the collection of Chulalongkorn University Museum of Zoology (CUMZ).

Species number of each species and sexes of all snake specimens were also recorded monthly throughout the study period. Live specimens were sexed using sexing probes. Sexing probe was gently inserted into the opening of the cloaca and to the specimen tail tip. Length of sexing probe inserted into the snake cloaca is longer in males than in females (Figure 4.5a). Dead specimens were sexed by other 2 methods, injection and dissection methods. First method, snake specimens were injected by water or 37% formaline solution using a small hypodermic syringe at about 10 to 15 subcaudal scales behind the opening of the cloaca at the ventral side of the snake tail. Hemipenis would come out from the opening of the cloaca if this snake specimen is a male but nothing would be shown from this opening if it is a female. Occasionally, the hemipenis would be out of the opening of the cloaca by hand compression at the tail base of some male snake specimens without using any equipment. The second method, dissection was performed at the ventral side around the posterior part of snake specimens. Dead specimens were dissected from the opening of the cloaca toward the anterior part for about one-third of the SVL (snout-vent length). Thus, male was considered from testis and/or ductus deferens whereas female was considered from embryos, follicles, ovary and/or uterus. Determining the sex of snake specimens was shown in Figure 4.5.



Species richness, evenness and number of collected snake specimens per day of the Bung Ka Loh wetland were calculated for comparing with the previous studies on freshwater snake community in the central plain of Thailand. Species evenness was calculated following the Shannon-Wiener's evenness index, *J'*. Species overlap between freshwater snake communities was also calculated by following the Sorensen species overlap index, QS.

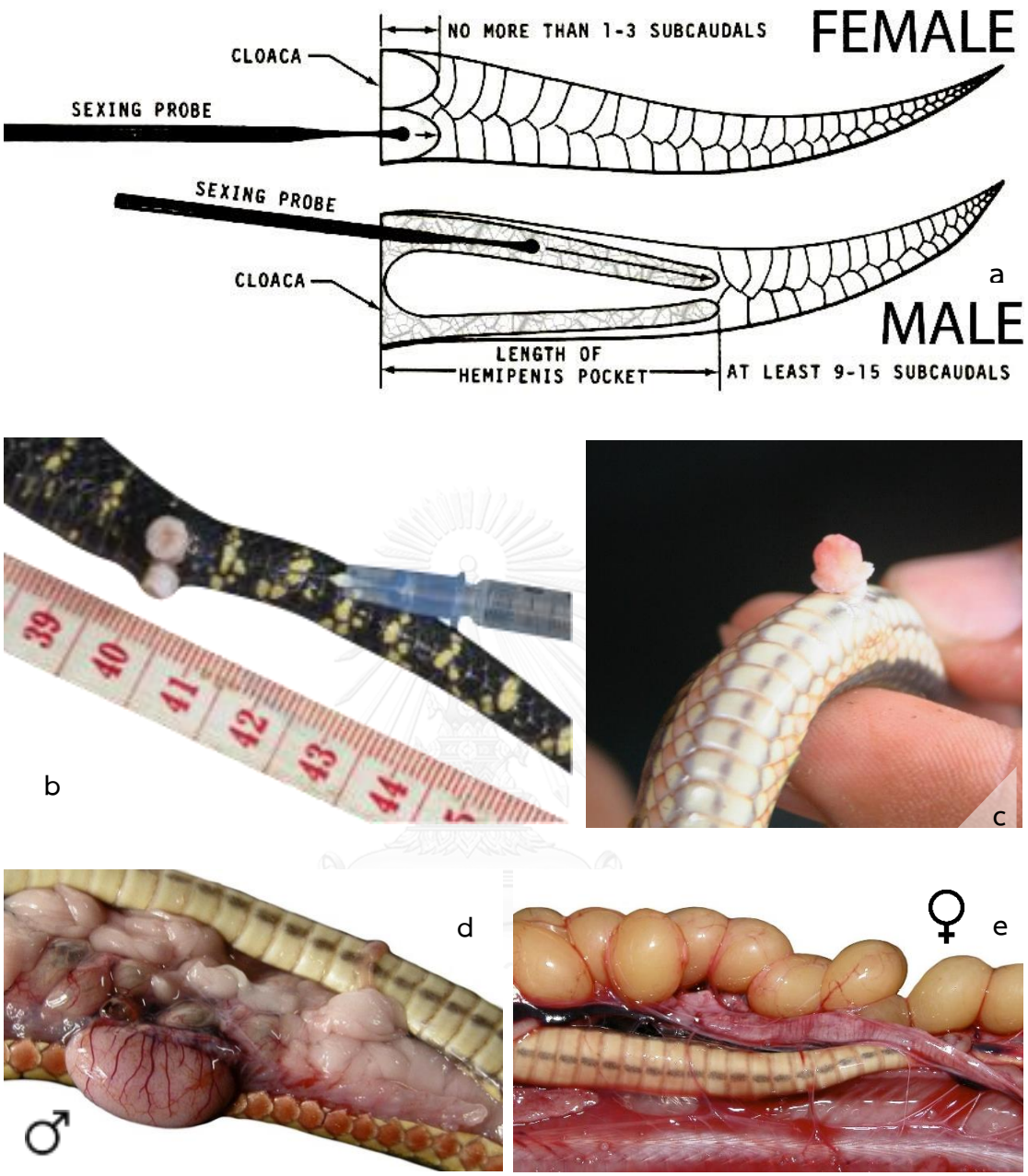


**Figure 4.5**: Photographs of sex determination of the snake specimens. (a) Determining the sex of snake specimens using sexing probes in live specimens. For dead specimens, sex was determined by injection and dissection methods. (b, c) Snakes were injected by water or 10% formaldehyde solution at the tail base, hemipenes would be exhibited if the specimens are males but nothing were shown if the specimens are females. (d, e) Dissection was also used to determine the sex of snake specimens, males exhibited testis and ductus deferens whereas females exhibited embryos, follicles, ovary and uterus.

**Shannon-Wiener's evenness index, *J'***

$$J' = \frac{H'}{H'_{\max}}$$

*J'* is between 0 and 1, the higher *J'* means the less variation between communities

*H'* is the number derive from Shannon-Wiener's diversity index.

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

$p_i$ is the proportion between the sample number of *i* species divided by the total number of all species samples.

$H'_{max}$ is the maximum value of *H'*.

$$H'_{\max} = -\sum_{i=1}^{S} \frac{1}{S} \ln \frac{1}{S} = \ln S.$$

*S* is the total number of species.

**Sorensen overlap index, QS**

$$QS = \frac{2C}{A+B}$$

A and B are the number of species in samples A and B.

C is the number of species shared by these two samples.

4.3 Result

From October 2010 to August 2012, three hundred and fifty one specimens were collected from local fisherman's gill nets and funnel traps at the study site inside Bung Ka Loh wetland. The specimens consisted of 6 species which could be divided into two groups; freshwater snake and other snake groups. The first group had 4 species in Family Homalopsidae; Cox's masked water snake, *Homalopsis mereljcoxi*, rainbow water snake, *Enhydris enhydris*, Bocourt's water snake, *Subcessor bocourti* and Jagor's water snake, *Enhydris jagorii*. The second group had 2 species; the common keelback, *Xenochrophis flavipunctatus* in Family Colubridae which is a semi-aquatic snake species and the red-tailed pipe snake or Asian pipe snake, *Cylindrophis ruffs* in Family Cylindrophiidae which is a terrestrial snake species. Photographs of the 6 species captured inside the wetland were shown in Figure 4.6.

During twenty-three months of the investigation period, there was a remarkable notice about specimen collection on March and December 2011, and from January to May 2012. In these seven months, no single snake specimen was collected from local fisherman's fish traps inside this wetland. Nevertheless, collected snake specimens besides these months provided the information on snake community here at Bung Ka Loh wetland. The highest number of all collected snake specimens was 57 specimens in November 2011 followed by 43 specimens in October 2011 and 42 specimens in August 2011, respectively. Despite the months with no collected specimen, the lowest number was only one specimen in April 2011 followed by 2 specimens in January and February 2011. All of these five specimens were *Enhydris jagorii.* Snake species and the number of each species separated by sexes collected in each months are shown in Table 4.1.


**Figure 4.6**: Photographs of 6 species of snakes captured by local fisherman's fish traps inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. Freshwater snakes in Family Homalopsidae; (a) Cox's masked water snake, *Homalopsis mereljcoxi*, (b) rainbow water snake, *Enhydris enhydris*, (c) Bocourt's water snake, *Subcessor bocourti* and (d) Jagor's water snake, *Enhydris jagorii*. The other snake group; (e) common keelback, *Xenochrophis flavipunctatus* in Family Colubridae and (f) red-tailed pipe snake, *Cylindrophis ruffus* in Family Cylindrophiidae.

**Table 4.1:** Snake species, sex and the numbers of each species collected monthly by local fishermen's fish traps at Bung Ka Loh wetland, Uttaradit Province, Thailand, during study period from October 2010 to August 2012. The dominant species was the rainbow water snake, *Enhydris enhydris*, followed by Jagor's water snake, *Enhydris jagorii*, common keelback, *Xenochrophis flavipunctatus*, Cox's masked water snake, *Homalopsis mereljcoxi*, red-tailed pipe snake, *Cylindrophis ruffus,* and Bocourt's water snake, *Subcessor bocourti,* respectively.

| Species | Sex | 2010 | | | 2011 | | | | | | | | | | | | 2012 | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | |
| *Enhydris enhydris* | M | 1 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 8 | 15 | 6 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 25 | 0 | 79 |
| | F | 9 | 6 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 20 | 11 | 18 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 8 | 9 | 123 |
| | | 10 | 6 | 8 | 0 | 1 | 0 | 0 | 0 | 0 | 12 | 28 | 26 | 24 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 33 | 9 | 202 |
| *Enhydris jagorii* | M | 1 | 0 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 9 | 8 | 6 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 4 | 54 |
| | F | 4 | 0 | 2 | 1 | 1 | 0 | 1 | 8 | 3 | 3 | 2 | 4 | 6 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 8 | 54 |
| | | 5 | 0 | 5 | 2 | 2 | 0 | 1 | 8 | 3 | 5 | 11 | 12 | 12 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 4 | 12 | 108 |
| *Homalopsis mereljcoxi* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 9 |
| | F | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 |
| | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 14 |
| *Xenochrophis flavipunctatus* | M | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 9 |
| | F | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 12 |
| | | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 3 | 21 |
| *Cylindrophis ruffus* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | F | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| ***Subcessor bocourti*** | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | F | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| **Total specimens** | | 16 | 16 | 13 | 2 | 3 | 0 | 1 | 8 | 3 | 17 | 42 | 41 | 43 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 38 | 27 | 351 |

Of all the collected snake specimens, the rainbow water snake, *Enhydris enhydris* is the dominant species inside the Bung Ka loh wetland. Two hundred and two specimens (55.75%) were collected throughout the study period followed by 108 specimens (30.77%) of Jagor's water snake, *Enhydris jagorii*, 21 specimens (5.98%) of common keelback, *Xenochrophis flavipunctatus*, 14 specimens (3.99%) of Cox's masked water snake, *Homalopsis mereljcoxi*, 4 specimens (1.14%) of red-tailed pipe snake or Asian pipe snake, *Cylindrophis ruffus* and 2 specimens (0.57%) of Bocourti's water snake, *Subcessor bocourti*, respectively. The proportion of all collected specimens is shown in Figure 4.7.

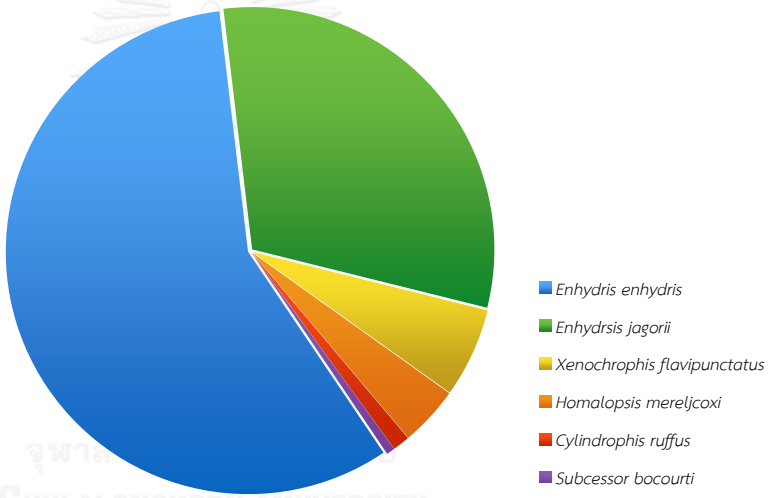


**Figure 4.7:** The proportion of all collected snake specimens at Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period from October 2010 to August 2012. The rainbow water snake, *Enhydris enhydris* (57.55%) was the dominant species followed by Jagor's water snake, *Enhydris jagorii* (30.77%), common keelback, *Xenochrophis flavipunctatus* (5.98%), Cox's masked water snake, *Homalopsis mereljcoxi* (3.99%), red-tailed pipe snake, *Cylindrophis ruffus* (1.14%) and Bocourt's water snake, *Subcessor bocourti* (0.57%), respectively.

Three hundred and twelve specimens of 4 species of freshwater snakes in Family Homalopsidae were collected during the specimen collection period. Among these species, the rainbow water snake, *Enhydris enhydris* was the dominant species in the wetland (63.27%) followed by Jagor's water snake, *Enhydris jagorii* (31.23%),

Cox's masked water snake, *buccata* (4.42%) and Bocourt's water snake, *Enhydris bocourti* (0.63%), respectively. The proportion of freshwater snake specimens in Family Homalopsidae collected inside the Bung Ka Loh wetand is shown in Figure 4.8.

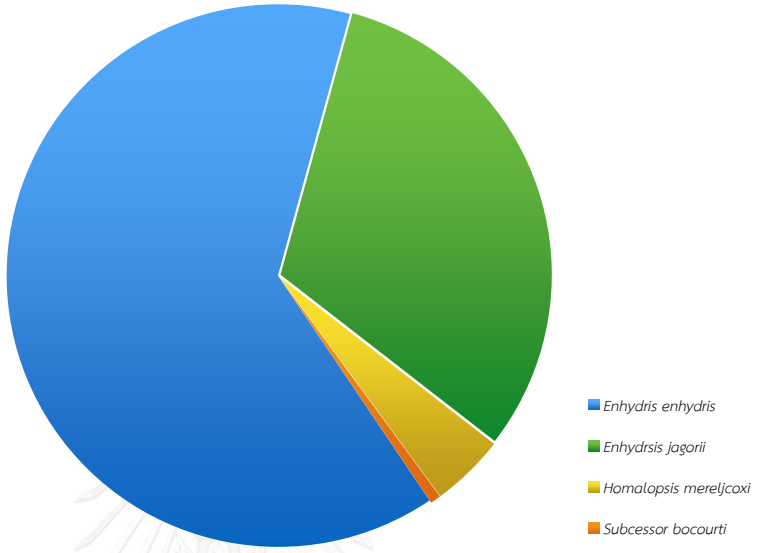


**Figure 4.8:** The proportion of freshwater snake specimens in Family Homalopsidae collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand during study period from October 2010 to August 2012. The dominant species was the rainbow water snake, *Enhydris enhydris* (63.72%) followed by Jagor's water snake, *Enhydris jagorii* (31.23%), Cox's masked water snake, *Homalopsis mereljcoxi* (4.42%) and Bocourt's water snake, *Subcessor bocourti* (0.63%), respectively.

According to 23 months of snake collection period, all specimens were collected for 15 months inside the wetland. For the group of freshwater snakes, the Jagor's water snakes, *Enhydris jagorii* were collected for 14 months such as in October and December 2010, January to February and April to November 2011, and June to August 2012. The highest number of collected specimens was 19 specimens occurred in November 2011 followed by September and October 2011 and August 2012 with 12 collected specimens each month. The lowest number of collected specimens occurred in April 2011 with a single specimen. The rainbow water snakes, *Enhydris enhydris* were collected for 11 months in October to December 2010, February and July to November 2011, and June to August 2012. The highest number of specimens

was 33 specimens in July 2012 followed by 31 and 28 specimens in August and November 2011, respectively. The lowest number of snake specimens occurred in February 2011 with a single specimen. The Cox's masked water snakes, *Homalopsis mereljcoxi* were collected for 6 months in October 2010, August, October and November 2011, and June and August 2012. The highest number was 6 specimens occurred in November 2011. The lowest number was a single specimen in October 2010, August 2011, and June 2012. The Bocourt's water snakes, *Subcessor bocourti* was found only in November 2010 with 2 specimens. For the group of other snakes, the common keelbacks, *Xenochrophis flavipunctatus* were collected for 8 months in November 2010, August to November 2011, and June to August in 2012. The highest number was 8 specimens occurred in November 2010. The lowest number was a single specimen in November 2011 and July 2012. The red-tailed pipe snakes, *Cylindrophis ruffus* were collected for 2 months in September and November 2011 with one and three specimens, respectively.

The numbers of female and male snakes of each species collected from Bung Ka Loh wetland were shown in Table 3.1. For freshwater snakes, the sex ratio varies due to species of snake. Two hundred and two collected specimens of the rainbow water snake, *Enhydris enhydris* consisted of 123 females and 79 males. The highest number of collected females was 20 specimens occurred in August and November 2011 whereas collected males was 25 specimens occurred in July 2012. Male snakes were collected less than female snakes and the sex ratio of this species is 0.64:1. Five females and nine males of the Cox's masked water snake, *Homalopsis mereljcoxi* were collected. The highest number of females was 2 specimens occurred in October 2012 whereas collected males was 6 specimens occurred in November 2011. Male snakes were collected more than female snakes and the sex ratio of this

species is 1.8:1. From 108 snake specimens, males and females of the Jagor's water snake, *Enhydris jagorii* were collected in equal number as 54 specimens. The highest number of female snakes was 8 specimens occurred in May 2011 and August 2012 whereas males was 14 specimens occurred in November 2011. Thus, the sex ratio of this species is 1:1. Unfortunately, only two female specimens of the Bocourt's water snake, *Subcessor bocourti* were collected from this wetland during the study period.

Female specimens of both species of the other snake group were collected more than male specimens. Twelve collected females of the common keelback, *Xenochrophis flavipunctatus* were collected with the highest number of 2 specimens occurred in October 2011 and June 2012. Nine specimens of male snakes were collected with the highest number of 2 specimens in August 2012. From 4 specimens of the red-tailed pipe snake, *Cylindrophis ruffus*, 3 females were collected with the highest number of 2 specimens in October 2011 whereas only one male of this species was collected in the same month.



Moreover, there are other snake species were observed and recorded in the vicinity area around the Bung Ka Loh wetland (Figure 4.9). These are 11 species of snakes belonging to 4 families such as Family Colubridae, Elapidae, Pythonidae and Xenopeltidae. Seven species are snakes in Family Colubridae such as the stripped kukri snake, *Oligodon taeniatus*, the Indochinese rat snake, *Ptyas korros*, the Oriental rat snake, *Ptyas mucosa*, the golden tree snake, *Chrysopelea ornata ornatissima*, the common bronzeback, *Dendrelaphis pictus*, the copperhead rat snake, *Coelognathus radiata* and the red-necked keelback, *Rhabdophis subminiatus*. Two species are snakes in Family Elapidae such as the monocle cobra, *Naja kaouthia* and the banded krait, *Bungarus fasciatus.* Another species is snake in Family Pythonidae such the reticulate

python, *Python reticulatus reticulatus.* The last species is the sunbeam snake, *Xenopeltis unicolor* in Family Xenopeltidae. Unfortunately, most of these snake species were found as road kill species like other kinds of animals around this wetland such as the Asian mongoose, *Herpestes javanicus*, the green bee-eater, *Merops orientalis*, the white-vented myna, *Acridotheres grandis,* the big-headed snail-eating turtle, *Malayemys macrocephala*.


**Figure 4.9:** Some of other snake species found in the vicinity around the Bung Ka Loh wetland, Uttaradit Province, Thailand; (a) sunbeam snake, *Xenopeltis unicolor*, (b) copperhead racer, *Coelognathus radiata*, (c) common bronzeback, *Dendrelaphis pictus*, (d) Indochinese rat snake, *Ptyas korros*, (e) golden tree snake, *Chrysopelea ornata ornatissima*, and (f) reticulate python, *Python reticulatus reticulatus*.

From previous studies on freshwater snake communities inside the central plain of Thailand, information on species richness, evenness and the number of collected snakes per day were provided. These information were also performed in this study and compared to the other previous reports. Species richness is 6 species of snakes and species evenness is 0.591 calculated from specimens collected inside this wetland. These are the highest number among the other communities in previous studies as same as reported by Karns et al. (2010). However, the number of snake specimens collected per day from this wetland in this study is the lowest number when compared to other studies. About one snake specimen per night was calculated from this study whereas about 87 snake specimens per night was reported in the previous study by Karns et al. (2010) at the same study site. From table 4.2, all of 4 study sites was dominated by the rainbow water snake, *Ehydris enhydris* both previous and recent studies. However, there are the differences between this study and previous study at Bung Ka Loh wetland by Karns et al. (2010) such as the red-tailed pipe snake, *Cylindrophis ruffus* specimens were collected in this study but not in the previous study, and the sunbeam snake, *Xenopeltis uniclor* specimen was collected in the previous study but not in this study. Total number of snake specimens, species richness, evenness and numbers of collected snakes per day from the Bung Ka Loh wetland and previous reports were calculated and shown in Table 4.3.

**Table 4.2:** The total number of collected snake specimens, species richness, species evenness, and the numbers of collected snakes per day inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. Information on these data of previous reports by Karns et al. (2010) were also shown.

| Species | Bung Ka loh (345) | Previous study sites | | | |
|---|---|---|---|---|---|
| | | Bung Boraphet (5) | Petchabun (14) | Bung Cho (11) | Bung Ka Loh (3) |
| **Homalopsid snakes** | | | | | |
| *Enhydris enhydris* | 202 | 180 | 163 | 91 | 196 |
| *Enhydris subtaeniata* | 0 | 54 | 0 | 0 | 0 |
| *Homalopsis mereljcoxi* | 14 | 3 | 0 | 0 | 29 |
| *Enhydris jagorii* | 108 | 0 | 0 | 0 | 26 |
| *Subcessor bocourti* | 2 | 0 | 0 | 0 | 3 |
| *Erpeton tentaculatum* | 0 | 3 | 0 | 0 | 0 |
| **Other snake group** | | | | | |
| *Xenochrophis flavipunctatus* | 21 | 0 | 10 | 8 | 7 |
| *Cylindrophis ruffus* | 4 | 1 | 2 | 3 | 0 |
| *Xenopeltis unicolor* | 0 | 0 | 0 | 0 | 1 |
| **Total specimens** | 351 | 241 | 176 | 107 | 262 |
| **Total specimen/day** | 1.02 | 48.2 | 12.6 | 9.7 | 87.3 |
| **Species richness** | **6** | 5 | 4 | 4 | 6 |
| **Species evenness** | **0.591** | 0.426 | 0.195 | 0.364 | 0.534 |

**Table 4.3:** The species richness and species overlap of snake specimens collected from 4 freshwater snake assemblages inside the Chao Phraya - Ta Chin basin, Thailand. Information of previous reports followed (Karns et al., 2010)). Number in parentheses indicate the number of collecting days at each study sites.

| | Bung Ka Loh | Bung Boraphet | Petchabun | Bung Cho | Species richness |
|---|---|---|---|---|---|
| **Bung Ka Loh** | 1.00 | 0.545 | 0.400 | **0.800** | 6 |
| **Bung Boraphet** | | 1.00 | 0.444 | 0.667 | 5 |
| **Petchabun** | | | 1.000 | 0.750 | 4 |
| **Bung Cho** | | | | 1.000 | 4 |

## 4.4 Conclusion and Discussion

Six species of snakes were collected from inside Bung Ka Loh wetland. Four of twelve species of all freshwater snake species (33.33%) in Family Homalopsidae were found; the rainbow water snake, *Enhydris enhydris*, the Bocourt's water snake, *Subcessor bocourti*, the Jagor's water snake, *Enhydris jagorii*, and the Cox's masked water snake, *Homalopsis mereljcoxi*. Other 2 snake species were semi-aquatic snake species such as the common keelback, *Xenochrophis flavipunctatus* in Family Colubridae and the red-tailed pipe snake, *Cylindrophis ruffus* in Family Cylindrophiidae. Beside, 11 species of other snake were also observed around the vicinity of this wetland and raised the number of snake species into 17 species of snakes living around this area. Number of collected snake specimens varied among the investigation period. Low number of collected samples occurred during dry season especially in 2011 which none of snake specimen was collected from this wetland. This situation may be an effect of a very long drought period which be affected by El Nino and human activities such as water drainage and agriculture site preparation throughout the wetland. From this reason, freshwater snakes inside this wetland might escape down to the mud bottom of the wetland or go deeper inside the root-tangled which are suitable for living across drought period. Due to hard to reach and collect of snake specimens, none of freshwater snake specimens was captured by local fisherman's fish traps during this period.

Among the collected snake specimens, the rainbow water snake, *Enhydris enhydris* was the dominant species inside this wetland (55.75% of all collected snake specimens). Despite the other 5 collected species that were commonly found in freshwater snake assemblages throughout the region, one

homalopsid species collected inside this wetland was a rare species and exhibit a very restricted geographic distribution. The Jagor's water snake, *Enhydris jagorii* is a endemic species found only in the Chao Phraya- Ta Chin Basin, Thailand (Cox, 1991; Cox et al., 2012; Gyi, 1970; IUCN Red List of Threatened Species, 2014; Karns et al., 2010; Murphy, 2007a; Murphy and Voris, 2005; Murphy et al., 2005; Reptile Database, 1995). Combined with the previous report by Karns et al. (2010), this location, the Bung Ka Loh wetland, Uttaradit Province, Thailand located in Nan sub-basin, is the only reported distribution of this mysterious freshwater species in this recent time. Surprisingly, this species is the subdominant species (30.77% of all collected snake specimens) in freshwater snake assemblage at this wetland.

Species richness of freshwater snake assemblage in this wetland was the highest (6 species) among other assemblages in the Chao Phraya - Ta Chin basin reported by previous studies; species of snake in Bung Boraphet and 4 species of snake in both Bung Cho and Phetchabun sub-basin. Karns et al. (2010) also reported the same species richness from the Bung Ka Loh wetland but different in species composition of semi-aquatic snake species. The specimens of red-tailed pipe snake, *Cylindrophis ruffus* in Family Cylindrophiidae were collected in this study but not in the previous study whereas the specimens of sunbeam snake, *Xenopeltis unicolor* in Family Xenopeltidae was not collected in this study but occurred in the previous study. Therefore, 7 species of snakes were documented from inside this freshwater wetland until now. Species evenness of freshwater snake assemblage inside this wetland was highest (0.591) among others, 0.426, 0.364 and 0.195 at Bung Boraphet, Bung Cho and Phetchabun sub-basin, respectively. Karns et al. (2010) was also reported that species evenness of snake assemblage inside this wetland is the highest (0.534) among other snake assemblages from their study. Thus, all these results from studies on freshwater

snake assemblages suggested that the Bung Ka Loh wetland has the highest diversity on freshwater snake species than other freshwater snake communities inside the Chao Phraya - Ta Chin basin, Thailand.

In contrast with Karns et al. (2010), calculated number of snake specimens collected per day are very different by 87.3 snake specimens per day during 3 days of collection in the previous study versus 1.02 snake specimens per day during 345 days of collection in this study. The highest species overlap between locations was occurred between the Bung Ka Loh and the Bung Cho wetland (Sorensen similarity index is 0.80) whereas the lowest species overlap occurred between The Bung Ka Loh wetland and Phetchabun sub-basin (Sorensen similarity index is 0.40). These similarity indices might be affected by the effects of distance, barriers and microhabitats between each locations. Specific locations of each freshwater habitats shown in Figure 4.10. The previous studies suggested that the differences in freshwater snake assemblages among locations were a reflection of numerous factors such as differences in collection efforts, historical and biological factors, barriers and the particular constellation of microhabitats between each study sites. However, these snake assemblages share one of the same character on species composition among locations. The rainbow water snake, *Enhydris enhydris* was also reported as a numerically dominant at all the localities where it is found (Karns et al., 2005; Karns, 1999-2000; Murphy, 2007a; Pongcharoen et al., 2008a, 2008b; Voris and Karns, 1996).


**Figure 4.10:** Picture showed the map of the four collection localities inside the central plain of Thailand in previous study by Karns et al. (2010) such Bung Ka Loh and Bung Cho at Uttaradit Province, Phetchabun sub-basin and Bung Boraphet at Nakhon Sawan Province (picture of map courtesy of Karns et al. (2010)).

Due to the low numbers of collected specimens of the Cox's masked water snake, *Homalopsis mereljcoxi* and the Bocourt's water snake, *Subcessor bocourti*, sex ratios of only two species of freshwater in Family Homalopsidae snakes such as the rainbow water snake, *Enhydris enhydris* and the Jagor's water snake, *Enhydris jagorii* were calculated. Sex ratio of the first freshwater species was being strongly female-biased (M:F is 0.64:1) whereas later freshwater species was equal (M:F is 1:1). Sex ratio of the first species showed that female snakes were more than male snakes inside this wetland. Previous studies also reported the same occurrences of the sex ratio of this freshwater homalopsid species even at the same and other study sites (Karns et al., 2010; Karns et al., 2005; Pongcharoen et al., 2008a). Thus, male snakes

have more opportunities to mate with female snakes. A combination of this result on sex ratio and multiple paternity in homalopsid snakes reported by Voris et al. (2008) might be the explanation of the numerical dominant of this freshwater species inside the Bung Ka Loh and other wetlands. However, there is difficult for determination of sex ratios in natural populations (Karns et al., 2010; Shine, 1994). Karns (1999-2000) and Karns et al. (2010) suggested that the specimen collection methods by using gill nets and funnel traps may influences the sex ratios of each study population, for examples; funnel traps with female snakes trapped inside attracted more male snakes, and gill nets is an important factor in sex ratio determination if study population play a strongly sexual size dimorphism.

# Chapter V

# Morphology and sexual dimorphism of the Jagor's water snake, Enhydris jagorii at Bung Ka Loh, Uttaradit Province, Thailand

## 5.1 Introduction

Sexual dimorphism, widespread in the animal kingdom, describes differences between males and females in size, shape and many other traits. Among snakes, this feature was frequently reported that females have a significantly larger and heavier in body size whereas males exhibit significantly longer tail (Areste and Cebrian, 2003; Mattison, 1995, 2002, 2007; Shine, 1994; Shine et al., 1999). Morphology of freshwater snakes in family Homalopsidae were usually performed in widely distributed and highly abundant species such as the rainbow water snake, *Enhydris enhydris* and the plumbeous water snake, *Hypsiscopus plumbea*. Significant differences in morphology were reported from these two species (Brooks et al., 2009; Karns et al., 1999; Pongcharoen et al., 2008a). Exhibition of female-biased sexual dimorphism was also found in other common species such as the Mekong water snake, *Enhydris subtaeniata* and the Cox's masked water snake, *Homalopsis mereljcoxi* (Karns et al., 2005; Pongcharoen et al., 2008a). However, information on morphology of rare and endemic species especially the Jagor's water snake, *Enhydris jagorii* is still unknown. Hence, this study aims to provide the knowledge on morphology and sexual dimorphism of this snake collected from Bung Ka loh, Uttaradit Province, Thailand.

5.2 Methodology

All mature specimens (88 specimens) of the Jagor's water snake, Enhydris jagorii collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand were used for morphology and sexual dimorphism investigations. Mature females were considered from having vitellogenic eggs, oviducal eggs, embryos or exhibited an obviously thickened and muscular oviducts. For males, size of mature specimens were considered from the same length of SVL of the smallest gravid females discovered in this study(Karns et al., 2010; Voris et al., 2012). Specimens were sexed and measured for 6 morphological characters and scalations as follows;

1. Sex: Sex of live specimens was determined using sexing probe whereas death specimens were checked by injection of water or 10% formaldehyde at the base of the snake tail or dissection methods.

2. SVL (snout-vent length): Specimens were measured from the tip of the nasal scale along the body length to the opening of the cloaca to the nearest 0.1 centimeters.

3. TL (tail length): Specimens were measured from the opening of the cloaca to the tip of specimen tail to the nearest 0.1 centimeters.

4. NG (neck girth): Girth around the neck of specimens was measured at the posterior end of jawbone to the nearest 0.1 centimeters.

5. BG (body girth): Body girth of specimens was measured at one-third of the specimen SVL to the nearest 0.1 centimeters.

6. BM (body mass): Specimens were weighed using a digital balance to the nearest 1 gram. Diets, vitellogenic eggs and embryos found inside the specimen digestive system have been removed before performing of the weigh measurement. Morphological measurements of the Jagor's water snake, Enhydris jagorii were shown in Figure 5.1.

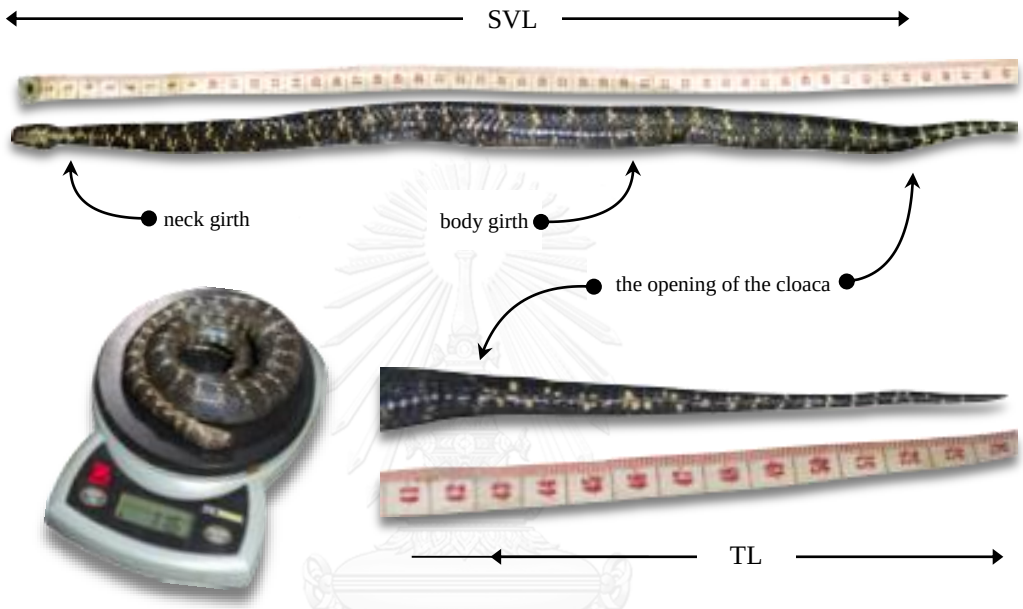


**Figure 5.1***:* Five morphological measurements on specimens of the Jagor's water snake, *Enhydris jagorii* collected inside Bung Ka Loh, Uttaradit Province, Thailand; snout-vent length (SVL), tail length (TL), neck girth (NG), body girth (BG) and body mass (BM). The measurements were conducted using 1 meter tapeline to the nearest 0.1 centimeter for the length measurements and digital balance to the nearest 1 gram for the weight.

Scalation: Scale counting in this study was performed following Dowling (1951). Dorsal, ventral and subcaudal scale rows of each sexes were counted for both live and dead specimens. Dorsal scale rows were counted at 3 parts of the snake body for each specimen; at the 10th ventral scales behind the jawbone, at the middle of the specimen body and at the 10th ventral scales before the opening of the cloaca, respectively. Ventral scale row was counted from the first enlarged and transversely elongated scales underside of the specimen body behind the gular scales to the last scale before the anal scale. For subcaudal scale count, the terminal scute was excluded from the number of subcaudal scale row. Body scale counts of this species were shown in figure 5.2.

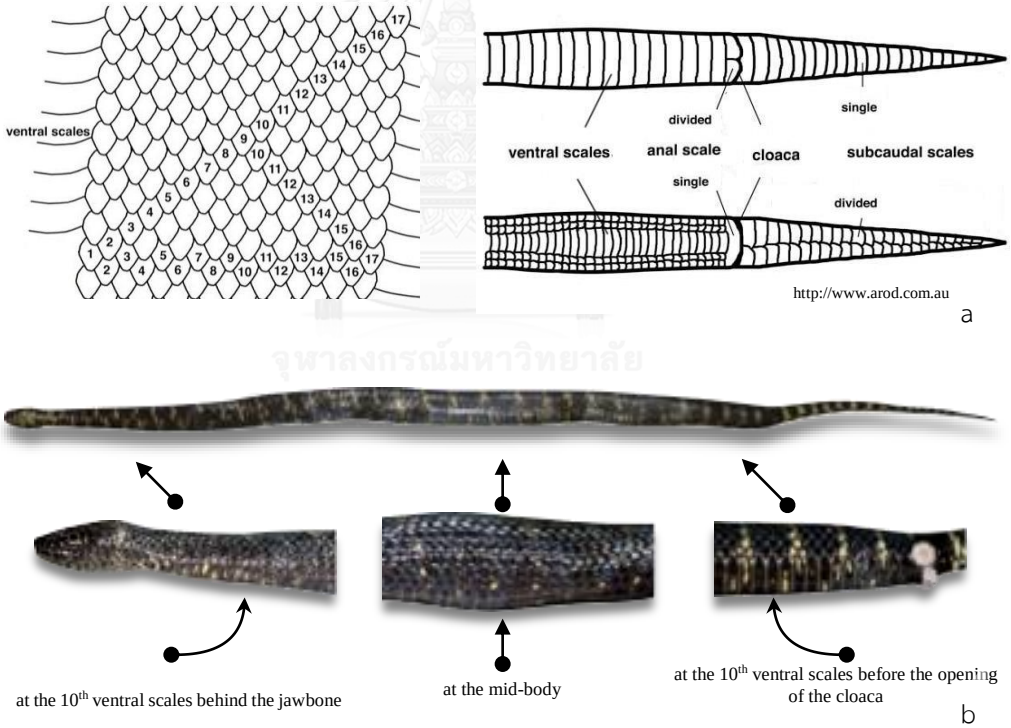


**Figure 5.2:** Body scale counts of the Jagor's water snake, *Enhydris jagorii* specimens collected inside the Bung Ka Loh, Uttaradit Province, Thailand; (a) three characters of body scale rows were counted; dorsal, ventral and subcaudal scale rows (Dowling, 1951) and (b) dorsal scale rows were counted at three parts of the specimen body; at 10th ventral scales behind the jawbone, at the middle of the specimen body and at the 10th ventral scales before the opening of the cloaca.

All the length measurements were conducted using 1 meter measuring tape. Three replications of each morphological measurements were conducted and mean value of each morphological characters had been used for statistical analysis. Sexual dimorphism index (SDI) was also performed for this species. The SDI was calculated by dividing the mean SVL of the larger sex by the mean SVL of smaller sex; a plus was assigned if females were the larger sex whereas a minus was assigned if males were the larger sex (Gibbons and Lovich, 1990). Three morphological characters of neonates born from live females were also measured and recorded in this study. However, sex determination of these offspring did not conducted because of incompatible size between the sexing probes and the body size of neonates.

Moreover, the differences in morphological characters between sexes of another species of freshwater snake in Family Homalopsidae such as the rainbow water snake, *Enhydris enhydris* was also calculated. Unfortunately, morphological and sexual dimorphism investigation were not performed for other snake species collected inside the wetland due to the low number of specimens. Morphological differences between sexes were compared using t-test or Mann-Whitney U-test ($p \leq 0.05$). Statistical analyses in this study were performed on Laptop computer using the SPSS program version 21.0 for MacOSX operating system version10.9.3.

## 5.3 Result

One hundred and eight specimens of the Jagor's water snake, *Enhydris jagorii* were collected from the Bung Ka Loh wetland at Uttaradit Province, Thailand. Eighty eight specimens (90.74%) were measured for morphological and sexual dimorphism investigations. Five morphological characters (mean values ±SD) such as snout-vent length (SVL), tail length (TL), neck girth (NG), body girth (BG) and body mass (BG), and the proportion between TL and SVL of 48 mature males and 50 mature females were conducted and shown in Table 5.1. In this study, the smallest gravid female of this species collected from the wetland was 34.0 centimeters in SVL. Thus, male and female specimens with SVL equal to or greater than this length were decided as a mature snake.

**Table 5.1:** Males and females morphological characters of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. Each column shows the mean (±SD) and range (minimum and maximum) values for 5 morphological characters; SVL, TL, neck girth, body girth and body mass, and the proportion between TL and SVL. Statistical analysis using T-test and Man - Whitney U-Test ($p \leq 0.05$).

| Species | Sex | Morphological characters (mean values ± SD) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SVL (cm) | TL (cm) | Neck girth (cm) | Body girth (cm) | Body mass (grams) | TL/SVL |
| *E. jagorii* | M (n=48) | 47.64 ± 4.82 (34.0 - 53.0) | 15.27 ± 1.97 (9.5 - 18.0) | 3.75 ± 0.47 (2.3 - 4.5) | 7.55 ± 1.05 (5.0 - 9.7) | 210.59 ± 58.97 (63.0 - 302.0) | 0.32 ± 0.02 (0.26 - 0.37) |
| | F (n=50) | 50.30 ± 7.24 (34.0 - 65.0) | 13.16 ± 1.87 (10.0 - 16.1) | 4.31 ± 0.86 (3.0 - 6.7) | 9.66 ± 2.07 (6.2 - 14.5) | 323.08 ± 152.18 (94.0 - 707.0) | 0.26 ± 0.02 (0.23 - 0.30) |
| | *p* | 0.021 | 0.000 | 0.002 | 0.000 | 0.002 | 0.000 |

From table 5.1, 48 males (88.89% of all collected males) were measured and calculated. The mean SVL was 47.64±4.82 centimeters ranged from 34.0 to 53.0 centimeters. The mean TL was 15.27±1.97 centimeters ranged from 9.5 to 18.0 centimeters. The mean NG was 3.57±0.47 centimeters ranged from 2.3 to 4.5 centimeters. The mean BG was 7.55±1.05 centimeters ranged from 5.0 to 9.7 centimeters. The mean body mass was 210.59±58.97 grams ranged from 63.0 to 302.0 grams. For females, 50 specimens (92.59% of all collected females) were measured and calculated. The mean SVL was 50.30±7.24 centimeters ranged from 34.0 to 65.0 centimeters. The mean TL was 13.16±1.87 centimeters ranged from 10.0 to 16.1 centimeters. The mean neck girth was 4.31±0.86 centimeters ranged from 3.0 to 6.7 centimeters. The mean body girth was 9.66±2.07 centimeters ranged from 6.2 to 14.5 centimeters. The mean body mass was 323.08±152.18 grams ranged from 94.0 to 707.0 grams. The proportion between TL/SVL of both sexes were also calculated. The mean value of the proportion between TL and SVL was 0.32±0.02 in males and 0.26±0.02 in females. The SDI of this species was 1.07.



In this study, 3 characters of body scale rows such as dorsal scale rows, ventral scale row and subcaudal scale row were conducted from 24 males (44.44% of all collected males) and 26 females (48.15% of all collected females). Dorsal scale rows of each specimens were counted at 3 parts of the snake body; at the $10^{th}$ ventral scales behind the jaw, at mid-body and at the $10^{th}$ ventral scales before the opening of the cloaca. 25-26 scale rows at $10^{th}$ ventral scales behind the jaw, 21-23 scale rows at mid-body and 19-21 at the $10^{th}$ ventral scales before the opening of the cloaca were found in males whereas 24-26 scale rows at the $10^{th}$ ventral scales behind the jaw, 21-23 scale rows at mid-body and 1-21 at the $10^{th}$ ventral scales before the opening of the cloaca were found in females. 117-124 scales of ventral scale row and

106-136 scales of subcaudal scale row were found in males whereas 116-124 scales of ventral scale row and 97-127 scales of subcaudal scale row were found in females. Body scale rows of the Jagor's water snake, *Enhydris jagorii* at the Bung Ka Loh wetland, Uttaradit Province, Thailand were shown in Table 5.2.

**Table 5.2**: Males and female scalations of the Jagor's water snake, *Enhydris jagorii*, collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. Each column shown the range of each body scale rows (minimum and maximum values) with the mean value (±SD). Statistical analysis using Mann-Whitney U-Test ($p \leq 0.05$).

| Species | Sex | Dorsal scale rows | | | Ventral scale row | Subcaudal scale row |
|---|---|---|---|---|---|---|
| | | the 10th ventrals behind the jaw | Mid-body | the 10th ventrals before cloaca | | |
| *Enhydris jagorii* | M (n=24) | 25 - 26 (25.25 ± 0.44) | 21 - 23 (21.17 ± 0.48) | 19 - 21 (19.79 ± 0.66) | 117 - 124 (121.65 ± 1.56) | 106 - 136 (128.65 ± 6.95) |
| | F (n=26) | 24 - 26 (25.23 ± 0.51) | 21 - 23 (21.08 ± 0.38) | 19 - 21 (19.73 ± 0.72) | 116 - 124 (120.54 ± 1.68) | 96 - 127 (112.52 ± 8.45) |
| | *p* | 0.329 | 0.153 | 0.885 | 0.03 | 0.000 |

Significant differences of morphological characters and body scale rows between sexes were found and shown in Table 4.1 and 4.2, respectively. According to the normality on data of 3 morphological characters such as SVL, body girth and body mass, statistical analyses of these 3 characters were performed using t-test whereas other 2 nonparametric characters such as TL and neck girth, were performed using Mann-Whitney U-test. Likewise, nonparametric characters of all body scale rows were analyzed using Mann-Whitney U-test.

Significant differences of all morphological characters of the Jagor's water snakes, *Enhydris jagorii* were found between males and females collected inside the wetland ($p \leq 0.05$). Comparison of the mean values of all morphological characters

showed that females exhibited significantly larger than males in body size in 4 morphological characters; SVL, NG, BG and BM with an exception of tail length (TL). Results from the proportion between TL and SVL showed that males had significantly longer in TL than females of the same length of SVL (Figure 5.3).

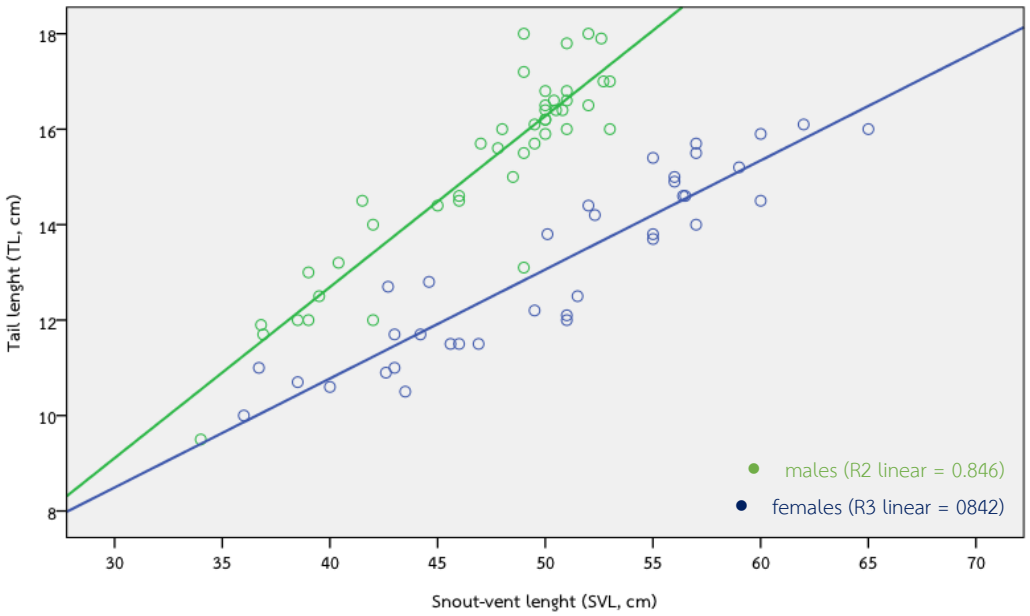


**Figure 5.3:** Graph of scattered plots and linear regression ($p$ = 0.05) of SVL versus TL of males and females collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period. Males exhibited the longer tail length than females at the same size of SVL.

For scalation, number of dorsal scale rows counted at 3 parts on the specimen's body were not significantly different between sexes ($p > 0.05$). The significant differences of number of ventral scale row and subcaudal scale row were found between males and females ($p \leq 0.05$). The mean value (±SD) of ventral scale row was 121.65±1.56 scales in males and was 120.54±1.68 scales in females. The mean value (±SD) of subcaudal scale row was 126.85±6.95 scales in males and was 112.52±8.45 scales in females. These results showed that males exhibited greater in

number of ventral scale row and subcaudal scale row than females. A photograph of male and female of the Jagor's water snake, *Enhydris jagorii* was shown in Figure 5.4.


**Figure 5.4:** Photograph of male and female of the Jagor's water snakes, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand.

Moreover, 48 neonates born from live females collected during the study period were investigated (Figure 4.5). Five morphological characters consisting of SVL, TL, NG, BG and BM were measured and calculated. Unfortunately, sex determination was not performed with these neonates due to the over size of the equipment. The mean values (±SD) of 5 morphological characters of neonates were 14.90±0.92 centimeters in SVL, 4.65±0.45 centimeters in TL, 1.44±0.16 in neck girth, 1.90±0.28 in body girth and 4.56±0.45 grams in body mass. Beside, neonates could swim and feed by themselves immediately after birth. Morphological characters (mean values ±SD) of neonates recorded from the Bung Ka Loh wetland during this study were shown in Table 5.3.

**Table 5.3:** Morphological characters of neonates of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period. Each column showed the mean (±SD) and the range (minimum and maximum) values of 5 morphological characters such as SVL, TL, neck girth, body girth and body mass of neonates.

| Species | Morphological characters (mean values) | | | | |
|---|---|---|---|---|---|
| | SVL (cm) | TL (cm) | Neck girth (cm) | Body girth (cm) | Body mass (grams) |
| neonates of *Enhydris jagorii* (n = 48) | 14.90 ± 0.92 (12.0 - 16.3) | 4.56 ± 0.45 (3.6 - 5.3) | 1.44 ± 0.16 (1.2 - 1.8) | 1.90 ± 0.28 (1.4 - 2.5) | 4.56 ± 0.83 (2.74 - 8.14) |

In addition, morphological investigation of other homalopsid species was conducted for the species with sufficient sample size. One hundred and eighty one mature specimens (89.60%) of the rainbow water snake, *Enhydris enhydris* were measured and calculated. Female of this species with 41.0 centimeters in SVL was the smallest female contained a small follicles in its oviducts. The mean values of morphological characters of 70 males were 51.66±5.71 centimeters in SVL, 14.04±1.44 centimeters in TL, 2.28±0.29 centimeters in neck girth, 5.52±0.72 centimeters in body girth and 118.75±35.42 grams in body mass whereas the mean values of these characters from 111 females were 61.62±8.18 centimeters in SVL, 14.23±1.60 centimeters in TL, 3.25±1.92 centimeters in neck girth, 7.38±1.45 centimeters in body girth and 237.49±93.44 grams in body mass. The mean values of the proportion between SVL and TL of males and females were 0.27±0.02 and 0.23±0.02, respectively. Five morphological characters measured from the rainbow water snake, *Enhydris enhydris* were significantly different between sexes such as SVL, neck girth, body girth, body mass and proportion between TL/SVL. Females exhibited larger and heavier body size than males. Only the length of tail was longer in males than in females at the SVL.

Five morphological characters (mean values ±SD); SVL, TL, neck girth, body girth and body mass, and the proportion between TL and SVL of males and females of the rainbow water snake, *Enhydris enhydris* were conducted and shown in Table 5.4.

**Table 5.4:** Morphological characters of the rainbow water snake, *Enhydris enhydris* at the Bung Ka Loh wetland, Uttaradit Province, Thailand. Each column shows the mean (±SD) and range (minimum and maximum) values for 5 morphological characters; SVL, TL, neck girth, body girth and body mass, and the proportion between TL and SVL. Statistical analysis using Man - Whitney U-Test ($p \leq 0.05$).

| Species | Sex | Morphological characters (mean values ±SD) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SVL (cm) | TL (cm) | Neck girth (cm) | Body girth (cm) | Body mass (grams) | TL/SVL |
| *E. enhydris* | M (n=111) | 52.29 ± 4.84 (41.0 - 60.0) | 14.16 ± 1.35 (9.5 - 16.5) | 2.29 ± 0.28 (1.8 - 3.0) | 5.54 ± 0.73 (4.2 - 7.2) | 121.41 ± 33.69 (50.0 - 202.0) | 0.27 ± 0.014 (0.23 - 0.31) |
| | F (n=70) | 61.62 ± 8.19 (41.0 - 78.5) | 14.24 ± 1.60 (10.3 - 19.8) | 3.25 ± 1.92 (2.0 - 4.9) | 7.38 ± 1.45 (4.2 - 11.1) | 237.48 ± 93.44 (53.0 - 492.0) | 0.23 ± 0.018 (0.19 - 0.33) |
| | *p* | 0.000 | 0.403 | 0.000 | 0.000 | 0.000 | 0.000 |

## 5.4 Discussion

Differences in morphological characters between males and females in many kinds of snakes were documented and reported (Bertona and Chiaraviglio, 2003; Cox, 1991; Hendry et al., 2014; King, 2008; Mattison, 1995, 2002, 2007; Rival and Burghardt, 2001; Shine et al., 1999; Tomovic et al., 2002; Zug et al., 2001)Likewise, the differences in morphological characters between sexes of freshwater snakes in Family Homalopsidae were reported such the rainbow water snake, *Enhydris enhydris*, the Mekong water snake, *Enhydris subtaeniata,* the plumbeous water snake, *Enhydris plumb* and etc. Females exhibited greater in body size than males with an exception of tail length. (Brooks et al., 2009; Karns et al., 2010; Karns et al., 2005; Karns et al., 2002; Murphy, 2007a; Murphy et al., 1999; Pongcharoen et al., 2008b; Voris et al., 2012).

In this study, the significant differences in morphological characters between sexes of the Jagor's water snakes, *Enhydris jagorii* collected inside the Bung Ka Loh wetland were also found. Four characters such as SVL, neck girth, body girth and body mass indicated that females had a significantly larger and heavier body than males ($p < 0.05$). Contrary with other characters, the tail length and the proportion between TL/SVL indicated that males had a significantly longer tail length than females at the same SVL ($p < 0.05$). These data were supported by short-term study by Karns et al. (2010). Despite the small sample size ($n_{(females)}$ =16 and $n_{(male)}$ =8), females of the Jagor's water snake, *Enhydris jagorii* collected at the same wetland in their study showed the larger and heavier in SVL and body mass whereas males shown the longer tail length. The SDI values on pervious and this study were indicated that this freshwater species exhibited the female-biased sexual size dimorphism, the SDI values were 1.09 and 1.07, respectively. Males of this freshwater species had a significantly

longer tail length than females which was strongly supported by the number of subcaudal scales counted from collected specimens. Subcaudal scale row was the only character in scalation which significant difference was found between sexes in which males had more subcaudal scales than females ($p < 0.05$). Significant differences in scalation between sexes were also reported in other homalopsid species. For example, males of the Mekong water snake, *Enhydris subtaeniata* from 3 localities collected from Thailand had more scales in ventral and subcaudal scale rows than females ($p < 0.05$) (Voris et al., 2012).

In addition, morphological characters of the rainbow water snake, *Enhydris enhydris* collected in this wetland also exhibited the sexual dimorphism which are similar to the previous study by Karns et al. (2010). Moreover, sexual dimorphism commonly occurred among the snakes in Family Homalopsidae throughout its ranges, especially in freshwater species such as the Cox's masked water snake, *Homalopsis buccata*, the plumbeous water snake, *Hypsiscopus plumbea* and the Bocourt's water snake, *Subcessor bocourti* (Brooks et al., 2007; Karns et al., 2005; Karns, 1999-2000; Murphy et al., 1999; Pongcharoen et al., 2008a; Voris et al., 2012).



Exhibition of female-biased sexual size dimorphism with a longer in tail length and greater in the number of subcaudal scales of males was a common sexually dimorphic trait in snakes (Karns et al., 2010; Voris et al., 2012). The origin and maintenance of this dimorphism have been proposed and clarified by many researches into 3 primary categories such as sexual selection on male size through mechanism of male-male competition, selection related to fecundity on females such as relationship between reproductive biology and female size and ecological divergence in size mediated by intraspecific competition due to niche partitioning (Cox et al., 2012;

Hendry et al., 2014; Shine, 1989). Nevertheless, the benefit of the larger in body size of females was related to their reproductive biology. Many studies reported that the larger females reproduced the larger clutch size and clutch mass which were great for reproductive success (Aubret et al., 2002; Bertona and Chiaraviglio, 2003; Bonnet et al., 2000; Brooks et al., 2009; Murphy et al., 2002; Pongcharoen et al., 2008a, 2008b; Seigel et al., 1987; Wangkulangkul et al., 2005). For males, the benefit of the longer tails was suggested by Shine et al. (1999) that males with the longer tails achieve greater reproductive success.

# Chapter VI

# Diets from stomach contents of the Jagor's water snake, *Enhydris jagorii* at Bung Ka Loh, Uttaradit Province, Thailand

## 6.1 Introduction

Previous researches on diets of most of freshwater snakes in family Homalopsidae indicated that these snakes were piscivorous. Most of them fed mainly on fish whilst some species also fed on amphibians and tadpoles. Cyprinids and osphronemids were reported as the dominant prey types found in their digestive system. Prey were usually small in size (less than 10% of snake body mass) and multiple prey items were found in their stomachs (Brooks et al., 2009; Karns et al., 2005; Karns et al., 2002; Murphy, 2007a; Murphy et al., 1999; Pongcharoen et al., 2008a; Voris and Murphy, 2002). For the Jagor's water snake, *Enhydris jagorii*, diet from their stomach contents were reported by Karns et al. (2010). Despite a difficulty of identifying stomach content, three families of fish were identified. All prey items composed of fish in three families: Cyprinidae, Osphronemidae, and Anabantidae. However, this information was obtained only from 3 females and collected in a short period of time. Hence, this study aims to investigate diets in detail of Jagor's water snake, *Enhydris jagorii*, both males and females, collected inside the Bung Ka loh, Uttaradit Province.

6.2 Methodology

Stomach contents from the specimens of the Jagor's water snake, *Enhydris jagorii* collected inside Bung Ka Loh wetland, Uttaradit Province, Thailand, were investigated. Live specimens with diets were gently forced to regurgitate their stomach contents by hands whereas dead specimens were examined by dissection. Specimens contained items in their stomachs were measured and weighted following the methods in Chapter V. Prey items were immediately identified and weighted to the nearest 0.1 gram using precise digital balance (Figure 5.1). Intact prey items were identified to the species whereas partially digested prey items were identified at least to the family. Almost digested fish with fin rays, scales and bones were classified to the unidentifiable fish. Partially digested prey items were estimated its weight by comparing to intact conspecific specimens (Voris and Murphy, 2002). Prey types, the proportion of prey types and the proportion between prey mass and specimen mass of each sex were investigated and compared using Mann-Whitney U-test ($p < 0.05$). In addition, the predator of the Jagor's water snakes, *Enhydris jagorii* was also documented in this study.

Stomach contents from other collected snake species inside the wetland were also documented. Niche breadth of each species and niche overlap between species were also performed only for the species with sufficient specimens. Niche breadth and niche overlap were calculated by Shannon-Weiner measurement and Simplified Morisita Index, respectively. Statistical analyses in this study were performed on laptop computer with the SPSS program version 21.0 for MacOSX operating system version10.9.3, Maverick.


**Figure 6.1:** Photographs of (a) stomach content investigation using dissection method for dead specimens of the Jagor's water snake, *Enhydris jagorii* collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand. Prey items were immediately identified (b) measured to the nearest 0.1 centimeter and (c) weighted to the nearest 0.1 gram.

## 6.3 Result

Twenty two prey items were found in the stomachs of twenty specimens (18.52%, 5 males and 15 females) of the Jagor's water snake, *Enhydris jagorii* collected at the Bung Ka Loh, Uttaradit Province, Thailand during the study period. All prey items were fish in various kinds. Of the twenty-two prey specimens, seventeen prey items (77.27%) were identified at least to the family and five of them (22.73%) were unidentifiable fish. Data on diets from the stomach contents of males and females of the Jagor's water snake, *Enhydris jagorii* were shown in Table 6.1.

**Table 6.1:** Prey items from the stomach contents of 5 males and 15 females of the Jagor's water snake, *Enhydris jagorii* collected at the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period (23 months from October, 2010 to August, 2012).

| Sex | Mass (g) | Prey type | | Prey mass (g) | % weight |
|---|---|---|---|---|---|
| | | Family | Species | | |
| F | 561 | Anabantidae | *Anabas testudineus* | 25.0 | 4.46 |
| F | 248 | Anabantidae | *Anabas testudineus* | 4.7 | 1.90 |
| F | 320 | Anabantidae | *Anabas testudineus* | 4.0 | 1.25 |
| | | Anabantidae | *Anabas testudineus* | 2.6 | 0.81 |
| F | 150 | Bagridae | *Mytus mysticetus* | 16.0 | 10.67 |
| F | 456 | Channidae | *Channa striata* | 15.0 | 3.29 |
| F | 318 | Channidae | *Channa striata* | 41.0 | 12.89 |
| F | 511 | Nandidae | *Pristolepis fasciatus* | 32.2 | 6.30 |
| F | 254 | Osphronemidae | *Trichopodus trichopterus* | 0.8 | 0.31 |
| F | 236 | Cyprinidae | - | 6.5 | 2.75 |
| F | 152 | Cyprinidae | - | 10.0 | 6.58 |
| | | Cyprinidae | - | 12.0 | 7.89 |
| F | 51 | Cyprinidae | - | 12.7 | 24.90 |
| F | 310 | Unidentifiable fish | - | - | - |
| F | 387 | Unidentifiable fish | - | - | - |
| F | 423 | Unidentifiable fish | - | - | - |
| M | 263 | Unidentifiable fish | - | - | - |
| M | 165 | Osphronemidae | *Trichopodus trichopterus* | 9.7 | 5.88 |
| M | 43 | Cyprinidae | - | 5.77 | 13.42 |
| M | 47 | Cyprinidae | - | 5.05 | 10.74 |
| M | 267 | Cyprinidae | - | 5.0 | 1.87 |
| M | 222 | U nidentifiable fish | - | - | - |

Seventeen prey items were found in the stomachs of 15 collected females. Most females contained only one prey item in their stomachs whereas two females (11.77%) contained two prey items. Females of the Jagor's water snakes, *Enhydris jagorii* totally fed on fish in 6 families. Fish in Family Cyprinidae (24%) and Anabantidae (23.53%) were the dominant prey types followed by fish in Family Channidae (11.76%), Bagridae (5.88%), Nandidae (5.88%) and Osphronemidae (5.88%), respectively (Figure 6.2). Nevertheless, 4 prey items (23.53%) from female stomachs were fin rays and bones of unidentifiable fish. Family Anabantidae composed of 4 climbing perches, *Anabas testudineus* whereas Family Channidae was two common snakehead, *Channa striata*, Family Bagridae was one striped catfish, *Mystus mysticetus,* Family Nandidae was one banded leaffish, *Pristolepis fasciatus* and Family Osphronemidae was one three spotted gourami, *Trichopodus trichopterus*. However, the species of fish in Family Cyprinidae was not identified due to the limited to identifiable scales, bone and undigested flesh. The mean value of prey mass was 14.04±12.09 grams. The largest prey type of females was the common snakehead, *Channa striata* in Family Channidae with 41.0 grams whereas the smallest prey type was three spotted gourami, *Trichopodus trichopterus* in Family Osphronemidae with 0.80 grams. The mean value of proportion between prey mass and female mass was 6.46±6.75%. The lowest and the highest proportion of prey mass and female mass were three spotted gourami, *Trichopodus trichopterus* in Family Osphronemidae (0.31%) and common snakehead, *Channa striata* in Family Cyprinidae (24.90%), respectively.

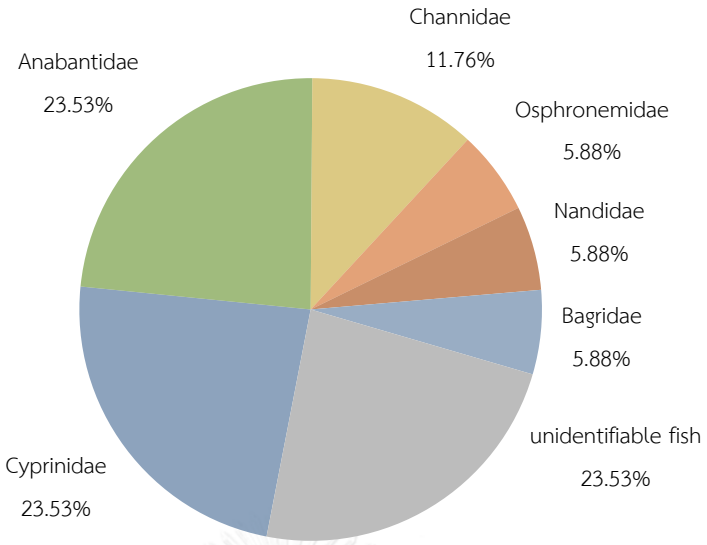


**Figure 6.2:** The proportion of prey types from stomach contents of females of the Jagor's water snake, *Enhydris jagorii* collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand. The highest proportion of prey types was fish in Family Cyprinidae (23.53%) and Anabantidae (23.53%) followed by fish in Family Channidae (11.76%), Osphronemidae (5.88%), Nandidae (5.88%) and Bagridae (5.88%). However, 23.53% of stomach contents were unidentifiable fish.

For males, diets of 5 males of the Jagor's water snake, *Enhydris jagorii,* were found from stomach contents in their digestive system. All of them contained only one prey item in their stomachs. Despite the unidentifiable fish (20%), the highest proportion of prey types was fish in Family Cyprinidae (60%) followed by three spotted gourami in Family Osphronemidae (20%) (Figure 6.3). The mean value of prey mass was 6.38±2.24 grams. The largest prey type of males was the three spotted gourami, *Trichopodus trichopterus* in Family Osphronemidae with 9.70 grams whereas the smallest prey type was fish in Family Cyprinidae with 5.0 grams. The mean value of the proportion of prey mass and male mass was 6.38±5.13% and ranged from 1.87% to 13.42%. The highest and the lowest proportion were fish in Family Cyprinidae.

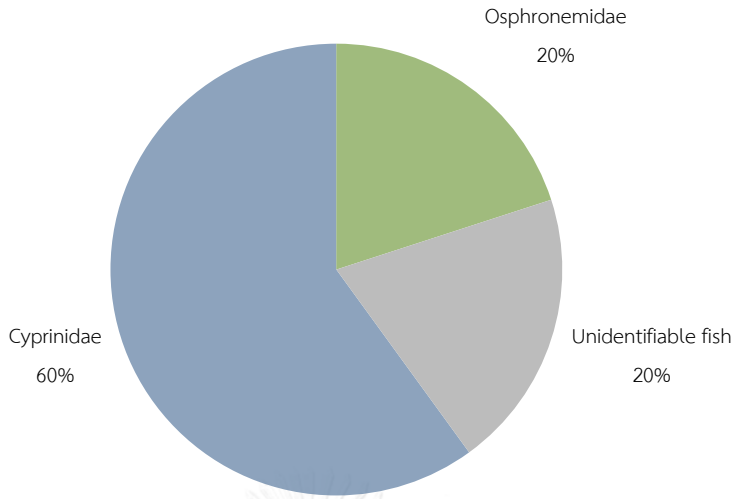


**Figure 6.3:** The proportion of prey types from stomach contents of males of the Jagor's water snake, *Enhydris jagorii* collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand. The highest proportion of prey types was fish in Family Cyprinidae (60%) followed by fish in Family Osphronemidae (20%) whereas another 20% of stomach contents were unidentifiable fish.

From a ll of collected specimens with diet, the highest proportion of prey type was fish in Family Cyprinidae (31.28%) followed by Family Anabantidae (18.18%), Family Osphronemidae (9.09%), Family Channidae (9.09%), Nandidae (4.55%) and Family Bagridae (4.55%), respectively (Figure 6.4). The proportion of unidentifiable fish was 23% of all of the stomach contents found in this species. The mean value of prey mass was 12.24±11.04 grams. The largest and the smallest prey item were found in female stomachs. The mean value of proportion of prey mass and specimen mass was 6.82±6.29% ranged from 0.31% to 24.90%. The highest and the lowest proportion of prey mass and specimens mass were found from the stomachs of females. Prey types, prey mass and proportion between prey and specimens mass from stomach contents of the Jagor's water snake, *Enhydris jagorii* were not significantly different between sexes ($p > 0.05$).

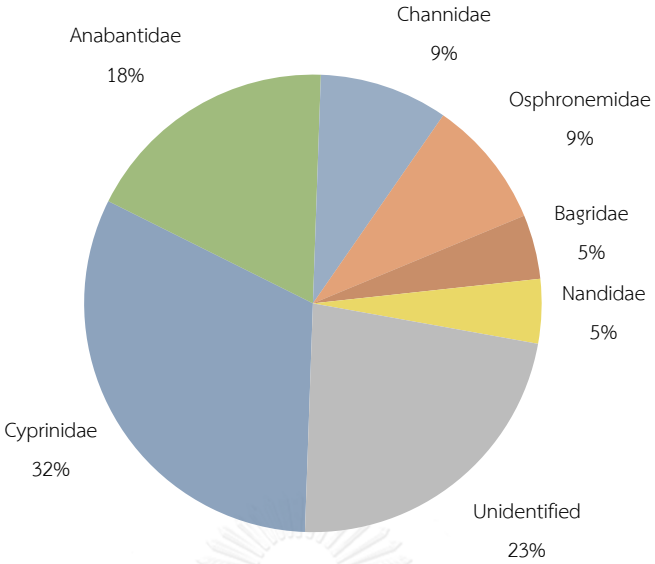


**Figure 6.4:** The proportion of prey types from stomach contents of males and females of the Jagor's water snake, *Enhydris jagorii* collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand. The highest proportion of prey types was fish in Family Cyprinidae (32%) followed by fish in Family Anabantidae (18%), Channidae (9%), Osphronemidae (9%), Bagridae (5%) and Nandidae (5%), respectively. However, 23% of stomach contents were unidentified.

In addition, stomach contents of 4 species of other collected snakes such as the rainbow water snake, *Enhydris enhydris* and the Cox's masked water snake, *Homalopsis mereljcoxi* in Family Homalopsidae, and the common keelback, *Xenochrophis flavipunctatus* in Family Colubridae were investigated. Stomach contents of other collected snake species inside the Bung Ka Loh Uttaradit Province, Thailand were shown in Table 6.2.

Fifty three specimen (26.24%) of the collected rainbow water snake, *Enhydris* enhydris contained prey items in their digestive tracts. For females, 46 prey items were found inside 42 female guts (79.25% of all collected females) whereas 13 prey items were found inside 11 male guts (20.75% of all collected males). The highest proportion of prey type was fish in Family Cyprinidae (38.98%) followed by fish in

**Table 6.2:** Prey items from the stomach contents of other 3 species of collected snakes at the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period.

| Species | Sex | Mass (g) | Prey types | | prey mass (g) | % weight |
|---|---|---|---|---|---|---|
| | | | Family | Species | | |
| *Enhydris enhydris* | F | 136 | Osphronemidae | *Trichopodus trichogaster* | 5.10 | 3.75 |
| *Enhydris enhydris* | F | 110 | Osphronemidae | *Trichopodus trichopterus* | 1.00 | 0.91 |
| *Enhydris enhydris* | F | 452 | Osphronemidae | *Trichopodus trichopterus* | 20.00 | 4.42 |
| *Enhydris enhydris* | F | 194 | Osphronemidae | *Trichopodus trichopterus* | 3.00 | 1.55 |
| *Enhydris enhydris* | F | 237 | Osphronemidae | *Trichopodus trichopterus* | 15.00 | 6.33 |
| *Enhydris enhydris* | F | 287 | Osphronemidae | *Trichopodus trichopterus* | 8.00 | 2.79 |
| *Enhydris enhydris* | F | 106 | Osphronemidae | *Trichopodus trichopterus* | 10.50 | 9.91 |
| *Enhydris enhydris* | F | 450 | Channidae | *Channa striata* | 16.80 | 3.73 |
| *Enhydris enhydris* | F | 237 | Channidae | *Channa striata* | 11.00 | 4.64 |
| *Enhydris enhydris* | F | 267 | Channidae | *Channa striata* | 8.23 | 3.08 |
| *Enhydris enhydris* | F | 163 | Anabantidae | *Anabas testudineus* | 6.00 | 3.68 |
| *Enhydris enhydris* | F | 310 | Notopteridae | *Notopterus notopterus* | 18.52 | 5.97 |
| *Enhydris enhydris* | F | 112 | Cyprinidae | *Puntius orphoides* | 8.20 | 7.32 |
| *Enhydris enhydris* | F | 103 | Cyprinidae | *Puntius orphoides* | 17.00 | 16.50 |
| *Enhydris enhydris* | F | 321 | Cyprinidae | - | 2.00 | 3.77 |
| *Enhydris enhydris* | F | 222 | Cyprinidae | - | 4.00 | 1.25 |
| *Enhydris enhydris* | F | 300 | Cyprinidae | - | 8.23 | 2.74 |
| *Enhydris enhydris* | F | 292 | Cyprinidae | - | 44.00 | 15.07 |
| *Enhydris enhydris* | F | 309 | Cyprinidae | - | 5.00 | 1.62 |
| *Enhydris enhydris* | F | 134 | Cyprinidae | - | 6.50 | 4.85 |
| *Enhydris enhydris* | F | 200 | Cyprinidae | - | 3.46 | 1.73 |
| *Enhydris enhydris* | F | 197 | Cyprinidae | *Barbonymus gonionotus* | 5.00 | 2.54 |
| | | | Cyprinidae | - | 4.00 | 2.03 |
| *Enhydris enhydris* | F | 95 | Cyprinidae | - | 4.00 | 4.21 |
| | | | Cyprinidae | - | 3.10 | 3.26 |
| *Enhydris enhydris* | F | 147 | Cyprinidae | - | 5.02 | 3.41 |
| | | | Cyprinidae | - | 5.00 | 3.40 |
| *Enhydris enhydris* | F | 53 | Cyprinidae | - | 2.00 | 3.77 |
| | | | Cyprinidae | - | 1.00 | 1.89 |
| *Enhydris enhydris* | F | 104 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 176 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 452 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 126 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 130 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 200 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 214 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 199 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 212 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 231 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 267 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 265 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 378 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 375 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 276 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 314 | unidentified fish | - | - | - |
| *Enhydris enhydris* | F | 352 | unidentified fish | - | - | - |
| *Enhydris enhydris* | M | 130 | Channidae | *Channa striata* | 5.05 | 3.88 |
| *Enhydris enhydris* | M | 131 | Channidae | *Channa striata* | 13.40 | 10.23 |
| *Enhydris enhydris* | M | 48 | Notopteridae | *Notopterus notopterus* | 2.10 | 4.38 |
| | | | Notopteridae | *Notopterus notopterus* | 3.00 | 6.25 |
| *Enhydris enhydris* | M | 128 | Osphronemidae | *Trichopodus trichopterus* | 6.00 | 4.69 |
| *Enhydris enhydris* | M | 170 | Cyprinidae | - | 3.50 | 2.06 |
| *Enhydris enhydris* | M | 182 | Cyprinidae | - | 3.66 | 2.01 |
| *Enhydris enhydris* | M | 56 | Cyprinidae | - | 3.00 | 5.36 |
| *Enhydris enhydris* | M | 40 | Cyprinidae | - | 3.19 | 7.98 |
| | | | Cyprinidae | - | 3.00 | 7.50 |
| *Enhydris enhydris* | M | 57 | Cyprinidae | - | 4.36 | 7.65 |
| *Enhydris enhydris* | M | 130 | unidentified fish | - | - | - |
| *Enhydris enhydris* | M | 138 | unidentified fish | - | - | - |
| *Homalopsis mereljcoxi* | F | 114 | Osphronemidae | *Trichopodus trichopterus* | 16.89 | 14.82 |
| *Xenochrophis flavipunctatus* | F | 753 | Anabantidae | *Anabas testudineus* | 41.63 | 5.53 |
| *Xenochrophis flavipunctatus* | F | 368 | Anabantidae | *Anabas testudineus* | 31.78 | 8.64 |
| *Xenochrophis flavipunctatus* | M | 238 | Anabantidae | *Anabas testudineus* | 29.08 | 12.22 |

Family Osphronemidae (13.56%), Family Channidae (8.47%), Family Notopteridae (5.08%) and Family Anabantidae (1.69%), respectively. However, 32.20% of stomach contents could not be identified. The proportion of stomach contents found inside the rainbow water snake, *Enhydris enhydris* were shown in Figure 6.5. The mean value of prey mass was 7.52±7.73 grams. The largest prey item was fish in Family Cyprinidae with 44.0 grams whereas the smallest prey types were fish in Family Cyprinidae and the three spotted gourami in Family Osphronemidae with 1.0 gram in each prey type. The mean value of the proportion between prey mass and specimen mass was 4.80±3.42% ranged from 16.50% to 0.91%. The highest and the lowest proportion between prey and specimen mass were found in female stomachs such as the red cheeked barb, *Puntius orphoides* in Family Cyprinidae and the lowest proportion was the three spotted gourami, *Trichopodus trichopterus* in Family Osphronemidae, respectively. For other homalopsid species, three spotted gourami, *Trichopodus trichopterus* in Family Osphronemidae was the only one prey type found in stomach of female of the Cox's masked water snake, *Homalopsis mereljcoxi* with 16.89 grams in mass and 14.82% in the proportion between prey mass and specimen mass. Moreover, 3 specimens of the common keelback were also found prey items in their stomachs. Only type of prey item was the climbing perch, *Anabas testudineus* in Family Anabantidae. The mean value of prey mass was 34.16±6.61 grams with the largest and the smallest prey were 41.63 grams and 29.08 grams, respectively. The mean proportion between prey mass and specimen mass was 8.79% ranged from 5.53% to 12.22%. Photographs of prey types of the freshwater snakes collected inside the Bung Ka Loh wetland were shown in Figure 6.6.

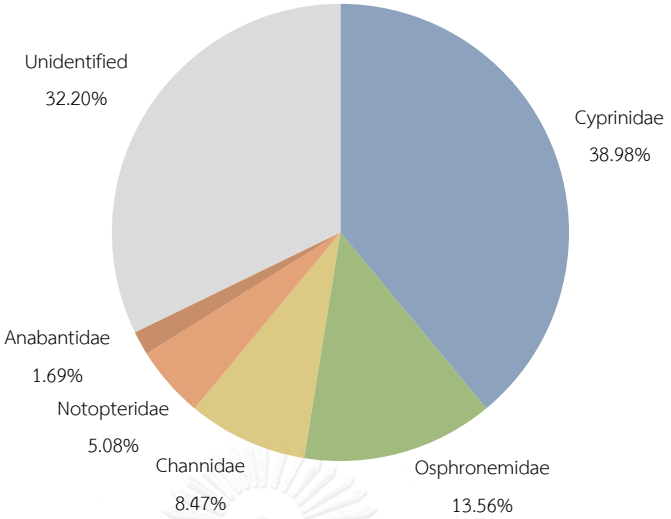


**Figure 6.5:** The proportion of prey types from stomach contents of the rainbow water snake, *Enhydris enhydris* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The highest proportion of prey types was fish in Family Cyprinidae (32.20%) followed by fish in Family Osphronemidae (13.56%), Family Channidae (8.47%), Family Notopteridae (5.08%) and Family Anabantidae (1.69%), respectively. However, 32.20% of stomach contents were unidentified fish.

Niche breadth and niche overlap were calculated from only 2 freshwater homalopsid species with sufficient specimens; the Jagor's water snake, *Enhydris jagorii* and the rainbow water snakes, *Enhydris enhydris*. Niche breadth of the first and second species were 1.98 and 1.52, respectively. Niche overlap between these two freshwater species was 0.86. Niche breadth and niche overlap between these two freshwater species were shown in Table 6.3.

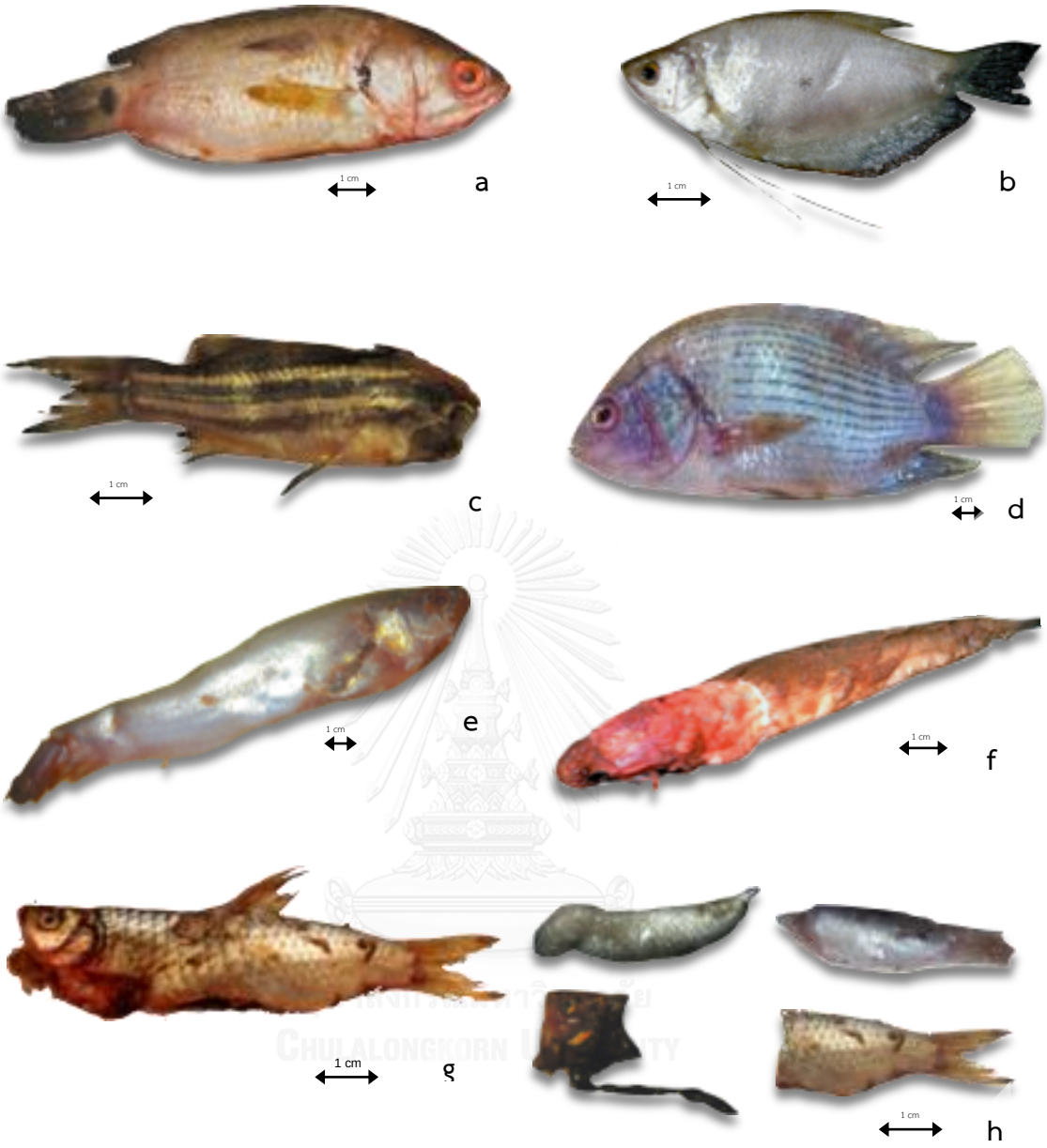


**Figure 6.6:** Prey types found inside the digestive system of freshwater homalopsid snakes collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period; (a) climbing perch, *Anabas testudineus* in Family Anabantidae, (b) three spotted gourami, *Trichopodus trichopterus* in Family Osphronemidae, (c) stripped catfish, *Mytus mysticetus* in Family Bagridae, (d) banded leaffish, *Pristolepis fasciatus* in Family Nandidae, (e) bronze featherback, *Notopterus notopterus* in Family Notopteridae, (f) common snakehead, *Channa striata* in Family Channidae, (g) silver barb, *Barbonymus gonionotus* in Family Cyprinidae and (h) partially digested fish in Family Cyprinidae.

**Table 6.3:** The proportion of prey types, niche breadth and niche overlap of two freshwater homalopsid snakes; the Jagor's water snake, *Enhydris jagorii* and the rainbow water snake, *Enhydris enhydris* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period.

| Prey types | *Enhydris jagorii* | | *Enhydris enhydris* | |
|---|---|---|---|---|
| | number | % | number | % |
| Cyprinidae | 7 | 31.82 | 23 | 38.98 |
| Anabantidae | 4 | 18.18 | 1 | 1.69 |
| Osphronemidae | 2 | 9.09 | 8 | 13.56 |
| Channidae | 2 | 9.09 | 5 | 8.47 |
| Notopteridae | 0 | 0 | 3 | 5.08 |
| Nandidae | 1 | 4.55 | 0 | 0 |
| Bagridae | 1 | 4.55 | 0 | 0 |
| Unidentified | 5 | 22.73 | 19 | 32.20 |
| Niche breadth | **1.98** | | **1.52** | |
| Niche overlap | **0.86** | | | |

In addition, predation on freshwater snakes in Family Homalopsidae at the Bung Ka Loh wetland, Uttaradit Province, Thailand, was recorded during the study period. Male of the jagor's water snake, *Enhydris jagorii* was found inside the stomach of female of the red tailed pipe snake, *Cylindrophis ruffus* in Family Cylindrophiidae (Figure 6.7). The proportion between prey mass and specimen mass was 57.71% (161.0 grams of prey mass and 279.0 grams of predator mass). From the interviews with local fishermen during the study period, dead freshwater snakes trapped by gill nets were eaten by invertebrates such the paddy field crab, *Sayamia sexunctatum* in Family Gecarcinucidae.


**Figure 6.7:** Predation on freshwater homalopsid snakes was recorded during the study period at the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period. Male of the Jagor's water snake, *Enhydris jagorii* (48 centimeters in SVL and 161.0 grams in body mass) was found inside the stomach of female of the red tailed pipe snake, *Cylindrophis ruffus* in Family Cylindrophiidae (61.7 centimeters in SVL and 279.0 grams in body mass).

## 6.4 Discussion

Most species of the freshwater homalopsid snakes in Genus *Enhydris* were reported as piscivorous and fed only on fish especially the rainbow water snake, *Enhydris enhydris*, the Mekong water snake, *Enhydris subtaeniata* and the Bocourt's water snake, *Subcessor bocourti* (Brooks et al., 2009; Cox et al., 2012; Karns et al., 2005; Murphy, 2007b; Murphy et al., 2002; Pongcharoen et al., 2008a; Voris and Murphy, 2002). The Jagor's water snakes, *Enhydris jagorii* inside the Bung Ka Loh, Uttaradit Province, Thailand, are also piscivorous and feed only on fish of many types. At least, six families of fish such as Family Cyprinidae, Anabantidae, Osphronemidae, Channidae, Bagridae and Nandidae were found as prey items from stomach contents in this study. The highest proportion of prey type was fish in Family Cyprinidae (31.28%) whereas the lowest proportion was fish in Family Bagridae and Nandidae (4.55%). The dominant proportion of cyprinid fish might be explained by the abundance of this kind of fish in freshwater habitat at this study site. This freshwater homalopsid species fed only on fish were supported by a short term study on the stomach contents of 12 female snakes by (Karns et al., 2010). However, the proportion of unidentified fish in the stomach contents was a bit high in this study (22.73%). Multiple prey items were also recorded from 2 females. Two fish in Family Anabantidae and other two fish in Family Cyprinidae were found inside each of female stomachs. Prey items were usually small in mass with the proportion between prey mass and specimen mass was 12.24±11.04%. Nevertheless, a few large prey items were occasionally found in this study such as fish in Family Cyprinidae inside female and male stomachs with 24.90% and 13.42% of the proportion between prey and specimen mass, respectively. Multiple and small prey items were usually reported in previous studies on diets of freshwater homalopsid snakes (Brooks et al., 2009; Pongcharoen et al., 2008a; Voris and Murphy,

2002). (Voris et al., 2012) suggested that a high rate of passage of small prey items brought the high percentage of stomach contents with unidentified fish remains.

Significant differences on diets between males and females of homalopsid snakes have been documented. Previous studies by Karns et al. (2005) and Pongcharoen et al. (2008a) reported that the rainbow water snake, *Enhydris enhydris* at Ban Borthong, Prachinburi Province, Thailand, had a significant differences on diets between sexes. Males fed on larger prey items than females (0.85±5.52% in males and 3.39±3.21% in females for the mean value of the proportion between prey mass and specimen mass, $p < 0.05$). Researcher also reported that the proportion between prey mass and specimen mass of males of the Mekong water snake, *Enhydris subtaeniata* at Ban Badan, Nakhon Ratchasima Province, Thailand, had a significantly larger than females (5.97±2.52% in males and 1.31±1.30% in females for the mean value of the proportion between prey mass and specimen mass, $p < 0.05$). Karns et al. (2010) reported that frequency of feeding of the rainbow water snake, *Enhydris enhydris* was significantly different between sexes by females contained prey items in their stomachs more than males (39.5% of females and 18.8% of males contained prey items in their stomachs , $p < 0.01$). In this study, the mean proportion of prey mass and specimen mass of males and females of the rainbow water snake, *Enhydris enhydris* had significantly different between sexes. Prey items fed by males were significantly larger than females (5.64±2.57% in males and 4.49±3.68% in females, $p < 0.05$). However, prey types, prey mass and the proportion between prey mass and specimen mass were not significantly different between males and females of the collected Jagor's water snake, *Enhydris jagorii* in this study.

Niche breadth showed that the Jagor's water snake, *Enhydris jagorii* fed on variety of prey types more than the rainbow water snake, *Enhydris enhydris* at the study site, niche breadth was 1.98 and 1.52, respectively. Previous study by Pongcharoen et al. (2008a) on diets of homalopsid snakes also reported that niche breadth of the rainbow water snake, *Enhydris enhydris* was not high such as niche breadth was 1.5 at Ban Borthong, Kabinburi Province and 0.86 at Ban Badan, Nakhon Ratchasima Province. This homalopsid species can feed on various prey types but mainly on fish in Family Cyprinidae and Osphronemidae according to the location. In this study, the mainly prey type of the rainbow water snack, *Enhydris enhydris* was fish in Family Cyprinidae (38.98%). Moreover, prey types of these two freshwater homalopsid snakes collected inside the Bung Ka Lo wetland at Uttaradit Province were not completely overlap but had a strong similarity (niche overlap was 0.86).

For other collected snakes with stomach contents, the literatures also reported that the Cox's masked water snake, *Homalopsis mereljcoxi* in Family Homalopsidae and the common keelback, *Xenochrophis flavipunctatus* in Family Colubridae fed on fish, mice and amphibians such as the green paddy frog, *Hylarana erythraea* and the Taiwanese frog, *Hoplobatrachus rugulosus* in Family Ranidae (Cox et al., 1998; Pongcharoen et al., 2008a; Voris and Murphy, 2002). In this study, only type of prey recorded from the stomach contents of these two species were fish in two families such as Family Osphronemidae and Family Anabantidae.

In addition, two exotic fish species such the Nile tilapia, *Oreochromis niloticus* in Family Ciclidae and the red bellied pacu, *Piaractus brachypomus* in Family Characidae were accepted as prey by live gravid females of the Jagor's water snake, *Enhydris jagorii* during the captive period. The guppy, *Poecillia reticulate* in Family

Porciliidae were accepted as a prey items by neonates given birth by captive gravid female snakes of the Jagor's water snake, *Enhydris jagorii* before released at the Bung Ka Loh, Uttaradit Province, Thailand. Karns et al. (2010) also reported that the Nile tilapia, *Oreochromis niloticus* was found as the stomach contents of the Cox's masked water snake, *Homalopsis mereljcoxi* collected from the Bung Ka Loh wetland. Feeding on the exotic prey types of the Jagor's water snake, *Enhydris jagorii* were shown in Figure 6.8.

Snakes in Family Homalopsidae have a variety of predators, both invertebrates and vertebrates. Crabs and snails were reported as invertebrate predators of the freshwater and marine homalopsid snakes (Murphy, 2007a; Murphy et al., 1999; Pongcharoen et al., 2008a; Voris and Murphy, 2002). For vertebrates, many kinds of animals were reported such as fish, mammals, birds and reptiles especially snakes (Murphy, 2007a; Pongcharoen et al., 2008a; Voris and Murphy, 2002). Previous studies reported that many species of snakes in various families were the most important predators of homalopsid snakes in many localities such as the spectacled cobra*, Naja naja* and the many banded krait, *Bungarus multicinctus* fed on the plumbeous water snake, *Hypsiscopus plumbea,* and the sunbeam snake, *Xenopeltis unicolor* in Family Xenopeltidae fed on the rainbow water snake, *Enhydris enhydris* and the Mekong water snake, *Enhydris subtaeniata* (Pongcharoen et al., 2008a; Voris and Murphy, 2002). The red tailed pipe snake, *Cylindrophis ruffus* was also reported as the predator of Homalopsid and other snakes such as the puff faced water snake, *Homalopsis buccata* and the Reuss's water snake, *Enhydris alternans* in Family Homalopsidae and the common keelback, *Xenochrophis flavipunctatus* in Family Colubridae. In this study, the red tailed pipe snake, *Cylindrophis ruffus* were also recorded as the predator of the Jagor's water snake, *Enhydris jagorii*.

From these results, data on prey and predators of the freshwater homalopsid snakes at the Bung Ka Loh wetland, Uttaradit Province, Thailand not only provide more understanding of the freshwater ecosystem of this wetland but is also useful for the conservation and management programs such as captive breeding and reintroduction for the Jagor's water snake, *Enhydris jagorii* and the other freshwater homalopsid snakes.

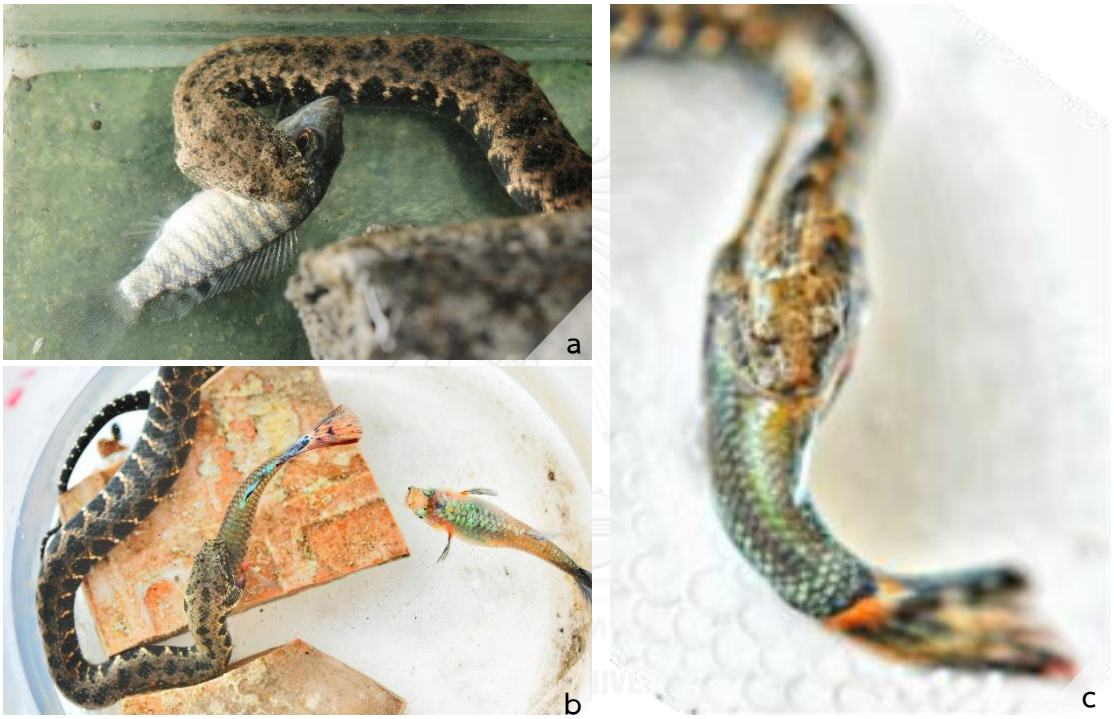


**Figure 6.8:** Exotic species of fish fed by the Jagor's water snake, *Enhydris jagorii* in captivity; (a) live gravid female fed on the Nile tilapia, *Oreochormis niloticus* in Family Ciclidae and (b, c) neonates, given birth by captive gravid females fed on the guppy, *Poecillia reticulata* in Family Porciliidae. Gravid females and neonates were released at the Bung Ka Loh wetland, Uttaradit Province, Thailand when the study was finished.

# Chapter VII

# Female reproductive biology and the relationship between reproductive activities and the environmental factors at Bung Ka Loh, Uttaradit Province, Thailand

## 7.1 Introduction

Oriental-Australian rear-fanged water snake in Family Homalopsidae was a viviparous species (Cox, 1991; Cox et al., 2012; Murphy, 2007a). Among freshwater species, reproduction was well studied for females of the rainbow water snake, *Enhydris enhydris* and the Mekong water snake, *Enhydris subtaeniata* (Karns et al., 2010; Karns et al., 2005; Karns, 1999-2000; Murphy et al., 2002; Voris et al., 2012). Significant correlations between morphology of females and their clutches indicated the female-sized fecundity by larger female reproduced larger clutch size and clutch mass. Both continuous and seasonal reproduction, related to the rainy season, were reported from this group of snake (Pongcharoen et al., 2008a). Multiple paternity was also found in genus *Enhydris* (Voris et al., 2008). They suggested that high population density might influence multiple paternity by increasing frequency of contact between males and females. Nevertheless, all of these studies were performed on a widespread and common species. Although Karns et al. (2010) reported life-pattern of the Jagor's water snake, *Enhydris jagorii* in some respects, information on female reproduction of this endemic and rare species still unrevealed. Hence, this study aims to investigate on the reproduction of this species found inside the Bung Ka Loh, Uttaradit Province, Thailand.

7.2 Methodology

Live and dead collected gravid females of the Jagor's water snake, *Enhydris jagorii* from the Bung Ka Loh wetland, Uttaradit Province, Thailand were used in the female productive investigation. Specimens were measured and weight following the methods in Chapter IV. Live gravid females were kept in captivity until they gave birth then neonates and females were released at the study site. For dead gravid females, abdominal cavities of the specimens were dissected. Data on follicles and vitellogenic eggs, clutch mass, clutch size and the stage of the embryos were recorded from gravid females throughout the study period. The smallest size at maturation of females was considered from the smallest female contained enlarged vitellogenic follicles, oviducal eggs or exhibited thickened and muscular oviducts which indicating the postpartum period (Karns et al., 2010; Voris et al., 2012). The number of gravid females with small follicles in its ovary, gravid females with developing embryos and postpartum gravid females in each month were recorded. Digital balance was used for weighing clutches and embryos to the nearest 0.1 gram.



The stages of embryos were identified following Zehr (1962). From 37$^{th}$ stage of embryo developments, 4 periods of visible developing stages were categorized. First period was considered as the early developing stage of embryos. Second period was considered as the middle developing stage of embryos. Third period was considered as the late developing stage of embryo. Last period was considered as the full-term stage of embryos. Ova and embryos removed from the dead gravid female carcasses were labeled and stored in 10% buffered formaldehyde solution.

Data on physical factors throughout the study period such as precipitation, air temperature and relative humidity were collected from the Thai Meteorological Department. Obtained data were recorded from the nearest weather station close to the study area. Uttaradit Weather Station located at downtown of Uttaradit Province was selected to be the representative of the environmental factors at the study site (17°37’28”N and 100°5’49”E, about 5 kilometers in displacement between localities). Location of the weather station at Uttaradit Province was shown in Figure 7.1.

The relative clutch mass (RCM) was calculated as the ratio of clutch mass to maternal mass (excluded clutch mass). The relationship between female morphological characters with clutch mass and clutch size were examined using Pearson’s correlation. Correlation between female reproduction and physical factors were correlated by Pearson’s test. Statistical analyses in this study were performed on laptop computer with the SPSS program version 21.0 for MacOSX operating system version10.9.3, Maverick.

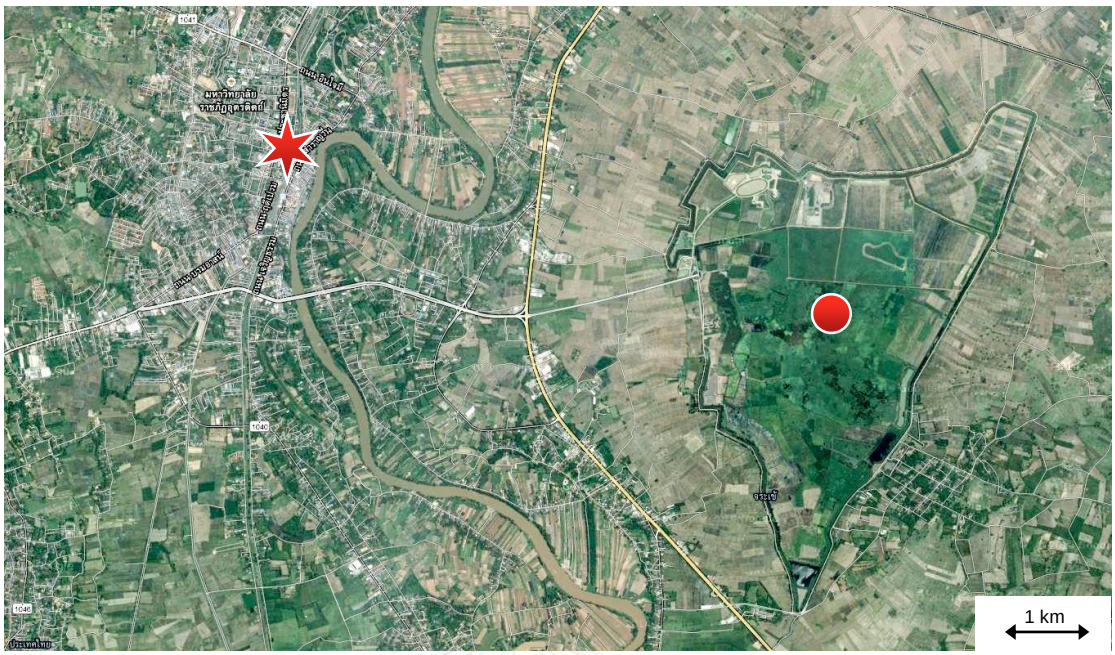


**Figure 7.1:** Locations of Uttaradit Weather Station (red star; 17°37’28”N and 100°5’49”E) at downtown of Meuang District and the study site at Bung Ka Loh wetland Uttaradit Province, Thailand (red circle; 17°36’51”N and E100°9’20”E). Distance between these two localities was about 5 kilometers. Photograph was captured from Google Maps program.

## 7.3 Result

### 7.3.1 Reproductive biology

54 specimens of female of the Jagor's water snake, *Enhydris jagorii* were collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. 50 specimens (92.59%) were the mature females whereas 36 specimens (66.67%) of them were gravid females contained vitellogenic follicles, oviducal eggs, embryos and exhibited the thickened and muscular oviducts (postpartum stage) (Figure 7.2). The smallest gravid females collected from this study site was 34.0 centimeters in SVL. Six vitellogenic eggs were found inside the ovary of this female.

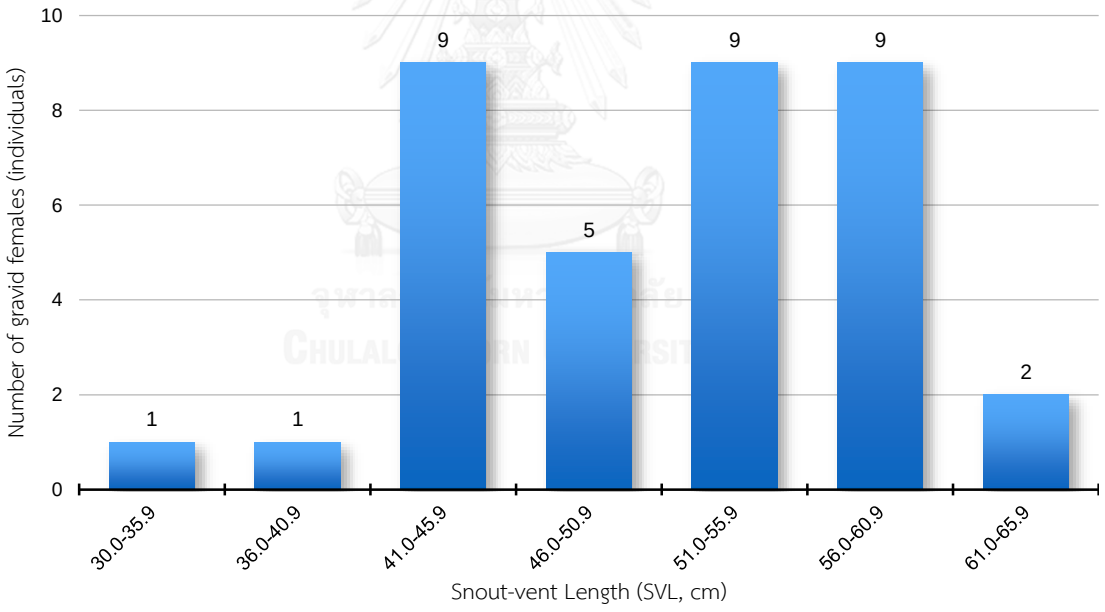


**Figure 7.2:** The number of gravid females of the Jagor's water snake, *Enhydris jagorii* collected in the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period from October 2010 to August 2012. Data were categorized by snout-vent length (SVL).

Five morphological characters such as snout-vent length (SVL), tail length (TL), neck girth (NG), body girth (BG) and body mass of gravid females collected inside the Bung Ka Loh wetland were measured and calculated. The mean values (±SD) were 50.73±13.34 centimeters for snout-vent length (ranged from 34.0 to 65.0 centimeters), 13.34±1.83 centimeters for tail length (ranged from 10.0 to 16.1 centimeters), 4.35±0.89 centimeters in neck girth (ranged from 3.0 to 6.7 centimeters), 10.36±1.97 centimeters in body girth (ranged from 6.5 to 14.5 centimeters), and 345.25±154.93 grams in mass (ranged from 94.0 to 707 grams). The proportion between TL and SVL of gravid female was also calculated and the mean value (±SD) was 0.26±0.02 ranged from 0.23 to 0.30. The mean values (±SD) of gravid female morphological characters were shown in Table 7.1.

**Table 7.1:** Gravid female morphological characters of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. Each column shows the mean value (±SD) and range values (minimum and maximum) for 5 morphological characters; SVL, TL, neck girth, body girth and body mass, and the proportion between TL and SVL.

| Species | Morphological characters (mean values ± SD) | | | | | |
|---|---|---|---|---|---|---|
| | SVL (cm) | TL (cm) | Neck girth (cm) | Body girth (cm) | Body mass (grams) | TL/SVL |
| *E. jagorii* | 50.73 ± 7.07 (34.0 - 65.0) | 13.34 ± 1.83 (10.0 - 16.1) | 4.35 ± 0.89 (3.0 - 6.7) | 10.36 ± 1.97 (6.5 - 14.5) | 345.25 ± 154.93 (94.0 - 707.0) | 0.26 ± 0.02 (0.23 - 0.30) |

In this study, clutch size, clutch mass and relative clutch mass (RCM) were recorded and calculated from collected gravid females. For clutch size, the smallest clutch size was only one embryo and the largest clutch size was 28 embryos.

The mean value of clutch size was 11±9 embryos (n=18). For clutch mass, the smallest clutch mass was 3.10 grams and the largest clutch mass was 123.0 grams. The mean value of clutch mass was 56.43±50.56 grams (n=14). The relative clutch mass (RCM) recorded from gravid females collected at this study site ranged from 0.03 to 0.52 with the mean values was 0.18±0.14 (n=14). In addition, fat body of gravid females was also documented. The mean value of fat body of gravid females was 25.58±11.63 grams and ranged from 10.19 to 47.67 grams (n=16).

Significant relationship between morphological characters of gravid females and its clutches were found. Clutch size was significantly related with 3 morphological characters of gravid females such as SVL (r=0.575, $p$ = 0.013, Figure 7.3), TL (r=0.607, $p$ = 0.036, Figure 7.4) and body mass (r=0.526, $p$ = 0.025, Figure 7.5). For clutch mass, significant relationships were found with 2 morphological characters of gravid females such as SVL (r=0.595, $p$ = 0.019, Figure 7.6) and body mass (r=0.533, $p$ = 0.041, Figure 7.7). In addition, significant relationship between fat body and 2 morphological characters of gravid females; SVL (r=0.610, $p$ = 0.006) and body mass (r=0.549, $p$ = 0.015) were found.



For other snakes, gravid females of other 3 species were collected. Two species were freshwater snakes in Family Homalopsidae such as the rainbow water snake, *Enhydris enhydris* and the Cox's masked water snake, *Homalopsis mereljcoxi*, another species was the common keelback, *Xenochrophis flavipunctatus* in Family Colubridae.

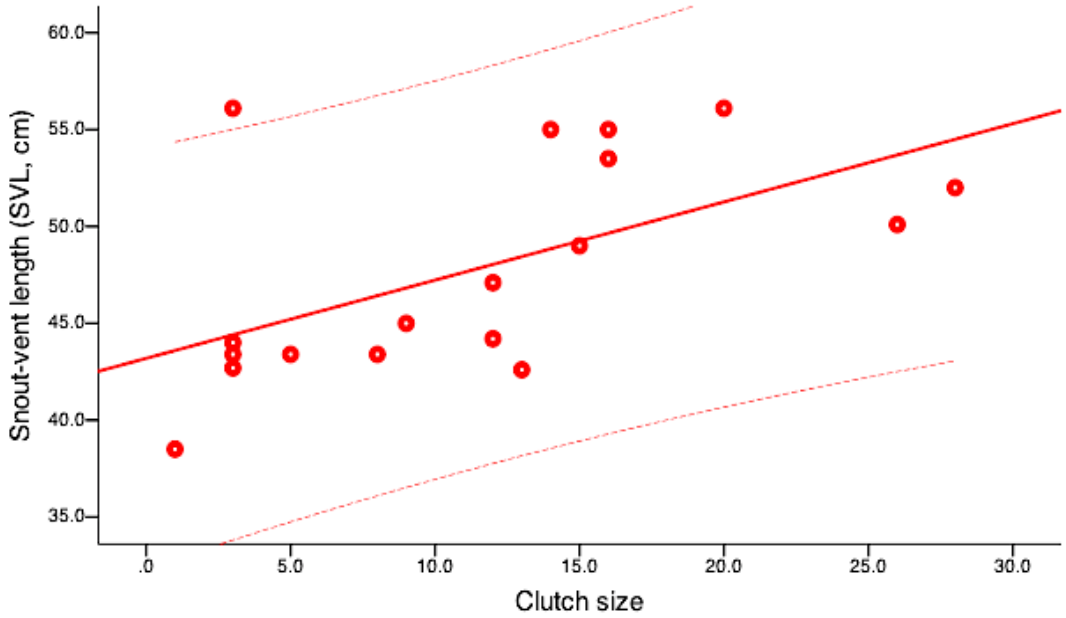


**Figure 7.3**: Regression and 95% confidence limits of snout-vent length (SVL) versus clutch size of 18 gravid females of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.575, p = 0.013).

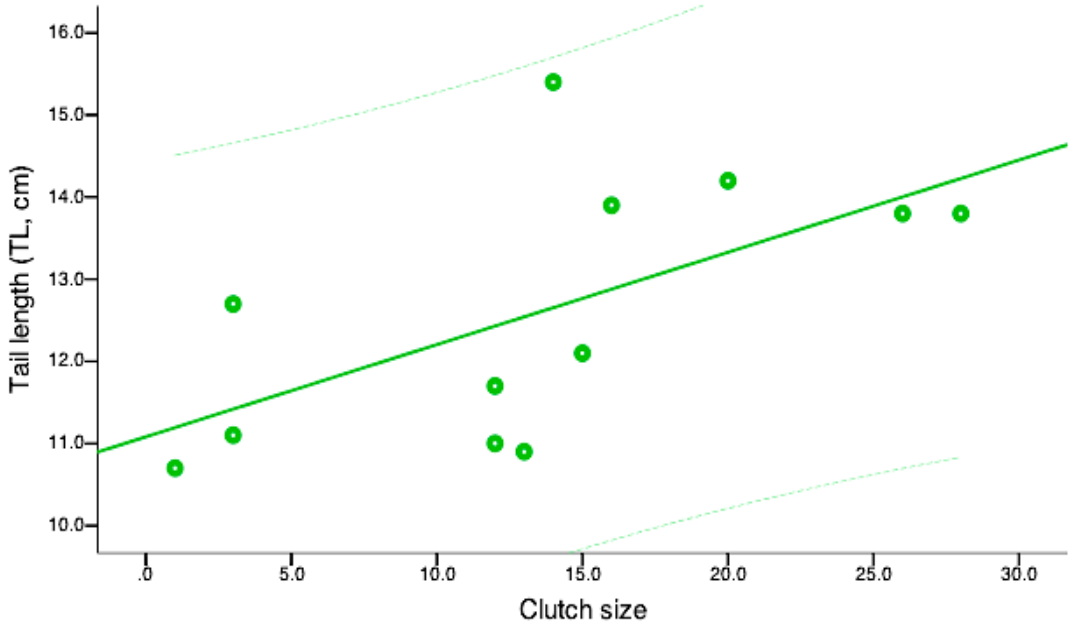


**Figure 7.4**: Regression and 95% confidence limits of tail length (TL) versus clutch size of 12 gravid females of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.607, *p* = 0.036).

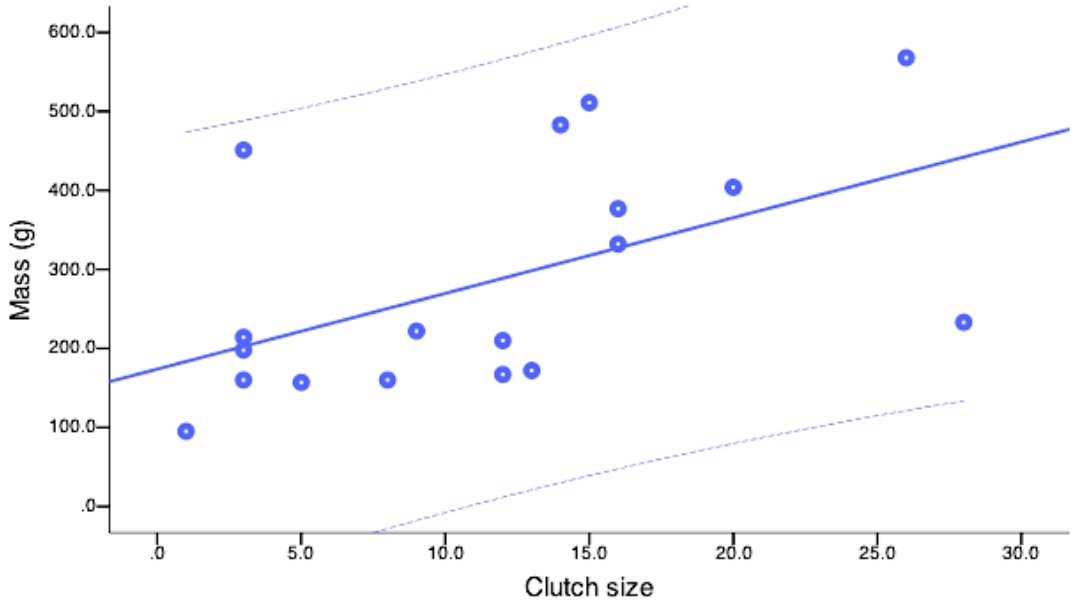


**Figure 7.5**: Regression and 95% confidence limits of body mass versus clutch size of 18 gravid females of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.526, $p$ = 0.025).

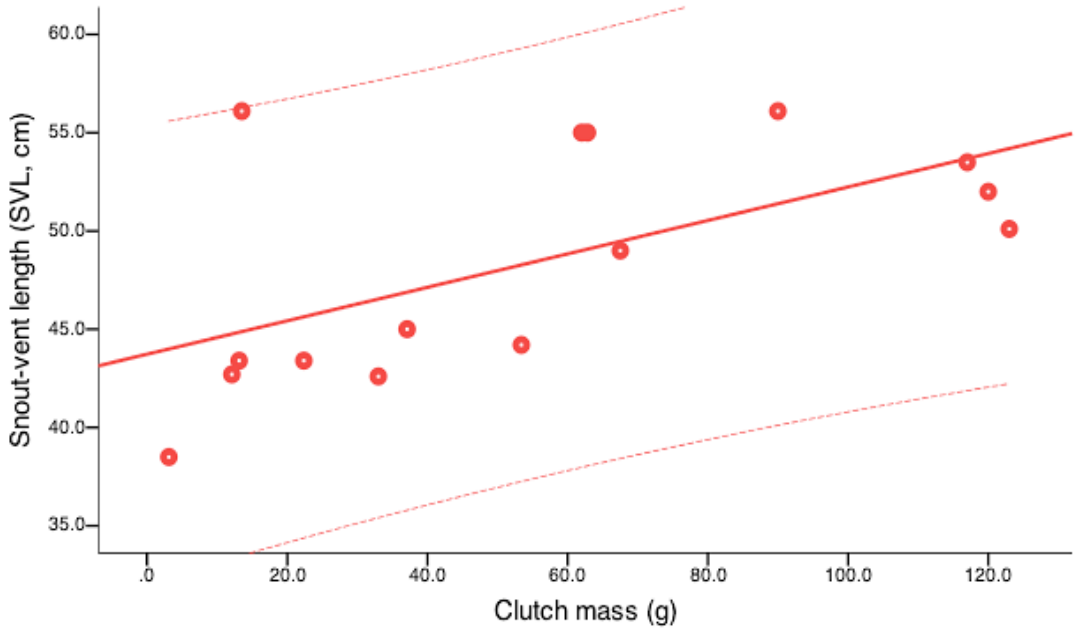


**Figure 7.6:** Regression and 95% confidence limits of snout-vent length (SVL) versus clutch mass of 15 gravid females of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.595, $p$ = 0.019).

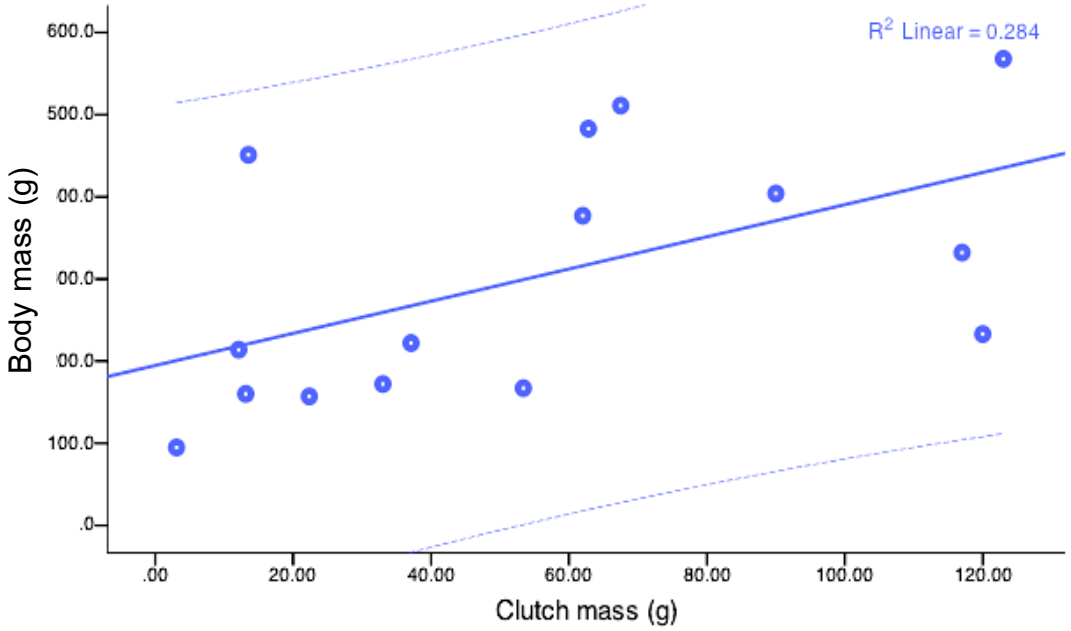


**Figure 7.7:** Regression and 95% confidence limits of body mass versus clutch mass of 15 gravid females of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.533, $p$ = 0.041).

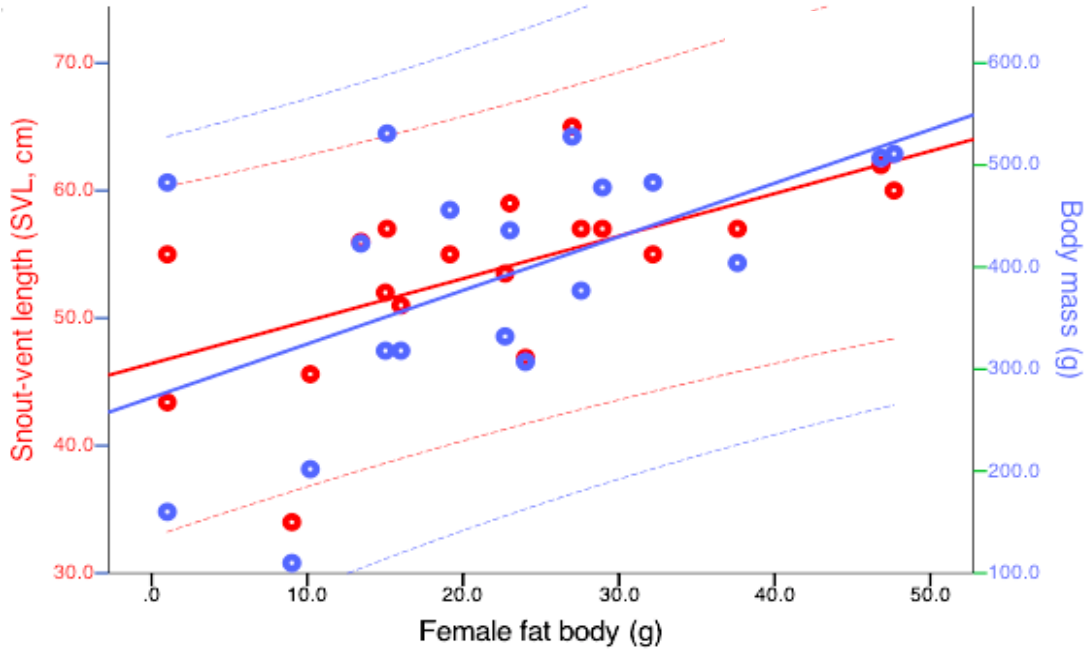


**Figure 7.8:** Regression and 95% confidence limits of SVL and body mass versus fat body of 19 gravid females of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. Correlations are significant ($r_{(SVL)}$=0.610, $p$ = 0.006 and $r_{(mass)}$=0.549, $p$ = 0.015).

48 collected specimens (39.02%) of the rainbow water snake, *Enhydris enhydris* were gravid females. Gravid female with 44.30 centimeters in SVL and 95.0 grams in mass was the smallest gravid female collected in this study. The mean values (±SD) of gravid females were 64.49±7.75 centimeters in SVL (ranged from 44.30 to 78.50 centimeters), 14.71±1.59 centimeters in TL (ranged from 12.10 to 19.80 centimeters), 3.25±0.55 centimeters in neck girth (ranged from 2.20 to 4.90 centimeters), 8.13±1.40 centimeters in body girth (ranged from 4.80 to 11.10 centimeters), 279.50±99.68 grams in mass (ranged from 95.0 to 492.0 grams) and 0.23±0.02 in the proportion between SVL and TL (ranged from 0.20 to 0.30). The mean clutch size (±SD) was 19.22±6.21 embryos ranged from 9 to 31 embryos. Morphological characters of collected gravid females of the rainbow water snake, *Enhydris enhydris* captured from this study site were shown in Table 7.2.

**Table 7.2:** Gravid female morphological characters of the rainbow water snake, *Enhydris enhydris* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. Each column shows the mean value (±SD) and range values (minimum and maximum) for 5 morphological characters; SVL, TL, neck girth, body girth and body mass, and the proportion between TL and SVL.



| Species | Morphological characters (mean values ± SD) | | | | | |
|---|---|---|---|---|---|---|
| | SVL (cm) | TL (cm) | Neck girth (cm) | Body girth (cm) | Body mass (grams) | TL/SVL |
| *E. jagorii* (n=48) | 64.49 ± 7.75 (44.3 - 78.5) | 14.71 ± 1.59 (12.1 - 19.8) | 3.25 ± 0.55 (2.2 - 4.9) | 8.13 ± 1.40 (4.8 - 11.1) | 279.50 ± 99.68 (95.0 - 492.0) | 0.23 ± 0.02 (0.20 - 0.30) |

For the Cox's masked water snake, *Homalopsis mereljcoxi*, 2 collected females (40%) were gravid females with 89.0 and 114.0 centimeters in SVL with 777.0 and 1023.0 grams in body mass, respectively. Only vitellogenic eggs were found in the

reproductive system of these gravid females. Eight vitellogenic eggs were found in the ovary of gravid female with 89.0 centimeters in SVL and 30 vitellogenic eggs were found in the ovary of gravid female with 114 centimeters in SVL. Only one gravid female (8.33%) of the common keelback, *Xenochrophis flavipunctatus* was found during the study period. 35 vitellogenic eggs were found in the ovary of 65.0 centimeters of SVL and 258.0 grams of female body mass.

Correlations between the morphological characters of gravid females and its clutch were performed only for the species with suitable sample size such as the rainbow water snake, *Enhydris enhydris*. Significant relationships between clutch size and 4 morphological characters of gravid females of this species such as SVL (r=0.766, $p$ = 0.000, Figure 7.9), TL (r=0.696, $p$ = 0.000, Figure 7.10), body girth (r=0.697, $p$ = 0.000, Figure 7.11) and body mass (r=0.818, $p$ = 0.000, Figure 7.12) were found. Unfortunately, the relative clutch mass (RCM) and the correlation between morphological characters of gravid females and its clutch mass of these other 3 collected species were not performed due to the lack of embryos at the 37$^{th}$ stage (the full-term stage of embryo development).

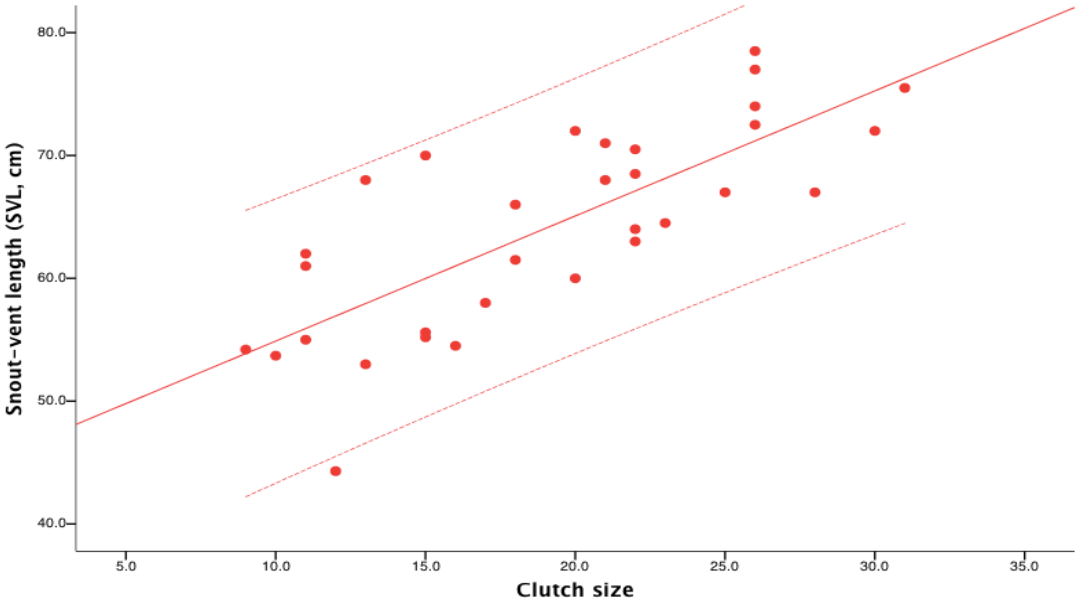


**Figure 7.9:** Regression and 95% confidence limits of snout-vent length (SVL) versus clutch size of gravid females of the rainbow water snake, *Enhydris enhydris* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.766, *p* = 0.000).

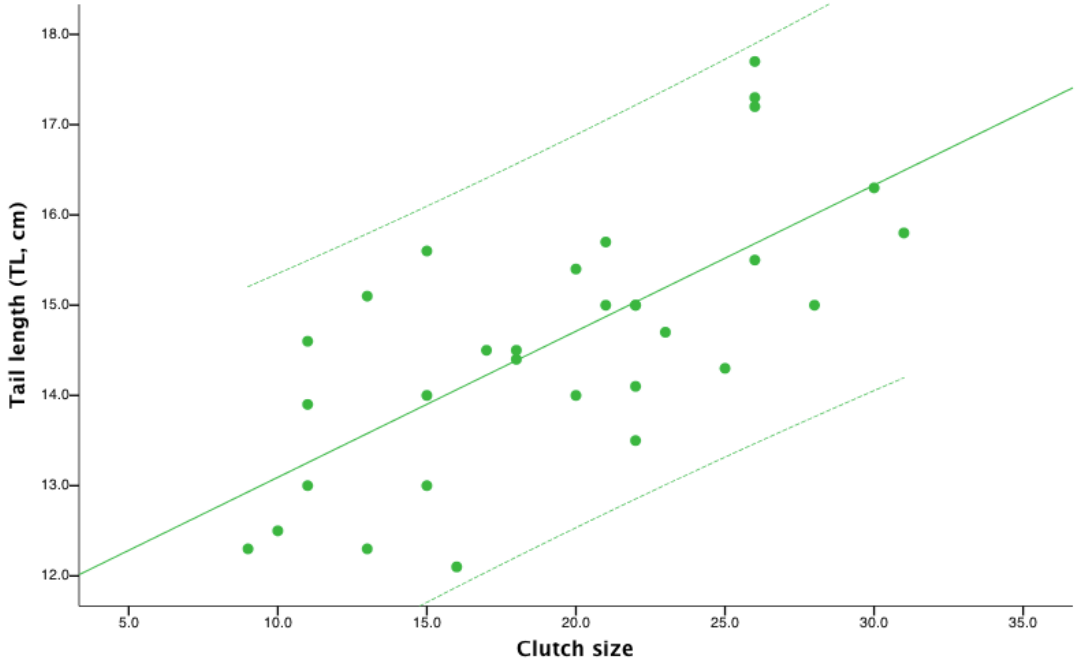


**Figure 7.10:** Regression and 95% confidence limits of tail length versus clutch size of gravid females of the rainbow water snake, *Enhydris enhydris* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.696, *p* = 0.000).

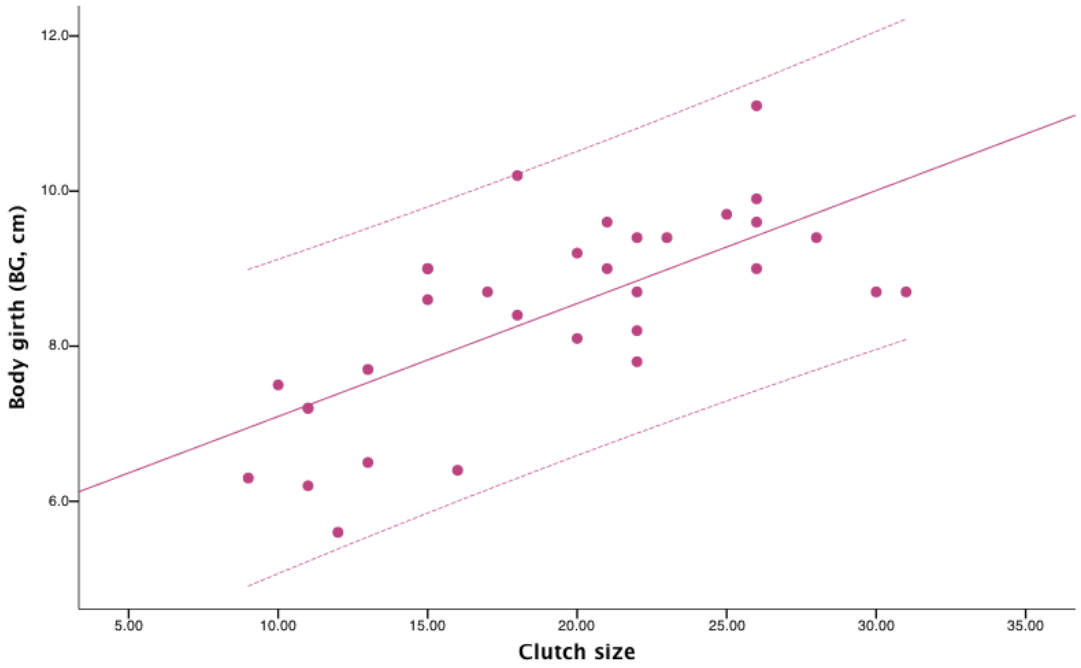


**Figure 7.11:** Regression and 95% confidence limits of body girth versus clutch size of gravid females of the rainbow water snake, *Enhydris enhydris* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.697, p = 0.000).

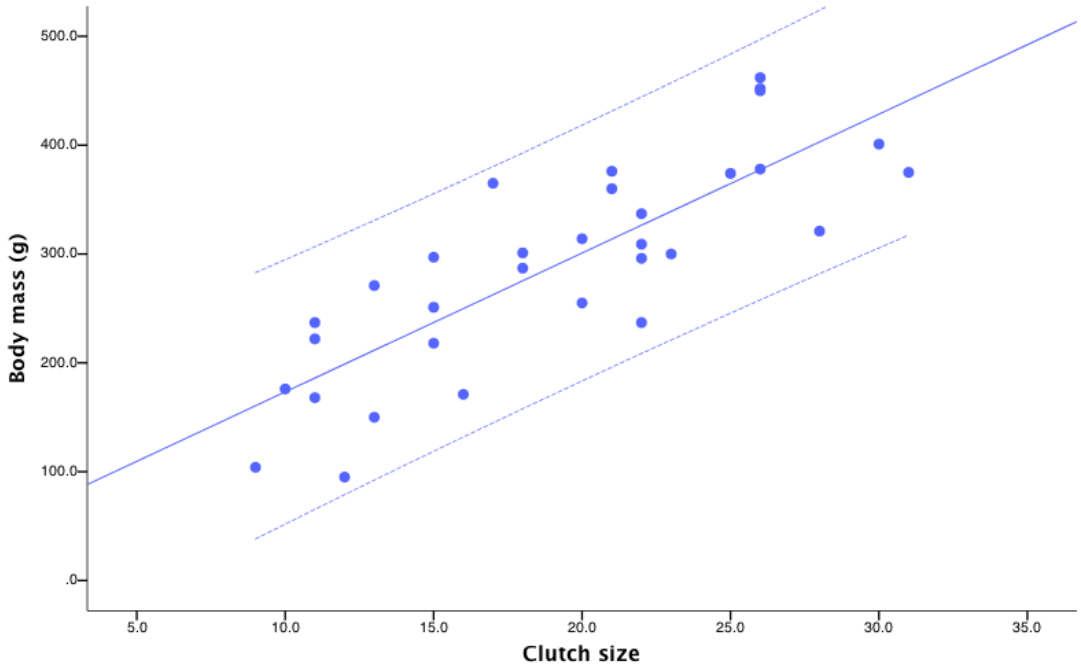


**Figure 7.12:** Regression and 95% confidence limits of body mass versus clutch size of gravid females of the rainbow water snake, *Enhydris enhydris* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand. The correlation is significant (r=0.818, *p* = 0.000).

7.3.2 Reproductive cycle

In this study, reproductive cycle of the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand was recorded. Despite 8 months of no collected specimens in November 2010, March 2011 and during December 2011 to May 2012, 49 females (90.74% of all collected females) contained small follicles in the ovary were found in 15 months such October and December in 2010 (2 months), January, February and April to November in 2011 (10 months) and July to August in 2012 (3 months). The highest number of collected females contained small follicles was 8 specimens collected in May 2011 and August 2012. Contrary, the lowest number of collected gravid females contained small follicles was one specimen occurred in December 2010 and January, February and April 2011 (4 months). Gravid females with developing embryos were collected in 13 months during the study period (23 months during October 2010 to August 2012). 36 gravid females (66.67% of all collected females) were collected with the highest number of collected gravid females was 8 specimens occurred in May 2011. The number of gravid females contained small follicles and embryos in developing stage collected in the study site were shown in Table 7.3.



According to 4 categories of the development of embryos, all the developing period were found in this study. First, the early development stage of embryos (lower than $10^{th}$ to $20^{th}$ stage) was found in December 2010, May and September to November 2011 and August 2012 (6 months). 16 specimens of gravid females contained embryos in the early developing stage were collected. The highest number of collected specimens was 5 specimens in November 2011 followed by 4 specimens in August 2012, 3 specimens in October 2011, 2 specimens in May 2011 and a single specimen in December 2010 and September 2011, respectively. Second, the

**Table 7.3:** The number of gravid females with small follicles in the ovary, gravid females with embryos and postpartum gravid females of the Jagor's water snake, *Enhydris jagorii* collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period (October 2010 to August 2012). Data were separated by month. Empty cells indicated no specimens were collected.

| | 2010 | | | 2011 | | | | | | | | | | | 2012 | | | | | | | | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | |
| **females with small follicles** | 2 | | 1 | 1 | 1 | | 1 | 8 | 3 | 3 | 2 | 4 | 4 | 5 | | | | | | | 4 | 2 | 8 | 49 |
| **gravid females** | 1 | | 1 | | 1 | | 1 | 8 | 3 | 3 | | 1 | 3 | 5 | | | | | | | 4 | 1 | 4 | 36 |

middle developing stage of embryos (21$^{st}$ to 29$^{th}$ stages) was found in February and April 2011. One specimen of gravid females contained embryos in the middle stage was collected in each month. Third, only one gravid female contained embryos in the late developing stage (30$^{th}$ to 36$^{th}$ stages) was collected in May 2011. Last, the full-term stage of embryos (37$^{th}$ stage) was found from May to July 2011 and June 2012. 15 specimens of gravid females contained embryos in the full-term stage were collected. The highest number of collected specimens was 5 specimens in May 2011 followed by 4 specimens in June 2012 and 3 specimens in June and July 2011. Photographs of gravid females of the Jagor's water snake, *Enhydris jagorii* with embryos were shown in Figure 7.13.

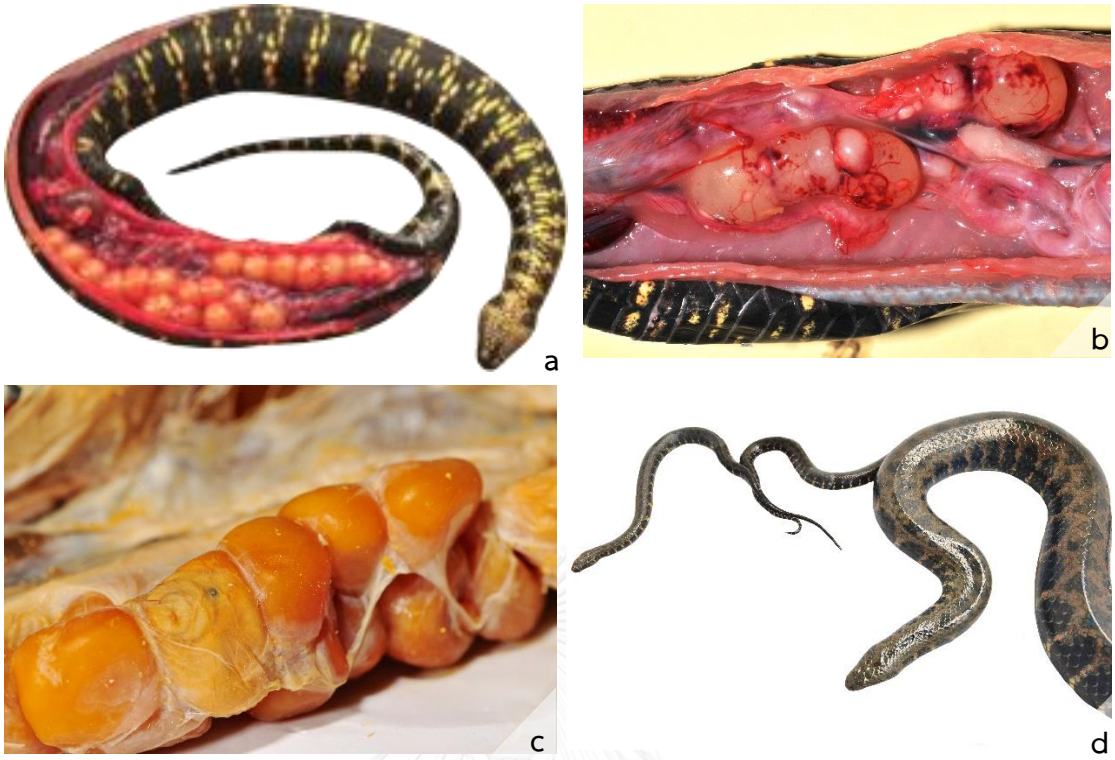


**Figure 7.13:** Photographs of gravid females with embryos in the reproductive system of the Jagor's water snake, *Enhydris jagorii* collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand; (a and b) gravid female with embryos in the early developing stage, (c) gravid female with embryos in the middle developing stage and (d) gravid female with full-term stage embryos.



During the study period, two gravid females at postpartum stage were found in October 2010 and July 2012. These gravid females were 46.9 centimeters in SVL and 307.0 grams in mass and 62.0 centimeters in SVL and 507.0 grams in mass, respectively. Nevertheless, small follicles were also found in the ovaries of these gravid females. The reproductive stages of collected gravid females of the Jagor's water snake, *Enhydris jagorii* in each month during the study period were shown in Table 7.4.

**Table 7.4:** The number of collected gravid females contained embryos in each developing stage of the Jagor's water snake, *Enhydris jagorii* from the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period (23 months from October 2010 to August 2012). Collected gravid females at postpartum stage were also shown. Data were separated by month. Empty cells indicated no specimens were collected.

| Categories | 2010 | | | 2011 | | | | | | | | | | | 2012 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. |
| early developing stage | | | 1 | | | | | 2 | | | | 1 | 3 | 5 | | | | | | | | | 4 |
| middle developing | | | | | 1 | | 1 | | | | | | | | | | | | | | | | |
| late developing stage | | | | | | | | 1 | | | | | | | | | | | | | | | |
| full-term stage | | | | | | | | 5 | 3 | 3 | | | | | | | | | | | 4 | | |
| Postpartum stage | 1 | | | | | | | | | | | | | | | | | | | | | 1 | |

For other homalopsid species, females with the small follicles of the rainbow water snake, *Enhydris enhydris* were collected in 11 months. 87 specimens (70.73% of collected females) were collected from October to December 2010, July to November 2011 and June to August in 2012. The highest number of collected gravid females was 15 specimens occurred in October 2011 and the lowest number of collected gravid females was one specimen occurred in December 2010. The early developing stage of embryos was the only category of embryo development found from the gravid females of this species in this study. 30 specimens of gravid females with the early developing stage of embryos were found in 6 months; November 2010, July to August and November 2011 and June to July 2012. The highest number of collected gravid females with the early developing stage of embryos was 11 specimens occurred in November 2011 and the lowest number was 2 specimens occurred in November 2010 and August 2011. 18 specimens of gravid females with postpartum stage were found in 6 months; October to November 2010, August and October to

November 2011 and July 2012. The highest and the lowest number of collected gravid females with postpartum stage were 6 and 1 specimen occurred in August 2011 and October 2010, respectively. Gravid females with small follicles and developing embryos of the rainbow water snake, *Enhydris enhydris* collected in each month during the study period were shown in Table 7.5.

**Table 7.5:** The number of gravid females contained small follicles in the ovary, gravid females with embryos in each developing stage and gravid females with postpartum stage of the rainbow water snake, *Enhydris enhydris* collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period (23 months during October 2010 to August 2012). Data were separated by month.

| Categories | 2010 | | | 2011 | | | | | | | | | | | 2012 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. |
| small follicles | 4 | 6 | 1 | | | | | | | 9 | 1 | 8 | 1 | 1 | | | | | | | 6 | 7 | 5 |
| early stage | | 2 | | | | | | | | 5 | 2 | | | 1 | | | | | | | 5 | 5 | |
| middle stage | | | | | | | | | | | | | | | | | | | | | | | |
| late stage | | | | | | | | | | | | | | | | | | | | | | | |
| full-term stage | | | | | | | | | | | | | | | | | | | | | | | |
| Postpartum stage | 1 | 2 | | | | | | | | | 6 | | 4 | 3 | | | | | | | | 2 | |

In addition, gravid females with embryos in its reproductive system of other 2 collected snake species were found such as the Cox's masked water snake, *Homalopsis mereljcoxi* and the common keelback, *Xenochrophis flavipunctatus*. One gravid female with embryos of each species were collected in October 2011 and June 2012, respectively. The early developing stage of embryos was the only category of embryo development found from gravid females of the Cox's masked water snake, *Homalopsis mereljcoxi* whereas the common keelback, *Xenochrophis flavipunctatus* was found only vitellogenic eggs in the ovary. Photographs of gravid females with

embryos in its reproductive system of other snake species collected from this study site were shown in Figure 7.14.


**Figure 7.14:** Photographs of gravid females with embryos in the reproductive system of other snake species collected from the Bung Ka Loh, Uttaradit Province, Thailand during the study period; (a) gravid female with embryos in the early developing stage of the rainbow water snake, *Enhydris enhydris*, (b) gravid female with embryos in the early developing stage of the Cox's masked water snake, *Homalopsis mereljcoxi* and (c) gravid female with vitellogenic eggs of the common keelback, *Xenochrophis flavipunctatus* in Family Colubridae.

7.3.3 The correlation between female reproduction and the physical factors

Data on 5 physical factors such precipitation, temperature, barometric, evaporation and relative humidity of the Bung Ka Loh wetland were obtained from the nearest weather station of Thai Meteorological Department at the downtown of Muang District, Uttaradit Province, Thailand. The total precipitation was used for determining season at the study site. During the study period, the rainy season occurred in October 2010, March to October in 2011 (8 months) and May to August in 2012 (4 months) whereas the dry season occurred during November 2010 to February 2011 (4 months) and November 2011 to April 2012 (6 months). The average mean precipitation was 167.0 ±164.0 millimeters. The highest and lowest precipitation were 507.8 millimeters occurred in May 2012 and 0.3 millimeters occurred in November 2011, respectively. However, no precipitation was recorded for 2 months in November 2010 and February 2011 (Figure 7.15).

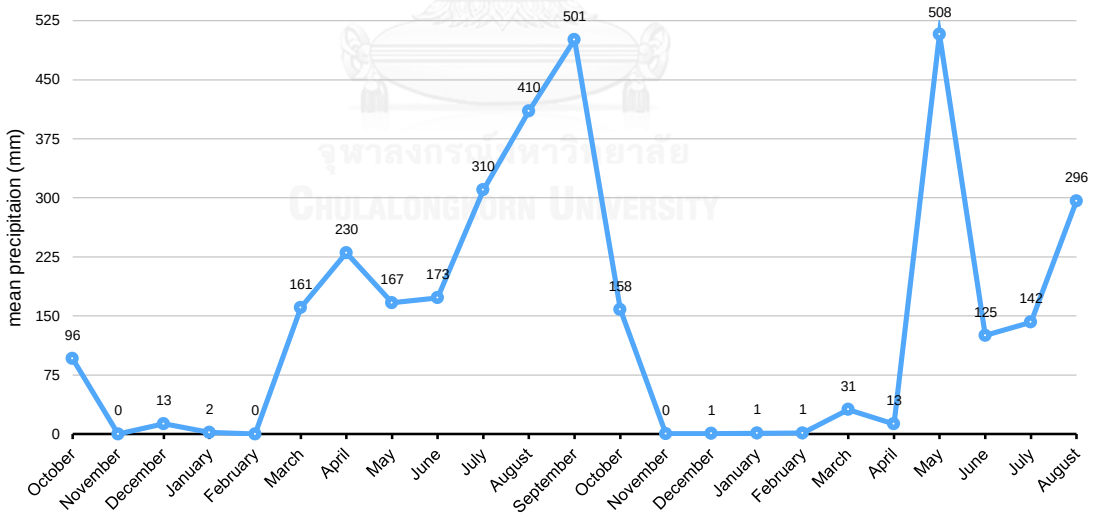


**Figure 7.15:** Mean precipitation (mm) in each month at the Bung Ka Loh wetland, Uttaradit Province, Thailand during October 2010 to August 2012 (23 months).

The average mean temperature was 27.22 ±1.75 degree celsius. The highest degree of temperature was 41.5 degree celsius occurred in April and May 2012 whereas the lowest temperature was 14.5 degree celsius occurred in December 2011 (Figure 7.16).

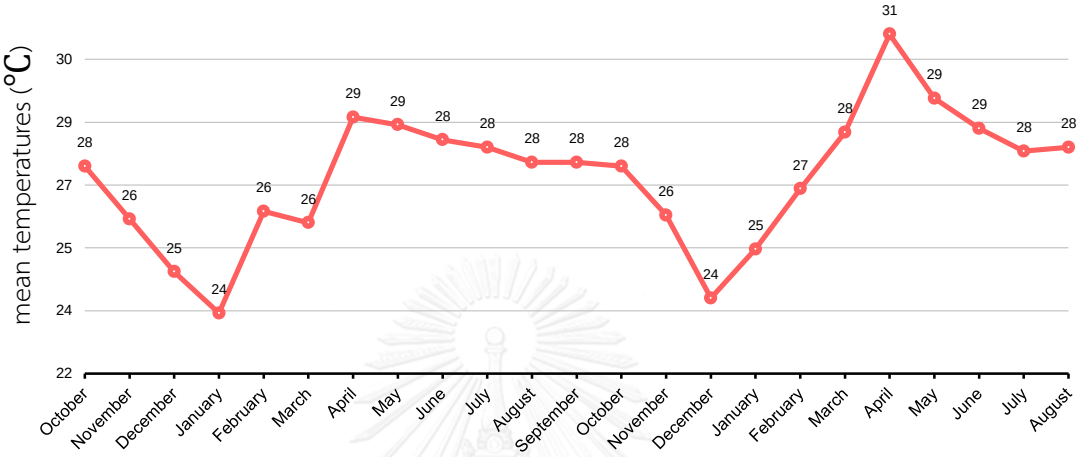


**Figure 7.16:** Mean temperature (°C) in each month at the Bung Ka Loh wetland, Uttaradit Province, Thailand during October 2010 to August 2012 (23 months).

The average mean air pressure was 1008.46 ±2.84 hectopascal. The highest air pressure was 1013.66 hectopascal occurred in December 2011 whereas the lowest air pressure was 1004.28 hectopascal occurred in June 2012 (Figure 6.17).

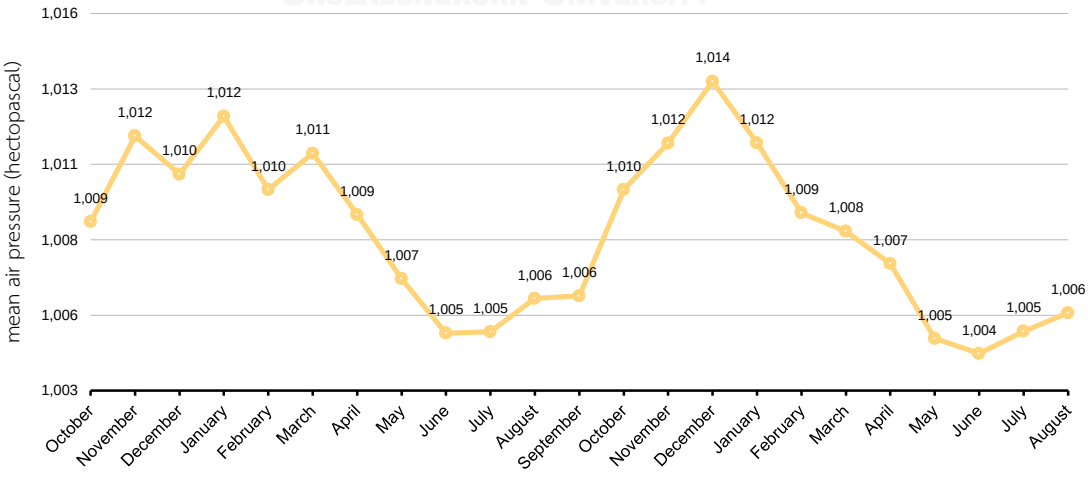


**Figure 7.17**: Mean air pressure (hectopascal) in each month at the Bung Ka Loh wetland, Uttaradit Province, Thailand during October 2010 to August 2012 (23 months).

The average mean evaporation was 3.97 ±0.65 inch per day. The highest evaporation was 5.9 inch per day occurred in April 2012 whereas the lowest evaporation was 3.2 inch per day occurred in December 2012 (Figure 7.18).

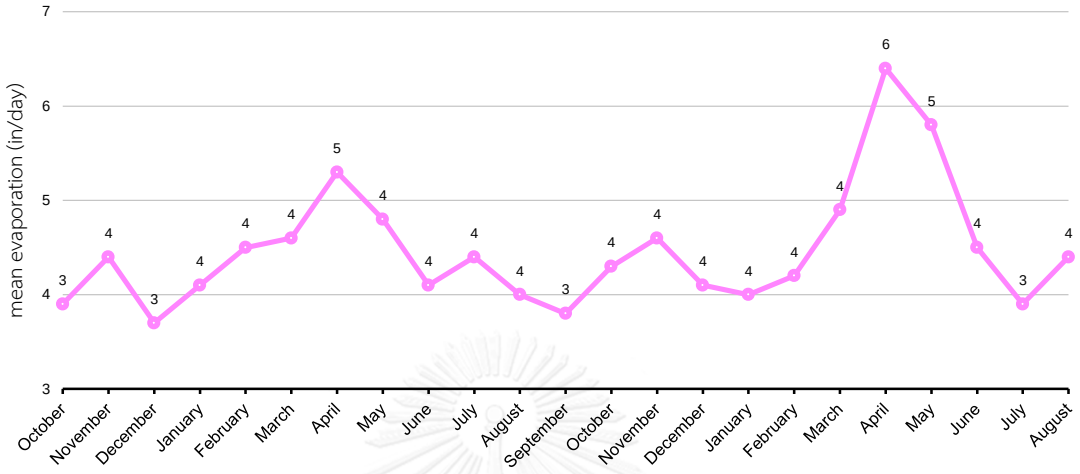


**Figure 7.18**: Mean evaporation (inch per day) in each month at the Bung Ka Loh wetland, Uttaradit Province, Thailand during October 2010 to August 2012 (23 months).

The average relative humidity was 72.83 ±6.82%. The highest relative humidity was 83% occurred in August and October 2011 whereas the lowest relative humidity was 62% occurred in April 2012 (Figure 7.19).

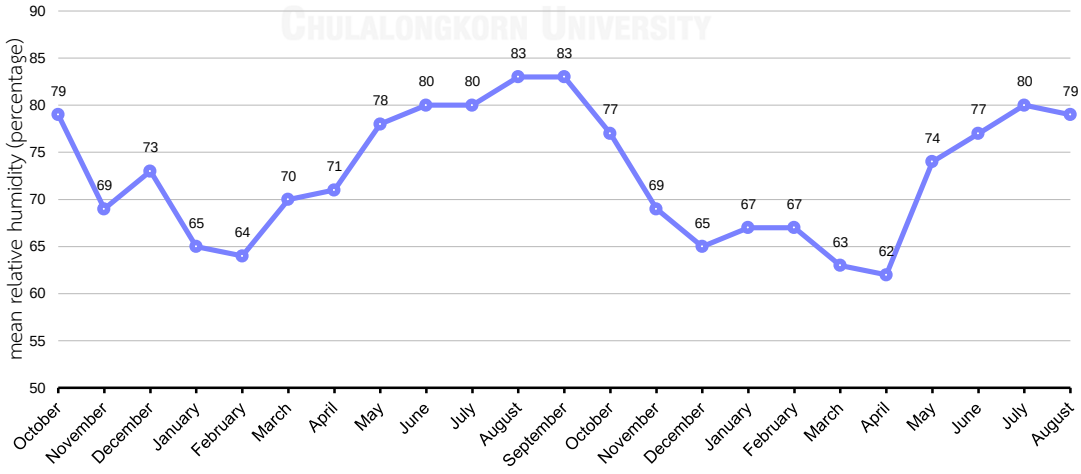


**Figure 7.19:** Mean relative humidity (percentage) in each month at the Bung Ka Loh wetland, Uttaradit Province, Thailand during October 2010 to August 2012 (23 months).

Five physical factors recorded from the study site during the study period were calculated for correlation between each factor. Significant correlation between physical factors were found between mean precipitation and mean relative humidity (r=0.693, $p$ = 0.000), mean precipitation and mean air temperature (r=0.449, $p$ = 0.031) mean evaporation and mean air temperature (r=0.647, $p$ = 0.001), mean precipitation and mean air pressure (r=-0.641, $p$ = 0.002), mean relative humidity and mean air pressure (r=-0.673, $p$ = 0.000), and mean air temperature and mean air pressure (r=-0.768, $p$ = 0.000).

Correlations between the number of gravid females contained embryos in each developing stage and physical factors were also performed. Significant relationship between the number of gravid females with small follicles and the mean relative humidity was found in the positive direction (r=0.595, $p$ = 0.003). However, the relationship between the number of gravid females with small follicles and the mean air pressure was close to significance (r=-0.410, $p$ = 0.052). For the number of gravid females with embryos in developing stage, 2 significant relationships with the physical factors were found. First, the negative relationship was found between the number of gravid females with embryos in full-term stage and the mean air pressure (r=-0.486, $p$ = 0.019). Second, the positive relationship between the total number of gravid females with developing embryos and the mean relative humidity was found (r=0.418, $p$ = 0.047).

## 7.4 Discussion

### 7.4.1 Female reproductive biology

Larger female reproduce the larger clutch have been reported in the studies of other species of freshwater snake in Family Homalopsidae. Larger gravid female of the rainbow water snake, *Enhydris enhydris* and the Mekong water snake, *Enhydris subtaeniata* at other study site reproduce the larger clutch size and clutch mass (Brooks et al., 2008; Karns et al., 2010; Karns et al., 2005; Murphy et al., 2002; Pongcharoen et al., 2008a).

The Jagor's water snake, *Enhydris jagorii* at Bung Ka Loh, Uttaradit Province, Thailan

d has been reported in previous study by Karns et al. (2010) but no information on reproduction was provided. Thus, first information of the female reproduction of the Jagor's water snake, *Enhydris jagorii* is reported in this study. The mean SVL of gravid females collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand was 50.73±7.07 centimeters with 34.0 centimeters as the smallest size of gravid female in this study site. The mean clutch size was 11±9 embryos with the largest clutch size was 28 embryos. The mean clutch mass was 56.43±50.56 grams ranged from 3.10 to 123.0 grams. The mean relative clutch mass (RCM) was 0.18 ± 0.14 ranged from 0.03 to 0.52. The significant correlation and positive relationship between clutch size and 3 morphological characters of gravid females such snout-vent length (SVL, r=0.575, $p$ = 0.013, Figure 6.3), tail length (TL, r=0.607, $p$ = 0.036, Figure 6.4) and body mass were found (r=0.526, $p$ = 0.025, Figure 6.5). Moreover, the significant correlation and positive

relationship between clutch mass and 2 morphological characters of gravid females such such snout-vent length (SVL, r=0.595, $p$ = 0.019, Figure 6.6) and body mass (r=0.533, $p$ = 0.041, Figure 6.7) were also found. These results indicated that larger gravid females of the Jagor's water snakes, *Enhydris jagorii* in this wetland reproduce the larger clutch size and clutch mass. Furthermore, gravid females of the rainbow water snake, *Enhydris enhydris* collected from this study site also exhibited significant positive size-fecundity relationship (Figure 7.9 to 7.12).

7.4.2 Female reproductive cycle

Both seasonal and continuous reproduction have been reported in females of freshwater homalopsid snakes in Thailand especially for the rainbow water snake, *Enhydris enhydris*. Brooks et al. (2008), Saint Girons and Pfeffer (1971) and (Voris et al., 2012) reported that a seasonal distinct reproductive peak occurred in females from the Tonle Sap, Cambodia. Pongcharoen et al. (2008a) also reported that a seasonal reproduction was found in females collected from Ban Badan, Nakhon Ratchasima Province inside the Khorat plateau whereas a continuous reproduction could possibly occur in females collected from Ban Borthong, Kabinburi Province outside the Khorat Plateau, Thailand.

Despite no gravid female were collected for 8 months in December 2012, March 2011 and from December 2011 to April 2012, gravid females with small follicles were found throughout the study period whereas a peak of gravid females with embryos in each developing stages was found during the study period (Figure 7.20). The high number of collected gravid females with embryos during the rainy season (2 periods during March to October in 2011 and May to August in 2012) indicated that gravid females of the Jagor's water snake, *Enhydris jagorii* possibly has a seasonal

reproduction and might be related to the rainy season. Unfortunately, other snakes species collected inside this wetland were not performed in this topic due to the

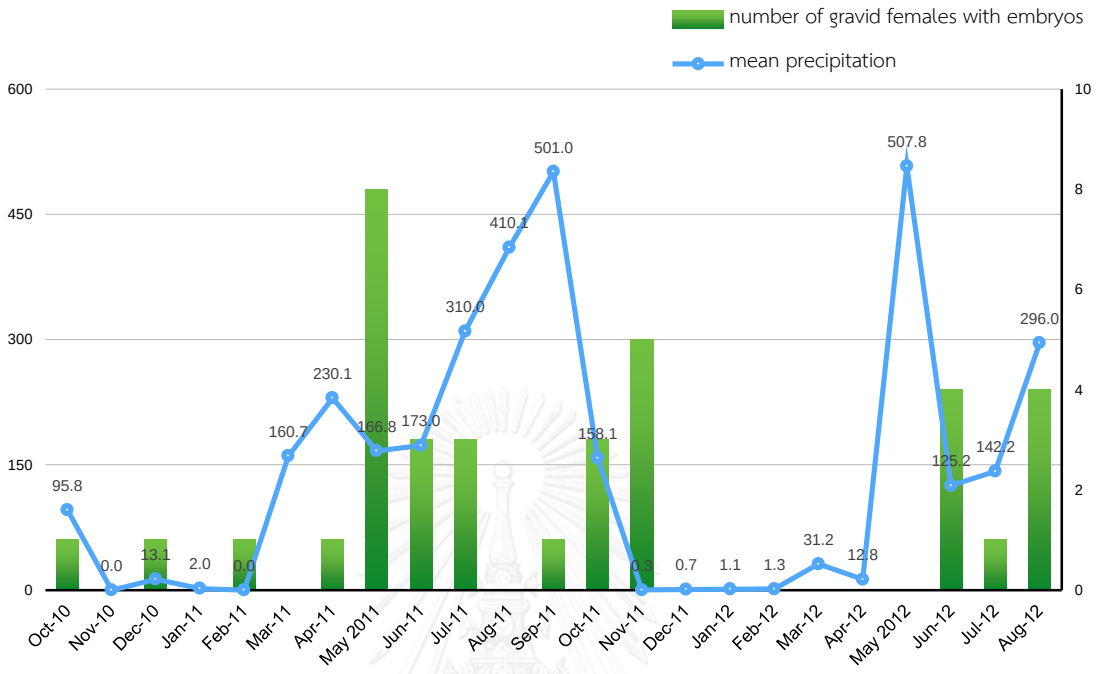


**Figure 7.20:** Chart between the mean precipitation and the number of gravid females with embryos in developing stages collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand during the study period (23 months from October 2010 to August 2012). The peak of the gravid female specimens occurred during the rainy season (March to October in 2011 and May to August in 2012)



sample size issue.

7.4.3 Correlation between reproduction and the physical factors

Relationships between the physical factors and the reproduction of freshwater snake in Family Homalopsidae have been reported in the previous studies. Brooks et al. (2008) and (Voris et al., 2012) reported that a seasonal distinct reproductive peak corresponding to seasonal variation in rain fall and water level occurred in females from the Tonle Sap. Pongcharoen et al. (2008a) also reported the

strong relationships between female reproduction with physical factors, especially the mean precipitation and the mean air temperature. These researchers suggest that the difference in reproductive biology of the same species from various habitats might be effected by many factors such as local environment conditions, food availability and human activities. However, most of studies are based on the widely distributed and abundance species such as the rainbow water snake, *Enhydris enhydris*.

In this study, relationships between the physical factors and the reproduction of endemic species of Homalopsid snakes, the Jagor's water snake, *Enhydris jagorii* collected inside the Bung Ka Loh wetland, Uttaradit Province, Thailand was performed. From the results, three significant relationship were found. The mean relative humidity has a significant relationship with the number of gravid females with small follicles and gravid females with embryos in developing stage (r=0.595, $p$ = 0.003 and r=0.418, $p$ = 0.047, respectively). The mean air pressured also has a significant relationship with the number of gravid females contained full-term stage of embryos (r=-0.486, $p$ = 0.019). The positive correlation between number of gravid females with small follicles and embryos in each developing stages with the mean relative humidity and the negative correlation with the mean air pressure found in this study supported that the reproduction of gravid females of this freshwater homalopsid species has been related to the rainy season (March to October in 2011 and May to August in 2012).

# Chapter VIII

# Distribution and the status of the Jagor's water snake, *Enhydris jagorii* at the Chao Phraya - Ta Chin basin, Thailand

## 8.1 Introduction

Since the widespread of freshwater habitats exist in Thailand, freshwater snakes in family Homalopsidae have been recorded throughout this country. According to 10 species of freshwater snakes recorded from this region, 2 species were reported as an endemic species: Chan-ard's water snake, *Enhydris chanardi* and Jagor's water snake, *Enhydris jagorii* (Cox et al., 2012; Karns et al., 2010; Murphy, 2007a; Murphy and Voris, 2014). Since 1863, distributions of the later species were reported in scattered researches. These researches reported that this snake was found only in the Chao Phraya – Ta Chin basin but no certain locality was provided. For international conservation status, a lot of homalopsid snakes were classified to the Data Deficient (DD) of IUCN red data lists and only one species was classified to Appendices III of CITES. Likewise, ONEP also classified a lot of homalopsid species to Data Deficient (DD) for national level. These status showed that conservation of homalopsid snakes were underestimated due to lacks on their information. Hence, this study aims to investigate the distribution of Jagor's water snake, *Enhydris jagorii* inside the central plain of Thailand and re-classify new conservation status of this snake, both international and national levels.

## 8.2 Methodology

The distribution of the Jagor's water snake, *Enhydris jagorii* was investigated mainly by interviewing local fishermen at selected wetlands inside the Chao Phraya basin, Thailand. Wetlands located around the rivers Ping, Wang, Yom, Nan and Chao Phraya were the observation areas in this study. Furthermore, a few potential wetlands located at the other nearby basins were also observed. Each selected wetlands was about 2.0 square kilometers or larger in area size, approximately one-fifth in area size of the Bung Ka Loh wetland, and covered with dense vegetation at the water body and along the edge of wetland (Figure 8.1). Traps were also set in each selected wetland according to local fishermen's interviews. Location and area of each selected wetland was estimated using satellite picture and Polygon Measurement in Ruler option of Google Earth program. Then, local fishermen around the selected wetland were interviewed for the Jagor's water snake, *Enhydris jagorii* using photographs and live specimens. Traps for specimen collection were also asked at some selected wetlands and if possible, the traps were set at each selected wetland for one night, at least.

**Figure 8.1**: An example of selected wetlands inside the Chao Phraya basin, Thailand.

Global Positioning System (GPS) was used for investigation on the distribution of this freshwater homalopsid snake. Coordinates of each selected wetlands were marked in Universal Transverse Mercator (UTM) format using Garmin 60CSx with software version 4.20. Localities of wetlands with and without snake found were transferred into the Google Earth program for mapping. Moreover, the distribution of this snake species in other publications were also mentioned in this investigation. Mapping program were performed on Apple laptop computer with the Google Earth program version 7.1.2.2014 for MacOSX operating system version 10.9.3, Maverick.

The present status of the Jagor's water snake, *Enhydris jagorii* was referred from the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN) and the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) for the international level and the Office of Natural Resources and Environmental Policy and Planning (ONEP) for the national level. These information were gathered and collected from the publications and official internet website of each organization such as

www.IUCNredlist.org, www.CITES.org and www.ONEP.go.th, respectively. Therefore, the conservation status of this freshwater homalopsid snake were using the information obtained from this study. The IUCN Red List Categories and Criteria version 3.1: IUCN (2001) was used for the status classification of this freshwater homalopsid snake in the IUCN red data list of threatened species.

## 8.3 Result and Discussion

### 8.3.1 Distribution of the Jagor's water snake, *Enhydris jagorii*

From October 2010 to August 2014, 40 wetlands, each about 2 square kilometers in area size or larger located inside the Chao Phraya basin, were observed for the existence of the Jagor's water snake, *Enhydris jagorii*. Local fishermen from 3 wetlands around Ping River, 4 wetlands around Wang River, 7 wetlands around Yom River, 8 wetlands around Nan River and 18 wetland from Chao Phraya River were interviewed and asked for trapping the snake specimen. Coordinates of each observed wetland inside the Chao Phraya basin were shown in Table 8.1.

Inside the central plain of Thailand, most local fishermen from the selected wetlands around Ping (P01 - P03), Wang (W01 - W04) and Yom River (Y01 - Y07) did not recognize the Jagor's water snake and no specimen was observed from these wetlands. Nevertheless, this species was notified from some local fishermen. However, it was found that there were misidentifications between this species and the Bocourt's water snake, *Subcessor bocourti*. Eighteen wetlands located close to the Chao Phraya River were also observed. From the interviews, there was no recognition for this species from local fishermen lived around these selected wetlands. Traps were also set but no specimen was observed or collected inside these wetlands. Even the high biodiversity and largest freshwater wetland of the Chao Phraya basin, Bung Boraphet wetland (C01), also had no evidence on the existence of this species during this study period. For the selected wetlands around Nan River, the Jagor's water snake, *Enhydris jagorii* was recognized by local fishermen from 2 localities (N01 - N02). According to the previous chapters in this study, the existence of this study species inside Bung Ka Loh wetland (N01) was confirmed by observation and specimen

**Table 8.1:** Location, area size, elevation and locality of each selected wetland locate in Chao Phraya basin, Thailand which were observed during the study. Coordinates were marked by Garmin 60 CS with software version 4.20 in UTM format.

| Locations | Area ($km^2$) | Coordinate (UTM) | | | Elevation (m) | Locality |
|---|---|---|---|---|---|---|
| | | Zone | E | N | | |
| Ping river | | | | | | |
| P01 | 2.45 | 47 P | 512044 | 1868738 | 112 | Nong Luang, Ban Mai Ngam, Muang Tak District, Tak Province |
| P02 | 2.18 | 47 P | 614755 | 1747676 | 31 | Nong Sung, Ban Kaeng, Muang Nakhon Sawan District, Nakhon Sawan Province |
| P03 | 3.00 | 47 P | 621372 | 1740843 | 25 | Bueng Se-nat, Bueng Se-nat Subdistrict, Muang Nakhon Sawan District, Nakhon Sawan Province |
| Wang river | | | | | | |
| W01 | 8.68 | 47 Q | 585791 | 2144143 | 404 | Nong Leng Sai, Ban San Khwang, Mae Chai District, Phayao Province |
| W02 | 21.50 | 47 Q | 599703 | 2113301 | 401 | Kwan Phayao, Muang Phayao District, Phayao Province |
| W03 | 2.10 | 47 Q | 507295 | 1917775 | 141 | Nong Kae, Yok Krabat Subdistrict, Sam Ngao District, Tak Province |
| W04 | 3.64 | 47 Q | 510134 | 1904617 | 135 | Bung Cham, Wang Man Subdistrict, Sam Ngao District, Tak Province |
| Yom river | | | | | | |
| Y01 | 2.37 | 47 Q | 575794 | 1923416 | 66 | Bung Chorakae, Sarachit Subdistrict, Si Satchanalai District, Sukhothai Province |
| Y02 | 1.98 | 47 Q | 583431 | 1931598 | 65 | Tung Mae Rawing, Pa Kum Ko Subdistrict, Sawankhalok District, Sukhothai Province |
| Y03 | 11.90 | 47 Q | 589338 | 1883855 | 49 | Tung Tale Luang, Pak Khwae Subdistrict, Muang Sukhothai District, Sukhothai Province |
| Y04 | 3.60 | 47 Q | 594986 | 1887230 | 49 | Tung Yai, Tan Tia Subdistrict, Muang Sukhothai District, Sukhothai Province |
| Y05 | 1.75 | 47 Q | 621720 | 1864528 | 42 | Bung Mae Rahan, Ban Krang Subdistrict, Muang Phitsanolok, Phitsanulok Province |
| Y06 | 2.47 | 47 Q | 614719 | 1849274 | 44 | Bang Rakam Subdistrict, Bang Rakam District, Phitsanulok Province |
| Y07 | 3.92 | 47 Q | 618696 | 1846206 | 42 | Bung Raman, Ban Plak Raet Subdistrict, Bang Rakam District, Phitsanulok Province |
| Nan river | | | | | | |
| N01 | 10.50 | 47 Q | 622245 | 1944102 | 65 | Bung Ka Loh, Ban Pa Sao Subdistrict, Muang Uttaradit District, Uttaradit Province |
| N02 | 7.31 | 47 Q | 605838 | 1937115 | 57 | Bung Mai, Dan Mae Kham Man Subdistrict, Laplae District, Uttaradit Province |
| N03 | 3.17 | 47 Q | 613714 | 191878 | 57 | Bung Cho, Ban Dara Subdistrict, Phichai Subdistrict, Uttaradit Province |
| N04 | 5.10 | 47 Q | 625967 | 1902716 | 50 | Bung Lom, Dong Prakham Subdistrict, Phrom Phiram District, Phitsanulok Province |
| N05 | 5.99 | 47 Q | 642235 | 1856979 | 45 | Bung Ratchanok, Wang Thong Subdistrict, Wang Thong District, Phitsanulok Province |
| N06 | 8.98 | 47 Q | 642316 | 1815595 | 34 | Bung Sifai, Muang Phichit District, Phichit Province |
| N07 | 2.16 | 47 Q | 649678 | 1812125 | 33 | Bung Tao Khanom Chin, Ban Bueng Subdistrict, Muang Phichit District, Phichit Province |
| N08 | 2.10 | 47 P | 632131 | 1752026 | 26 | Bung Sam Mum, Khok Mo Subdistrict, Chum Saeng District, Nakhon Sawan Province |

**Table 8.1 (continued):** Location, area size, elevation and locality of each selected wetland locate in Chao Phraya basin, Thailand which were observed during the study. Coordinates were marked by Garmin 60 CS with software version 4.20 in UTM format.

| Locations | Area ($km^2$) | Coordinate (UTM) | | | Elevation (m) | Locality |
|---|---|---|---|---|---|---|
| | | Zone | E | N | | |
| Chao Phraya river | | | | | | |
| C01 | 132.74 | 47 P | 632847 | 1733016 | 26 | Bung Boraphet, Phra Non Subdistrict, Muang Nakhon Sawan District, Nakhon Sawan Province |
| C02 | 2.10 | 47 P | 616597 | 1731578 | 22 | Bung Or, Nakhon Sawan Tok Subdistrict, Muang Nakhon Sawan District, Nakhon Sawan Province |
| C03 | 3.81 | 47 P | 610486 | 1724670 | 23 | Bung Krachang Ngam, Kok Phra Subdistrict, Krok Phra District, Nakhon Sawan Province |
| C04 | 4.38 | 47 P | 614653 | 1723362 | 22 | Bung Whai, Bang Ma Phor Subdistrict, Krok Phra District, Nakhon Sawan Province |
| C05 | 2.97 | 47 P | 617560 | 1709840 | 21 | Bung Nam Song, Nam Song Subdistrict, Phayuha Khiri District, Nakhon Sawan Province |
| C06 | 2.22 | 47 P | 619243 | 1681740 | 23 | Bung Hat Kong Sin, Hat Tha Sao Subdistrict, Muang Chai Nat District, Chai Nat Province |
| C07 | 2.61 | 47 P | 618880 | 1680740 | 21 | Bung Hat Tha Sao, Hat Tha Sao Subdistrict, Muang Chai Nat District, Chai Nat Province |
| C08 | 1.96 | 47 P | 649680 | 1654854 | 11 | Unnamed wetland, Nam Tan Subdistrict, In Buri District, Sing Buri Province |
| C09 | 4.12 | 47 P | 658694 | 1653898 | 11 | Klong Ban Kham, Ban Kham Subdistrict, Ban Mi District, Lopburi Province |
| C10 | 4.90 | 47 P | 652627 | 1607533 | 8 | Unnamed wetland, Mahat Thai Subdistrict, Mueang Ang Thong District, Ang Thong Province |
| C11 | 4.65 | 47 P | 655868 | 1604347 | 7 | Unnamed wetland, Pa Mok Subdistrict, Pa Mok District, Ang Thong Province |
| C12 | 22.30 | 47 P | 655031 | 1602326 | 10 | Unnamed complex wetlands, Pa Mok Subdistrict, Pa Mok District, Ang Thong Province |
| C13 | 2.32 | 47 P | 660858 | 1590166 | 6 | Unnamed wetland, Mahar Phram Subdistrict, Bang Ban District, Phra Nakhon Si Ayutthaya Province |
| C14 | 1.67 | 47 P | 657794 | 1585815 | 4 | Unnamed wetland, Ban Khlang Subdistrict, Bang Ban District, Phra Nakhon Si Ayutthaya Province |
| C15 | 4.19 | 47 P | 669782 | 1550107 | 6 | Unnamed canal, Bang Phun Subdistrict, Mueang Pathum Thani District, Pathum Thani Province |
| C16 | 3.96 | 47 P | 686323 | 1553626 | 7 | Bung Rama 9, Khlong Hok, Khlong Luang District, Pathum Thani Province |
| C17 | 7.69 | 47 P | 677334 | 1499249 | 3 | Unnamed complex wetlands, Bang Pu Subdistrict, Muang Samut Prakan District, Samutparkan Province |
| C18 | 2.68 | 47 P | 646626 | 1600637 | 6 | Bung Nong Ngam Yai, Nong Nam Yai Subdistrict, Phak Hai District, Phra Nakhon Si Ayutthaya Province |

collection. For Bung Mine wetland (N02), local fishermen also recognized *E. jagorii* from photographs and live specimens during the interview. Unfortunately, specimen of this species was not observed or collected from traps setting inside Bung Mine wetland during the study period.

Furthermore, other 9 wetlands outside the Chao Phraya basin were also selected for the study on the distribution of the Jagor's water snake, *Enhydris jagorii* (Table 8.2). However, none of local fishermen lived around these wetlands recognized the Jagor's water snake, *Enhydris jagorii* and no specimen of this snake was observed or collected from these wetlands.

**Table 8.2:** Localities, area size and elevation of each selected wetland outside the Chao Phraya basin, Thailand observed in this study. Coordinates were marked by Garmin 60 CS with software version 4.20 in UTM format.

| Locations | Area ($km^2$) | Coordinate (UTM) | | | Elevation (m) |
|---|---|---|---|---|---|
| | | Zone | E | N | |
| Pa Sak River | | | | | |
| Pa01 | 9.93 | 47 P | 725345 | 1700985 | 102 |
| Pa02 | 4.10 | 47 P | 722251 | 1754987 | 79 |
| Pa03 | 4.94 | 47 P | 687871 | 1616794 | 16 |
| Pa04 | 2.53 | 47 P | 676821 | 1607696 | 14 |
| Ta Chin River | | | | | |
| T01 | 2.10 | 47 P | 609175 | 1659018 | 14 |
| T02 | 2.31 | 47 P | 612068 | 1651235 | 11 |
| T03 | 4.55 | 47 P | 643519 | 1523485 | 5 |
| T04 | 2.10 | 47 P | 644775 | 1506288 | 3 |
| Sake Krang River | | | | | |
| S01 | 6.16 | 47 P | 600261 | 1713092 | 26 |

According to the literatures, distributions of the Jagor's water snake, *Enhydris jagorii* were scattered. Peters (1863) described this freshwater homalopsid

snake as a valid species from the holotype collected from the vicinity of Bangkok, Thailand. Murphy (2007a) reported that this freshwater homalopsid snake was the endemic species and restricted to the Chao Phraya River inside the central plain of Thailand. He also mentioned that some previous reports on distributions of this freshwater homalopsid snake might be a misidentification or accidentally dispersed from the habitat area (Murphy, 2007a; Smith, 1915; Tirant, 1885). Karns et al. (2010) reported that specimens of this species were collected from the Bung Ka Loh wetland, Uttaradit Province, Thailand. Cox et al. (2012) and Nabhitabhata and Chan-ard (2005) added the area of Nakhon Sawan Province, Thailand inside the Chao Phraya basin as the new distribution of this freshwater homalopsid snake. Nevertheless, most of them did not provide the exact locality of this species except Karns et al. (2010). Hence, that report was the only study that provided the exact locality of the Jagor's water snake, *Enhydris jagorii* until now.

From all 40 selected wetlands, evidence on the existence of this species occurred only at the Bung Ka Loh wetland during investigation period. Therefore, previous and recent information on the distribution of the Jagor's water snake, *Enhydris jagorii* showed that this freshwater homalopsid snake is an endemic species found only inside the central plain of Thailand and Bung Ka Loh wetland at Meuang District in Uttaradit Province is the only wetland inside the Chao Phraya - Ta Chin basin with the existence of this species. Locations of each selected wetland with and without the existence of the Jagor's water snake, *Enhydris jagorii* inside the Chao Phraya basin were shown in Figure 8.2. Distributions of this freshwater homalopsid snake from the previous literatures were also provided. Nevertheless, further researches on the distribution of this species should be continued with more efforts, time and advance instruments, to fulfil their information.

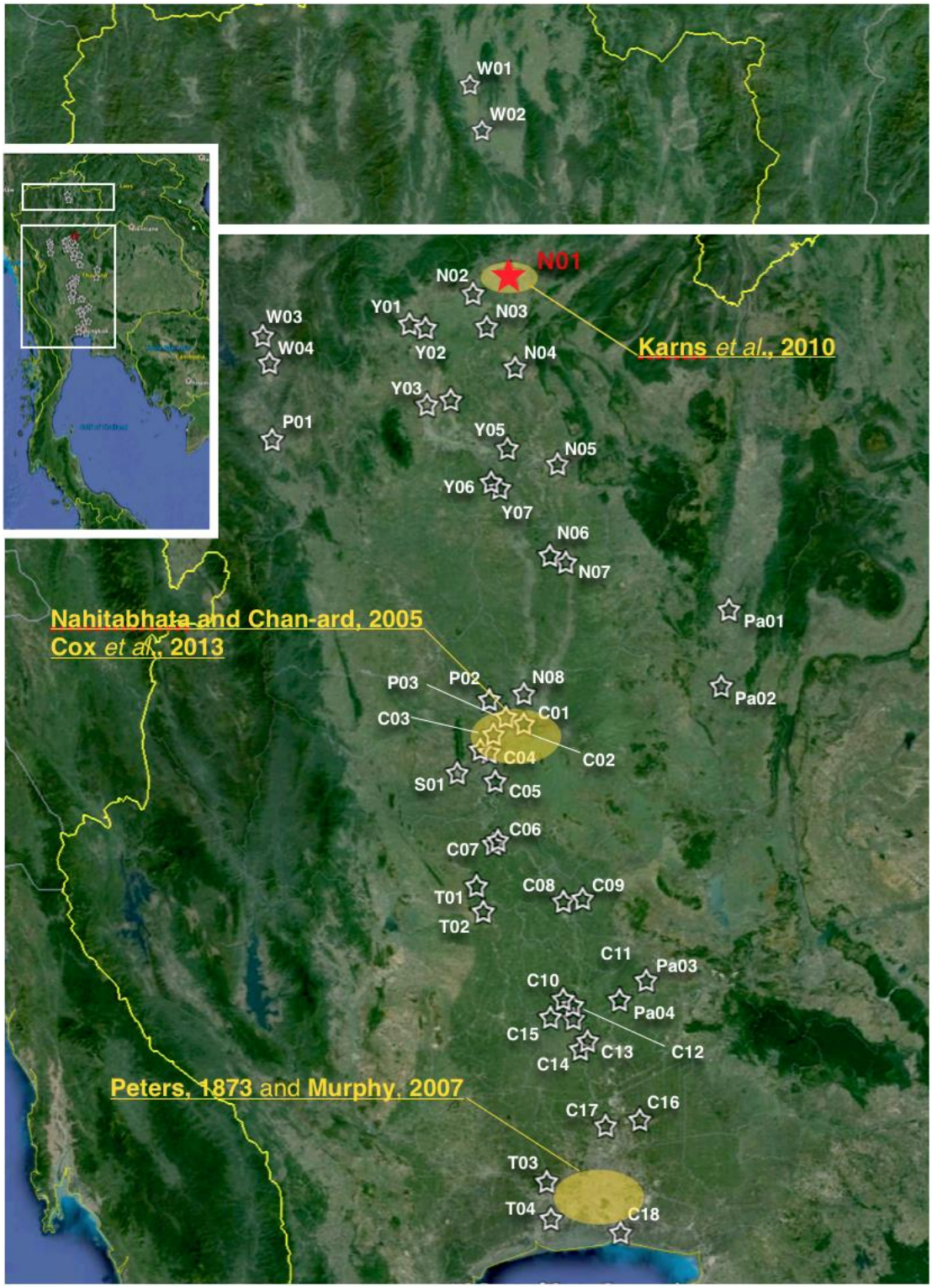


**Figure 8.2:** Map of observed wetland inside the Chao Phraya - Ta Chin basin for the Investigation on distribution of the Jagor's water snake, *Enhydris jagorii*; red star for the wetland with the existence and white star for wetland without the existence of this freshwater homalopsid snake species. Yellow circles referred to the distribution from literature reviews.

8.3.2 The status of the Jagor's water snake, *Enhydris jagorii*

For the present status of IUCN threatened species, the IUCN council adopted the IUCN red list categories and criteria version 3.1: IUCN (2001) as the latest version. In consequence, 4,256 species of reptiles were classified, of which 39 homalopsid species were classified into 4 categories; 16 species were listed into Data Deficient (DD), 20 species were listed into Least Concern (LC), one species was listed into Vulnerable (VU) and other 2 species was listed into Endangered (EN) (Table 8.3). Last two species were classified into criteria of Endangered (EN) due to their geographic ranges, the dog-faced water snake, *Cerberus microlepis* (Lake Buhi in Philippines) and the Voris water snake, *Enhydris vorisi* (Ayeyarwady River delta in Myanmar) were indicated into Endangered (EN) by the Criteria B1a, b(iii, v) and B2a, b(iii), respectively. Unfortunately, the Jagor's water snake, *Enhydris jagorii* was categorized as Data Deficient species (DD) according to the lacks of their basic information (IUCN Red List of Threatened Species, 2014). However, the status of this species should be changed due to the current information on their distribution. This species is an endemic species restricted to the Chao - Phraya basin, inside the central plain of Thailand, found only at Bung Ka Loh wetland, Uttaradit Province (an area is about 10 $km^2$) and facing the continuing decline on habitat area and locations. These current information on the distribution indicated that this freshwater snake should be put into the Criteria B1a, b(i, ii, iii, iv) and c(i, ii, iii) and B2a, b(i, ii, iii, iv) and c(i, ii, iii) of the Criteria for Critically Endangered (CR) (Appendix IV). Therefore, the Jagor's water snake, *Enhydris jagorii* should be re-classified from Data Deficient (DD) to Critically Endangered (CR) of the IUCN red list of threatened species in this study.

For homalopsid snakes, the awareness on trading is certainly low. The dog-faced water snake, *Cerberus rynchops* was the only one species of snakes in Family

Homalopsidae that is arranged into the CITES Appendices III due to their skin trade in the leather business (Appendices of CITES, 2013). The Jagor's water snake, *Enhydris jagorii* is not arranged into the CITES appendices I, II or III. This might be the lack on the evidence in trading of this freshwater homalopsid snake. However, there is no evidence on trading of this freshwater homalopsid snake occurred in the study area throughout the study period. Recently, trading is not the major threat to this freshwater homalopsid snake.

About the national level, the Office of Natural Resources and Environmental Policy and Planning (ONEP) classified amphibians and reptiles found in Thailand following the IUCN red list categories and criteria version 3.1: IUCN (2001) as a guideline. Three hundred and fifty species of reptiles in Thailand were classified into 11 species as Critically Endangered (CR), 5 species as Endangered (EN), 16 species as Vulnerable (VU), 48 species as Near Threatened (NT), 183 species as Least Concerned (LC), and 82 species as Data Deficient (DD) (Nabhitabhata and Chan-ard, 2005). For homalopsid snakes, ONEP classified 5 species into criteria of Least Concerned (LC) and other 7 species into criteria of Data Deficient (DD) (Table 8.4). From this classification, the Jagor's water snake, *Enhydris jagorii* was classified into the Data Deficient (DD). Likewise to the IUCN Red List of Threatened Species, the status of the Jagor's water snakes should be changed from Data Deficient (DD) to Critically Endangered (CR). However, the status of other species of homalopsid snake classified by ONEP was still underestimated and incorrect evaluated. Thus, the study on the basic information such as the study on population and distribution should be performed. In addition, the new status of international and national levels provided in this study would bring the correct information that contributed the precise conservation and management programs for this freshwater homalopsid snake in Thailand.

| Species | IUCN Red List Categories and Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | EX | EW | CR | EN | VU | LC | DD | NT |
| *Enhydris jagorii* (study species) | | | | | | | ■ | |
| *Bitia hydroides* | | | | | | ■ | | |
| *Brachyorrhos albus* | | | | | | | ■ | |
| *Brachyorrhos jobiensis* | | | | | | | ■ | |
| *Cantoria annulata* | | | | | | | ■ | |
| *Cerberus australis* | | | | | | ■ | | |
| *Cerberus microlepis* | | | | ■ | | | | |
| *Cerberus rynchops* | | | | | | ■ | | |
| *Enhydris albomaculata* | | | | | | | ■ | |
| *Enhydris alternans* | | | | | | | ■ | |
| *Enhydris bennettii* | | | | | | | ■ | |
| *Enhydris bocourti* | | | | | | ■ | | |
| *Enhydris chanardi* | | | | | | | ■ | |
| *Enhydris chinensis* | | | | | | ■ | | |
| *Enhydris doriae* | | | | | | ■ | | |
| *Enhydris dussumieri* | | | | | | ■ | | |
| *Enhydris enhydris* | | | | | | ■ | | |
| *Enhydris gyii* | | | | | | | ■ | |
| *Enhydris indica* | | | | | | | ■ | |
| *Enhydris innominata* | | | | | | | ■ | |
| *Enhydris longicauda* | | | | | ■ | | | |
| *Enhydris maculosa* | | | | | | | ■ | |
| *Enhydris matannensis* | | | | | | | ■ | |
| *Enhydris pahangensis* | | | | | | | ■ | |
| *Enhydris pakistanica* | | | | | | ■ | | |
| *Enhydris plumbea* | | | | | | ■ | | |
| *Enhydris polylepis* | | | | | | ■ | | |
| *Enhydris punctata* | | | | | | | ■ | |
| *Enhydris sieboldii* | | | | | | ■ | | |
| *Enhydris subtaeniata* | | | | | | ■ | | |
| *Enhydris vorisi* | | | | ■ | | | | |
| *Erpeton tentaculatum* | | | | | | ■ | | |
| *Fordonia leucobalia* | | | | | | ■ | | |
| *Gerarda prevostiana* | | | | | | ■ | | |
| *Heumia ventromaculata* | | | | | | | ■ | |
| *Homalopsis buccata* | | | | | | ■ | | |
| *Homalopsis nigroventralis* | | | | | | ■ | | |
| *Myron richardsonii* | | | | | | ■ | | |

**Table 8.3:** The present status of the Jagor's water snake, *Enhydris jagorii* and other homalopsid snakes listed by IUCN red list of threatened species. Data obtained from (IUCN Red List of Threatened Species, 2014).

| Species | ONEP status | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | EX | EW | CR | EN | VU | LC | DD | NT |
| *Enhydris jagorii* (study species) | | | | | | | ■ | |
| *Bitia hydroides* | | | | | | | ■ | |
| *Cantoria annulata* | | | | | | | ■ | |
| *Cerberus rynchops* | | | | | | ■ | | |
| *Enhydris bocourti* | | | | | | ■ | | |
| *Enhydris enhydris* | | | | | | ■ | | |
| *Enhydris plumbea* | | | | | | ■ | | |
| *Enhydris subtaeniata* | | | | | | ■ | | |
| *Erpeton tentaculatum* | | | | | | ■ | | |
| *Fordonia leucobalia* | | | | | | | ■ | |
| *Gerarda prevostiana* | | | | | | | ■ | |
| *Homalopsis buccata* | | | | | | ■ | | |
| *Homalopsis nigroventralis* | | | | | | | ■ | |

**Table 8.4:** The present status of the Jagor's water snake, *Enhydris jagorii* and other homalopsid snakes found in Thailand classified by the Office of Natural Resources and Environmental Policy and Planning (ONEP) (Nabhitabhata and Chan-ard, 2005).

# Chapter IX

## Conclusion and Recommendation

The Jagor's water snake, *Enhydris jagorii*, one of the most interesting homalopsid species was collected and studied. One hundred and eight specimens of this species were collected at Bung Ka Loh wetland located close to Nan River at Uttaradit Province, Thailand. All specimens were captured by gill nets and funnel traps of local fishermen from October, 2010 to August, 2012. A total of 6 species of snakes were collected in this study, of which 4 species are freshwater snakes in Family Homalopsidae. The most common freshwater snake in this wetland is the rainbow water snake, *Enhydris enhydris* (63.72%) followed by the Jagor's water snake, *Enhydris jagorii* (31.23%), the Cox's masked water snake, *Homalopsis mereljcoxi* (4.42%) and the Bocourt's water snake, *Subcessor bocourti* (0.63%), respectively. Previous studies reported that the rainbow water snake, *Enhydris enhydris* is the dominant species in other wetlands in this region (Karns et al., 2010; Karns et al., 2005; Murphy, 2007a; Pongcharoen et al., 2008a, 2008b; Voris and Karns, 1996). This phenomenon might be caused by the generalist and effective reproduction of this freshwater homalopsid species (Pongcharoen et al., 2008a). Moreover, Bung Ka Loh wetland has the highest diversity of freshwater snake in Family Homalopsidae, the species richness (6 species) and species evenness (0.591) were highest among the nearby wetland. In addition, the common keelback, *Xenochrophis flavipunctatus* and the red tailed pipe snake *Cylindrophis ruffus* were also collected from this wetland.

Sexual dimorphism was found between sexes of the Jagor's water snake, *Enhydris jagorii*. The study on morphological character measurements suggested that females exhibit the significantly larger and heavier in body size and mass than males but males exhibited the significantly longer tail length than females in the same snout-vent length (SVL) ($p < 0.05$). For the scalations study, the ventral scale rows and subcaudal scale rows are significantly different between sexes ($p < 0.05$). Females have more ventral scale rows whereas males have more subcaudal scale rows. These morphological characters also support the sexual dimorphism that females exhibit lager size and mass than males but not in tail length. Sexual dimorphism of snake species with larger size of females were reported by many authors (Bertona and Chiaraviglio, 2003; Cox, 1991; Hendry et al., 2014; King, 2008; Mattison, 1995, 2002, 2007; Shine et al., 1999; Tomovic et al., 2002; Zug et al., 2001). They suggested that the lager in body size had a lots of benefits in the female reproduction. In addition, morphological characters of neonates of the Jagor's water snake, *Enhydris jagorii* were also measured and documented in this study.



Investigations on diets from stomach contents of the Jagor's water snake, *Enhydris jagorii* were also performed in this study. From the results, this freshwater homalopsid snake feed mainly on small fish. Twenty two prey items of fish in 6 families were found in the stomach contents of 20 specimens. Significant difference on diets between males and females was not found. The most common prey items was fish in Family Cyprinidae (32%) followed by fish in Family Anabantidae (18%), Channidae (9%), Osphronemidae (9%), Bagridae (5%) and Nandidae (5%), respectively. Prey items were usually small, the proportion between prey mass and snake mass was 12.24±11.04%. Niche breadth and niche overlap were also calculated. From the results, the Jagor's water snake, *Enhydris jagorii* fed on various type of fish

more than other homalopsid snakes found inside this wetland. However, the highly overlap of prey types from the stomach contents were found between the study species and the rainbow water snake, *Enhydris enhydris* (niche overlap = 0.86). Thus, there could be highly competition between the freshwater homalopsid snakes occurred inside the Bung Ka Loh wetland if there resources are limited. Moreover, the first predation record on the study species was found. Gravid female of the Jagor's water snake was found as a prey items inside the stomach of the red tailed pipe snake, *Cylindrophis ruffus*.

The information on the female reproduction of the Jagor's water snake, *Enhydris jagorii* was forst documented in this study. The average size of gravid female SVL was 50.72±7.07 centimeters with 34 centimeters in SVL was the smallest gravid female found in this study. The 56.43±50.56 grams as the average clutch mass, 11±9 embryos as the average clutch size with the largest clutch of 28 embryos and 0.18±0.14 as the average RCM were recorded. The significant relationships between clutch and morphological characters of gravid females ($p < 0.05$) suggested that females of this freshwater homalopsid snake have a positive size-fecundity relationship. The larger females in body size and body mass reproduce the larger clutch size and clutch mass. According to the number of collected gravid females in the rainy season and significant correlations between the number of collected gravid females and the physical factors, the Jagor's water snake, *Enhydris jagorii* inside the Bung Ka Loh wetland was considered as having the seasonal reproduction. The physical factors at each location that affected to the reproduction of gravid female of homalopsid snakes were documented in the previous studies. Pongcharoen et al. (2008a) reported the different in reproductive cycle of gravid female of the rainbow water snake, *Enhydris enhydris* collected from different localities. Gravid females collected from inside the Khorat basin has a

seasonal reproduction whereas gravid females collected from inside the central plain of Thailand has a continuous reproduction. However, both seasonal and continuous reproduction of other freshwater homalopsid snakes were reported in previous studies (Brooks et al., 2008; Pongcharoen et al., 2008a, 2008b; Voris et al., 2012). In addition, reproduction of the other collected freshwater homalopsid snakes were also documented and the results showed that reproduction of the gravid females of the rainbow water snake, *Enhydris enhydris* collected from this wetland was more effective than the Jagor's water snake, *Enhydris jagorii*.

The distributions of the Jagor's water snake, *Enhydris jagorii* were reported in scattered literatures (Cox et al., 2012; Murphy, 2007a; Nabhitabhata and Chan-ard, 2005; Peters, 1863). They reported that this freshwater homalopsid snake is an endemic species restricted to the Chao - Phraya basin in the central Plain of Thailand but no specific locality was provided. However, Karns et al. (2010) add the new locality into the distribution of this freshwater homalopsid snake. They collected a number of specimens from Bung Ka Loh wetland located closed to Nan River at Uttaradit Province, Thailand. Thus, this wetland was chosen to be the study site in this research. Nevertheless, the investigation on the distribution of this freshwater homalopsid snake was also performed in this study. Forty wetlands located inside and other 9 wetlands located outside the Chao Phraya - Ta Chin basin at the central plain of Thailand, were selected for this investigation. Unfortunately, there is no evidence on the existence of this freshwater homalopsid snake occurred outside the Bung Ka Loh wetland during this study period. Hence, the locality that the Jagor's water snake, *Enhydris jagorii*, can be found at present is only at the Bung Ka Loh wetland.

Data Deficient (DD) is the status of the Jagor's water snake, *Enhydris jagorii* on the IUCN red list of threatened species following the classification of the IUCN red list categories and criteria version 3.1: IUCN (2001), nowadays. Likewise, the Office of Natural Resources and Environmental Policy and Planning (ONEP) also classified this freshwater species into Data Deficient (DD) for the national level. However, the status of this species should be re-classified due to the results in this study. The information on the distribution in this study indicated this freshwater homalopsid snake into the Criteria B1a, b(i, ii, iii, iv) and c(i, ii, iii) and B2a, b(i, ii, iii, iv) and c(i, ii, iii) of Critically Endangered (CR) of the IUCN red list categories and criteria version 3.1: IUCN (2001). Therefore, the new status of the Jagor's water snake*, Enhydris jagorii* should be Critically Endangered (CR) instead of Data Deficient (DD) for both of international and national level. In addition, this freshwater species was not listed into the CITES Appendices I, II or III at the moment. Although, there is no trading evidence on this freshwater homalopsid snake was found during the study period. Thus, trading of this freshwater snakes inside and outside this country are still be unconcerned.

# Conservation

Due to most of wetlands inside the central plain of Thailand become uncontrollable urbanized and converted into agricultural areas, the large number of homalopsid species endemic to specific drainages, coastlines and islands raises particularly concerns for conservation. Nevertheless, they have received very little intention and overlooked. (Murphy, 2007a) suggested that two freshwater homalopsid snakes are in need of immediate protection: the Chan-ard's water snake, *Enhydris chanardi* and the Jagor's water snake, *Enhydris jagorii*. According to the information in this study, the later species is considered as the endemic species found only at Chao Phraya - Ta Chin basin inside the central plain of Thailand. This study informed that Bung Ka Loh wetland, Uttaradit Province, is the only habitat site of this freshwater homalopsid snake. Nowadays, there are a lot of human and animal conflicts occur throughout the wetland such as overfishing, cattle ground, agricultures and pollutions. The main cause of death observed in this wetland is that these freshwater homalopsid snakes have been trapped and drowned by the small mesh-sized gill nets (about 2.5 to 3.5 centimeters). Furthermore, the worst situation in this wetland is the habitat change and destruction caused by the local authorities. The large area of the northern part of this wetland has been transformed to the campus of a local university, local government offices and a power plant (Figure 9.1). This is the greatest threat on the survival of all homalopsid snakes inside this wetland. Moreover, the abandon gill nets and fish traps can become death traps not only for freshwater homalopsid snakes but also for other aquatic fauna and animals living inside the wetland, as well. Because of these threats, the Jagor's water snake, *Enhydris jagorii* is at risk of extinction. Hence, conservation and management on this freshwater homalopsid snake is very urgently needed both on procedure and policy. Fortunately, an area in the southern part of this wetland is still be a good natural habitat which should be urgently protected for

all aquatic lifeforms. For fishery, fishing time period and fishing gears should be controlled to reduce risk of snake death. Gill net with size of mesh smaller than snake body girth (10 centimeters in body girth, approximately) should not be allowed in this wetland. Other fishing gears for trapping small fish should be promoted such as funnel traps which top of these traps should be exposed to the air for snake breathing. Moreover fishery in this wetland should be restrained during rainy season according to female reproduction that females will give birth during this period. Furthermore, captive breeding could be possible for this snake due to their easy feeding and nurture in captivity. However, the knowledge on microhabitats of the Jagor's water snake, *Enhydris jagorii* needs to be studied in more details which are important information for their introduction to nature. Therefore, further researches on this freshwater homalopsid snake should be conducted for more precise and complete information.


**Figure 9.1:** Aerial pictures of habitat change at the northern part of Bung Ka Loh, Uttaradit Province, Thailand during 2010 to 2014.

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# APPENDICES

# Appendix I Recent species of snakes in Family Homalopsidae

Following Murphy and Voris (2014)

Family Homalopsidae

| No. | Species | Common Name | Geographic distribution |
|---|---|---|---|
| **Genus *Brachyorrhos* Kuhl in Schlegel, 1826** | | | |
| 1 | *Brachyorrhos albus* (Linnaeus) | Seram Short-tailed Snake | Indonesian islands of Seram and its satellites |
| 2 | *Brachyorrhos gastrotaenius* (Bleeker) | Buru Short-tailed Snake | Buru, Indonesia |
| 3 | *Brachyorrhos raffrayi* (Sauvage) | Ternate Short-tailed Snake | Ternate, Indonesia |
| 4 | *Brachyorrhos wallacei* Murphy, Mumpuni, de Lang, Gower, and Sanders | Halmahera Short-tailed Snake | Halmahera, Indonesia |
| **Genus *Calamophis* Meyer** | | | |
| 5 | *Calamophis jobiensis* Meyer | Yapen Island Stout-tailed Snake | Yapen Island, Indonesia |
| 6 | *Calamophis katesandersae* Murphy | Andian Stout-tailed Snake | Andia, West Papua, Indonesia |
| 7 | *Calamophis ruuddelangi* Murphy | Kebar Stout-tailed Snake | Kebar Valley, West Papua, Indonesia |
| 8 | *Calamophis sharonbrooksae* Murphy | Arfak Stout-tailed Snake | Mount Arfak, West Papua, Indonesia |
| **Genus *Karnsophis* Murphy and Voris** | | | |
| 9 | *Karnsophis siantaris* Murphy and Voris | Sumatran Short-tailed Snake | Siantar, Sumatera Utara, Sumatra, Indonesia |
| **Genus *Bitia* Gray** | | | |
| 10 | *Bitia hydroides* Gray | Keel-bellied Mud Snake | Coastal waters of southern Myanmar, Thailand, Malaysia, Singapore, and Borneo. Possibly in other areas of the Greater Sundas |
| **Genus *Cantoria* Girard, 1858** | | | |
| 11 | *Cantoria violacea* Girard | Cantor's Water Snake | Andaman Islands, Andaman coasts of Myanmar, Thailand, peninsular Malaysia, possibly Sumatra and Borneo |
| **Genus *Cerberus* Cuvier, 1829** | | | |
| 12 | *Cerberus australis* Gray | Australian Bockadam | Northern coastal Australia and the south coast of New Guinea |
| 13 | *Cerberus dunsoni* Murphy, Voris, and Karns | Palau Bockadam | Palau Islands, Micronesia |
| 14 | *Cerberus microlepis* Boulenger | Lake Buhi Bockadam | Lake Buhi area, Luzon Island, Philippines |
| 15 | *Cerberus rynchops* (Schneider) | South Asian Bockadam | West coast of India to Myanmar and Thailand in vicinity of Phuket Island |
| 16 | *Cerberus schneiderii* (Schlegel) | Southeast Asian Bockadam | Andaman sea coast of Thailand eastward to the Philippines and southward throughout peninsular Malaysia and Indonesia to Halmahera and Seram |
| **Genus *Dieurostus* Berg, 1901** | | | |
| 17 | *Dieurostus dussumierii* (Dume´ril, Bibron, and Dume´ril) | Kerala Mud Snake | Coastal plain of Kerala, India, from Vembanadkole wetlands of Kerala Vellayani Lake to Neyyar River, southern Kerala |
| **Genus *Djokoiskandarus* Murphy** | | | |
| 18 | *Djokoiskandarus annulatus* (de Jong, 1926) | Trans-Fly Mangrove Snake | Southern coast of New Guinea, Trans-Fly region |

| | | | |
|---|---|---|---|
| **Genus *Enhydris* Sonnini and Latreille** | | | |
| 19 | *Enhydris chanardi* Murphy and Voris | Chanard's Mud Snake | Restricted to vicinity of Bangkok, possibly as far west as Chantaburi, Thailand |
| 20 | *Enhydris enhydris* (Schneider) | Rainbow Mud Snake | Widespread from eastern India to Indochina (and possibly southern China), southward to Greater Sunda Islands as far east as Borneo |
| 21 | *Enhydris innominata* (Morice) | Tay Ninh Mud Snake | Lower Mekong drainage of Vietnam and possibly into Cambodia |
| 22 | *Enhydris jagorii* (Peters) | Bangkok Mud Snake<br>Jagor's water snake | DISTRIBUTION: Probably restricted to Thailand's Central Plain. Historical evidence suggests it occurs in the vicinity of Bangkok. Only extant population known is from the northern edge of Thailand's Central Plain. |
| 23 | *Enhydris longicauda* (Bourret) | Long-tailed Mud Snake | Restricted to Tonle' Sap area, Cambodia |
| 24 | *Enhydris subtaeniata* (Bourret) | Mekong Mud Snake | Mekong drainage from Laos southward; outside the Mekong drainage at Bung Boraphet, Thailand |
| **Genus *Erpeton* La´ce`pede** | | | |
| 25 | *Erpeton tentaculatus* La´ce`pede | Tentacled Snake | Southern Thailand, Cambodia, southern Vietnam |
| **Genus *Ferania* Gray** | | | |
| 26 | *Ferania sieboldii* (Gray) | Siebold's Mud Snake | Northwest peninsular India, Bangladesh, and Nepal; endemic to the Jumna, Ganges, and Brahmaputra river drainages. However, Whitaker and Captain (2004) report it from Nepal, Bangladesh, and Myanmar. |
| **Genus *Fordonia* Gray** | | | |
| 27 | *Fordonia leucobalia* (Schlegel) | Crab-eating Snake | Mainland coastal habitats from Bangladesh, Myanmar, Thailand, peninsular Malaysia, and southern Vietnam. Also Singapore, Nicobar Islands, and Greater Sunda Islands eastward to New Guinea and northern Queensland, Australia |
| **Genus *Gerarda* Gray** | | | |
| 28 | *Gerarda prevostiana* (Eydoux and Gervais) | Gerard's Water Snake | Widespread from vicinity of Gulf of Kutch, India, eastward to Sri Lanka, Myanmar, Thailand, Cambodia, peninsular Malaysia, and the Philippines |
| **Genus *Gyiophis* new genus** | | | |
| 29 | *Gyiophis maculosa* (Blanford) | Blanford's Mud Snake | Bajo in Ayeyarwady River Delta, Myanmar |
| 30 | *Gyiophis vorisi* (Murphy) | Voris' Mud Snake | The vicinity of Maubin in the Ayeyarwady River Delta, Myanmar |
| **Genus *Heurnia* de Jong** | | | |
| 31 | *Heurnia ventromaculata* de Jong | Mamberano Mud Snake | Northwestern West Papua, Indonesia |
| **Genus *Homalophis* Peters** | | | |
| 32 | *Homalophis doriae* Peters | Sarawak Mud Snake | Borneo |
| 33 | *Homalophis gyii* (Murphy, Voris, and Auliya) | Kapuas Mud Snake | Kapuas River drainage in Kalimantan, Indonesia |
| **Genus *Homalopsis* Kuhl and Hasselt** | | | |
| 34 | *Homalopsis buccata* (Linnaeus) | Linne's Water Snake | Extreme southern Thailand, peninsular Malaysia, Indonesian Archipelago from Sumatra to Borneo |

| | | | |
|---|---|---|---|
| 35 | *Homalopsis hardwickii* (Gray) | Hardwick's Water Snake | Northeast India or Nepal |
| 36 | *Homalopsis mereljcaxl* Murphy, Voris, Murthy, Traub, and Cumberbatch | Jack's Water Snake | Thailand and the Indochinese Peninsula |
| 37 | *Homalopsis nigroventralis* Deuve | Deuve's Water Snake | Mekong River Valley from Laos and Thailand to at least Cambodia |
| 38 | *Homalopsis semizonata* Blyth | Martaban Water Snake | Irrawaddy Delta, Myanmar; also occurs at Kawkareik on the east side of Gulf of Martaban |
| **Genus *Hypsiscopus* Fitzinger, 1843** | | | |
| 39 | *Hypsiscopus matannensis* (Boulenger) | Matana Mud Snake | Endemic to southeast Sulawesi |
| 40 | *Hypsiscopus plumbea* (Boie) | Boie's Mud Snake | Widely distributed, ranging from the Andaman Islands (India) and central Myanmar eastward across the Indochinese Peninsula and southern China southward into Indonesia. Present on many, if not all, Indonesian islands and extends its distribution eastward to Sulawesi |
| **Genus *Kualatahan* new genus** | | | |
| 41 | *Kualatahan pahangensis* (Tweedie) | Pahang Mud Snake | Kuala Tahan, River Tembeling, Pahang, peninsular Malaysia |
| **Genus *Intonophis* new genus** | | | |
| 42 | *Mintonophis pakistanicus* (Mertens) | Sind River Mud Snake | Indus River Delta of Pakistan |
| **Genus *Miralia* Gray** | | | |
| 43 | *Miralia alternans* (Reuss) | Reuss' Mud Snake | Greater Sunda Islands (Sumatra, Java, Borneo) and smaller islands of Bangka and Beliting |
| **Genus *Myron* Gray** | | | |
| 44 | *Myron karnsi* Murphy | Aru Mangrove Snake | Indonesia Aru, Kobroor, Selrutti |
| 45 | *Myron resetari* Murphy | Broome Mangrove Snake | Broome, Western Australia |
| 46 | *Myron richardsonii* Gray | Richardson's Mangrove Snake | Coastal north Australia from Gulf of Carpentaria to Western Australia and northward to south coast of New Guinea |
| **Genus *Myrrophis* Kumar, George, Sanders, and Murphy** | | | |
| 47 | *Myrrophis bennettii* (Gray) | Bennett's Mud Snake | South coast of China from Hong Kong southward to Hainan |
| 48 | *Myrrophis chinensis* (Gray) | Chinese Mud Snake | Southern China, North Vietnam, Taiwan, Hong Kong, Hainan |
| **Genus *Phytolopsis* Gray** | | | |
| 49 | *Phytolopsis punctata* Gray | Blackwater Mud Snake | Peninsular Malaysia, Sumatra, Borneo |
| **Genus *Pseudoferania* Ogilby** | | | |
| 50 | *Pseudoferania polylepis* (Fischer) | Macleay's Mud Snake | Coastal plain of Queensland, Northern Terri- tory, Papua New Guinea; Groote Island |
| **Genus *Raclitia* Gray** | | | |
| 51 | *Raclitia indica* Gray | Selangor Mud Snake | Selangor, peninsular Malaysia |
| **Genus *Subsessor* new genus** | | | |

| | | | |
|---|---|---|---|
| 52 | *Subsessor bocourti* (Jan) | Bocourt's Mud Snake | Southern Thailand, peninsular Malaysia, Cambodia, Vietnam |
| **Genus *Sumatranus* new genus** | | | |
| 53 | *Sumatranus albomaculatus* Dume'ril, Bibron, and Dume'ril | Sumatran Mud Snake | Sumatra satellite islands of Nias, Pulo, Simeulue[**], Sibigo, and Sinabang |

# Appendix II Homalopsid snake and their distribution in Thailand

Following Cox et al. (1998), Cox et al. (2012), Murphy (2007a), Murphy (2007a), Murphy and Voris (2014) and Nabhitabhata and Chan-ard (2005)

Family Homalopsidae

| No. | Species | Common Name | Thai Name | Distribution in Thailand |
|---|---|---|---|---|
| **Genus *Bitia* Gray** | | | | |
| 1 | *Bitia hydroides* Gray | Keel-bellied Mud Snake | งูเขี้ยว งูปากกว้างท้องสัน | Bangkok, Phuket, Ranong |
| **Genus *Cantoria* Girard, 1858** | | | | |
| 2 | *Cantoria violacea* Girard | Cantor's Water Snake | งูปลาหลังม่วง | Phuket |
| **Genus *Cerberus* Cuvier, 1829** | | | | |
| 3 | *Cerberus rynchaps* (Schneider) | South Asian Bockadam | งูปากกว้างน้ำเค็ม | Bangkok, Chon Buri, Chumphon, Nakhon Si Thammarat, Narathiwat, Pattani, Phang-nga, Phetchaburi, Phuket, Ranong, Rayong, Samut Prakan, Satun, Songkhla, Surat Thani, Trang, Trat. |
| 4 | *Cerberus schneideri* (Schlegel) | Southeast Asian Bockadam | – | Phuket, Satun |
| **Genus *Enhydris* Sonnini and Latreille** | | | | |
| 5 | *Enhydris chanardi* Murphy and Voris | Chanard's Mud Snake | งูสายรุ้งจันอาจ | Bangkok, Chanthaburi |
| 6 | *Enhydris enhydris* (Schneider) | Rainbow Mud Snake | งูสายรุ้งธรรมดา | Bangkok, Chaiyaphum, Chiang Mai, Chon Buri, Kalasin, Khon Kaen, Lop Buri, Maha Sarakham, Nakhon Phanom, Nakhon Ratchasima, Nakhon Sawan, Nakhon Si Thammarat, Narathiwat, Phatthalung, Pattani, Pathum Thani, Phetchaburi, Prachin Buri, Prachuap Khiri Khan, Rayong, Sa Kaeo, Samut Prakan, Saraburi, Satun, Songkhla, Trang, Uthai Thani, Uttaradit. |
| 7 | *Enhydris jagorii* (Peters) | Bangkok Mud Snake<br>Jagor's water snake | งูสายรุ้งดำ | Bangkok, Nakhon Sawan, Uttaradit. |
| 8 | *Enhydris subtaeniata* (Bourret) | Mekong Mud Snake | งูสายรุ้งลาย งูสายรุ้งลายเส้น | Khon Kaen, Nakhon Ratchasima, Nakhon Sawan, Prachin Buri, Songkhla, Udon Thani. |
| **Genus *Erpeton* La'ce'pede** | | | | |
| 9 | *Erpeton tentaculatus* La'ce'pede | Tentacled Snake | งูกระด้าง | Bangkok, Nakhon Pathom, Nakhon Si Thammarat, Pathum Thani, Phatthalung, Phetchaburi, Prachin Buri, Prachuap Khiri Khan, Songkhla. |
| **Genus *Fordonia* Gray** | | | | |
| 10 | *Fordonia leucobalia* (Schlegel) | Crab-eating Snake | งูปลาหลังเทา | Phuket, Ranong, Satun. |
| **Genus *Gerarda* Gray** | | | | |
| 11 | *Gerarda prevostiana* (Eydoux and Gervais) | Gerard's Water Snake | งูปลาตาแมว งูปากกว้างตาเล็ก | Chon Buri. |
| **Genus *Homalopsis* Kuhl and Hasselt** | | | | |
| 12 | *Homalopsis buccata* (Linnaeus) | Linne's Water Snake | งูหัวกระโหลก งูเหลือมอ้อย | Pattani, Trang. |
| 13 | *Homalopsis hardwickii* (Gray) | Hardwick's Water Snake | | Northeast India or Nepal |
| 14 | *Homalopsis mereljcaxi* Murphy, Voris, Murthy, Traub, and Cumberbatch | Jack's Water Snake | งูหัวกระโหลกไทย งูเหลือมอ้อยไทย งูเหลือมอ้อยแจ็กคอกซ์ | Bangkok, Chachoengsao, Chaiyaphum, Chon Buri, Khon Kaen, Nakhon Ratchasima, Nakhon Si Thammarat, Narathiwat, Pathum Thani, Phatthalung, Phang-nga, Phetchabun, Phetchaburi, Phuket, Prachin Buri, Ranong, Ratchaburi, Sakon Nakhon, Samut Prakan, Songkhla, Surat Thani, Trang, Ubon Ratchathani, Uttaradit. |
| 15 | *Homalopsis nigroventralis* Deuve | Deuve's Water Snake | งูหัวกระโหลกท้องดำ งูเหลือมอ้อยท้องดำ | Sakon Nakhon. |
| 16 | *Homalopsis semizonata* Blyth | Martaban Water Snake | | Irrawaddy Delta, Myanmar; also occurs at Kawkareik on the east side of Gulf of Martaban |
| **Genus *Hypsiscopus* Fitzinger, 1843** | | | | |
| 17 | *Hypsiscopus plumbea* (Boie) | Boie's Mud Snake | งูปลิง | Bangkok, Chachoengsao, Chanthaburi, Chiang Mai, Chiang Rai, Chon Buri, Kanchanaburi, Khon Kaen, Lampang, Loei, Mae Hong Son, Nakhon Ratchasima, Nakhon Sawan, Nakhon Si Thammarat, Narathiwat, Nong Khai, Pattani, Phatthalung, Phetchaburi, Phrae, Prachin Buri, Prachuap Khiri Khan, Ranong, Sa Kaeo, Sakon Nakhon, Saraburi, Songkhla, Surat Thani, Tak, Trang, Ubon Ratchathani, Udon Thani, Uthai Thani. |
| **Genus *Subsessor* new genus** | | | | |
| 18 | *Subsessor bocourti* (Jan) | Bocourt's Mud Snake | งูไซ | Bangkok, Nakhon Ratchasima, Nakhon Sawan, Nakhon Si Thammarat, Narathiwat, Pattani, Phatthalung, Phetchaburi, Prachin Buri, Surat, Thani, Trang, Uttaradit |

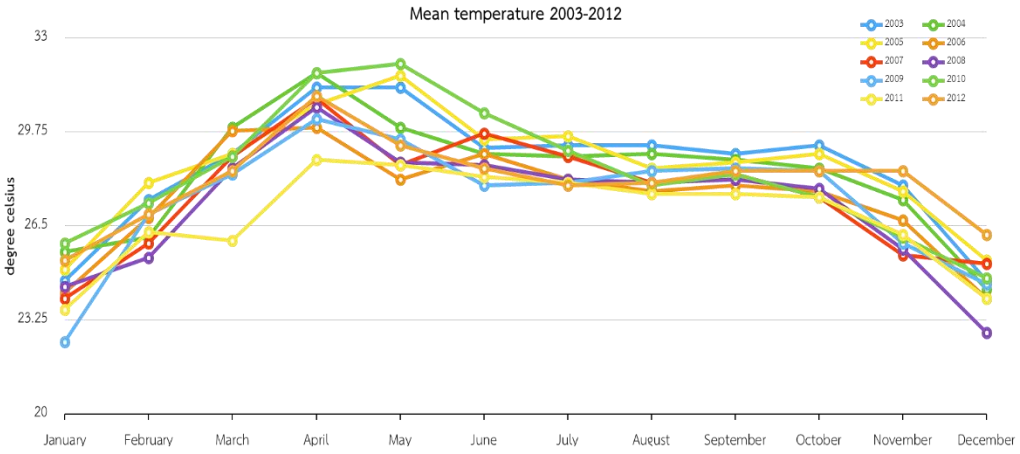
# Appendix III Physical Factors at the Bung Ka Loh, Uttaradit Province, Thailand

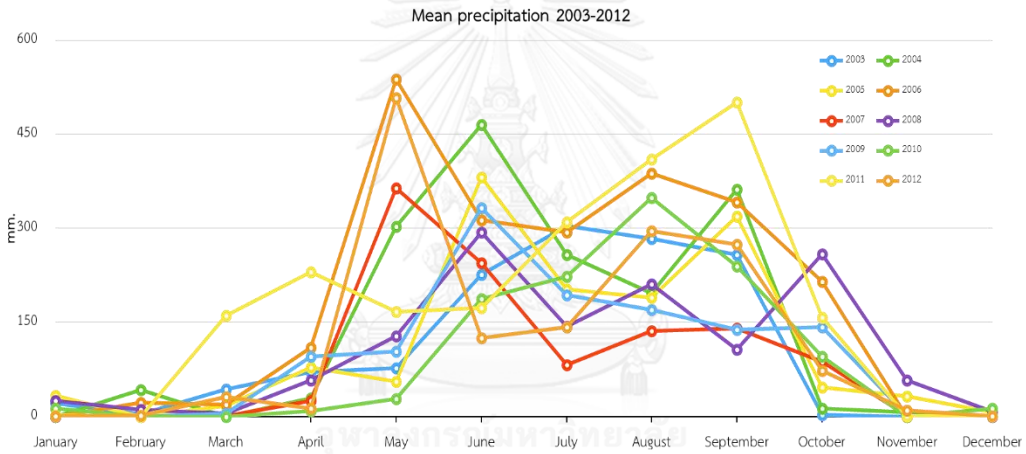
Data collected from the Uttaradit Weather Station located at downtown of Uttaradit Province

| Year | Month | Averaged | | | | | |
|---|---|---|---|---|---|---|---|
| | | Precipitation (mm.) | Rainy day (days) | Relative Humidity (%) | Evaporation (inch/day) | Temperature (℃) | Air Pressure (hectopascal) |
| 2003 | 1 | 20.9 | 4 | 73 | 3.4 | 24.6 | 1014.54 |
| | 2 | 3.2 | 1 | 66 | 4.2 | 27.4 | 1011.88 |
| | 3 | 43.3 | 7 | 67 | 4.8 | 29 | 1010.45 |
| | 4 | 71.6 | 4 | 66 | 6 | 31.3 | 0.00 |
| | 5 | 76.9 | 11 | 68 | 5.9 | 31.3 | 0.00 |
| | 6 | 226.7 | 19 | 80 | 4.1 | 29.2 | 1005.36 |
| | 7 | 303.9 | 21 | 80 | 4 | 29.3 | 1006.08 |
| | 8 | 283.1 | 15 | 81 | 4 | 29.3 | 1005.08 |
| | 9 | 257.7 | 24 | 84 | 3.7 | 29 | 1006.97 |
| | 10 | 2.5 | 3 | 74 | 4.4 | 29.3 | 1010.69 |
| | 11 | 0 | 0 | 70 | 4.2 | 27.9 | 1011.88 |
| | 12 | 0 | 0 | 64 | 3.9 | 24.6 | 1014.89 |
| 2004 | 1 | 0 | 0 | 66 | 3.5 | 25.6 | 1012.58 |
| | 2 | 42.1 | 1 | 65 | 4.1 | 26.1 | 1011.48 |
| | 3 | 0.1 | 1 | 59 | 5.1 | 29.9 | 1008.57 |
| | 4 | 28.8 | 6 | 59 | 6.2 | 31.8 | 1007.39 |
| | 5 | 302.8 | 16 | 76 | 5 | 29.9 | 1006.38 |
| | 6 | 465.1 | 18 | 80 | 4.2 | 29 | 1005.91 |
| | 7 | 258.1 | 21 | 80 | 4.1 | 28.9 | 1005.97 |
| | 8 | 196.8 | 19 | 82 | 3.6 | 29 | 1005.23 |
| | 9 | 362.6 | 21 | 82 | 3.9 | 28.8 | 1008.91 |
| | 10 | 12.9 | 4 | 75 | 4 | 28.5 | 1012.51 |
| | 11 | 6.9 | 4 | 70 | 4.2 | 27.4 | 1013.13 |
| | 12 | 0 | 0 | 64 | 3.7 | 24.3 | 1013.88 |
| 2005 | 1 | 33.1 | 3 | 70 | 3.1 | 25 | 1012.39 |
| | 2 | 0 | 0 | 67 | 4 | 28 | 1010.50 |
| | 3 | 16.9 | 3 | 62 | 4.9 | 29 | 1010.76 |
| | 4 | 78.2 | 6 | 68 | 5.4 | 30.7 | 1008.97 |
| | 5 | 56.1 | 5 | 67 | 5.4 | 31.7 | 1005.26 |
| | 6 | 381.5 | 21 | 82 | 4.2 | 29.5 | 1003.68 |
| | 7 | 203.2 | 17 | 78 | 4.2 | 29.6 | 1005.40 |
| | 8 | 189.6 | 21 | 83 | 3.2 | 28.5 | 1005.37 |
| | 9 | 318.9 | 23 | 84 | 3.7 | 28.7 | 1007.05 |
| | 10 | 46.9 | 7 | 76 | 4.3 | 29 | 1010.76 |
| | 11 | 32.7 | 5 | 76 | 3.7 | 27.7 | 1011.49 |
| | 12 | 6.9 | 2 | 68 | 3.9 | 25.3 | 1013.28 |
| 2006 | 1 | 0 | 0 | 65 | 4 | 24.2 | 1011.73 |
| | 2 | 22.1 | 5 | 65 | 4.3 | 26.8 | 1011.46 |
| | 3 | 19.3 | 3 | 62 | 5.2 | 29.8 | 1008.13 |
| | 4 | 109.4 | 10 | 67 | 5.9 | 29.9 | 1007.30 |
| | 5 | 538.2 | 17 | 77 | 5 | 28.1 | 1007.71 |
| | 6 | 313.3 | 19 | 77 | 5.1 | 29 | 1005.95 |
| | 7 | 294.1 | 22 | 81 | 3.7 | 28.1 | 1004.71 |
| | 8 | 387.7 | 21 | 83 | 4.1 | 27.7 | 1004.87 |
| | 9 | 341.4 | 18 | 82 | 4.1 | 27.9 | 1007.97 |
| | 10 | 215.5 | 9 | 79 | 4.2 | 27.7 | 1011.08 |
| | 11 | 0 | 0 | 72 | 4 | 26.7 | 1011.63 |
| | 12 | 0 | 0 | 68 | 3.9 | 24 | 1014.20 |

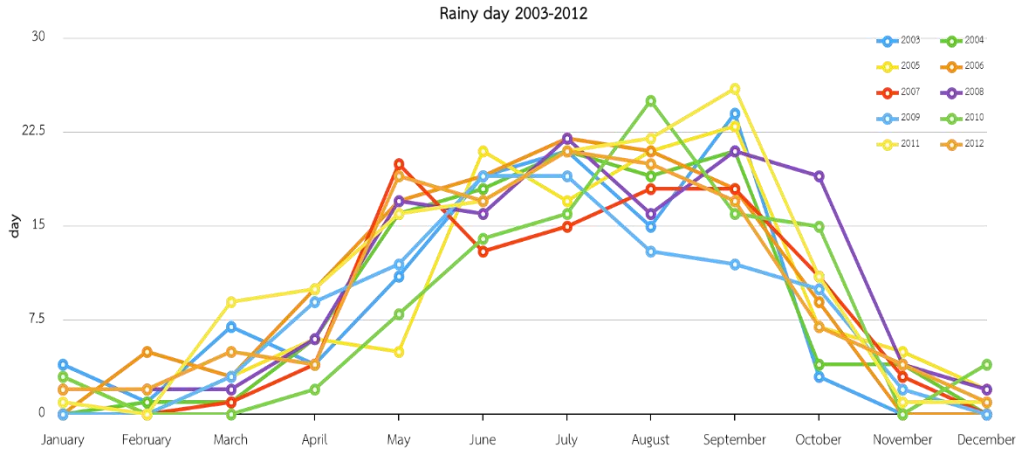
| Year | Month | Averaged | | | | | |
|---|---|---|---|---|---|---|---|
| | | Precipitation (mm.) | Rainy day (days) | Relative Humidity (%) | Evaporation (inch/day) | Temperature (℃) | Air Pressure (hectopascal) |
| 2007 | 1 | 0 | 0 | 65 | 3.8 | 24 | 1014.45 |
| | 2 | 0 | 0 | 61 | 4.1 | 25.9 | 1011.60 |
| | 3 | 1 | 1 | 62 | 4.8 | 28.9 | 1008.52 |
| | 4 | 25 | 4 | 61 | 6 | 30.9 | 1008.94 |
| | 5 | 363.9 | 20 | 78 | 4.5 | 28.6 | 1007.23 |
| | 6 | 244.8 | 13 | 76 | 4.9 | 29.7 | 1005.35 |
| | 7 | 82.3 | 15 | 76 | 3.9 | 28.9 | 1005.94 |
| | 8 | 136.6 | 18 | 81 | 3.1 | 28 | 1005.26 |
| | 9 | 140.7 | 18 | 80 | 3.8 | 28.3 | 1006.79 |
| | 10 | 87.7 | 11 | 77 | 3.7 | 27.5 | 1009.80 |
| | 11 | 1.8 | 3 | 69 | 4 | 25.5 | 1012.74 |
| | 12 | 0 | 0 | 67 | 3.7 | 25.2 | 1012.02 |
| 2008 | 1 | 25 | 2 | 66 | 3.7 | 24.4 | 1012.25 |
| | 2 | 11 | 2 | 66 | 3.8 | 25.4 | 1012.02 |
| | 3 | 4.6 | 2 | 62 | 4.9 | 28.5 | 1009.14 |
| | 4 | 57.8 | 6 | 65 | 5.6 | 30.6 | 1007.41 |
| | 5 | 128.6 | 17 | 74 | 4.6 | 28.7 | 1005.39 |
| | 6 | 293.6 | 16 | 76 | 4.6 | 28.6 | 1005.84 |
| | 7 | 143.7 | 22 | 78 | 3.9 | 28.1 | 1005.72 |
| | 8 | 210.7 | 16 | 79 | 3.6 | 28 | 1006.13 |
| | 9 | 106.5 | 21 | 80 | 3.8 | 28.1 | 1006.99 |
| | 10 | 258.9 | 19 | 78 | 4.1 | 27.8 | 1010.08 |
| | 11 | 57.4 | 4 | 71 | 4.2 | 25.7 | 1012.53 |
| | 12 | 7.9 | 2 | 68 | 3.3 | 22.8 | 1013.95 |
| 2009 | 1 | 0 | 0 | 64 | 3.8 | 22.5 | 1014.78 |
| | 2 | 0 | 0 | 65 | 4 | 26.9 | 1009.38 |
| | 3 | 5 | 3 | 64 | 4.6 | 28.3 | 1009.17 |
| | 4 | 95.6 | 9 | 65 | 5.6 | 30.2 | 1007.17 |
| | 5 | 103.3 | 12 | 73 | 5 | 29.5 | 1006.23 |
| | 6 | 332.7 | 19 | 80 | 4.1 | 27.9 | 1005.07 |
| | 7 | 193.7 | 19 | 79 | 3.7 | 28 | 1005.34 |
| | 8 | 169.9 | 13 | 79 | 4.1 | 28.4 | 1006.01 |
| | 9 | 138.1 | 12 | 79 | 4.2 | 28.5 | 1006.77 |
| | 10 | 143 | 10 | 79 | 4.2 | 28.4 | 1009.23 |
| | 11 | 2 | 2 | 70 | 4.1 | 25.9 | 1012.31 |
| | 12 | 0 | 0 | 68 | 3.5 | 24.5 | 1013.02 |
| 2010 | 1 | 12.5 | 3 | 70 | 3.2 | 25.9 | 1013.19 |
| | 2 | 0 | 0 | 65 | 4.1 | 27.3 | 1010.53 |
| | 3 | 0 | 0 | 59 | 4.6 | 28.9 | 1010.02 |
| | 4 | 8.7 | 2 | 58 | 5.8 | 31.8 | 1007.88 |
| | 5 | 27.8 | 8 | 62 | 6.3 | 32.1 | 1005.45 |
| | 6 | 187.5 | 14 | 70 | 5.4 | 30.4 | 1005.92 |
| | 7 | 222.9 | 16 | 76 | 4.3 | 29.1 | 1006.31 |
| | 8 | 348.8 | 25 | 82 | 3.3 | 27.9 | 1006.52 |
| | 9 | 239.6 | 16 | 80 | 4.1 | 28.3 | 1007.80 |
| | 10 | 95.8 | 15 | 79 | 3.4 | 27.5 | 1008.82 |
| | 11 | 0 | 0 | 69 | 3.9 | 26.1 | 1011.78 |
| | 12 | 13.1 | 4 | 73 | 3.2 | 24.7 | 1010.46 |
| | | | | | | | |

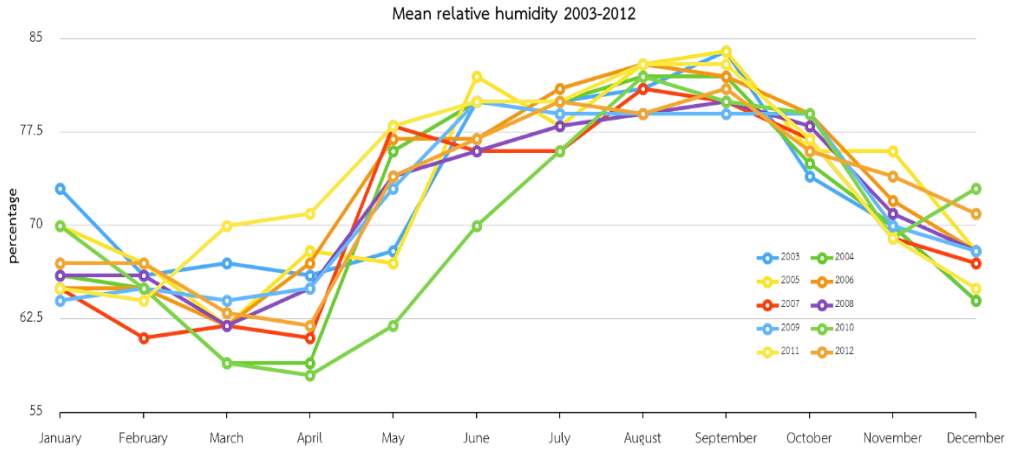
| Year | Month | Averaged | | | | | |
|---|---|---|---|---|---|---|---|
| | | Precipitation (mm.) | Rainy day (days) | Relative Humidity (%) | Evaporation (inch/day) | Temperature (℃) | Air Pressure (hectopascal) |
| 2011 | 1 | 2 | 1 | 65 | 3.6 | 23.6 | 1012.46 |
| | 2 | 0 | 0 | 64 | 4 | 26.3 | 1009.93 |
| | 3 | 160.7 | 9 | 70 | 4.1 | 26 | 1011.18 |
| | 4 | 230.1 | 10 | 71 | 4.8 | 28.8 | 1009.07 |
| | 5 | 166.8 | 16 | 78 | 4.3 | 28.6 | 1006.86 |
| | 6 | 173 | 17 | 80 | 3.6 | 28.2 | 1004.98 |
| | 7 | 310 | 21 | 80 | 3.9 | 28 | 1005.03 |
| | 8 | 410.1 | 22 | 83 | 3.5 | 27.6 | 1006.18 |
| | 9 | 501 | 26 | 83 | 3.3 | 27.6 | 1006.27 |
| | 10 | 158.1 | 11 | 77 | 3.8 | 27.5 | 1009.93 |
| | 11 | 0.3 | 1 | 69 | 4.1 | 26.2 | 1011.53 |
| | 12 | 0.7 | 1 | 65 | 3.6 | 24 | 1013.66 |
| 2012 | 1 | 1.1 | 2 | 67 | 3.5 | 25.3 | 1011.54 |
| | 2 | 1.3 | 2 | 67 | 3.7 | 26.9 | 1009.13 |
| | 3 | 31.2 | 5 | 63 | 4.4 | 28.4 | 1008.49 |
| | 4 | 12.8 | 4 | 62 | 5.9 | 31 | 1007.38 |
| | 5 | 507.8 | 19 | 74 | 5.3 | 29.3 | 1004.80 |
| | 6 | 125.2 | 17 | 77 | 4 | 28.5 | 1004.28 |
| | 7 | 142.2 | 21 | 80 | 3.4 | 27.9 | 1005.05 |
| | 8 | 296 | 20 | 79 | 3.9 | 28 | 1005.68 |
| | 9 | 274 | 17 | 81 | 4 | 28.4 | 1007.75 |
| | 10 | 73.3 | 7 | 76 | 4.3 | 28.4 | 1010.21 |
| | 11 | 10 | 4 | 74 | 3.8 | 28.4 | 1010.39 |
| | 12 | 0.4 | 1 | 71 | 3.5 | 26.2 | 1011.33 |

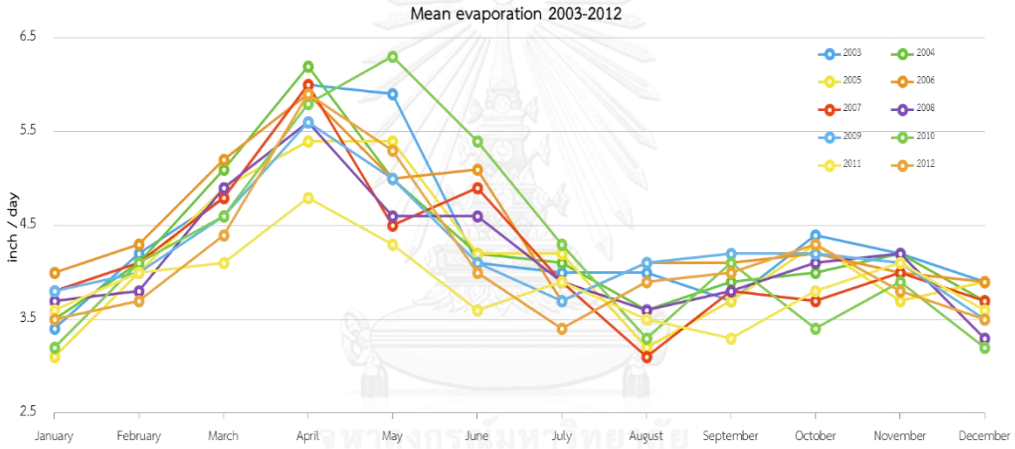


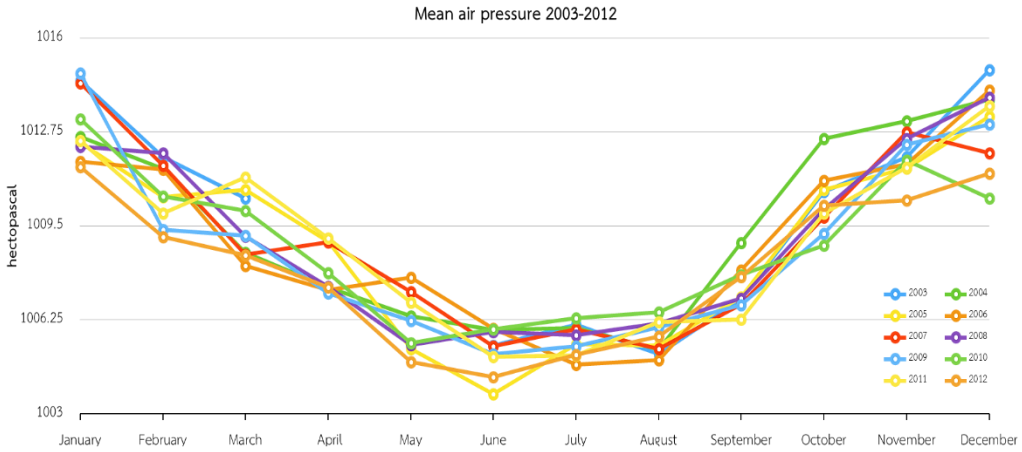






Appendix IV The criteria for Critically Endangered, Endangered and Vulnerable

## V. THE CRITERIA FOR CRITICALLY ENDANGERED, ENDANGERED AND VULNERABLE

### CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥90% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
   (a) direct observation
   (b) an index of abundance appropriate to the taxon
   (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
   (d) actual or potential levels of exploitation
   (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of ≥80% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of ≥80%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

4. An observed, estimated, inferred, projected or suspected population size reduction of ≥80% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 100 km², and estimates indicating at least two of a–c:

   a. Severely fragmented or known to exist at only a single location.

   b. Continuing decline, observed, inferred or projected, in any of the following:
      (i) extent of occurrence
      (ii) area of occupancy
      (iii) area, extent and/or quality of habitat
      (iv) number of locations or subpopulations
      (v) number of mature individuals.

   c. Extreme fluctuations in any of the following:
      (i) extent of occurrence
      (ii) area of occupancy
      (iii) number of locations or subpopulations
      (iv) number of mature individuals.

2. Area of occupancy estimated to be less than 10 km², and estimates indicating at least two of a–c:

   a. Severely fragmented or known to exist at only a single location.

   b. Continuing decline, observed, inferred or projected, in any of the following:
      (i) extent of occurrence
      (ii) area of occupancy
      (iii) area, extent and/or quality of habitat
      (iv) number of locations or subpopulations
      (v) number of mature individuals.

   c. Extreme fluctuations in any of the following:
      (i) extent of occurrence
      (ii) area of occupancy
      (iii) number of locations or subpopulations
      (iv) number of mature individuals.

C. Population size estimated to number fewer than 250 mature individuals and either:

1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer, (up to a maximum of 100 years in the future) OR

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a–b):

   a. Population structure in the form of one of the following:
      (i) no subpopulation estimated to contain more than 50 mature individuals, OR
      (ii) at least 90% of mature individuals in one subpopulation.

   b. Extreme fluctuations in number of mature individuals.

D. Population size estimated to number fewer than 50 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years).

# VITA

Chattraphas Pongcharoen, male, was born on April 26, 1983 in Thailand. He received his bachelor degree in Forestry from the Department of Forest Biology, Faculty of Forestry, Kasetsart University in 2005. His interest in amphibians and reptiles was happened during his class of herpetology at Department of Zoology at Faculty of Science, Kasetsart University. He decided to start his master degree by an advice from his beloved and respected teacher. Then, he finished his master degree in the topic of "life history patterns of homalopsid snakes inside and outside the Khorat basin, Thailand" from Department of Biology, Faculty of Science, Chulalongkorn University in 2008.

During a field study of freshwater snake community program by John C. Murphy and Daryl R. Karns in 2007, the re-discovery of Jagor's water snake at Bung Ka Loh, Uttardit province, Thailand is the starting point of his study in Ph.D. program. Therefore, he furthered his education in the term of this freshwater homalopsid snake in Biological Science Program, Faculty of Science, Chulalongkorn University in 2010. His research was supported by the 90th Anniversary of Chulalongkorn University Fund (Ratchadaphiseksomphot Endowment Fund) (16/2011) and the Center of Excellence in Biodiversity under the Research Program on Conservation and Utilization of Biodiversity (CEB_D_27_2011).