

พลวัตประชากรและการบินออกจากที่เกาะนอนของค้างคาวปีกถุงเครา
ด้า *Taphozous melanopogon* Temminck, 1841 ที่หมู่เกาะแสมสาร จังหวัดชลบุรี



บทคัดย่อและแฟ้มข้อมูลฉบับเต็มของวิทยานิพนธ์ตั้งแต่ปีการศึกษา 2554 ที่ให้บริการในคลังปัญญาจุฬาฯ (CUIR)
เป็นแฟ้มข้อมูลของนิสิตเจ้าของวิทยานิพนธ์ ที่ส่งผ่านทางบัณฑิตวิทยาลัย

The abstract and full text of theses from the academic year 2011 in Chulalongkorn University Intellectual Repository (CUIR)
are the thesis authors' files submitted through the University Graduate School.

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาสัตววิทยา ภาควิชาชีววิทยา

คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2559

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

Population dynamics and emergence of black-
bearded tomb bat *Taphozous melanopogon* Temminck, 1841 at Samaesan Islands, Chon
buri Province



A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Zoology

Department of Biology

Faculty of Science

Chulalongkorn University

Academic Year 2016

Copyright of Chulalongkorn University

Thesis Title	Population dynamics and emergence of black-bearded tomb bat <i>Taphozous melanopogon</i> Temminck, 1841 at Samaesan Islands, Chonburi Province
By	Mr. Kasidit Rison
Field of Study	Zoology
Thesis Advisor	Thongchai Ngamprasertwong, Ph.D.

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

..... Dean of the Faculty of Science
(Associate Professor Polkit Sangvanich, Ph.D.)

THESIS COMMITTEE

..... Chairman
(Assistant Professor Duangkhae Sitthicharoenchai, Ph.D.)

..... Thesis Advisor
(Thongchai Ngamprasertwong, Ph.D.)

..... Examiner
(Assistant Professor Buntika Areekul Butcher, Ph.D.)

..... External Examiner
(Assistant Professor Art-ong Pradatsundarasar, Ph.D.)

กษิตติ วิสสอน : พลวัตประชากรและการบินออกจากที่เกาะนอนของค้างคาวปีกถุงเคราดำ *Taphozous melanopogon* Temminck, 1841 ที่หมู่เกาะแสมสาร จังหวัดชลบุรี (Population dynamics and emergence of black-bearded tomb bat *Taphozous melanopogon* Temminck, 1841 at Samaesan Islands, Chonburi Province) อ.ที่ปริกษาวิทยานิพนธ์หลัก: อ.ดร. ธงชัย งามประเสริฐวงศ์, หน้า.

การศึกษาในครั้งนี้มุ่งเน้นศึกษาการเปลี่ยนแปลงขนาดและโครงสร้างประชากร และการเปลี่ยนแปลงที่ส่งผลถึงเวลาการบินออกจากที่เกาะนอนของค้างคาวปีกถุงเคราดำ 2 โคลินี้ คือ โคลินี้บนเกาะขาม และ โคลินี้บนเกาะนางเกลือ ที่หมู่เกาะแสมสาร จังหวัดชลบุรี ในช่วงเดือน มกราคม พ.ศ. 2558 ถึงเดือน เมษายน พ.ศ. 2559 เป็นระยะเวลา 16 เดือน โดยใช้วิธีการนับจำนวนค้างคาวที่บินออกจากที่เกาะนอนด้วยกล้องวิดีโอแบบอินฟราเรด และการทำเครื่องหมายและจับซ้ำ ผลการศึกษาประชากรพบว่า ค้างคาวปีกถุงเคราดำเข้ามาอาศัยอยู่ในถ้ำที่ศึกษาตลอดทั้งปี โดยมีการเปลี่ยนแปลงขนาดและโครงสร้างของโคโลนี และการเปลี่ยนย้ายรังตลอดเวลา จำนวนค้างคาวในแต่ละโคโลนีและสัดส่วนของค้างคาวเพศผู้เพิ่มขึ้น ในช่วงเดือนพฤศจิกายน พ.ศ. 2558 ถึงเดือนกุมภาพันธ์ พ.ศ. 2559 ซึ่งคาดว่าเป็นฤดูผสมพันธุ์ ช่วงระหว่างเดือนมีนาคม ถึงเดือนตุลาคม พ.ศ. 2558 จำนวนค้างคาวในโคโลนีลดจำนวนลงพร้อมทั้งสัดส่วนเพศผู้ที่ลดลง พบค้างคาววัยตั้งท้องในเดือน เมษายน ถึงเดือนมิถุนายน พ.ศ. 2558 และค้างคาววัยให้นมลูกในเดือนพฤษภาคม ถึง มิถุนายน เริ่มพบค้างคาววัยอ่อนบินออกจากถ้ำตั้งแต่วันที่ มิถุนายน ถึงเดือนสิงหาคม พ.ศ. 2558 และค้างคาววัยอ่อนช่วงปลาย ตั้งแต่เดือนสิงหาคม ถึงเดือนธันวาคม จำนวนค้างคาวในโคโลนีที่มีการเปลี่ยนแปลงตลอดเวลา และการที่ผลจากการติดเครื่องหมาย พบค้างคาวที่ถูกจับซ้ำเพียง 26 ตัว จากการติดเครื่องหมายทั้งหมด 581 ตัว บ่งชี้ว่า ค้างคาวชนิดนี้เป็นการเปลี่ยนย้ายที่เกาะนอนบ่อย บ่งชี้ว่า ค้างคาวชนิดนี้มีรูปแบบการเปลี่ยนย้ายรังและเครือข่ายรังที่เกาะนอนที่ซับซ้อน ผลการศึกษาด้านเวลาการบินออกจากที่เกาะนอน พบว่า เวลาพระอาทิตย์ตกเป็นปัจจัยหลักที่กระตุ้นให้ค้างคาวเริ่มบินออกจากที่เกาะนอน อย่างไรก็ตาม สภาพอากาศก็ส่งต่อการบินออกจากที่เกาะนอน พบว่า ค้างคาวจะชะลอการออกบินในวันที่ลมแรง เนื่องจากสภาพอากาศที่ไม่เหมาะกับการบิน นอกจากนี้ การเปลี่ยนแปลงโครงสร้างประชากรส่งผลต่อเวลาการบินออกของค้างคาวเช่นกัน และพบว่า เวลาที่ค้างคาวทั้งโคโลนีใช้ในการบินออกจะนานขึ้นในเดือนเมษายน ถึงเดือนกรกฎาคม พ.ศ. 2558 ซึ่งช่วงนั้นจะมีค้างคาวในวัยตั้งท้องและให้นมลูก ซึ่งบินออกช้ากว่าค้างคาวตัวอื่น เพื่อลดความเสี่ยงจากการถูกล่าเนื่องจากสรีรภาพในการบินที่ลดลง และค้างคาวในโคโลนีมีแนวโน้มบินออกไวกว่าปกติในเดือนสิงหาคม ถึงเดือนธันวาคม พ.ศ. 2558 เนื่องจากในช่วงนั้นพบค้างคาววัยอ่อนซึ่งมีความต้องการสารอาหารในการเจริญเติบโต และส่งผลให้ค้างคาววัยอ่อนบินออกเร็วกว่าค้างคาววัยอื่น

ภาควิชา ชีววิทยา

ลายมือชื่อนิสิต

สาขาวิชา สัตววิทยา

ลายมือชื่อ อ.ที่ปรึกษาหลัก

ปีการศึกษา 2559

5671911323 : MAJOR ZOOLOGY

KEYWORDS: BLACK-BARDED TOMB BAT / COLONY SIZE VARIATION / REPRODUCTIVE PERIOD / EMERGENCE ACTIVITY

KASIDIT RISON: Population dynamics and emergence of black-bearded tomb bat *Taphozous melanopogon* Temminck, 1841 at Samaesan Islands, Chonburi Province.
ADVISOR: THONGCHAI NGAMPRASERTWONG, Ph.D., pp.

This study aimed to investigate population dynamics and emergence activity of *Taphozous melanopogon* in 2 maternity colonies (the Kham and Changkleua colonies) at Samaesan Islands, Chonburi Province. From January 2015 to April 2016 using emergence counts from infrared video camera and mark and recapture method were conducted at cave entrance, the results showed that *T. melanopogon* resided in studied caves throughout the year and exhibited variation on colony size, composition and movement. Increasing of colony size and proportion of male bats into colonies during November 2015–February 2016 probably indicated mating season. From March to October 2015, colony size and proportion of male bats declined concordant with observing pregnant females during April–June 2015 and lactating female during June–August 2015. Fledgling juveniles were captured from June to August 2015 and late juveniles were captured from August to December 2015. Results from mark and recapture method revealed that only 26 individuals were recaptured from a total of 581 banded adult bats. Colony size fluctuation and low fidelity on roosts suggested the complexity of movement pattern and roost network in this species. Observation on emergence activities indicated that sunset time had greatly impact on bat emergence. In addition, weather conditions, which were wind speed and cloud cover, influenced on bat emergence as well. Late emergence times were observed in windy evening due to unsuitable condition for flight. Late emergence were also observed in cloudy nights, but reason for this was unclear. Change in colony composition also affected to bat emergence. The Results revealed that emergence duration tended to longer during April–July 2015. The reason was that pregnant and lactating females tended to emerge later than other individuals due to less flight maneuverability, which increased predation risks. Early emergence during August–December 2015 were observed because juveniles tended to emerge early to find food which is important for their growth and development compared to adults bats.

Department: Biology

Student's Signature

Field of Study: Zoology

Advisor's Signature

Academic Year: 2016

ACKNOWLEDGEMENTS

I would like to express my gratitude to everyone who contributed to completion of this thesis. First and foremost, I thank my academic advisor, Dr. Thongchai Ngamprasertwong, for accepting me into his research group and giving me the opportunity to conduct this project. Throughout academic years of my Master degree, he always guide me to work as a research scientist. I also thank thesis committee members, Assistant Professor Dr. Duangkhae Sitthicharoenchai, Assistant Professor Dr. Buntika Areekul Butcher and Assistant Professor Dr. Art-ong Pradatsundarasar for their comments and suggestions in my work.

I am grateful to the Plant Genetic Conservation Project Under the Royal Initiative of Her Royal Highness Princess Maha Chakri Sirindhorn and Spacial Warfare Command, Royal Thai Navy for permission to access the research areas and facilitates me during the fieldwork.

Thanks to the members of Thai turtle laboratory at Chulalongkorn University for their supports in the field.

The thesis was funded by the Plant Genetic Conservation Project Under the Royal Initiative of Her Royal Highness Princess Maha Chakri Sirindhorn (RSPG) replied by Chulalongkorn University, 90th Anniversary of Chulalongkorn University Fund (Ratchadaphiseksomphot Endowment Fund) and the Development and Promotion for Science and Technology talents project (DPST).

Finally, I would like to express my deepest appreciation to my family for their love, understanding and supports.

CONTENTS

	Page
THAI ABSTRACT	iv
ENGLISH ABSTRACT	v
ACKNOWLEDGEMENTS.....	vi
CONTENTS.....	vii
LIST OF TABLE.....	1
LIST OF FIGURE.....	2
CHAPTER I INTRODUCTION	1
1.1 Rationale	1
1.2 Objectives	4
CHAPTER II LITERATURE REVIEWS	5
2.1 General biology of bats.....	5
2.2 Population of bats	6
2.3 Black-bearded tomb bats	9
2.4 Emergence of bats.....	13
CHAPTER III MATERIALS AND METHODS	18
3.1 Studied site	18
3.2. Studied period.....	18
3.3 Emergence recording	20
3.4 Bat capture and determination	22
3.5 Astronomical variables, weather and seasonality	28
3.6 Data analyses.....	29
CHAPTER IV RESULTS	33

4.1 Population dynamics of <i>T. melanopogon</i>	33
4.1.1 Change in colony size and composition.....	33
4.1.2 Reproductive period of <i>T. melanopogon</i>	44
4.1.3 Morphological difference among sexes and developmental stages	50
4.2 Emergence activities of <i>T. melanopogon</i>	54
4.2.1 Bat activities at cave entrance in relation to local sunset time and sunrise	54
4.3 Effect of moon phase, weather conditions and reproduction to bat emergence ..	62
4.3.1 Effect of moon phase to bat emergence	62
4.3.2 Effect of climatic conditions to bat emergence	63
4.3.4 Effect of reproductive conditions and developmental stages to bat emergence	67
CHAPTER V DISCUSSION	73
5.1 Population dynamics of <i>T. melanopogon</i>	73
5.1.1 Change in colony size and composition.....	73
5.1.2 Reproduction of <i>T. melanopogon</i>	77
5.2 Emergence activities of <i>T. melanopogon</i>	80
5.2.1 Bat activities at cave entrance in relation to local sunset time and sunrise	80
5.2.2 Effect of moon phase to bat emergence	82
5.2.3 Effect of weather conditions to bat emergence.....	82
5.2.4 Effect of reproductive conditions and developmental stages to bat emergence	84

	Page
CHAPTER VI CONCLUSIONS AND RECOMENDATIONS	86
6.1 Conclusions.....	86
6.2 Recommendations	88
REFERENCES.....	89
APPENDIX	99
VITA	104



LIST OF TABLE

Table 4.1 Estimated colony sizes of adult male and non-reproductive female <i>T. melanopogon</i> at Kham colony during January 2015–April 2016 using Jolly-Seber method.....	35
Table 4.2 Estimated colony sizes of adult male and non-reproductive female <i>T. melanopogon</i> at Changkleua colony during January 2015–April 2016 using Jolly-Seber method, deficient capture data in March 2015 due to the inaccessible studied area.....	36
Table 4.3 Colony sizes from emergence counts of <i>T. melanopogon</i> at Kham and Changkleua colonies during January 2015–April 2016.....	37
Table 4.4 Data of recapture <i>T. melanopogon</i> in the Kham and Changkleua colonies from January 2015 to April 2016.....	40
Table 4.5 Chi-squared analysis for equality of monthly adult sex ratio.	43
Table 4.6 Morphological difference among sexes of developmental stages of <i>T. melanopogon</i>	50
Table 4.7 Pearson's correlation coefficient matrix for relationship between median emergence and six weather variables, <i>p-values</i> were shown in parentheses.	65
Table 4.8 Multiple regression between median emergence and six weather variables, i.e. air temperature, relative humidity, cloud cover, wind speed, precipitation and air pressure.	66
Table 5.1 Variation in colony size of <i>T. melanopogon</i> from other studies.	75

LIST OF FIGURE

Figure 2.1 Photograph of adult <i>T. melanopogon</i> taken at the Changkleua Island in April 25, 2014.	10
Figure 2.2 Map area from South to Southeast Asia, yellow color represented distribution range of <i>T. melanopogon</i> (Csorba et al., 2008).	11
Figure 3.1 Location of the Kham and Changkleua Islands, situated in Samaesan Islands, Chonburi Province, distance between both islands is 2 km.	19
Figure 3.2 Cave entrance of the two resident colonies of <i>T. melanopogon</i> at the Kham Island (left) and Changkleua Island (right).	19
Figure 3.3 Infrared video camera installed at cave entrance at the Changkleua Island.	21
Figure 3.4 Setting up harp trap in front of cave entrance at the Changkleua Island.	22
Figure 3.5 Epiphyseal–diaphyseal fusion of the fourth metacarpal–phalangeal joint of <i>T. melanopogon</i> : unfused cartilage in juveniles (left) and fused cartilage in adults (right), arrow represented zone of epiphyseal–diaphyseal fusion.	25
Figure 3.6 Color pelage of <i>T. melanopogon</i> : dark color of juvenile furs (left) and bright and orange in color of adult furs (right).	25
Figure 3.7 Adult female showing pregnant stage with swelling in abdomen (left) and sign of leaking milk at nipple (right).	26
Figure 3.8 Adult males with testis descended to scrotum (left) and without testis descended to scrotum (right), arrows represented scrotum.	26
Figure 3.9 Beard character in adult males: presence of bread at gulag area at the arrow (left) and absence of bread at gulag area (right).	27
Figure 3.10 Plastic numbered collars (modified from Balasingh et al., 1992) used in the study (left), the tag attached to adult <i>T. melanopogon</i> at its neck.	27

Figure 3.11 Climatic plot between precipitation (continuous line) and monthly ambient temperature (dash line). Duration between intersections of lines at April and November indicated rainy season.	29
Figure 4.1 Change of <i>T. melanopogon</i> colony sizes in the Kham and the Changkleua colonies during studied period from January 2015 to April 2016.	38
Figure 4.2 Sex composition of <i>T. melanopogon</i> in the Kham colony (top) and Changkleua colony (bottom) during January 2015–April 2016. Total numbers of examined adult bats each month were shown above the bars. Data at the Changkleua in March 2015 was not available due to inaccessibility.	42
Figure 4.3 Proportion of female <i>T. melanopogon</i> in different reproductive statuses in the Kham colony (top) and the Changkleua colony (bottom) during January 2015–April 2016. Total numbers of examined adult female bats each month were shown above the bars. Data at the Changkleua in March 2015 was not available due to inaccessibility.	45
Figure 4.4 Change in proportion of adult male of <i>T. melanopogon</i> with beard and testis descended to scrotum from the two colonies during January 2015–April 2016 . Total numbers of examined adult male bats each month were shown on the top.	47
Figure 4.5 Relationship between present of male with scrotal testis (line) and day length (yellow bar) during studied period.....	48
Figure 4.6 Proportion of adults, late juveniles and juveniles of <i>T. melanopogon</i> in the Kham colony (top) and the Changkleua colony (bottom) during January 2015–April 2016. Total numbers of examined bats each month were shown above the bars. Data at the Changkleua in March 2015 was not available due to inaccessibility.	49
Figure 4.7 Mean of three morphological characters of developmental stages (FA = forearm length, 3 META = third metacarpal finger length and BM =body mass). Error bars represented standard error and significant differences were shown in alphabets above bars.	51

Figure 4.8 Monthly average of body mass of female <i>T. melanopogon</i> during January 2015–April 2016, error bars represented standard deviation. Error bars represented standard error and significant differences were shown in alphabets above bars.....	52
Figure 4.9 Monthly average of body mass of female <i>T. melanopogon</i> during January 2015–April 2016, error bars represented standard deviation, significant differences were shown in alphabets above bars. Error bars represented standard error	53
Figure 4.10 Numbers of bats flying out after dusk in the Kham colony and flying in before dawn from 26 August 2015, the data were shown in 15 minutes intervals throughout the night.	55
Figure 4.11 Timings of bat activities (emergence and return) at the cave entrance from 10 entire nights in relation to sunset and sunrise time from January to December 2015, Data was pool from the Kham and Changkleua colonies.	56
Figure 4.12 Onset, median and end of emergence of <i>T. melanopogon</i> in relation to sunset time. Data from the Kham and Changkleua colonies were pooled. Solid lines represented fitting linear regression model.	58
Figure 4.13 Timing of emergence (onset, median and end) of <i>T. melanopogon</i> at the Kham and Changkleua colonies from January 2015 to April 2016. Dash line indicated local sunset time.	59
Figure 4.14 Returning activities (onset and end) of <i>T. melanopogon</i> in relation to sunrise time. Solid line represented linear regression model.	60
Figure 4.15 Average onset of emergence of <i>T. melanopogon</i> from the Kham and Changkleua colonies. Error bars represented standard deviation.	61
Figure 4.16 Average median emergence times of <i>T. melanopogon</i> from the Kham and Changkleua colonies. Error bars represented standard deviation.	61

- Figure 4.17** Average end of emergence *T. melanopogon* from the Kham and Changkleua colonies. Error bars represented standard deviation.62
- Figure 4.18** Average median emergence of *T. melanopogon* full moon, half moon, new moon nights. Error bars represented standard deviation.63
- Figure 4.19** Average monthly duration of emergence of *T. melanopogon* from January 2015 to April 2016, error bars represented standard deviation and significant differences were shown in alphabets above bars.68
- Figure 4.20** Average emergence time of *T. melanopogon* in various female reproductive statuses during April- June. Error bars represented standard deviation and significant differences were shown in alphabets above bars.69
- Figure 4.21** Average onset of emergence of *T. melanopogon* from January 2015 to April 2016, error bars represented standard deviation and significant differences were shown in alphabets above bars.71
- Figure 4.22** Average emergence time of *T. melanopogon* in various development stages during July-December 2015, error bars represented standard deviation and significant differences were shown in alphabets above bars.72

CHAPTER I

INTRODUCTION

1.1 Rationale

Bats are considered to be a slow species with fast-slow continuum of life histories (Barclay and Harder, 2003). Unlike many small mammals, bats have high survival rates (O'Shea et al., 2003; Papadatou et al., 2009), long lifespans (Brunet-Rossinni and Austad, 2004), and low reproductive outputs (Barclay and Harder, 2003). Bats constitute a quarter of all mammal species (over 1,300 species world-wide), with the majority occurring in the tropical regions (Findley, 1993). Bats are declining globally (Mickleburgh et al., 2002) and about 50 percent of microchiropteran species are considered to be imperilled or data deficient (Hutson et al., 2001). Reproduction of bats is known as one of major influence for population dynamics (O'Shea et al., 2011; Pryde et al., 2005), but little is known about typical reproductive timing. This basic demographic data obtained from reports are available mostly for temperate species (O'Shea et al., 2003), while data for tropical bats is still limited. Identifying factors affecting population dynamics as well as reproduction time would provide valuable information about how tropical bat populations respond to environment and help to apply conservation and management strategies (Pryde et al., 2005).

Movement between roosts of bats is also known as determining factor that regulates number of occupied bats in each roost. Although roosts provide bats for

shelter, protection, mating area, raise young, and interact with other individuals, roosts switching is commonly found in bats (Papadatou et al., 2009). In the tropics, distances of roost movement is normally short and may reflect by season. Swarming roosts may occurred during mating season (Kunz and Fenton, 2003). These may change number and composition of bats in colonies.

Black-bearded tomb bat, *Taphozous melanopogon*, is a medium size insectivorous bat that distribute throughout Brunei, Cambodia, China, India, Indonesia, Lao, Malaysia, Myanmar, Philippines, Singapore, Sri Lanka, Thailand, Timor-Leste, Vietnam (IUCN, 2008). This species is commonly founded in various types of habitats, including limestone caves. In each roost, a colony size varies from ten individuals to many hundreds (Brosset, 1962; Sapkal and Khamre, 1983; Molur et al., 2002). Sapkal and Khamre (1983) reported that colony sizes vary throughout the year and might affected by season, however, no further information about population dynamics was found in this species.

Preliminary survey on species diversity of bats at Samaesan Islands indicated that *T. melanopogon* was the dominant species among insectivorous bats, and at least 3 maternity colonies were found in close proximity at Samaesan Islands. Therefore, this area was suitable for study in population dynamics of these colonies.

Few researchs on bat ecology, management, and behavior have been conducted in Thailand. Thailand is one of biological hotspots which contains approximately 150 bat species. This study would leads to understand change in colony size and its interaction with environment factors. Knowledge about animal population is important in order to organize better management strategies.

In addition, change in number and structure throughout times may affect the activity patterns of bats. To date, report on this aspect focus on emergence activity. The evening emergence time are directly regulated by sunset time. Bats emerge every evening using decreasing of light intensity from sun as a cue to regulate fly out time (Erkert, 1982). However, some bats may change their routine by emergence early that may benefits by increasing foraging time and foraging opportunities (Jones and Rydell, 1994; Duvergé et al., 2000; Lee and McCracken, 2001). Against the benefits, there are the costs that risk of predation by avian predators would increased when emergence early (Speakman, 1991). From that trade-off between the risk of predation and foraging opportunities, bats with different nutrient needs would exhibit different time on onset of nighttime activities. With high energy need from raising their infants, lactating female would force to emerge earlier than non-reproductive females. Pregnant females tend to depart lately due to lower flight ability from swelling in abdomen. Juvenile bats that still being fed by from their mothers would emerge later due to less energetic demands.

In addition, other factors constraining the time of emergence are related to the weather variables (Duvergé et al., 2000). Differences in emergence times may be related to prevailing weather conditions (O'Donnell, 2000). Bats should emerge later on evenings with unfavorable weather conditions, for example, raining, windy or cold.

Although all these aspects were reported exclusively on temperate bat species, there are only few reports on tropical bats especially *T. melanopogon*, particularly a detail study of year round. Hence, the main objectives in this study is that monitoring on population size of *T. melanopogon* in complete year round and observation on emergence activity on the trade-off aspect of two maternity colonies at Samaesan Islands.

1.2 Objectives

1. To monitor the change in colony size and structure of *T. melanopogon* at Samaesan Islands (the Kham and Changkleua colonies)
2. To study emergence activity of *T. melanopogon*
3. To investigate the relationship between emergence activities and population structure as well as environmental factors

CHAPTER II

LITERATURE REVIEWS

2.1 General biology of bats

Bats are second richest species after Rodentia in Mammalia and have occupied nocturnal sky since 50 million years ago. Among 1,300 bat species around the world, all bats share the same wing structure. Bats wings have stretching membrane attached among fingers that allow them able to fly. Bats are divided into two major groups; Megachiroptera and Microchiroptera (Nowak, 1991). Megachiropteran bats are larger and less specialized in echolocation, there are only a single one family (Pteropodidae) with approximately 180 species, all feed primarily on plant materials, fruits, nectars or pollens. The remaining 16 families (approximately 1,100 species) are Microchiroptera, most of them are insectivorous, however, many microchiropterans have become specialized on consuming other kinds of diets. Some bats are carnivorous (feeding on rodents, other bats, reptiles, birds, amphibians, and fish) (Nowak, 1991), and one subfamily (three species in the subfamily Desmodontinae) feeds on blood of other vertebrates (Nowak, 1991). Megachiropteran and microchiropteran bats are also difference in many other ways, microchiropterans use highly sophisticated echolocation for orientation and navigation, while, megachiropterans orient primarily by their eyes, although members of the genus, *Rousettus*, can use a simple form of echolocation, however, not identical to echolocation in the microchiropterans (Vaughan et al., 2000).

Bats are found throughout the world in both tropical and temperate habitats. Typical habitats include temperate and tropical forests, deserts, open fields, agricultural areas, and in suburban and urban environments. Many bats forage near freshwater streams, lakes and ponds, preying on insects as they emerge from the water. Bats generally have very specific roosting requirements, which differ among species (Kunz and Fenton, 2003). They may roost in caves, crevices, trees, under logs, and in manmade-dwellings. Bats may also use different types of roosts at different times. For example, a species that hibernates in a cave during the winter may use crevices in tree holes as roosts during warm seasons (Nowak, 1991).

2.2 Population of bats

In this study, a population is defined as a group of individuals of a single species that inhabit in a specific area during a specific period of time. A colony is defined as a discrete group of bats that form a social unit during a specific period that limit to a specific site or caves. In many cases, population size can alters through time or population dynamics. Several studies tried to understand the process of animal population dynamics in animals in nature habitats, addressing limiting and regulatory factors accounted for population size variations (Krebs, 2000). The driving factors come from both biotic and abiotic, which affect the population fluctuations from reproduction, mortality, emigration and immigration (Camus and Lima, 2002).

Bats have distinctive life-history strategies among other mammals in their size. Most small animals have evolved to mature early, with brief gestation and lactation period, produce many small offsprings per litter, and have high mortality. In contrast, bats generally have life histories which are characterized by longevity of the lifespan and multiple reproductive events (Barclay and Harder, 2003). Podlutzky et al., (2005) reported that some individuals of *Myotis brandtii* lived more than 40 years. Timing and frequency of reproduction are major determinants of life-history strategies, which have evolved to maximize lifetime reproductive output (Barclay and Harder, 2003). Bat reproduction is characterized by four basic patterns: continuous reproduction throughout the year (seasonal polyestry); a single reproductive season per year (seasonal monestry); two or more well-defined reproductive season per year (seasonal bimodal polyestry); and no clearly defined reproductive pattern (aseasonal polyestry) (Fleming et al., 1972). Differences in these patterns are linked mainly to difference in diet and duration of food availability (Crichton and Krutzsch, 2000). Food supplies have reported to be essential to bat reproduction because reproduction, particularly lactation, is energetically cost (Loudon and Racey, 1987). Period of optimal food availability lead to determination of reproduction period (Bronson, 1985).

In tropical zone, there is often regarded as stable environments with little difference in physical factors between seasons and rather constant food availability (Ricklefs and Wikelski, 2002). Evidence indicated that reproductive timing of seasonality

in the tropical bats associated with the rainfall pattern. In insectivorous bats, it has been suggested that insect availabilities often follows rainfall patterns and reproductive activities shows remarkable association with the onset of annual precipitation (Rautenbach et al., 1988).

Unlike bats in temperate zone, major mortality of bats in the tropical area do not results from fluctuated and severe weather, however, predations are a key regulatory factor of small mammal populations including bats (Korpimäki and Krebs, 1996). Predator impacts on prey populations either direct or indirect interactions (Lima and Dill, 1990). The direct scenario is that predators influence population dynamics by removing individuals physically, whereas in the second case, the presence of predators induced behavioral responses of the preys by reducing the probability of being killed (Lima and Dill, 1990). Familiar predators of bats are diurnal and nocturnal bird of preys (diurnal: raptors; nocturnal: owls) (Hutson et al., 2001). Moreover, before juveniles become volant, it can be victim to predatory birds, reptiles, mammals, and even large insects (Sapkal and Khamre, 1983).

Migratory and short movements between roosts are commonly found in highly mobile animals, such as bats (Papadatou et al., 2009). Roosts provide bats for shelter, protection, mating area, raise juveniles, and interact with other individuals. Roost of bats may be caves, crevices, trees, under logs, and in manmade-dwellings (Kunz and Fenton, 2003). Among types of roosts, caves are the most stability of what compared to

other roost types. Moreover, bats reside in a cave roost tend to have higher fidelity than other roost types (Lausen and Barclay, 2003). Furthermore, most of tropical bat species appear to be sedentary or non-migration because their habitats tend to exhibit less seasonal fluctuation (Fleming and Eby, 2003), instead of migration, short distance movement can be found. Fleming (1988) reported short movement of roost in *Carollia perspicillata* between lowland in dry season and moister upland forest. O'Shea and Vaughan (1980) reported eight species of insectivorous bats switched the roosts seasonally from coastal forests to plentiful habitats in inland areas.

2.3 Black-bearded tomb bats

A species of microchiropteran bats, black-beard tomb bats (*Taphozous melanopogon*) (Figure 2.1) is classified to the Family Emballonuridae. *T. melanopogon* is a medium size insectivorous bat with forearm length about 63–68 mm. Living in Old world part, this species widespread throughout South and Southeast Asia (Corbet and Hill, 1992; Heaney, et al., 2002; Nowak, 1999) (Figure 2.2). Black-beard tomb bats usually inhabit in a variety types of habitats, from rainforests to urbans. Roosting might be caves, rock crevices or manmade-buildings. In roosts, the bat is very agile while crawling, and is able to cling to sheer roost surfaces. They may reside in well-lit areas that other bats avoid; this enables them to live places where other bats may not. *T. melanopogon* is gregarious and their large colonies have been recorded with up to 4,000 individuals (Nowak, 1991). Sometimes *T. melanopogon* coexists with other bat

species such as *T. perforatus* (Purohit et al., 2012). Males and females usually occupied different areas of roosting.



Figure 2.1 Photograph of adult *T. melanopogon* taken at the Changkleua Island in April 25, 2014.



Figure 2.2 Map area from South to Southeast Asia, yellow color represented distribution range of *T. melanopogon* (Csorba et al., 2008).

For morphological characteristics, length of an adult black-beard tomb bat from head to body ranges from 62 to 100 mm, a tail lengths from 20 to 35 mm, with weight ranges from 10 to 50 grams. At the dorsal, fur is pale brown to reddish. The fur on ventral side is lighter brown to white. Wing membranes are thin and usually white in color at ventral side. Legs and feet are covered with short fur. *T. melanopogon* has a simple muzzle, with no complex nose-leaf. Ears length 18 to 21 mm and have a rounded tragus. Wings with well-developed pouch which characteristic of genus that helps to distinguish them from other Emballonuridae species. Juveniles are typically darker than

adults. Adult males may have a black "beard" of fur at the bottom of their jaw/top of their throat. This make *T. melanopogon* easily to identify, but the beard does not always appear. Some record indicated this beard may reflect seasonal changes and may have a role in mating systems (Altringham, 1998). Unlike other *Taphozous* species, they do not have the glandular sac that characterizes others in this genus. Instead, there has a small pore situated in the sacs that open into the throat. Wing shape is long and narrow, contributing to fast and long flights to forage. *Taphozous melanopogon* able to fly high and fast, catching insects in the middle of air. Their wings are not adapted to agile flight or hovering, however, they do not glean prey off the ground or off of the plants, instead, *T. melanopogon* catch flying insects by "netting" them with their flight membranes and eating them mid-air. The tail of *T. melanopogon* penetrates the interfemoral membrane near the center and is exposed on the dorsal side. The dental formula is same as other members of Emballonuridae that is 2:1:2:3 (incisors: canines: premolars: molars) (Lekagul and Mcneely, 1977; Nowak, 1991).

Previous study in India revealed that *T. melanopogon* is polygynous, male mates with multiple females during the mating season. Mating season of *T. melanopogon* lasts from January to February. Female *T. melanopogon* produce a single juvenile during each mating season. The gestation period lasts for 3 to 4 months, and a single juvenile was born from April to May. This single offspring is nursed by its mother for 8 weeks. After this time, the juvenile was able to feed for itself and then left the mother forever.

There is no record of paternal care by the males. The mother would provide food, shelter, and protection for juvenile. However, information on the age at which the bat reach sexual maturity is unavailable (Lekagul and Mcneely, 1977; Payne et al., 1985) Predation is low because they are active at night. Black-beard tomb bats are quite agile flyer, enable predator avoidance, and are even harder to prey upon because they fly at such relatively high altitudes and speeds (Lekagul and Mcneely, 1977; Nowak, 1991)

2.4 Emergence of bats

Bats are nocturnal, during the day they remain in their roost and emerge at evening twilight to forage for food. The beginning and ending of bat emergence are directly regulated by sunset. Considering as a circadian rhythm, light intensity is a key factor to control timing of activities (Erkert, 1982). The endogenous rhythm synchronized with the external 24-h light and dark cycle of light conditions. However, besides intrinsic biological clock, bat activity can be predicted by other several factors such as weathers (Kunz and Anthony, 1996; Lee and McCracken, 2001), temperature (Kunz and Fenton, 2003), colony size and reproductive status (Korine et al., 1994), predators (Speakman, 1991).

The evening emergence time in bats has been suggested to be a function of food specializations, foraging strategy and ability to avoid predation (Jones and Rydell, 1994). Insectivorous bats feed mainly on small aerial preys which are dipterans tend to emerge earlier than other bats, that may related highly insect availabilities during dusk

time. Gleaner, which is specialized on eating large insects by slow searching prey, would emerge late. Frugivorous and pollen eaters also emerged later (Jones and Rydell, 1994). Furthermore, Fast flying species with a high aspect ratio of wing shape and a high wing loading emerge earlier than slow fliers as they are more likely to better avoid attacks from potential predators that relying on vision such as diurnal birds of prey (Jones and Rydell, 1994). The timing of emergence may also influenced by the roost location and the structure of the surrounding habitat. Bats inhabiting roosts located in a dense canopy may leave their roosts earlier than those using roosts in the open habitats which do not provide them protection from predators (Entwistle et al., 1996, Russo et al., 2002). Moreover, Griffin et al. (1960) suggested that lunar phobia has a strong negative impact on bat activities. The study found that moonlight sensitivity in bats and the corresponding changes in their activities may be an adaptation to reduce the risk of predation. Bats may also reduce their activities due to the indirect effects of moonlight on the availability of prey. On a bright night, preys are normally less available than the dark night (Lang et al., 2006). However, other studies have not found any relationship between moonlight intensity and activities (Russo and Jones, 2003; Thies et al., 2006). Therefore, there is no conclusion about the effect of lunar phobia on bat activities.

Other factors constraining the timing of emergence are related to the energy demands and the reproductive state of individuals (Durverge et al., 2000; Welbergen, 2006). Emergence time can be varied among individual bats depend on cost of

predation and advantages of approaching to foraging area earlier than other bats (Welbergen, 2008). Individuals have to trade-off between going to foraging area before others and rising predation risk by expose themselves when the external light is not completely dark. Several studies suggested that female bats with high energy demand, such as lactating female tend to emerge early, while, late pregnant females with loading bellies and less maneuverability, tend to depart later (Welbergen, 2006). Juveniles with little foraging experiences and less flight ability, also tend to emerge later than others member of the colony (Durverge et al., 2000).

Light intensity is linked to the risk of predation (Meyer et al., 2004; Lang et al., 2006). The higher the light intensity, the greater the risk of predation, especially with visually orienting predators (Meyer et al., 2004). The effect of the lunar light levels (as part of the monthly cycle) on animal behavior depend on whether the animal is a predator, a prey or both (Lang et al., 2006). Predators relying on vision to detect and catch their preys, therefore, they are benefit from bright moonlight as their prey would be easier to detect (Lang et al., 2006). Prey on the other hand would try to avoid bright light period in an attempt to elude predators (Lang et al., 2006). Animals that are both predators and prey must balance the risk of being predated with the benefit of foraging (Lima, 1998; Lang et al., 2006).

Effect of weather conditions (such as temperature, rainfall, cloud cover, and humidity) on the emergence and activity of animals depends on the cost-benefit ratio of

emerging in unfavorable conditions (Erkert, 1982) and might be expected to have a positive or a negative effect on weather conditions. In some case precipitation can encourage emergence (such as in spadefoot toad, *Scaphiopus* sp.) (Dimmitt and Ruibal, 1980) while in others it can delay or prevent emergence (such as in giant sand scorpion, *Paruroctonus mesaensis*) (Polis and Farley, 1980). Rainfall may also influence activities patterns of terrestrial animals for example some rodents decrease their activity as rainfall increases (O'Farrell, 1974).

Cloud cover generally has positive affect to emergence of bats because light levels were declined, predator's visions were decreased and therefore predation risks are decreased (such as masked shrew, *Sorex cinereus*, increased their activities on cloudy nights) (Doucet and Bider, 1974). Temperature extremes (such as too cold or too hot), on the other hand, tend to decrease or prevent emergence and other activities (Erkert, 1982) and animals would alter their emergence and activity patterns in response to temperature changes. Red foxes, *Vulpes fulva*, increase activity as temperature decreases (Ables, 1969). Owl monkeys, *Aotus azarsi*, increase activities when warmer temperatures (Fernandez-Duque, 2003).

Recently, several studies reported on impact of anthropogenic on bat activities. Light pollution seems to be a serious problem. Artificial light has negative affect on nocturnal animal activities, due to the disruption of natural circadian cycle, light-induced changes timing of onset of activity (Erkert, 1982). Another aspect from light pollution is

that increased predation risks to bats by expose them to nocturnal predators (Meyer et al., 2004). Moreover, Shirley et al. (2001) reported *Myotis daubentonii* tend to depart to forage lately when lights from music festival were found.



CHAPTER III

MATERIALS AND METHODS

3.1 Studied site

The study sites were located in 2 limestone caves at the Kham Island ($12^{\circ} 34.518' N$, $100^{\circ} 56.118' E$) and the Changkleua Island ($12^{\circ} 33.084' N$, $100^{\circ} 58.29'0 E$), situated at Samaesan Islands, Chonburi Province (Figure 3.1). The distance between both islands is 2 km. Each cave has only one entrance facing to the seaside (Figure 3.2). The entrances are higher than the sea level. At the Kham Island, the cave entrance is 2.2 m in height and 1.5 m in width. The dome inside is about 5 m in height, with many small cavities inside. The cave entrance at the Changkleua Island is 2.4 m in height and 4.2 m in width. The dome inside is about 4 m in height, with many small cavities inside.

3.2. Studied period

This study started from January 2015 to April 2016, 16 months in total.

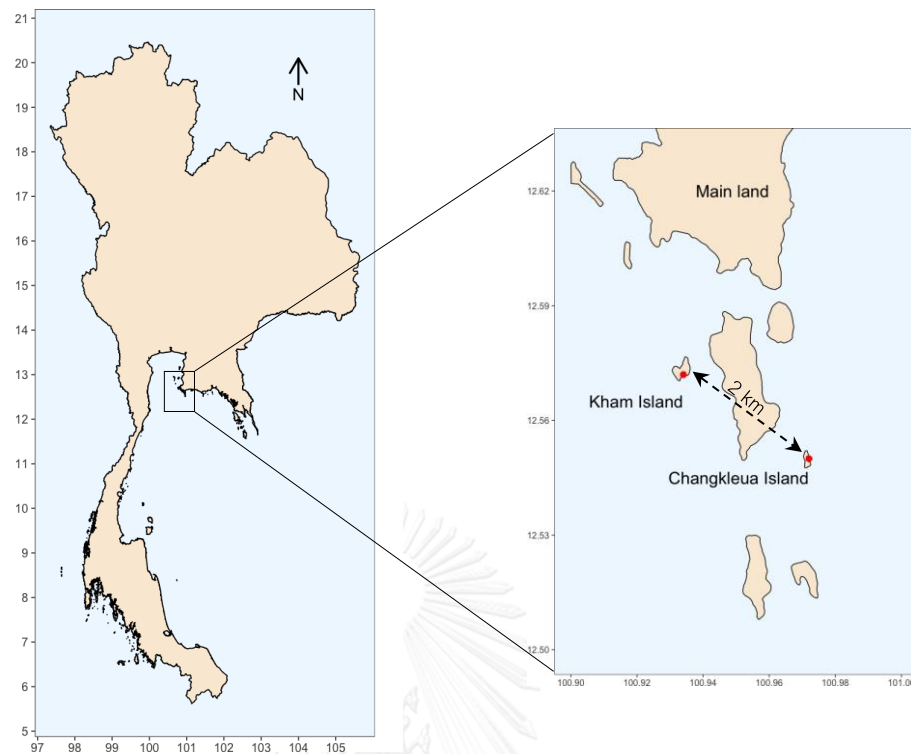


Figure 3.1 Location of the Kham and Changkleua Islands, situated in Samaesan Islands, Chonburi Province, distance between both islands is 2 km.



Figure 3.2 Cave entrance of the two resident colonies of *T. melanopogon* at the Kham Island (left) and Changkleua Island (right).

3.3 Emergence recording

Digital video cameras were set up with infrared mode at the cave entrance to record bat emergence (Figure 3.3). The cameras recorded from 1700 till 2200 for 4 nights per month with 7 night intervals from January 2015 to April 2016. Data of weekly colony sizes and emergence times of bats were obtained by counting bats from VDO footage. Colony sizes were determined by a cumulative number of flew out bats which have been recorded during the nights.

Bat emergence count was conducted every minute each night to define onset median, end of emergence, and emergence duration. The onset of emergence is the time when bats began leaving from daytime roost in a continuous bat emergence. Median emergence was defined as the time when 50% bats of colonies leaving the caves. The end of emergence is the time when bats stop continuously emerged. Emergence duration is the time between onset and end of emergence (Kunz and Anthony, 1996).

To study entire night of bat activities (emergence and returning activities) of *T. melanopogon*, 10 sample nights were recorded using the digital video cameras which continuously filmed from 1700 till 0700 of following days.



Figure 3.3 Infrared video camera installed at cave entrance at the Changkleua Island.

3.4 Bat capture and determination

Capture sessions were carried out monthly from January 2015 to April 2016. Each studied colonies (the Kham and Changkleua colonies) had only one session per month for data recording and no capture was undertaken in the same night of emergence count. In each session, a harp trap was used to catch bats during the evening emergence (Figure 3.4). The harp trap set up at cave entrance 30 minutes before sunset time and were taken down 3 hours later to ensure that bats in colonies were caught as much as possible.



Figure 3.4 Setting up harp trap in front of cave entrance at the Changkleua Island.

Captured bats were kept temporarily in soft cotton bags, then recorded individual data and released within an hour. The data, which were collected, were following this: some morphological characters (body mass, forearm length and third metacarpal finger), age, sex, reproductive status and time of capture. The morphological character are body mass (BM), forearm length (FA) and third metacarpal finger (3 META). Adults and juveniles were weight with spring balance. Forearm and third metacarpal finger were length by calliper. To determination *T. melanopogon* from *T. longinimus*, length of forearm and third metacarpal were compared, if forearm length was longer than third metacarpal, those bats were identified as *T. melanopogon*, if not, those were identified as *T. longinimus* (Bates and Harrison, 1997).

Captured bats were determined for age class, sex, and reproductive condition. Age classes (adult, late juvenile, and juvenile) were distinguished by illuminating the dorsal surface of the extended wing and examining the epiphyseal–diaphyseal fusion of the fourth metacarpal–phalangeal joint on the ventral surface (Brunet-Rossini and Wilkinson, 2009) (Figure 3.5). Bats with open joints were considered as juveniles and bats showing almost fused joints with pelage characteristic of juvenile, dark fur, were classified as late juveniles (Figure 3.6). Adults were recognized when epiphyses were completely fused with no remnant shadows of recent fusion and when the hair color was brighter than late juvenile. Reproductive condition of adult females was categorized as non-reproductive female, pregnant female and lactating female by abdominal palpation,

examination of teats (Brunet-Rossini and Wilkinson, 2009) (Figure 3.7). Those carrying the juvenile during foraging flight and presenting leaking milk at nipples were considered as lactating female. Pregnant female was considered by swelling abdomen. For adult males, they can be observed by looking at testis had either descended to scrotum or not (Figure 3.8). If it is so, length of testis was measured on bats using calliper. In addition, beard characteristic in adult males was also recorded as presence and absence (Figure 3.9). Adults and late juveniles were individually marked with plastic numbered collars (modified from Balasingh et al., 1992) (Figure 3.10) or bat rings.



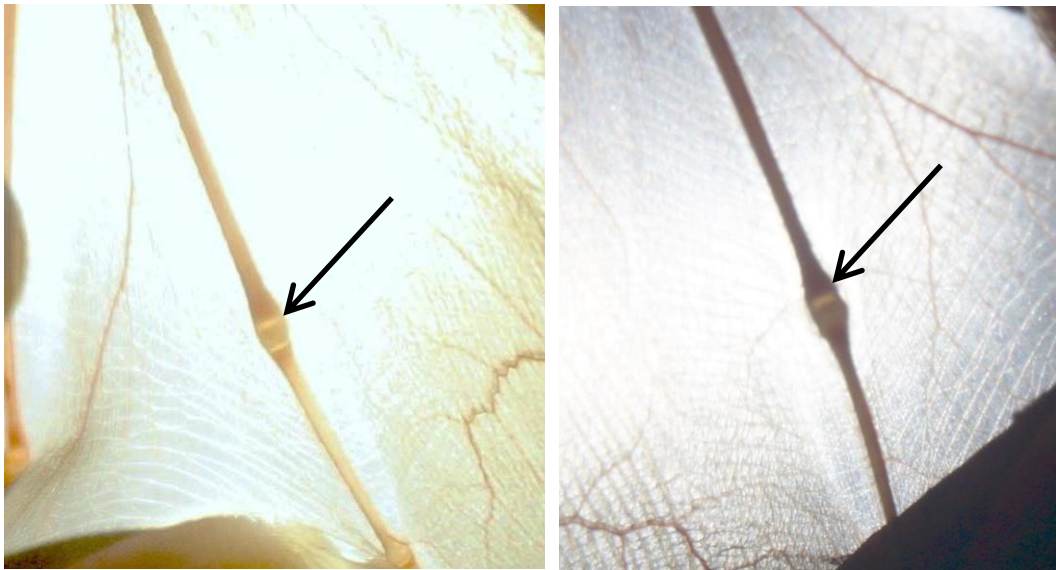


Figure 3.5 Epiphyseal–diaphyseal fusion of the fourth metacarpal–phalangeal joint of *T. melanopogon*: unfused cartilage in juveniles (left) and fused cartilage in adults (right), arrow represented zone of epiphyseal–diaphyseal fusion.



Figure 3.6 Color pelage of *T. melanopogon*: dark color of juvenile furs (left) and bright and orange in color of adult furs (right).



Figure 3.7 Adult female showing pregnant stage with swelling in abdomen (left) and sign of leaking milk at nipple (right).

Figure 3.8 Adult males with testis descended to scrotum (left) and without testis



descended to scrotum (right), arrows represented scrotum.



Figure 3.9 Beard character in adult males: presence of beard at gulag area at the arrow (left) and absence of beard at gulag area (right).



Figure 3.10 Plastic numbered collars (modified from Balasingh et al., 1992) used in the study (left), the tag attached to adult *T. melanopogon* at its neck.

3.5 Astronomical variables, weather and seasonality

Daily local sunset time and lunar cycle at Sattahip (latitude: 12°67'60 N) were provided by Hydrographic Department. All weather data were provided by Thai Meteorological Department (Sattahip weather station). The weather data consisted of precipitation in 24 h after 0700 hours (in millimeter), air temperature at 1900 hours (in degree Celsius), air pressure at 1900 hours (in kPa), relative humidity at 1900 hours (in percentage), wind speed at 1900 hours (in ten levels), and the cloud cover at 1900 hours (in knots).

Seasonality at eastern Thailand were categorized from annual rainfall and air temperature, which influenced by monsoon season (Walter et al., 1975). Precipitation during studied period was 101.21 mm in average (ranging from 0 to 255.5). From January 2015 to April 2016, rain fall for 159 days during studied period and exhibited two peaks in year round; minor and major peaks. Precipitation peaks were minor in May to late June 2015 starting rainy season and slightly decreased before reaching major peak in late September. Then, the sharply decline was in November 2015 matching the start of dry season. Average temperature and relative humidity were 28.09 degree in average and ranged, from 26.0 to 32.8. Thus, this study categorized season as follow: dry season, started from January to April 2015 and December 2015 to April 2016, and rainy season, started from May to September 2015 (Figure 3.11).

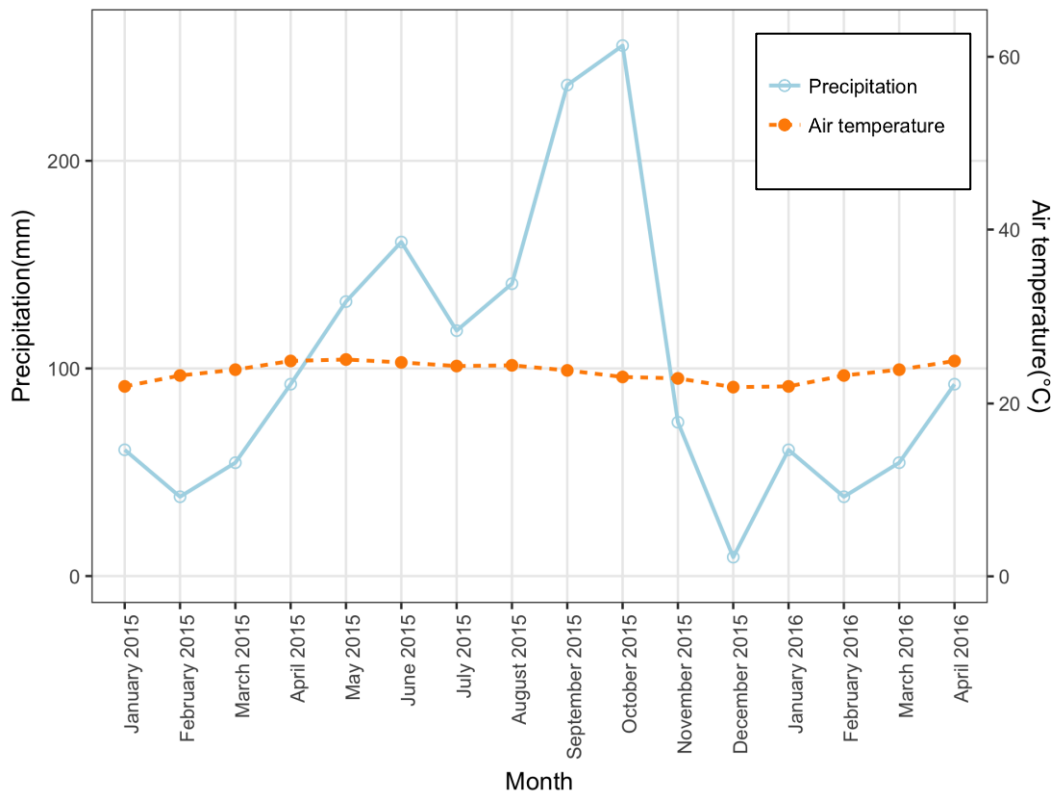


Figure 3.11 Climatic plot between precipitation (continuous line) and monthly ambient temperature (dash line). Duration between intersections of lines at April and November indicated rainy season.

3.6 Data analyses

Firstly, Kolmogorov–Smirnov test was used to analyze in order to examine whether the data were parametric or not (Zar, 1999). Then, statically tests were applied to investigate the hypotheses. All statistical tests were carried out using Program R (R core team, 2016). Data were manipulated using package “dplyr” (Wickham and Francois, 2016). Graphs and maps were visualized by package “ggplots2” (Wickham, 2009) and “ggfortify” (Horikoshi and Tang, 2016), respectively. All tests were two-tailed and significant at alpha is less than 0.05. Times, which are collected as hour: minute in

fields, were converted to minutes after a point of time when used in any calculations. Means are expressed as mean± standard deviation.

Population of *T. melanopogon*

From the video footages, colony sizes of the two colonies were determined as a cumulative number of flew out bats which have been recorded during the nights. Data were grouped into month to examine seasonal change. 16 months of weekly colony size data was pooled to analyze the significantly different between the two colonies and between seasons (dry and rainy) using Wilcoxon rank sum test (Zar, 1999).

Ratio of adult male and females from monthly captured sessions was examines to determine whether it was equal or not using Chi-squared Test (Zar, 1999).

To compare average body mass and forearm length among adults, subadults and juveniles, I used Kruskal-Wallis test, then Wilcoxon rank sum tests were applied to compare means of these aspects between sexes.

Significance of monthly body mass differences in adults between month and between sexes throughout 16 months was tested using a Kruskal-Wallis test. When the factors were significant, Wilcoxon rank sum tests was applied.

Emergence activities of *T. melanopogon*

Effect of locality of colonies on bat emergence time was determined. Emergence times calculated in this analysis were median emergence in purpose of reducing effect of first bat and last bat emergence. Student's *t*-test was applied to compare mean

emergence time of the two colonies. If that did not significant different, further analyses will pooled the data of the two colonies.

To test effect of sunset/sunrise on bat activities (bat emergence and return time), 10 continuously recorded nights were applied using general linear model with the emergence and return data as the dependent variable.

Data from the emergence recording were used to test which emergence data (the onset, median, and end of emergence) was used to analyze relationship with local sunset time using general linear model.

To test the influencing of weather to bat emergence, the number of weather variables were investigated with emergence data individually using a general linear model. Weather variables consisted of 24-hr precipitation, air temperature, relative humidity, wind speed, and cloud cover at 1900 hours.

Lunar phase was defined as three categories; new moon, full moon and half-moon. Full moon nights (minimum illumination) is nights from third quarter of waxing crescent to the first quarter of waning crescent. New moon night (maximum illumination) is the nights from third quarter of waxing gibbous to the first quarter of waxing gibbous. Half-moons (50 percent partly illumination) is defined as the first quarter and third quarter of the moons (Mello et al., 2013). Then, the average emergence time for each defined moon phase was analyzed using one way ANOVA.

To study an effect of emergence times in female reproductive status, data were obtained from capture bats by harp trap. The data were chosen only from April to

August 2015. Then, Kruskal-Wallis test was used. If the factors were significant, Wilcoxon rank sum tests was applied to compare the difference of emergence time among various female reproductive statuses.

Testing an effect of emergence times in various development stages, data were obtained from capture bats by harp trap. The data were chosen only from August to December 2015. Then, Kruskal-Wallis test was used. When the factors were significant, Wilcoxon rank sum tests was applied to compare the difference of emergence time among various development stages.



CHAPTER IV

RESULTS

4.1 Population dynamics of *T. melanopogon*

4.1.1 Change in colony size and composition

During the entire study period (16 months), sizes of both colonies were estimated from VDO footages for 147 nights. Flew out bats of the Kham and Changkleua colonies were counted for 75 and 72 nights, respectively. The Kham colony size was significantly larger than the Changkleua colony size (Two sample t-test: $t = -21.922$, $df = 116.52$, $p\text{-value} < 0.01$). Number of individuals in the Kham colony size ranged from 195 to 340 individuals (mean = 275.27 bats) and the Changkleua colony size ranged from 120 to 201 individuals (mean = 159.55 bats) (Table 4.3). However, these estimated colony sizes from Jolly-Seber method were far higher than the numbers of bats counted from evening emergence. Colony sizes estimated from Jolly-Seber method throughout the studied period ranged from 94 to 14,415 bats (mean 3,018. bats) (Table 4.1) at the Kham colony and from 40 to 8,112 bats (mean = 1,824 bats) at the Changkleua colony (Table 4.2).

Colony size of *T. melanopogon* varied significantly throughout the studied period (the Kham colony: Kruskal-Wallis test: chi-squared = 58.889, $df = 15$, $p\text{-value} < 0.01$; the Changkleua colony: Kruskal-Wallis test: chi-squared = 59.426, $df = 15$, $p\text{-value} < 0.01$). Changed of colony sizes in both colonies are in similar pattern (Figure 4.1). Colony sizes reached the peaks during January – February 2015 (283, 342 bats in the Kham colony

and 182, 210 bats in the the Changkleua colony) and then, sharply declined in March 2015. After that, the colony sizes increased and slightly fluctuated until October 2015. Colony sizes began to rise and reached the peaks again during November 2015 – January 2016. And colony sizes decreased again in February 2016 until April 2016. Colony sizes were different between dry and rainy seasons (the Kham: Two sample t-test, $t = 2.25232$, $df = 50.915$, $p\text{-value} = 0.0465$; the Changkleua colony: $t = 2.4759$, $df = 58.201$, $p\text{-value} = 0.01622$).



Table 4.1 Estimated colony sizes of adult male and non-reproductive female *T. melanopogon* at Kham colony during January 2015–April 2016 using Jolly-Seber method.

Recapture sessions	Number of caught bats	Number of recapture bats	Estimated number of bats in colony by Jolly-Seber method
January 2015	47	-	-
February 2015	21	0	484
March 2015	19	2	480
April 2015	14	0	162
May 2015	8	1	94
June 2015	8	0	9,375
July 2015	30	0	14,415
August 2015	19	2	2,014
September 2015	26	0	5,468
October 2015	20	0	7,056
November 2015	24	1	2,513
December 2015	31	4	896
January 2016	21	4	1953
February 2016	22	2	3,542
March 2016	15	4	1,037
April 2016	9	0	2,000

Table 4.2 Estimated colony sizes of adult male and non-reproductive female *T. melanopogon* at Changkleua colony during January 2015–April 2016 using Jolly-Seber method, deficient capture data in March 2015 due to the inaccessible studied area.

Recapture sessions	Number of caught bats	Number of recapture bats	Estimated number of bats in colony by Jolly-Seber method
January 2015	21	-	-
February 2015	19	0	800
March 2015*	-	-	-
April 2015	3	0	40
May 2015	6	0	147
June 2015	7	0	150
July 2015	28	0	7,569
August 2015	25	2	1,032
September 2015	14	0	2,250
October 2015	14	0	750
November 2015	24	2	2,517
December 2015	21	3	1,469
January 2016	25	0	8,112
February 2016	17	1	1,953
March 2016	9	2	407
April 2016	4	1	153

Table 4.3 Colony sizes from emergence counts of *T. melanopogon* at Kham and Changkleua colonies during January 2015–April 2016.

Month	Average number of bats in colony by emergence count (mean±SD, n=4)	Average number of bats in colony by emergence count (mean±SD, n=4)
January 2015	193.33±9.86	285.33±4.04
February 2015	182±18.09	295.83±26.8
March 2015	130±8.24	230±36.72
April 2015	135.83±9.17	268.83±34.39
May 2015	146.2±7.32	274±35.94
June 2015	158±3.82	237.25±35.39
July 2015	161.66±5.47	267±17.46
August 2015	153.75±2.5	261.25±8.46
September 2015	151.5±7.68	270.75±5.05
October 2015	144.6±11.9	259.8±6.14
November 2015	163±14.56	324.75±14.52
December 2015	192.25±5.31	328.25±8.84
January 2016	196.4±13.11	320.4±12.25
February 2016	170.75±10.77	275±18.81
March 2016	155.25±16.25	222.25±32.51
April 2016	131.5±15.17	222.5±32.27

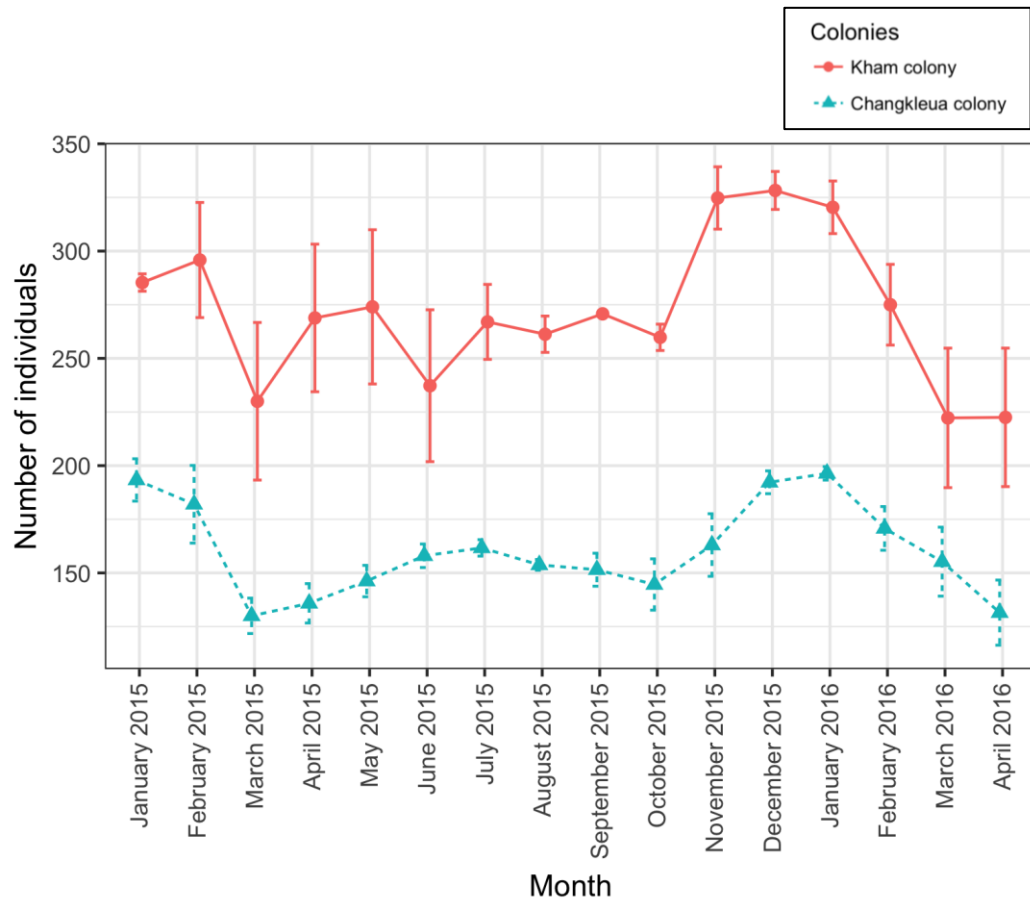


Figure 4.1 Change of *T. melanopogon* colony sizes in the Kham and the Changkleua colonies during studied period from January 2015 to April 2016.

A total of 703 bats, consisting of 252 adult males, 372 adult females, 44 late juveniles and 35 juveniles, were captured from both colonies. Males and females of *T. melanopogon* were observed in both colonies throughout the study period. No other bat species were found in both colonies during the studied period. Monthly capture data were shown in Figure 4.2. A total of 581 adult stage bats (344 bats in the Kham colony and 237 bats in the Changkleua colony) were banded consisting of 329 non-reproductive females and 252 males. Throughout the studied period, 26 individuals, 15 males and 11 females, were recaptured, of which 2 females and 1 male were recaptured twice (Table 4.4).



Table 4.4 Data of recapture *T. melanopogon* in the Kham and Changkleua colonies from January 2015 to April 2016.

No.	sex	capture session		first recapture session		second recapture session	
		month	colony	month	colony	month	colony
1	Male	Jan-15	Kham	Mar-15	Kham		
2	Female	Jan-15	Kham	Dec-15	Kham		
3	Female	Jan-15	Kham	Dec-15	Changkleua		
4	Male	Jan-15	Kham	Dec-15	Kham		
5	Male	Jan-15	Changkleua	Jan-16	Kham		
6	Female	Feb-15	Kham	May-15	Kham		
7	Female	Feb-15	Kham	Mar-15	Kham		
8	Female	Feb-15	Changkleua	Nov-15	Kham	Dec-15	Kham
9	Male	Feb-15	Changkleua	Feb-16	Changkleua		
10	Male	Mar-15	Kham	Dec-15	Kham		
11	Male	Jun-15	Changkleua	Dec-15	Changkleua		
12	Male	Apr-15	Changkleua	Feb-16	Kham		
13	Female	May-15	Changkleua	Mar-16	Changkleua		
14	Female	May-15	Changkleua	Mar-16	Changkleua		

Table 4.4 (continued) Data of recapture *T. melanopogon* in the Kham and Changkleua colonies from January 2015 to April 2016.

No.	sex	capture session		first recapture session		second recapture session	
		month	colony	month	colony	month	colony
15	Male	Apr-15	Kham	Aug-15	Kham		
16	Male	Apr-15	Kham	Aug-15	Kham		
17	Male	Apr-15	Changkleua	Apr-16	Changkleua		
18	Male	May-15	Kham	Jan-16	Kham	Mar-16	Kham
19	Female	May-15	Kham	Feb-16	Kham	Mar-16	Kham
20	Female	Jun-15	Changkleua	Dec-15	Changkleua		
21	Male	Sep-15	Kham	Jan-16	Kham		
22	Male	Oct-15	Changkleua	Nov-15	Changkleua		
23	Female	Oct-15	Changkleua	Nov-15	Changkleua		
24	Male	Dec-15	Kham	Jan-16	Kham		
25	Male	Dec-15	Kham	Mar-16	Kham		
26	Female	Dec-15	Kham	Mar-16	Kham		

Sex composition of *T. melanopogon* varied throughout the studied period (Figure 15). During January–February 2015, the equal ratios of adult males and females were found in both colonies (Table 4.5). After that, the colonies began to decrease in ratio of

male adults. The female-biased ratios were continuously occurred until October 2015. Coincident with reductions in colony size during March - October 2015, there were the decreases in the proportion of males in both colonies. Then, the proportion of male bats in both colonies began to rise in December 2015.

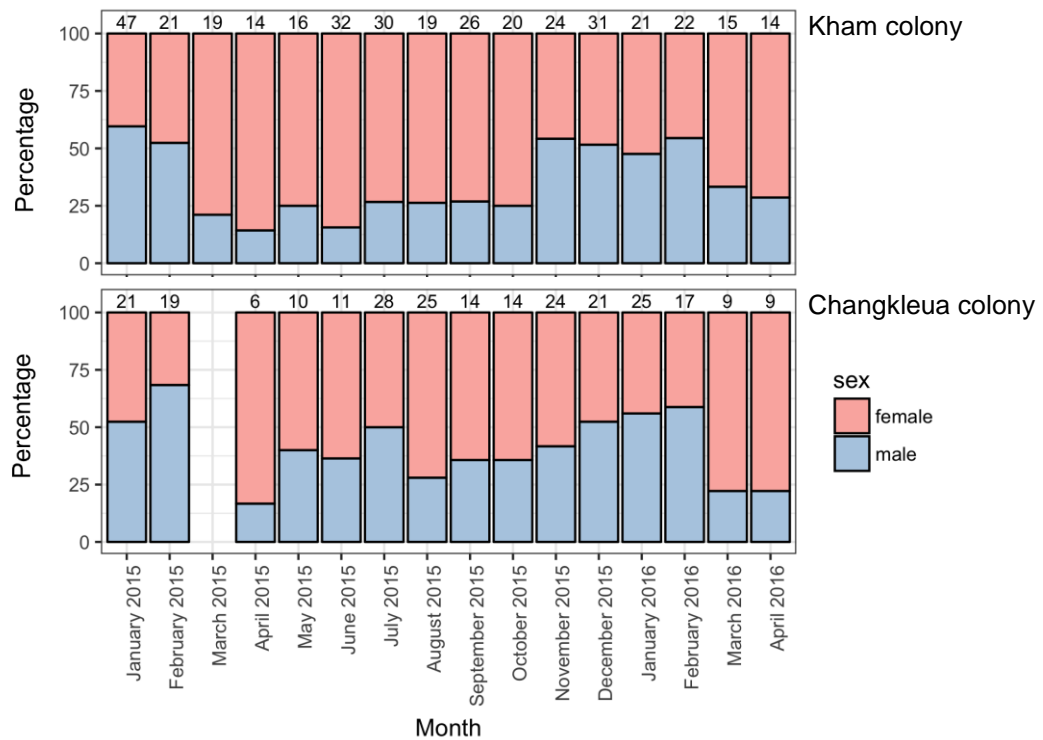


Figure 4.2 Sex composition of *T. melanopogon* in the Kham colony (top) and Changkleua colony (bottom) during January 2015–April 2016. Total numbers of examined adult bats each month were shown above the bars. Data at the Changkleua in March 2015 was not available due to inaccessibility.

Table 4.5 Chi-squared analysis for equality of monthly adult sex ratio.

Month	Kham colony			Changkleua colony		
	χ^2	df	<i>p-value</i>	χ^2	df	<i>p-value</i>
January 2015	1.88	1	0.17	0	1	1
February 2015	0.21	1	0.65	3.04	1	0.08
March 2015	6.84	1	0.008*	NA	NA	NA
April 2015	8.96	1	0.003*	6.40	1	0.01*
May 2015	5.38	1	0.02*	1.04	1	0.31
June 2015	17.05	1	0.001*	1.76	1	0.18
July 2015	8.112	1	0.004*	0	1	1
August 2015	4.75	1	0.03*	6.25	1	0.01*
September 2015	6.5	1	0.01*	1.09	1	0.29
October 2015	6.27	1	0.02*	1.09	1	0.29
November 2015	2.07	1	0.14	2.88	1	0.08
December 2015	0.33	1	0.56	0	1	1
January 2016	0.21	1	0.64	1.84	1	0.17
February 2016	1.35	1	0.25	0.4	1	0.53
March 2016	1.23	1	0.28	3.02	1	0.08
April 2016	4339	1	0.04*	2.82	1	0.09

Note: * significant difference ($p\text{-value} < 0.05$)

4.1.2 Reproductive period of *T. melanopogon*

For clearly analyze the reproductive timing of this species in the study, data from the two colonies were pooled into one dataset. From 372 captured females (the Kham colony: n= 232; the Changkleua colony: n=140) during 16 months of study period, pattern of female conditions revealed that parturition and lactation of female *T. melanopogon* in the studied area occurred once a year. Females showed no sign of reproductive activities during January-March 2015 and July 2015 to March 2016 (Figure 4.3). Peaks in pregnancy and lactation time of female coincided with the onset of the rainy season. Female reproductive activities were restricted in April to June 2015. In April 2015, almost 50% of captured females in both colonies showed sign of pregnancy. From May to June 2015, proportion of pregnant females decreased. Coincident with decline of pregnant females, lactating females began to appear in May 2015. Most females showed sign of lactation in May and June 2015.

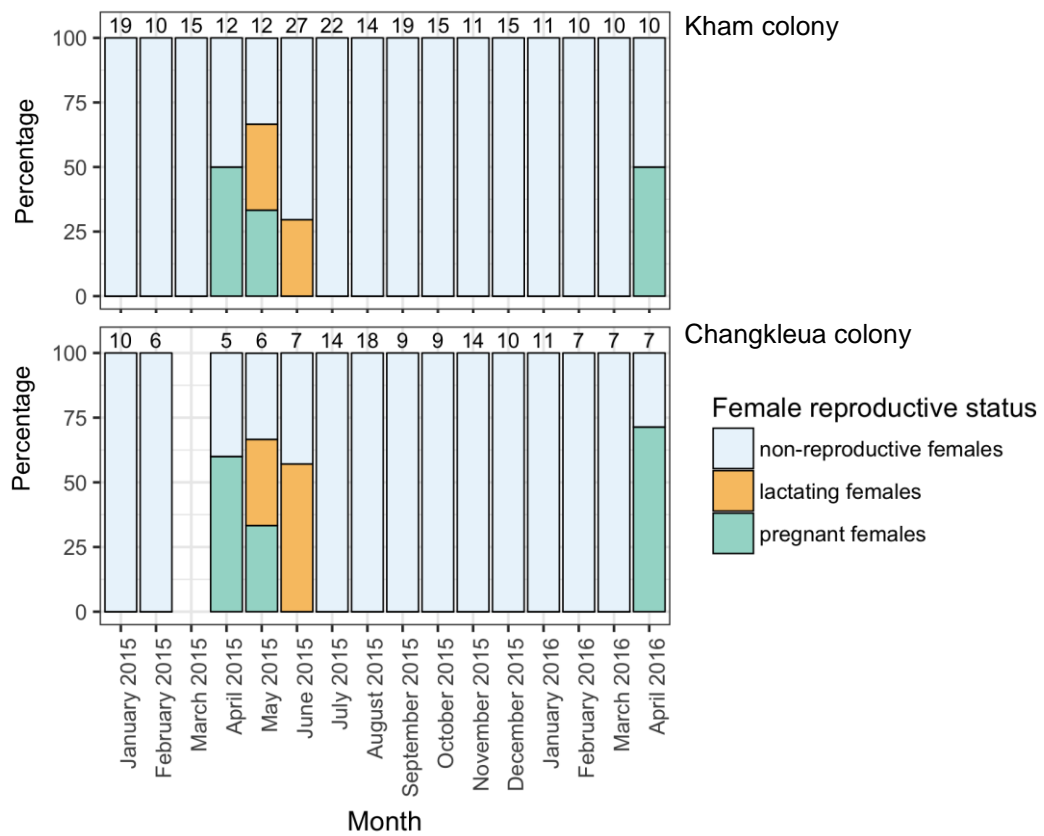


Figure 4.3 Proportion of female *T. melanopogon* in different reproductive statuses in the Kham colony (top) and the Changkleua colony (bottom) during January 2015–April 2016. Total numbers of examined adult female bats each month were shown above the bars. Data at the Changkleua in March 2015 was not available due to inaccessibility.

From pooled data of adult males ($n = 252$; 139 males from the Kham colony and 113 males from the Changkleua colony), proportion of males with scrotal testis to beard character changed throughout studied period. There was a strong relationship of the presence of scrotal testis and beard character (Chi-square test of association, chi-square = 6.5001, $df = 1$, $p\text{-value} = 0.01079$; Figure 4.4). Proportion of males with scrotal testis and beard reached the peak during January–March 2015, then, sharply declined in April 2015. After that, no scrotal testis males and beard male were observed in the two colonies until October 2015. Proportion of males with scrotal testis and beard began to rise and reached again during November 2015–January 2016. And ratios of males with scrotal testis and beard decreased again in February 2016 until April 2016. The ratio of scrotal males was significantly negatively correlated with length of day length (Spearman's rank correlation, $S = 1187.5$, $p\text{-value} = 0.0008987$, $\rho = -0.74$; Figure 4.5)

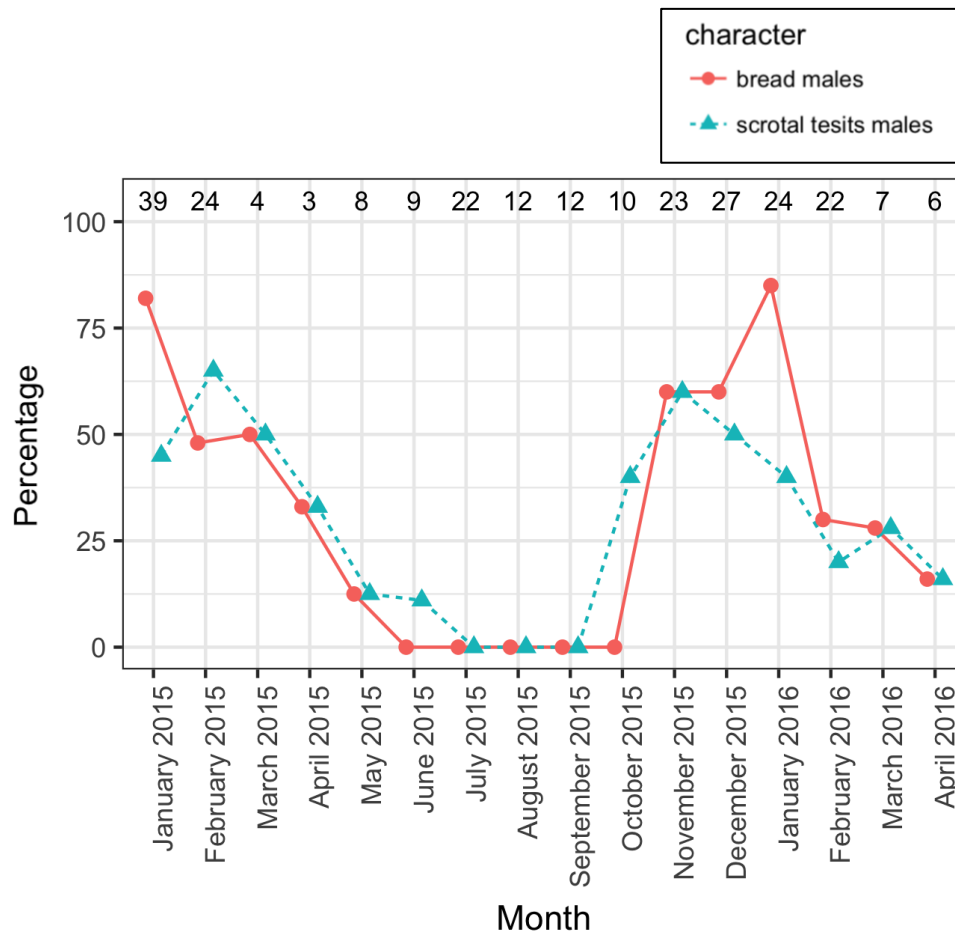


Figure 4.4 Change in proportion of adult male of *T. melanopogon* with beard and testis descended to scrotum from the two colonies during January 2015–April 2016 . Total numbers of examined adult male bats each month were shown on the top.

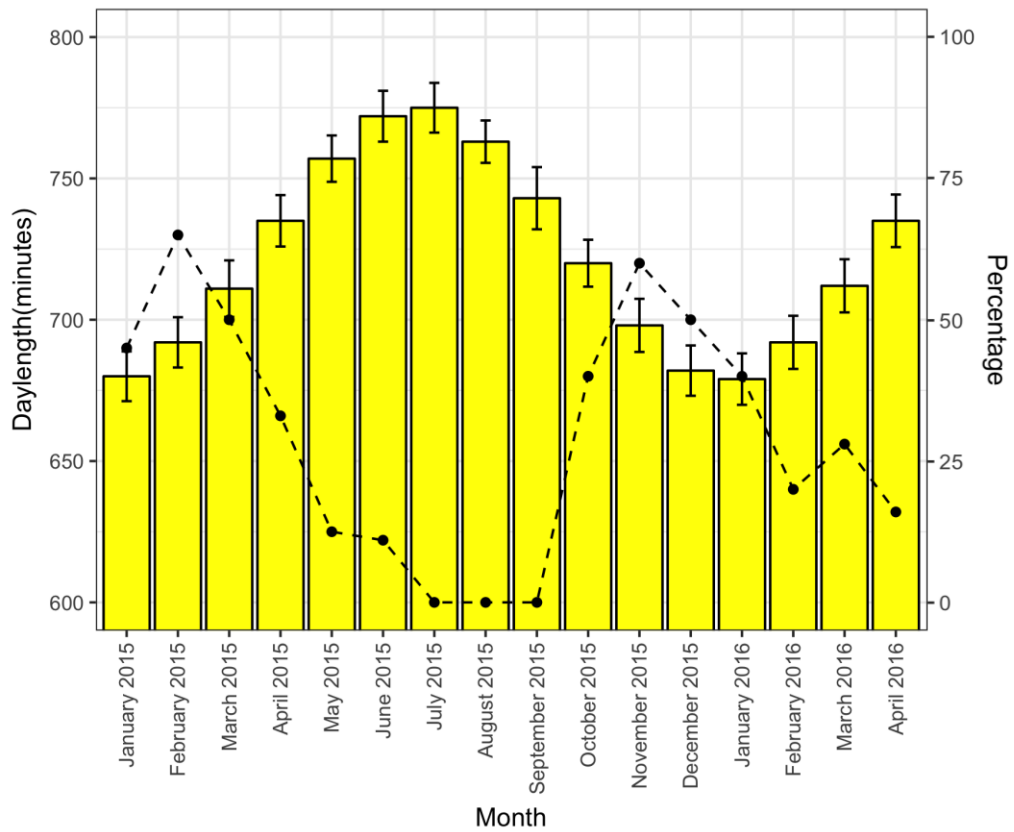


Figure 4.5 Relationship between present of male with scrotal testis (line) and day length (yellow bar) during studied period

Juveniles were captured only during June–August 2015. In August 2015, the highest proportion juveniles were found. The small proportion of late juvenile began to be appeared. Late juvenile individuals exhibited the highest proportion in October 2015 and they could also observed in November and December 2015 (Figure 4.6).

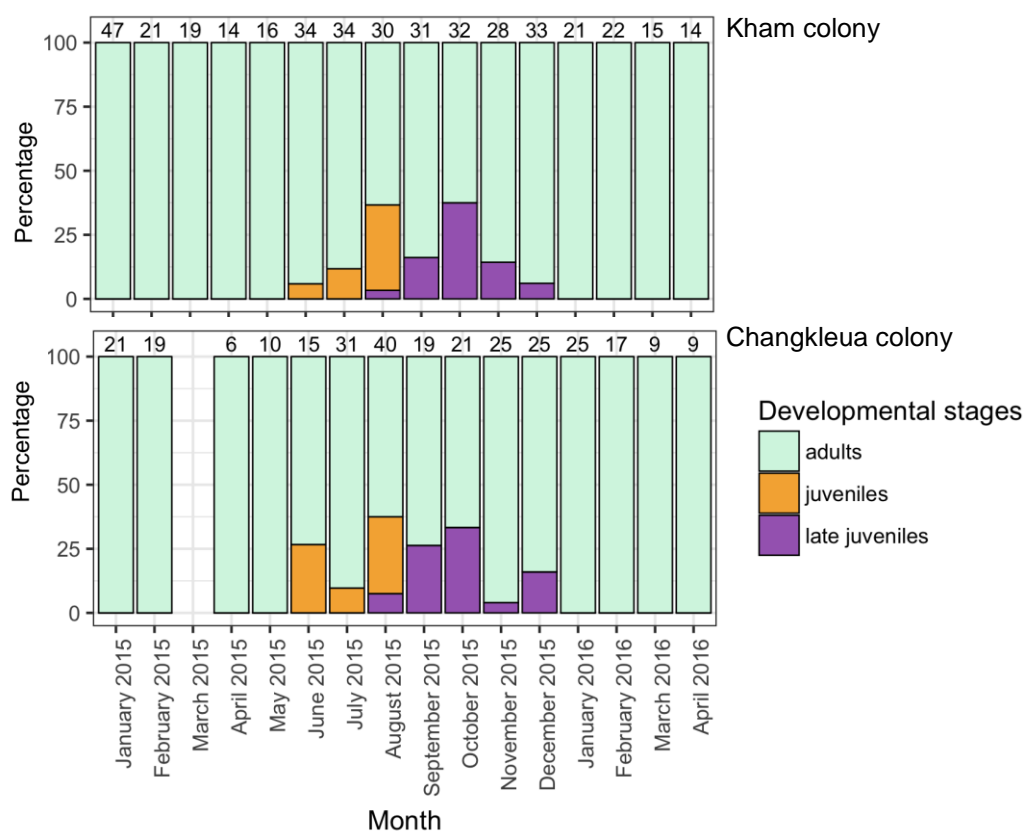


Figure 4.6 Proportion of adults, late juveniles and juveniles of *T. melanopogon* in the Kham colony (top) and the Changkleua colony (bottom) during January 2015–April 2016. Total numbers of examined bats each month were shown above the bars. Data at the Changkleua in March 2015 was not available due to inaccessibility.

4.1.3 Morphological difference among sexes and developmental stages

Morphological data of 703 bats from both colonies (the Kham colony: 371 adults, 24 late juveniles and 16 juveniles; the Changkleua colony: 253 adults, 20 late juveniles and 19 juveniles) were pooled for analyses (Table 4.6). No sexual dimorphism was detected in adults (BM: two sample t-test; p -value= 0.065; FA: p -value= 0.75; 3 META: p -values=0.88), late juveniles (BM: Mann–Whitney U test, p -value= 0.086; FA: p -value= 0.71; 3 META: p -values=0.69), juveniles (BM: Mann–Whitney U test, p -value= 0.07; FA: p -value= 0.28; 3 META: p -values=0.14). Then, data from male and female were pooled for morphological comparison among adults, late juveniles and juveniles. Significant differences were found in all three external morphological characters (BM: ANOVA, p -value=0.0107; FA: p -value=0.0247 and 3 META: p -value=0.02527) (Figure 4.7).

Table 4.6 Morphological difference among sexes of developmental stages of *T. melanopogon*

morphological variation	adults		late juveniles		juveniles	
	males	females	males	females	males	females
	n=252	n=372	n=26	n=18	n=16	n=19
bodymass (BM)	24.1 ± 2.8	25 ± 3.1*	22.1 ± 1.90	22.90 ± 1.55	19.27 ± 2.50	18.54 ± 2.77
forearm length(FA)	64.7 ± 1.5	64.9 ± 1.4	63.5 ± 1.87	63.2 ± 1.88	61.2 ± 6.60	60.89 ± 3.41
third metacarpal finger length (3 META)	58.70 ± 1.65	58.91 ± 1.89	58.10 ± 1.88	57.49 ± 1.23	55.50 ± 2.60	54.43 ± 2.13

Note: * data from only non-reproductive females

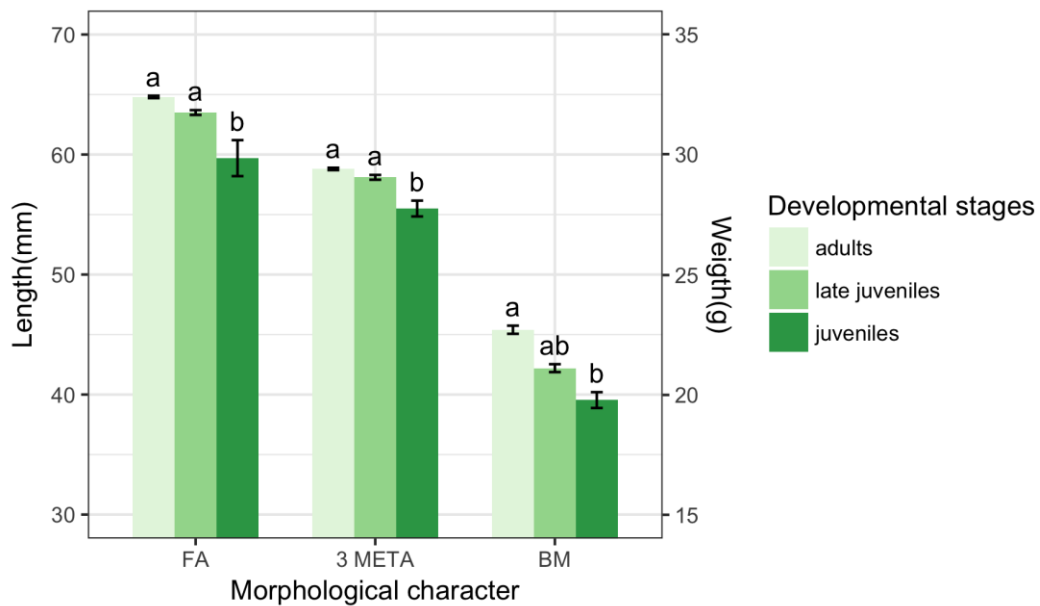


Figure 4.7 Mean of three morphological characters of developmental stages (FA = forearm length, 3 META = third metacarpal finger length and BM = body mass). Error bars represented standard error and significant differences were shown in alphabets above bars.

Monthly variation in body mass was detected in adults females (Kruskal-Wallis test, chi-square = 59.426, df = 15, p -value < 0.01) (Figure 4.8). Female body mass during February-April 2015 was higher than in other months. This was concordant with the presence of pregnant females during that time of year. Body mass of pregnant females (29.43 ± 2.75 , $n=25$) was much higher than non-reproductive females (25 ± 3.1 , $n=329$) and lactating females (23.51 ± 4.90 , $n=18$). In contrast, there was no difference in male body mass among months throughout the year (Kruskal-Wallis test, chi-square = 0.889, df = 15, p -value = 0.71) (Figure 4.9).

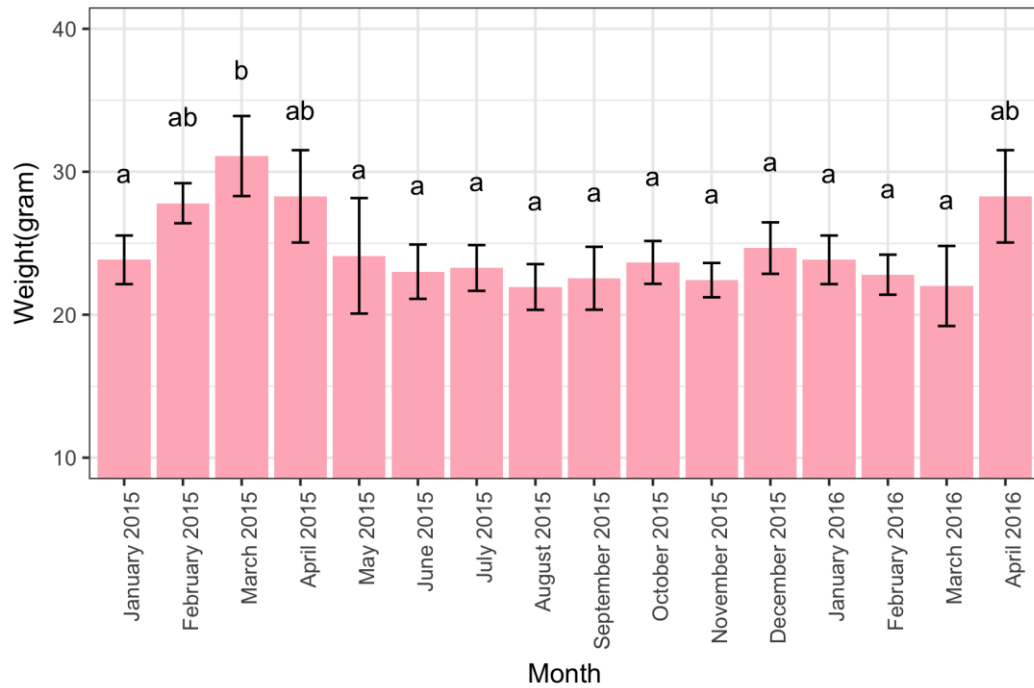


Figure 4.8 Monthly average of body mass of female *T. melanopogon* during January 2015–April 2016, error bars represented standard deviation. Error bars represented standard error and significant differences were shown in alphabets above bars.

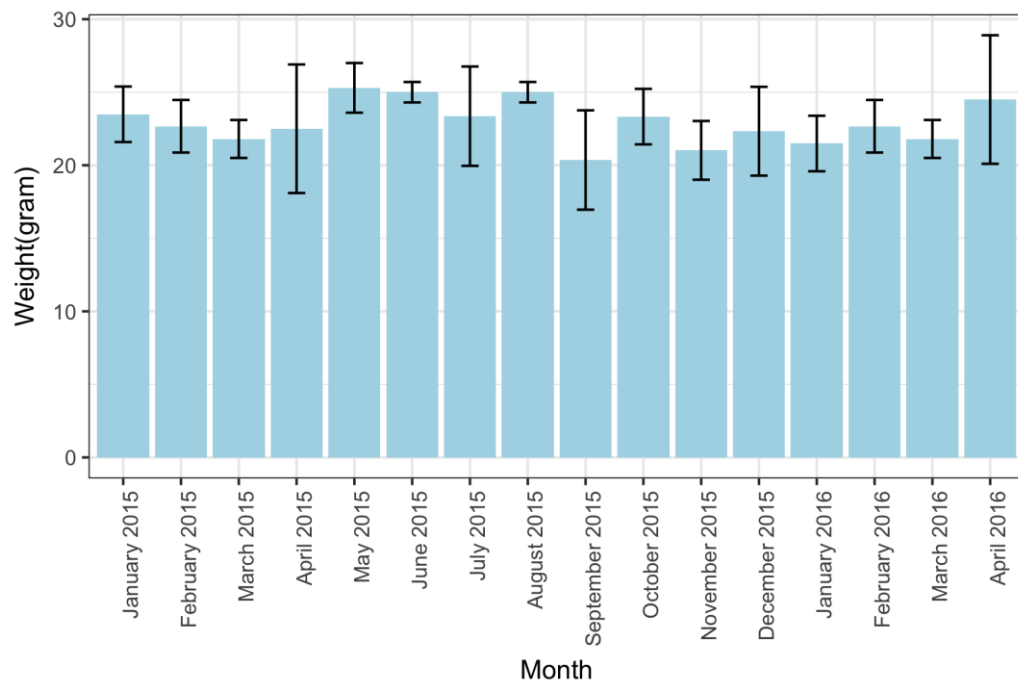
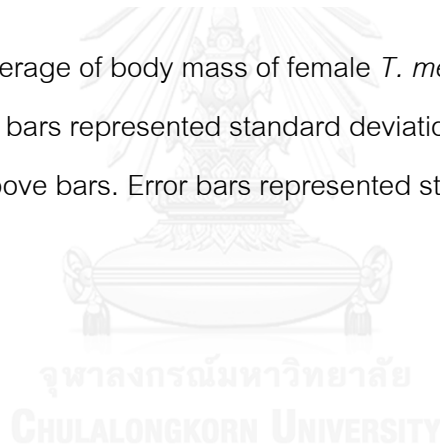


Figure 4.9 Monthly average of body mass of female *T. melanopogon* during January 2015–April 2016, error bars represented standard deviation, significant differences were shown in alphabets above bars. Error bars represented standard error .



4.2 Emergence activities of *T. melanopogon*

4.2.1 Bat activities at cave entrance in relation to local sunset time and sunrise

Bats activities in 10 nights (8 nights from the Kham colony and 2 nights from the Chnagkleua colony) were recorded for entire night and activities at the cave entrance could be divided into 2 major activities (Figure 4.10); emergence and returning (Figure 4.11). Bats began to depart at 34.75 ± 9.15 minutes (mean \pm SD) after sunset and bat emergence lasted until 96.63 ± 19.72 minutes after sunset. Emergence duration of *T. melanopogon* ranged from 28 to 102 minutes. From 176 ± 10.93 minutes (mean \pm SD) to 37.37 ± 7.35 minutes (mean \pm SD) before sunrise, individual bats began to fly back to the roost and return duration ranged from 106 to 165 minutes before sunrise. Throughout the study period, sunset time at Samaesan Islands ranged from 1747 to 1834 and sunrise time ranged from 0551 to 0643.

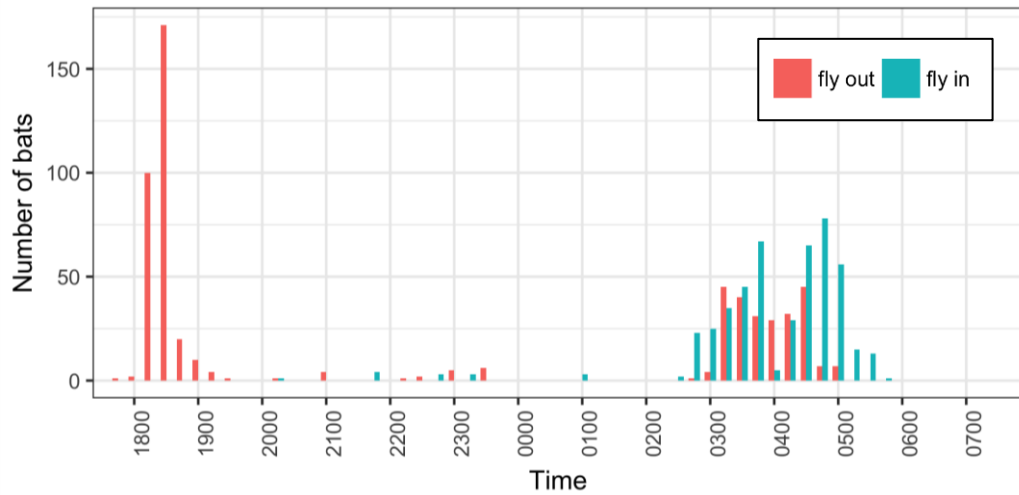


Figure 4.10 Numbers of bats flying out after dusk in the Kham colony and flying in before dawn from 26 August 2015, the data were shown in 15 minutes intervals throughout the night.

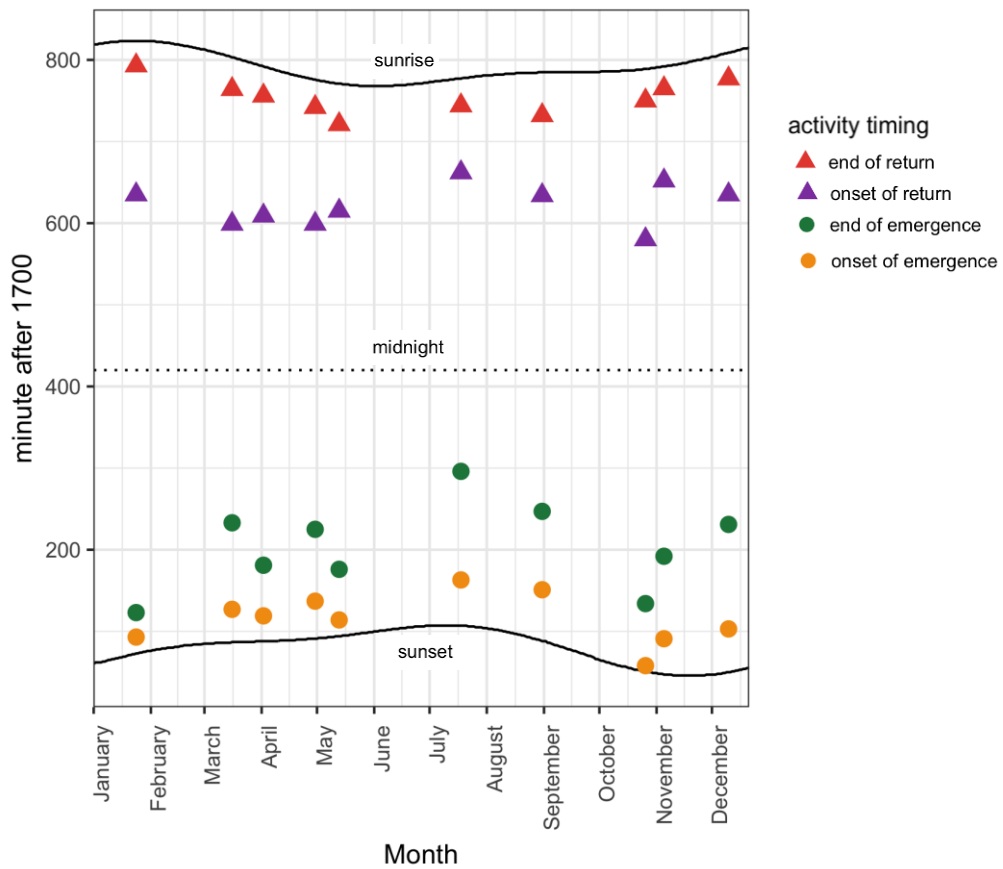


Figure 4.11 Timings of bat activities (emergence and return) at the cave entrance from 10 entire nights in relation to sunset and sunrise time from January to December 2015, Data was pool from the Kham and Changkleua colonies.

From 147 nights of emergence recording, emergence activities of *T. melanopogon* varied throughout 16 months (Figure 4.12, 4.13). All activities occurred after local sunset. Onset of emergence has a positive correlation with sunset time (Pearson's correlation, $t = 30.306$, $df = 146$, $p\text{-value} = 0.0327$, $r = 0.737420$). Bats began to depart from roosts at 1837 (ranged from 1800 to 1905). Being defined as the time when the fiftieth percent of individuals in colonies emerged, median of emergence time was 1846 on average (ranged from 1805 to 1923). Strongly positive correlation between median emergence time and local sunset time was revealed (Pearson's correlation, $t = 33.701$, $df = 146$, $p\text{-value} < 0.01$, $r = 0.9420609$). End of emergence, the time when the last bat leave caves, was 1920 on average (ranged from 1832 to 2120) and emergence duration ranged from 21 to 147 minutes. End of emergence also positively correlated with sunset time (Pearson's correlation, $t = 10.347$, $df = 146$, $p\text{-value} = 0.04317$, $r = 0.5530256$) (Figure 4.12).

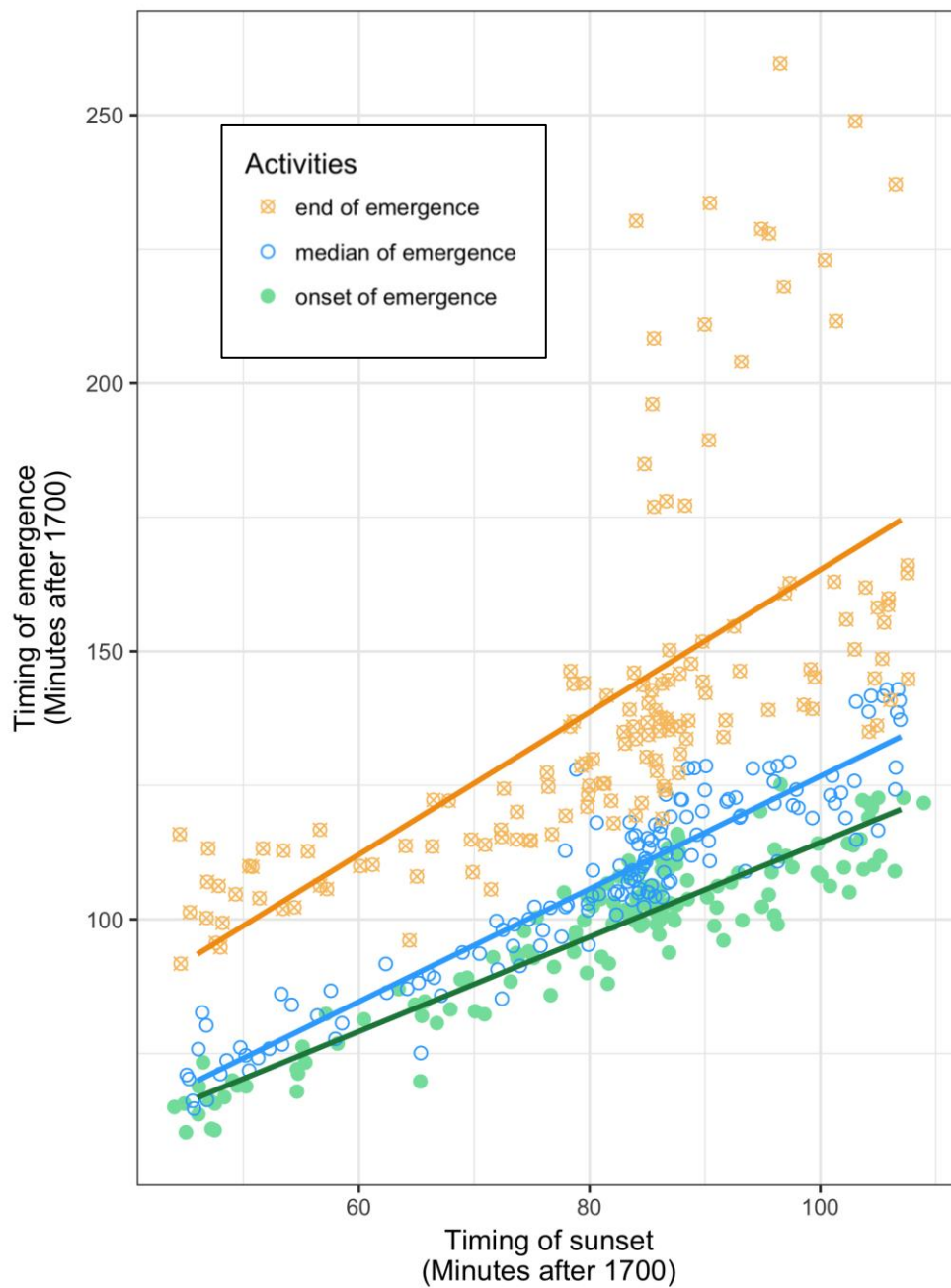


Figure 4.12 Onset, median and end of emergence of *T. melanopogon* in relation to sunset time. Data from the Kham and Changkleua colonies were pooled. Solid lines represented fitting linear regression model.

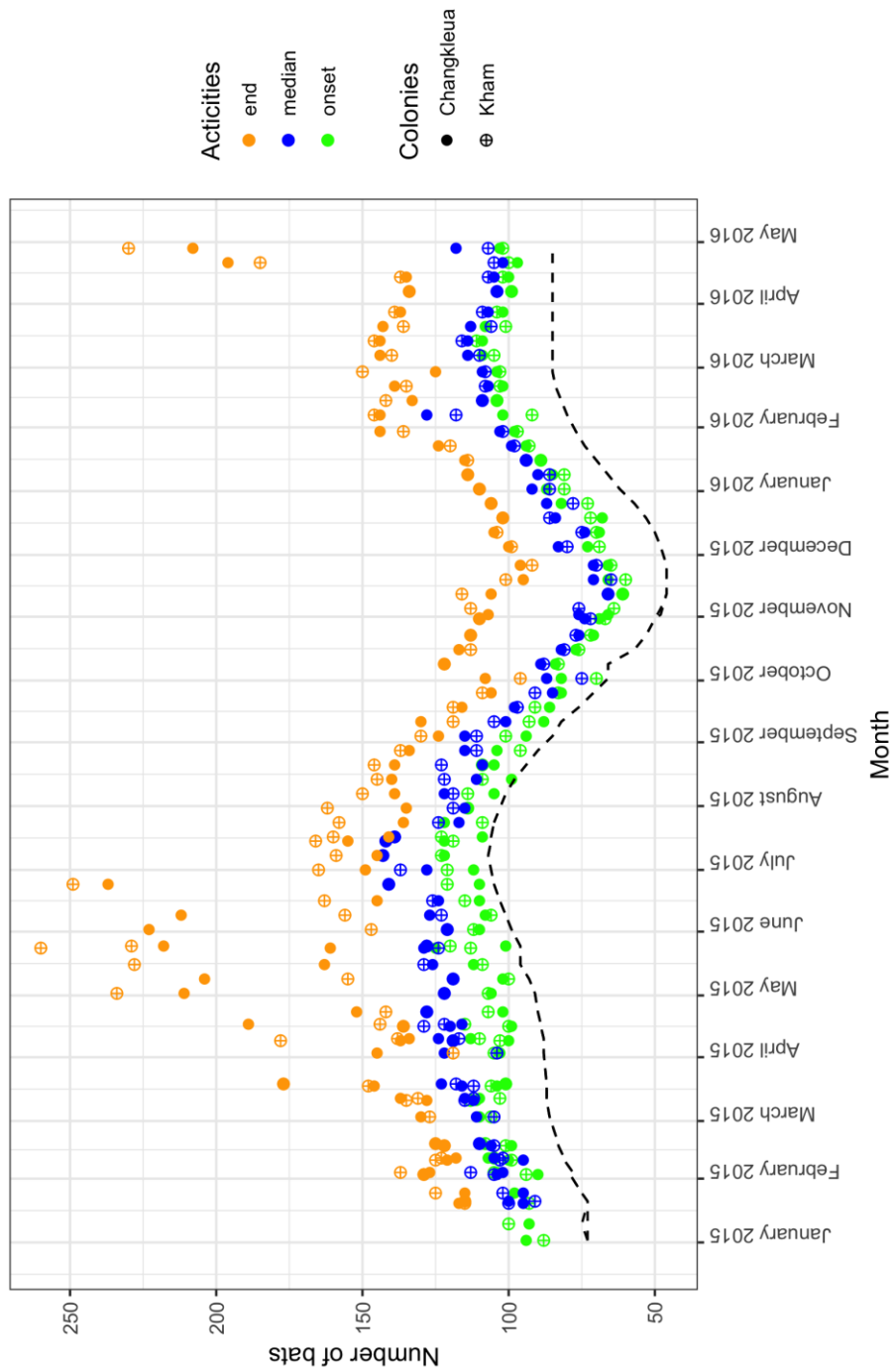


Figure 4.13 Timing of emergence (onset, median and end) of *T. melanopogon* at the Kham and Changkleua colonies from January 2015 to April 2016. Dash line indicated local sunset time.

Times of colony emergence (onset, median, and end of emergence) in both bat colonies (the Kham and Changkleua colonies) were not different (Two Sample t-test, $t = 0.010573$, $df = 143.22$, $p\text{-value} = 0.9916$ for onset of emergence; $t = -0.14691$, $df = 143.76$, $p\text{-value} = 0.8834$ for median emergence time; $t = 0.48662$, $df = 142.36$, $p\text{-value} = 0.6273$ for end of emergence; Figure 4.14-4.16).

Sunrise time did not correlated with the onset of return (Spearman's rank correlation, $S = 1187.5$, $\rho = 0.073$, $p\text{-value} = 0.841$) but correlated with the end of return ($\rho = -0.636$, $p\text{-value} = 0.049$) (Figure 4.14).

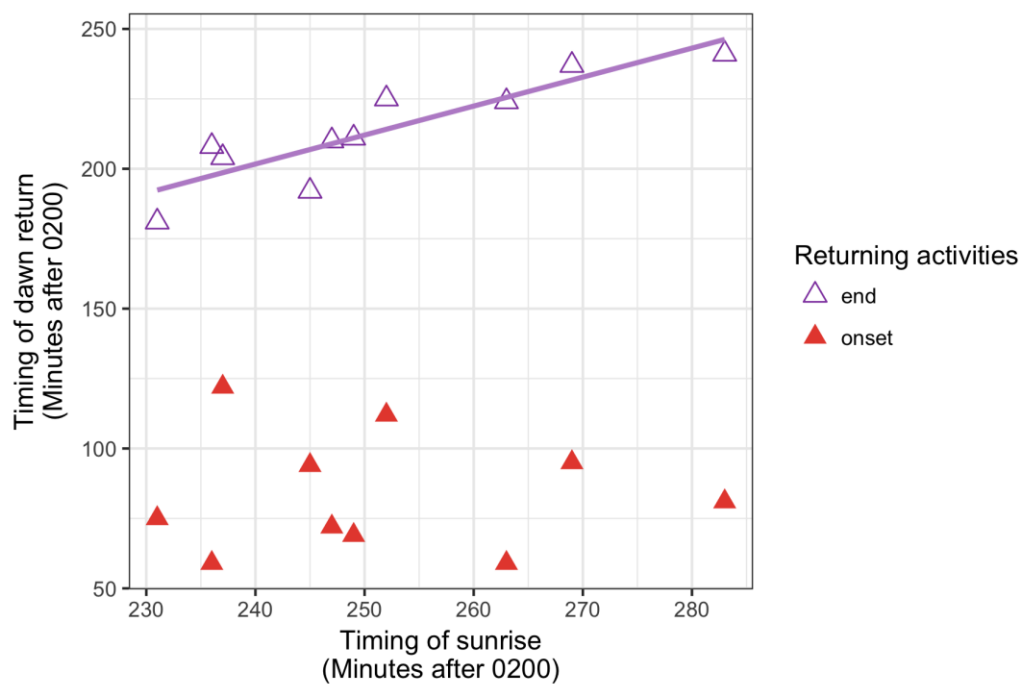


Figure 4.14 Returning activities (onset and end) of *T. melanopogon* in relation to sunrise time. Solid line represented linear regression model.

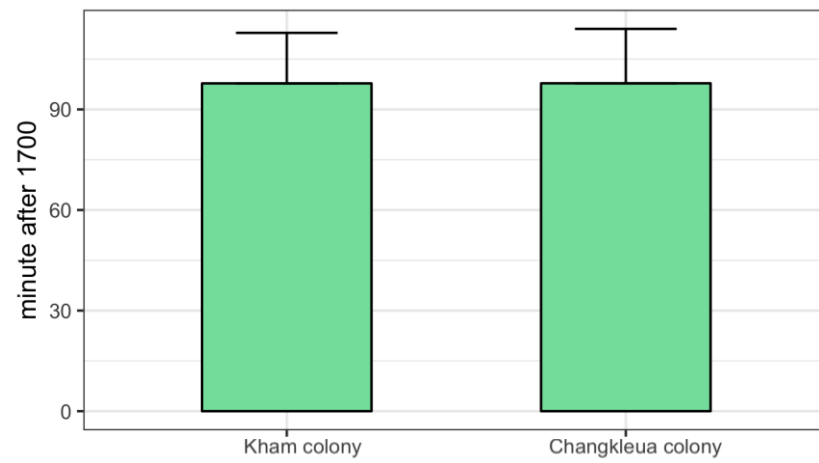


Figure 4.15 Average onset of emergence of *T. melanopogon* from the Kham and Changkleua colonies. Error bars represented standard deviation.

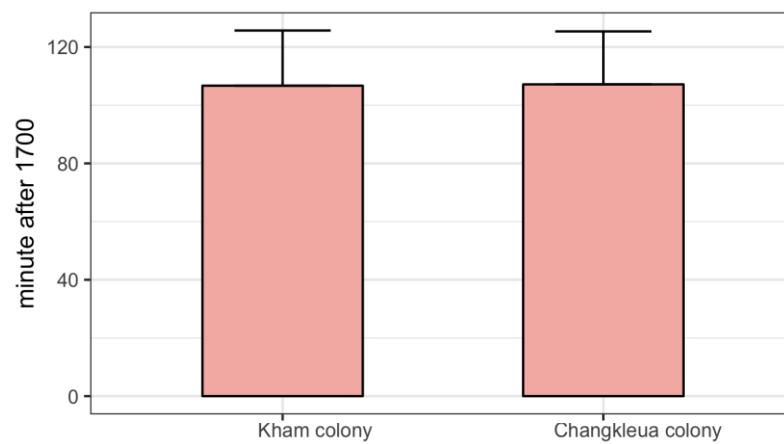


Figure 4.16 Average median emergence times of *T. melanopogon* from the Kham and Changkleua colonies. Error bars represented standard deviation.

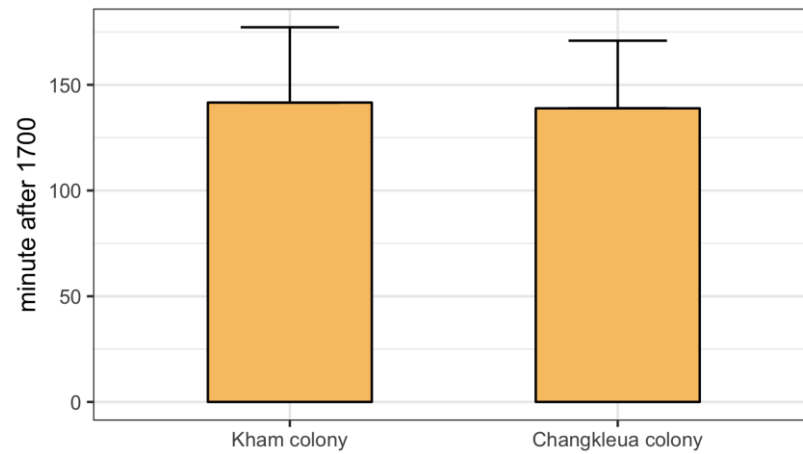


Figure 4.17 Average end of emergence *T. melanopogon* from the Kham and Changkleua colonies. Error bars represented standard deviation.

4.3 Effect of moon phase, weather conditions and reproduction to bat emergence

4.3.1 Effect of moon phase to bat emergence

Median emergence of *T. melanopogon* did not affected by illumination from lunar. No difference in median emergence time was found among full moon, half-moon and new moon nights (ANOVA, p -value=0.8247, $F_{2,145}$ =0.045). Bats departed from roosts at 23.91 ± 5.59 , 25.98 ± 6.03 and 26.78 ± 6.97 minutes in relative with local sunset time during full moon night, half and new moon night, respectively (Figure 4.18).

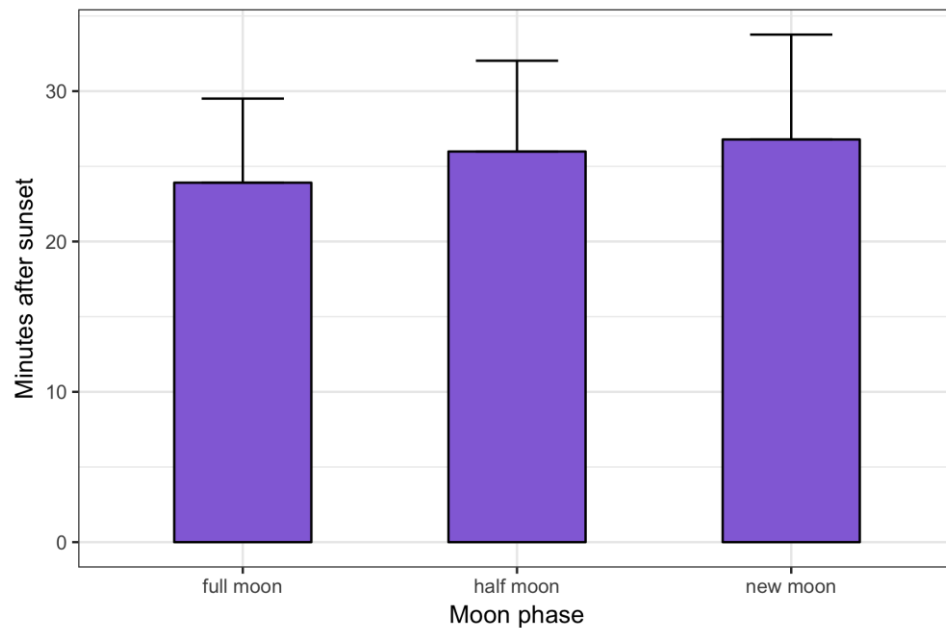


Figure 4.18 Average median emergence of *T. melanopogon* full moon, half moon, new moon nights. Error bars represented standard deviation.

4.3.2 Effect of climatic conditions to bat emergence

From January 2015 to April 2016, six weather variables at Samaesan Islands exhibited monthly fluctuation. Mean air temperature was 31.29 °C. Air temperature ranged from 25.5 to 35 °C and peaked at 33–35 °C during April- August 2015. Relative humidity was 65.63 percent in average and ranged from 37 to 96 percent. Humidity was lowest during January 2015 and peaked during September-October 2015 about 90 percent. On average, wind speed at studied site was 5.5 knots and ranged from 0 to 10 knots. Wind speed was highest during January-June 2015 and was lowest during July-

December 2015. Cloud cover was 7.6 on average and ranged from 4 to 10 in scale of ten. Air pressure was 1.005 kPa and ranged from 1.003 to 1.014 kPa.

Correlation between median emergence time and six weather variables were shown in Table 4.7. The results revealed that median emergence of *T. melanopogon* were positively correlated with, wind speed and cloud cover (Pearson's correlation, wind speed; $t = 2.525$, $df = 146$, $p\text{-value} = 0.01265$, $r = 0.2059112$; cloud cover: $t = 2.623$, $df = 146$, $p\text{-value} = 0.009633$, $r = 0.2136034$). Moreover, from multiple linear regression analysis with six weather variables as independent variables and median emergence as a dependent variable, it was found that air temperature, relative humidity, precipitation and air pressure had no effect on median emergence of *T. melanopogon* ($p\text{-value} > 0.05$). While cloud cover and wind speed were only two factors that influenced median emergence time (Multiple regression, cloud cover: $r = -0.2925322$, $p\text{-value} = 0.0164$; wind speed: $r = 0.21368586$, $p\text{-value} = 0.0149$) (Table 4.8).

Table 4.7 Pearson's correlation coefficient matrix for relationship between median emergence and six weather variables, *p-values* were shown in parentheses.

	median emergence	air temperature	relative humidity	wind speed	cloud cover	24 hours precipitation	air pressure
median emergence	1						
air temperature	-0.15 (0.05)	1					
relative humidity	-0.03 (0.7)	-0.58 (0.00*)	1				
wind speed	0.21 (0.009*)	0.18 (0.02*)	-0.33 (0.00*)	1			
cloud cover	0.21 (0.01*)	-0.46 (0.00*)	0.43 (0.00*)	0.23 (0.01*)	1		
24 hours precipitation	-0.05 (0.51)	-0.42 (0.00*)	0.41 (0.00*)	0.13 (0.11)	-0.29 (0.00*)	1	
air pressure	-0.05 (0.57)	-0.15 (0.07)	-0.25 (0.001*)	0.18 (0.03*)	-0.28 (0.001*)	-0.06 (0.41)	1

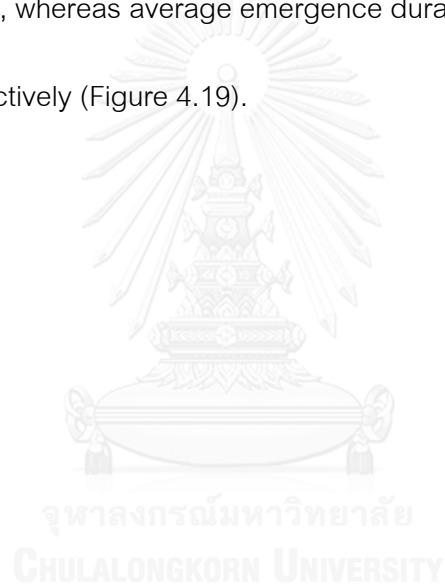
Note: * significant difference ($p\text{-value} < 0.05$)

Table 4.8 Multiple regression between median emergence and six weather variables, i.e. air temperature, relative humidity, cloud cover, wind speed, precipitation and air pressure.

Weather variables	Unstandardized coefficient		Standardized coefficient	<i>t</i>	<i>p</i> -value
	Estimated coefficient	Standard error			
(Intercept)	379.73951	221.24734		1.716	0.0883
air temperature	-0.56871	0.45723	-0.12540501	1.244	0.2157
humidity	-0.10977	0.06476	-0.18921522	-1.695	0.0923
wind speed	0.62849	0.25490	0.21368586	2.466	0.0149 *
cloud cover	1.0463	0.43068	0.2925322	2.429	0.0164 *
precipitation	-0.05656	0.07604	-0.06872252	-0.744	0.4583
air pressure	-0.31847	0.21005	-0.14587753	-1.518	0.1312

4.3.4 Effect of reproductive conditions and developmental stages to bat emergence

Variation in emergence duration was significantly detected (Kruskal-Wallis test, chi-square = 67.529, df = 15, *p-value* = 1.226e-08). During May- June 2015 and April 2016, duration of emergence was longer than other months (Mann-Whitney *U* test, *U* = 3891, *p-value* = 0.0001332), corresponding with presence of pregnant and lactating females. Average duration of emergence during May-June 2015 and April 2016 was 79.21 ± 28.72 minutes, whereas average emergence duration in other months was 39.04 ± 9.13 minutes, respectively (Figure 4.19).



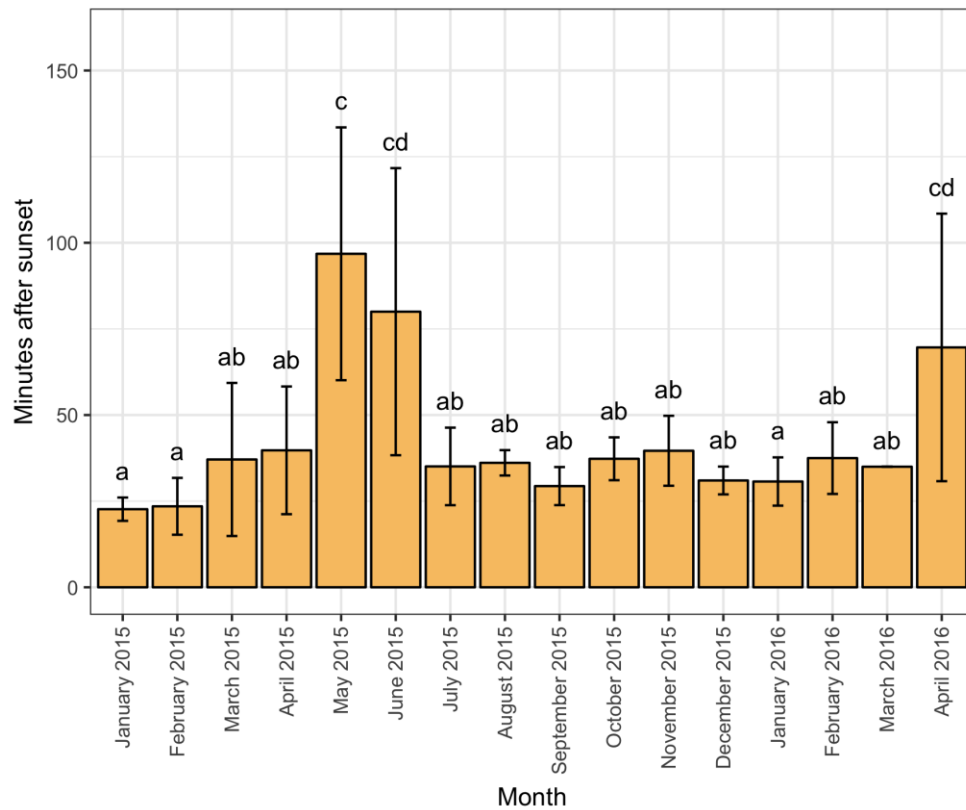


Figure 4.19 Average monthly duration of emergence of *T. melanopogon* from January 2015 to April 2016, error bars represented standard deviation and significant differences were shown in alphabets above bars.

During April-December 2015 and April 2016, 444 bats were captured for analysis of population structure, and their emergence time could be recorded. In pregnancy and lactation periods (April-June 2015 and April 2016), significant difference in emergence time related to sunset was found among adults, adults females of different reproductive stages (Kruskal-Wallis test, chi-square = 89.754, df = 3, p -value < 0.01). Emergence times of adult males (26.56 ± 3.44 minutes after sunset) was similar to non-reproductive females (22.98 ± 4.21 minute after sunset), whereas late emergence time

was found in pregnant female and lactating female (Figure 4.20). Pregnant females emerged later than lactating females (67.21 ± 11.43 minutes after sunset in pregnant female vs. 41.47 ± 9.42 minute after sunset).

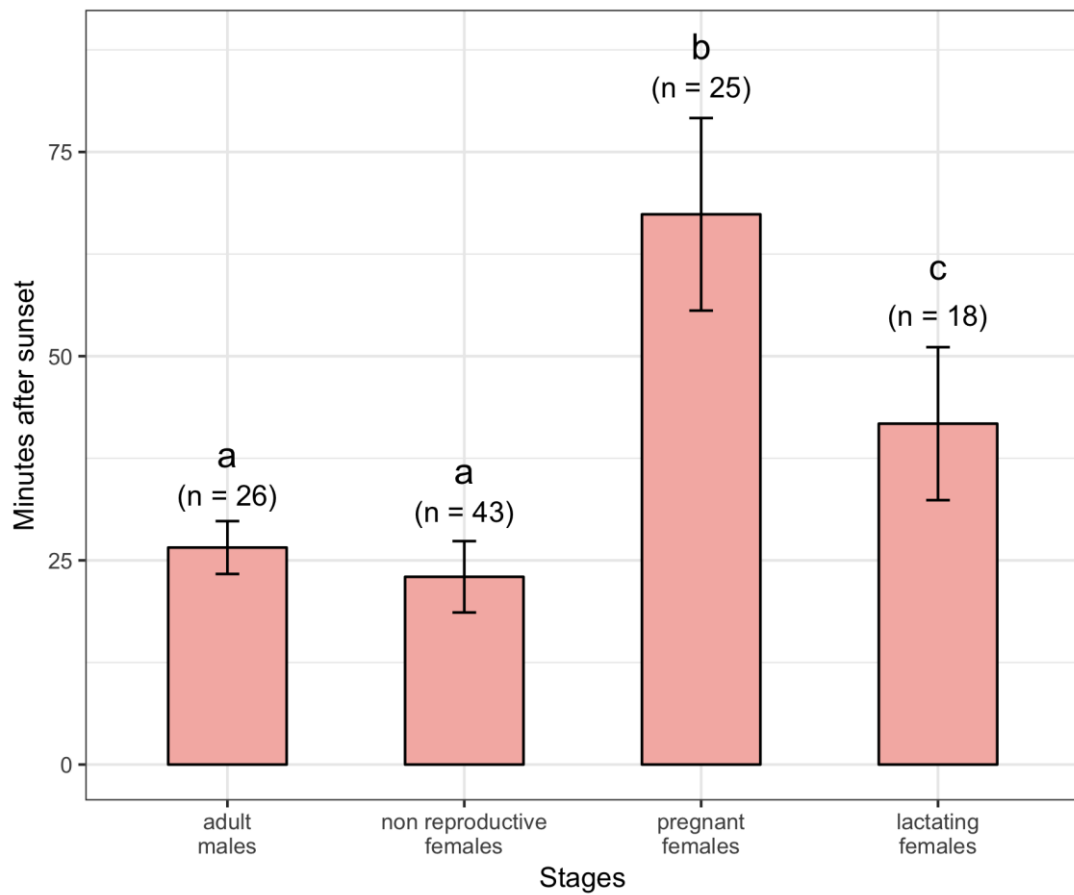


Figure 4.20 Average emergence time of *T. melanopogon* in various female reproductive statuses during April- June. Error bars represented standard deviation and significant differences were shown in alphabets above bars.

Variation in onset of emergence was significantly detected (Kruskal-Wallis test, chi-square = 56.467, df = 15, *p-value* < 0.01) (Figure 4.21). From July to December 2015, when juveniles and late juveniles were observed, significant difference in emergence time was also observe among adults, juveniles and late juveniles Kruskal-Wallis test, chi-square = 77.234, df = 2, *p-value* < 0.01; Figure 4.22). Early emergence times of late juveniles were similar to those of adults. Emergence times of juveniles, late juveniles, and adults were 27.56 ± 5.23 , 25.73 ± 4.49 and 16.12 ± 3.51 minutes after sunset, respectively.



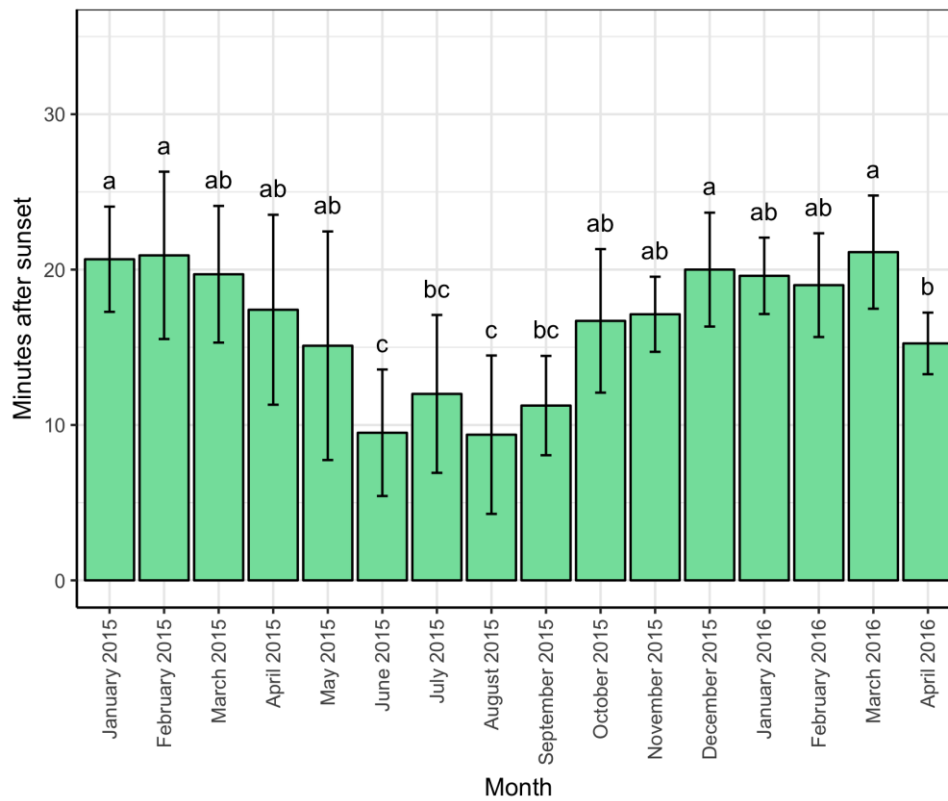


Figure 4.21 Average onset of emergence of *T. melanopogon* from January 2015 to April 2016, error bars represented standard deviation and significant differences were shown in alphabets above bars.

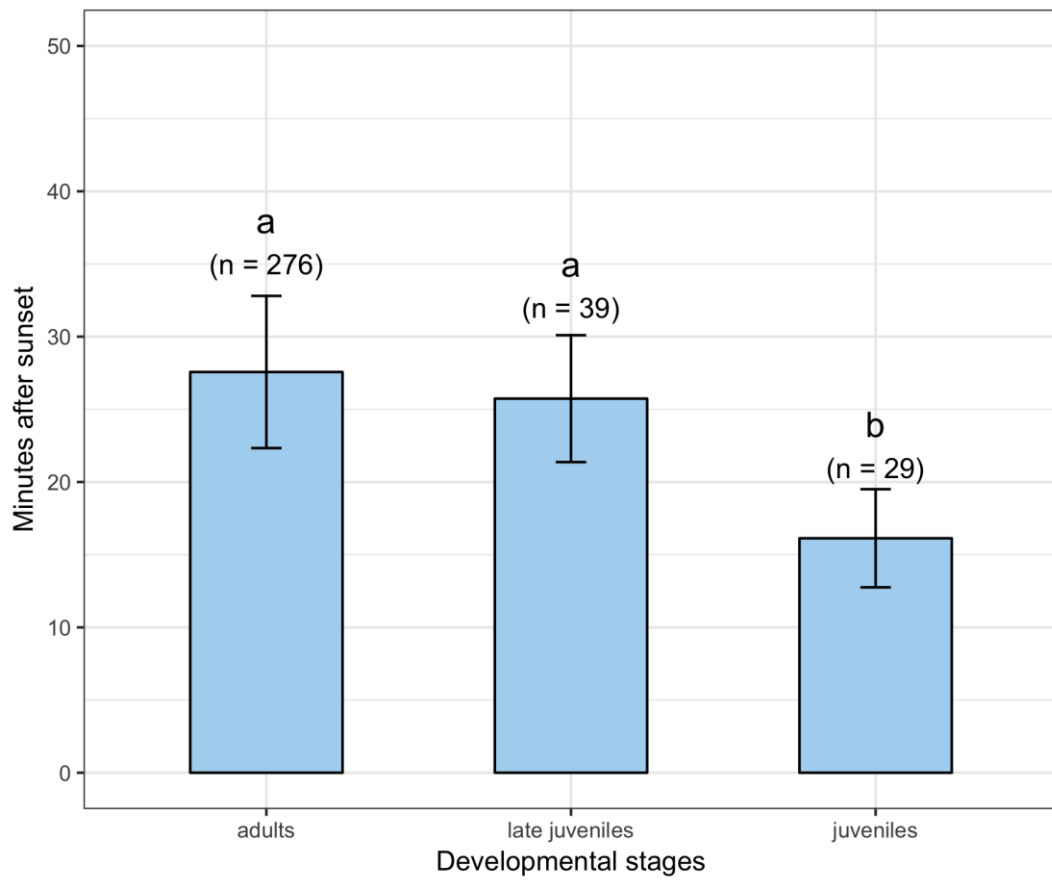


Figure 4.22 Average emergence time of *T. melanopogon* in various development stages during July-December 2015, error bars represented standard deviation and significant differences were shown in alphabets above bars.

CHAPTER V

DISCUSSION

5.1 Population dynamics of *T. melanopogon*

5.1.1 Change in colony size and composition

Trap shyness and avoidance would be low during the study because capture number and colony size from emergence count were constant in the next months. However, low recapture rate of marked bats were occurred due to frequency roost movement of bats. Many species of insectivorous bats are known that shift roosts regularly (Kunz and Fenton, 2003). For example, *Tadarida australis* switched roosts every 10.6 ± 7.9 days on average (Rhode, 2007), *Chalinolobus tuberculatus* shifted roosts almost daily (O'Donnell and Sedgely, 1999).

From low recapture rate and stable in colony size by emergence counts, it would be obvious that colony sizes estimated from various recapture sessions by Jolly-Seber method might not represented the bat colony sizes. Colony sizes estimated by Jolly-Seber method varied markedly month by month. This variability largely resulted from low percent of recapture of mark individual bats in each capture sessions. Population of *T. melanopogon* may be very large, the marked bats released to colonies would mixed with a greater number of unmarked bats, therefore, lower percent of recapture later capture sessions were occurred. In addition, data from emergence counts was reliable than estimated number from mark and recapture. Some sessions

exhibited estimated colony size by Jolly-Seber method reached over 10,000 bats in colonies, however, the observation by entering in studied cave expected that colony size of *T. melanopogon* would not exceeded to 10,000 individuals.

Results from this study confirm that Samaesan Islands is one of important area. At least 2 maternity roosts of *T. melanopogon* were found in caves at the Kham and Changkleua Island for *T. melanopogon*, bats used both caves throughout 16 months of the studied period. Moreover, some satellite roosts were also found in this area. From observation, small colony (5-10 individuals) was sometimes formed near studied colony at the Kham Island especially during lactation period. Recapture data (Table 1) indicated frequent roost switching in *T. melanopogon*. Bat might use the many roosting sites at Samaesan Islands and surrounding area. However, information about range of movement in this species is still concealed. Colony sizes of *T. melanopogon* in this study fluctuated throughout the year. The Kham colony consisted of around 195–342 individuals and the Changkleua consisted of 120–201 individuals. Colony size fluctuation might suggest the complexity of movement pattern and roost network. This bat species usually form colonies of 150–4,000 individuals (Lekagul and McNeely, 1977). Variation in colony size of *T. melanopogon* was also reported in other studies (Table 5.1).

Table 5.1 Variation in colony size of *T. melanopogon* from other studies.

colony sizes (individuals)	habitat type	studied site	references
350	cave	Guangxi, China	Wei et al, 2008
20	temple	Rajasthan, India	Purohit et al, 2012
22-130	abandoned building	Mandu and Raysen, India	Sapkal and Khaparde, 1983
50	crevices	Panay, Philippines	Mould, 2012
20-30	crevices	Kurunegala, Sri Lanka	Nanayakkara et al., 2010

Bats roost in permanent sites generally exhibit higher level of fidelity compared with ephemeral roosts (Kunz and Fenton, 2003). *T. melanopogon* showed low fidelity even they roosted in caves. Moreover, there are different degrees of roost fidelity by sex and age in different bat species. Palmeirim and Rodrigues (1995) found that female *Miniopterus schreibersii* have a strictly philopatric behavior during the nursing season, since they all returned to give birth in the colony where they had been born. Males also

showed a high level of loyalty to their birth site. However, Adult females and males of *Plecotus auritus* only showed about 39% and 48% return rates to roost sites in the following year at which they had first been captured (Entwistle et al., 2000).

It was clear that individuals in colonies move away from the roosts frequently. Based on the significant changes in sex ratio throughout the year, more males move away from the cave than females during March-October 2015. This period synced to rainy season and coincided with peak availability of food resources in the areas. Male individuals probably move away from maternity roosts for reducing diet competition.

Not only colony size but also sex ratio of *T. melanopogon* that change throughout the studied period. The greatest colony size from November 2015 to February 2016 as well as equal number of adult males and females indicated that mating season of *T. melanopogon* probably occurred during this time. Colony size and proportion of male bats declined when female entering pregnancy. These concurred with the study in India where *T. melanopogon* colony size was at a peak in January and rapidly decreased about 50% over next month (Khamre and Sapkal, 1983). And the study in Philippines where male ratio in non-maternity colony was similar to female ratio during mating season but significantly dominant during parturition which indicating female move away from their studied colonies (Nanayakkara et al., 2010).

Adult males were found in both maternity colonies of *T. melanopogon* throughout studied period, unlike some bat species which male and female bats roost in separate caves during pregnancy and lactation periods. In several vespertilionid bats of

the temperate zone such as *Myotis lucifugus* and *Pipistrellus pipistrellus* (Speakman, 1991) that males select cooler roosts to save energy and pregnant and lactating females choose warmer roosts for fetal development or postnatal growth of juvenile. From observations, satellite colonies (possibly bachelor colonies) of *T. melanopogon* were sometimes found in separate roosts. Males that roosted with females in breeding colonies might be gained some reproductive benefits by increasing the opportunities of finding mates (Bronson, 1962).

5.1.2 Reproduction of *T. melanopogon*

Female bred once a year and gave only one infant during breeding season. This result also found in previous studies (Kunz and Pierson, 1994; Lekagul and McNeely, 1977). Although swelling on abdomen indicating pregnancy in bats was observed during April-June 2015, the initiation of pregnancy probably occurred in February and March 2015 when average body mass of females slightly increase. Duration of pregnancy in *T. melanopogon* was about 4 months (Sapkal and Khamre, 1983), suggesting that copulation in *T. melanopogon* occurred around January. Previous studies indicated that, after parturition, babies will be carried by their mothers for at least 10-15 days (Lekagul and McNeely, 1977) until their weight reached to 15-17 grams (Sapkal and Khamre, 1983). In this study, during the early period of lactation in May 2015, lactating females carrying baby at their breasts were sometimes captured. One lactating females with a baby was captured on May 2014. Weight of mother and suckling were 23.5 and 8.0 grams, respectively. Weaning probably started in June when

independent juveniles were initially observed. Juveniles were found in maternity colonies during June-August 2015. They were significantly smaller than adults in term of weight and forearm length. After that, juveniles grew up in to late juvenile stage, while late juveniles were similar to adults in term of weight and body mass but fur of late juvenile were darker. Late juveniles were found in studied site from July to December.

Among the emballonurid bats, while *T. longimanus*, *Rhynchonycteris nano* breed throughout the year, while *T. georgianus* and *T. melanopogon* breed once per year in a restricted season. It is interesting that two closely allied species such as *T. melanopogon* and *T. longinus* live under the same climatic conditions but possesses divergence of breeding strategies.

High proportion of males with black beard was found from November 2015 and February 2016 suggesting the mating season of *T. melanopogon* during this time of yaer. Beard in males *T. melanopogon* situated on gradular area under the throat (Delany, 1989) which is noticable in adult males. This gland probably involved in agonistic or mating behavior because gradular area on several other species of bats playing a role in behavior particularly olfactory signal. For example, Pearson et al. (1952) recorded that the glandular snout of *Corynorhinus rafinesquei* is rubbed over females of that species during pre-copulatory behavior, apparently to induce submission. Bradbury and Vehrencamp (1977) observed male *Saccopteryx bilineata* voluntarily open the muscular opening tube of its wing gland and shake its wings during territorial display against female and during interaction within their territory with female.

Brosset (1962) reported that mating system of *T. melanopogon* was polygynous (one male mate with multiple females). This mating system is characterized by resource defense polygyny which male provides and defends essential resources such as nesting site to females. In cave where *T. melanopogon* often roost in large colonies of thousands of individuals, a safe nesting site is essential to the raising of juveniles. The quality of the nesting site and the ability of a male bat to defend it may determine male ranking. Most successful males in this resource defense are able to mate with more females (Lekagul and McNeely, 1977; Nowak, 1991).

An increasing of male ratio during mating season might also reflect polygynous. Mating system of *T. malanopogon* is likely to correlate with variation of testes size (Wilkinson and McCracken, 2003). In some bat species such as *T. longinimus*, testes migrate seasonally from abdomen to external inguinal ring, where they appear to lie within an unpigment sac of fascia. Benefit of this movement is to get more efficient in spermatogenesis when the ambient temperature is high (Jolly and Blackshaw, 1987)

Photoperiod may be the environmental factor regulating the timing of reproduction in temperate animals especially in males (Bronson, 1985; Heideman, 2000). However, the reproductive rhythms of male *T. melanopogon* from this study did not positively correlated with photoperiod. Racey and Entwistle (2000) suggested that food supply is a major factor determining the reproductive timing in tropical male bats. Rainfall is probably an important factor in seasonal reproduction in many bats (Racey and Entwistle, 2000). This factor influences plant availability and insect availability in the

tropic zones (Heideman, 2000). The period of late pregnancy, lactation and weaning are the most energetically costly reproductive stages in female bats (Speakman and Racey, 1987). In addition, the period immediately after weaning is the most critical for juvenile bats (Heideman, 2000). Reproduction should be timed so that pregnancy, lactation and weaning coincide with the period of high food availability (Heideman, 2000).

Although tropics are the place that climate are stability, several bat species including *T. melanopogon* also show seasonal in breeding. This is because of energy requirement for reproduction that breeding periods of bat time generally coincide with the period of greatest food resource availability (Racey and Entwistle, 2000).

5.2 Emergence activities of *T. melanopogon*

The results indicated that emergence activities of *T. melanopogon* strongly related to sunset. This study found no effect of location and lunar cycle to bat emergence. Moreover, the results also suggested that reproductive and developmental conditions, weathers (wind speed and cloud cover) affected emergence time of *T. melanopogon*.

5.2.1 Bat activities at cave entrance in relation to local sunset time and sunrise

In most bat species that have been studied to date, emergence activities are correlated with timing of sunset (Erkert, 1982; Swift, 1980; McAney and Fairley, 1988; Korine et al. 1994; Catto et al. 1995; Kunz and Anthony 1996; Lee and McCracken 2001). In this study, the results also conform to those studies that emergence timing was

strongly correlated with the time of sunset but varied with time of season, weather variables.

The mean emergence times at those two colonies were not significantly different. These because of the similar environmental variables and population structure in both caves. Similar results was found in *Rhinolophus hipposideros* (McAney and Fairley, 1988). Although colony size of the Kham was greater than colony size of the Changkleua, emergence rates of those two were not different significantly. Even though, some studies (Swift, 1980; Bullock et al., 1987) indicated that *Pipistrellus pipistrelles* in larger size of colony tend to spend longer of departure time. But this aspect did not conform in this study because colony size in this study was relative small.

Although timing of emergence was correlated with sunset time. It seemed that time of last fly out bat was less rely on the sunset. And this probably could be the effect of female reproductive stages. Onset of emergence is a less reliable indicator of the time of emergence than median emergence. In some bat species, there may be an unusually long time gap between the emergence of first bat and the main emergence (Bullock et al. 1987). Or that time of first bat may be affected by the size of the colony suggested that this bat emerge at lower light intensities (Kunz and Anthony, 1996).

Among insectivorous bats, *T. melanopogon* is generally considered as a late emergence (Rydell et al., 1996) when compared with fast flying species like *Noctulus*, *Serotine* and *Pipistrellus* (Catto et al., 1995; Bullock et al., 1987). Jones and Rydell

(1994) reported the time of first bat emerged for *T. melanopogon* of 24 minutes after sunset. Wei et al. (2008) reported the onset of emergence began within 31 minutes after sunset.

5.2.2 Effect of moon phase to bat emergence

The reason why bats respond to various lunar cycles came is the respond from predation. Bright nights during full moon should favor visually orienting predators. Most animals with strong lunar phobia have lifestyle searching for food in open spaces. Thus it was exposed to predators with nocturnal vision such as owls. Hence, lunar phobia is frequently seemed as an avoidance behavior towards the presence of predators (Rydell and Speakman. 1995). However, the results of this study did not conform to previous studies that bats adapted their behavior in relation to various illumination from lunar cycle. The possible reason was that predation at cave entrance may be low because diurnal predators had been never observed during bat emergence activities.

5.2.3 Effect of weather conditions to bat emergence

Weather conditions (air temperature, relative humidity, wind speed , cloud cover, rainfall and air pressure) were analyzed to investigate the relationship with median emergence in the study. There were only two weather variables that explained a significant variation in the timing of the median of emergence which were cloud cover and wind speed.

Early emergence on cloudy nights has been reported for other bat species (Kunz and Anthony, 1996; Welbergen, 2006). Those because cloud cover was associated with reduces the amount of light available from the sun. Emerging when light intensity was low seems to be adaptive with respect to predation from raptors whose hunting vision declines with decreasing light levels (Welbergen, 2006). However, this results exhibited a contrast of those studies. An increasing of cloud cover leaded to later emergence of the bat. The reason may be that cloud cover indicate bad weather situation for flight such as rain. This study indicated that cloud cover at 1900 was significantly correlated with 24 hours of precipitation. However, 24 hours of precipitation did not show significant difference on bat emergence. The reason was because precipitation data in 24 hours may not reflect whether rain was heavy or not. Light rain has no effect on bat emergence (Erkert, 1982). Several studies have reported that only heavy rain decreases bat activities (Erkert, 1982; Shiel and Fairley 1999).

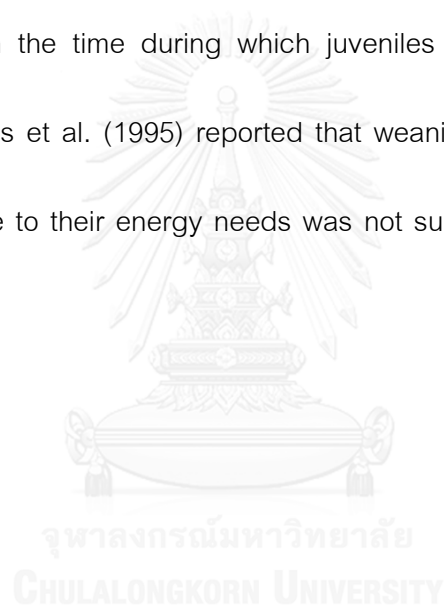
Wind speed had an effect on peak emergence time. The wind at Samaesan Islands can reach up to 8 m/s during the time of recording. Moderate wind speeds likely have no effect on bat activities (Welbergen, 2006; Russo et al., 2003). However, some studies have found bat activities to be reduced as a result of strong wind (O'Farrell and Bradley, 1970; Erkert, 1982). O'Farrell and Bradley (1970) found that wind only affected activities once it reached above 4.02 m/s. The reason that wind affects bat activities when it is very strong, such that bats may be physically unable to fly.

5.2.4 Effect of reproductive conditions and developmental stages to bat emergence

The emergence time varied in relation to bat reproductive periods. *T. melanopogon* tended to emerge later during April-May 2015 and April 2016 than during other periods, which that was pregnancy and lactation periods. Late emergence from late pregnancy and early lactation was also reported for *Nyctalus noctula* (Jones and Rydell, 1994), *Eptesicus nilssonii* (Duverge et al., 2000), *Rhinolophus ferrumequinum* (Duverge et al. 2000) and *Eptesicus serotinus* (Catto et al., 1996) which those bat species carry early juveniles during foraging flight. This study revealed significant differences in the timing of emergence between late-pregnancy and early-lactation periods with other periods, which has been suggested that pregnant and early lactating females tend to depart later as a consequence of an increased body loading that negatively affect maneuverability and increases predation risk (Duverge et al., 2000). On the other hand, late-lactating females, which have increased energetic demands, should be forced to emerge earlier to exploit the dusk peak in insect activities (Duverge et al., 2000). But this study did not conform that aspect. The reason might be this study carried out in tropical areas where the insect availability is abundance.

The emergence time of juvenile bats related to their body mass and wing morphologies. Juveniles are poor flyer and may be attacked more easily by predators. Several studies have shown that newly volant juvenile tend to emerge later than adults until a certain developmental stage (Kunz and Anthony, 1996; Lee and McCracken,

2001). The increasing of predation risk due to lesser flight ability (Kunz and Anthony, 1996; Duvergé et al., 2000; Lee and McCracken, 2002) and reducing of foraging needs because energy needs was supplied by milk from mothers (Jones et al., 1995) were the reasons that explained emergence time of newly volant juveniles. However, the results in this revealed that juvenile departed earlier compared to adult time. This was probably due to this juveniles were weaning which have high energy need to growth. This study overlapped with both the time during which juveniles were learning to fly and the weaning period. Jones et al. (1995) reported that weaning juveniles tended to depart earlier than adults due to their energy needs was not supplemented by milk from their mothers.



CHAPTER VI

CONCLUSIONS AND RECOMENDATIONS

6.1 Conclusions

From the study of population dynamics of *T. melanopogon* from January 2015 to April 2016 at 2 maternity colonies (the Kham and Changkleua colonies), the colony sizes changed seasonally throughout the studied period. An increasing of colony size as well as ratio of males in colonies coincided with sign of potential breeder in males (testes moved to scrotal pouch and substances recreating to gular pore), these indicated that mating season occurred during November 2015- February 2016. After that, colony size was sharply declined as well as proportion of male bats in colonies, and pregnancy and lactation in females were observed. Female bred once a year and gave only one infant during breeding season. Juveniles were weaned within two months after lactating females were observed. Parturition and lactation period synced to early rainy season and coincided with peak availability of food resources. Recapture data indicated that frequent roost switching in this species and, moreover, some satellite roosts were also observed nearby. Roosting flexibility in this species may suggest the complexity of roost network and movement pattern.

Bats exhibited two major activities at cave entrance, emergence and returning, which peaked in short period after dusk and before dawn. It suggested from foraging strategies and wing morphology of this species. The emergence activities may

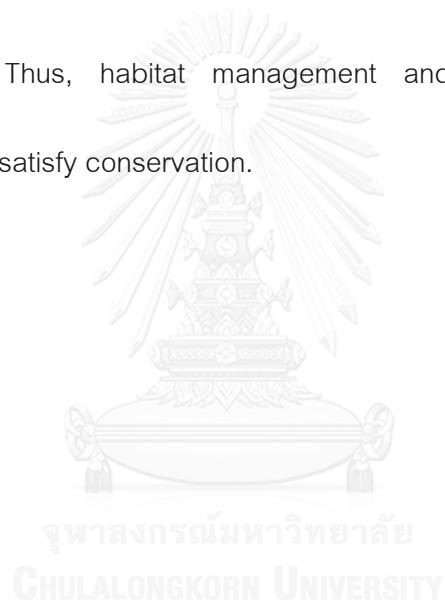
accompany light intensity at cave entrance. Thus onset and end of departure activities was mainly influenced from sunset time. However, initiation of returning was not influenced from sunrise, whereas end of returning was correlated to sunrise time. The reason was that bats may exhibited individual duration of foraging. No effect of roosts location to emergence times of bats in this study. Likewise, median emergence time of bat colonies, which was defined as the time when the fiftieth percent of individuals in colonies emerged, did not influence by lunar cycle. Two weather variables correlated with emergence time. Wind speed caused unfavorable flight condition to bats. However, less available data can explain why cloud cover influenced on emergence time of this species.

Duration of colony emergence varied significantly throughout the studied period which longest during parturition and lactation period. At this time, pregnant and lactating females changed their emergence time which emerge delay than usual. Pregnant and lactating female tended to lately departure and this may be resulted from reduction of flight performance with increasing of loading (babies).

Another variation in emergence times was also found when juveniles presented in colonies. During this time, emergence time of colony tend to start early than usual. Juveniles may be forced to emerge early from supple requirement because they lack of food supplements from mothers.

6.2 Recommendations

1. For better understanding the timing of reproduction in this species, period of study should be exceeded 2 years and hormone testing should be involved.
2. Larger area of study should be conducted for clear view of roost network in this species.
3. To date, large number of insectivorous bats is facing extinct due to habitat degradation. Thus, habitat management and understanding should be considered to satisfy conservation.



REFERENCES

- Ables, E.D. 1969. Activity studies of Red Foxes in Southern Wisconsin. The Journal of Wildlife Management 33: 145-153.
- Altringham, J. 1998. Bats: Biology and Behaviour. Reprint edition. Oxford University Press.
- Anthony, E.L.P. 2000. Endocrinology of reproduction in bats. Crichton, Elizabeth G. In Krutzsch, P.H. (ed.), Reproductive Biology of Bats, pp. 1-26. London: Academic Press.
- Balasingh, J., Isaac, S., and Subbaraj, R. 1992. A convenient device for tagging bats in the field. Bat Research News 33: 6.
- Barclay, R.M.R. and Harder, L.D. 2003. Life histories of bats: life in the slow lane. In Kunz, T.H. and Fenton, M.B. (ed.), Bat ecology, pp. 209-253.
- Bates, P.J.J. and Harrison, D.L. 1997. Bats of the Indian Subcontinent. Harrison Zoological Museum.
- Bradbury, J.W. and Vehrencamp, S.L. 1977. Social organization and foraging in Emballonurid Bats: IV. parental investment patterns. Behavioral Ecology and Sociobiology 2: 19-29.
- Bronson, F.H. 1985. Mammalian reproduction: an ecological perspective. Biology of Reproduction 32: 1-26.
- Brosset, A. 1962. The bats of Central and Western India. Part. iii. Journal of The Bombay Natural History Society 59: 707-746.
- Brunet-Rossinni, A.K. and Austad, S.N. 2004. Ageing studies on bats: a review. Biogerontology 5: 211-222.
- Brunet-Rossinni, A.K. and Wilkinson, G.S. 2009. Methods for age estimation and the study of senescence in bats. In Kunz, T.H. (ed.), Ecological and behavioral methods for the study of bats, pp. 315-325. Johns Hopkins University Press.

- Bullock, D.J., Combes, B.A., Eales, L.A., and Pritchard, J.S. 1987. Analysis of the timing and pattern of emergence of the pipistrelle bat (*Pipistrellus pipistrettus*). Journal of Zoology 211: 267-274.
- Camus, P.A. and Lima, M. 2002. Populations, metapopulations, and the open-closed dilemma: The conflict between operational and natural population concepts. Oikos 97: 433-438.
- Catto, C.M.C., Racey, P.A., and Stephenson, P.J. 1995. Activity patterns of the serotine bat (*Eptesicus serotinus*) at a roost in southern England. Journal of Zoology 235: 635-644.
- Corbet, G.B., and Hill, J.E. 1992. The Mammals of the Indomalayan Region: A Systematic Review. Oxford ; New York: Oxford University Press.
- Crichton, E.G. 2000. Sperm storage and fertilization. In (ed.), Reproductive Biology of Bats, pp. 295-320. London: Academic Press.
- Crichton, E.G. and Krutzsch, P.H. 2000. Reproductive Biology of Bats. London: Academic Press.
- Csorba, G., Bumrungsri, S., Helgen, K., Francis, C., Bates, P., Gumal, M., Balete, D., Heaney, L., Molur, S. and Srinivasulu, C. 2008. *Taphozous melanopogon*. The IUCN Red List of Threatened Species 2008: e.T21461A9281177. <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T21461A9281177.en>. Downloaded on 25 December 2016.
- Delany, M.J. 1989. The zoogeography of the mammal fauna of southern Arabia. Mammal Review 19: 133-152.
- Dimmitt, M.A. and Ruibal, R. 1980. Environmental Correlates of Emergence in Spadefoot Toads (*Scaphiopus*). Journal of Herpetology 14: 21-29.
- Doucet, G.J. and Bider, J.R. 1974. The effects of weather on the activity of the Masked Shrew. Journal of Mammalogy 55: 348-363.
- Duvergé, P.L., Jones, G., Rydell, J., and Ransome, R.D. 2000. Functional significance of emergence timing in bats. Ecography 23: 32-40.

- Entwistle, A.C., Racey, P.A., and Speakman, J.R. 1996. Habitat Exploitation by a Gleaning Bat, *Plecotus auritus*. Philosophical Transactions of the Royal Society of London B: Biological Sciences 351: 921-931.
- Entwistle, A.C., Racey, P.A., and Speakman, J.R. 2000. Social and population structure of a gleaning bat, *Plecotus auritus*. Journal of Zoology 252: 11-17.
- Erkert, H.G. 1982. Ecological Aspects of Bat Activity Rhythms. In Kunz, T.H. (ed.), Ecology of Bats, pp. 201-242. Springer US.
- Fernandez-Duque, E. 2003. Influences of moonlight, ambient temperature, and food availability on the diurnal and nocturnal activity of owl monkeys (*Aotus azarai*). Behavioral Ecology and Sociobiology 54: 431-440.
- Findley, J.S. 1993. Bats: A Community Perspective. CUP Archive.
- Fleming, T.H. 1988. The Short-Tailed Fruit Bat: A Study in Plant-Animal Interactions. University of Chicago Press.
- Fleming, T.H. and Eby, P. 2003. Ecology of bat migration. In Fenton, T.H. (ed.), Bat ecology, pp. 156-208. Chicago, Illinois: University of Chicago Press.
- Fleming, T.H., Hooper, E.T., and Wilson, D.E. 1972. Three central american bat communities: structure, reproductive cycles, and movement patterns. Ecology 53: 556-569.
- Gaffney, M.F. and Hodos, W. 2003. The visual acuity and refractive state of the American kestrel (*Falco sparverius*). Vision Research 43: 2053-2059.
- Griffin, D.R., Webster, F.A., and Michael, C.R. 1960. The echolocation of flying insects by bats. Animal Behaviour 8: 141-154.
- Heideman, P.D. 1988. The timing of reproduction in the fruit bat *Haplonycteris fischeri* (Pteropodidae): geographic variation and delayed development. Journal of Zoology 215: 577-595.
- Heideman, P.D. 2000. Environmental Regulation of Reproduction. In Krutzsch, P.H. (ed.), Reproductive Biology of Bats, pp. 469-499. London: Academic Press.

- Horikoshi, M. and Tang, Y. 2016. ggfortify: Data Visualization Tools for Statistical Analysis Results (Version R package version 0.2.0.). Retrieved from <https://CRAN.R-project.org/package=ggfortify>.
- Hutson, A.M., Mickleburgh, S.P., and Racey, P.A. 2001. Microchiropteran bats: global status survey and conservation action plan. Gland, Switzerland ;: IUCN.
- Jolly, S.E. and Blackshaw, A.W. 1987. Prolonged epididymal sperm storage, and the temporal dissociation of testicular and accessory gland activity in the common sheath-tail bat, *Taphozous georgianus*, of tropical Australia. Journal of Reproduction and Fertility 81: 205-211.
- Jolly, S.E. and Blackshaw, A.W. 1988. Testicular migration, spermatogenesis, temperature regulation and environment of the sheath-tail bat, *Taphozous georgianus*. Journal of Reproduction and Fertility 84: 447-455.
- Jones, G. and Rydell, J. 1994. Foraging Strategy and Predation Risk as Factors Influencing Emergence Time in Echolocating Bats. Philosophical Transactions of the Royal Society of London B: Biological Sciences 346: 445-455.
- Khaparde, M.S. and Sapkal, V.M. 1976. Notes on the Breeding Habits of the Indian Sheath tailed Bat *Taphozous melanopogon*. Journal of The Bombay Natural History Society 73: 321-324.
- Korine, C., Izhaki, I., and Makin, D. 1994. Population structure and emergence order in the fruit-bat (*Rousettus aegyptiacus*: Mammalia, Chiroptera). Journal of Zoology 232: 163-174.
- Korpimäki, E. and Krebs, C.J. 1996. Predation and Population Cycles of Small Mammals. BioScience 46: 754-764.
- Krebs, C.J. 2000. Ecology: The Experimental Analysis of Distribution and Abundance, Package. 5 edition. San Francisco: Benjamin Cummings.
- Kunz, T.H. and Anthony, E.L.P. 1996. Variation in the timing of nightly emergence behavior in the little brown bat, *Myotis lucifugus* (Chiroptera: Vespertilionidae). In (ed.), mammalogy: a memorial volume honoring Dr. J. Knox Jones Jr., pp. 225-235. Texas: Texas Tech University.

- Kunz, T.H., and Fenton, M.B. 2003. Bat Ecology. University of Chicago Press.
- Kunz, T. H. and E. D. Pierson. 1994. Bats of the world: an introduction. In(ed.), Walker's Bats of the World: pp 1-46.
- Lang, A.B., Kalko, E.K.V., Römer, H., Bockholdt, C., and Dechmann, D.K.N. 2006. Activity levels of bats and katydid in relation to the lunar cycle. Oecologia 146: 659-666.
- Lausen, C.L. and Barclay, R.M.R. 2003. Thermoregulation and roost selection by reproductive female big brown bats (*Eptesicus fuscus*) roosting in rock crevices. Journal of Zoology 260: 235-244.
- Lee, Y.F. and McCracken, G.F. 2001. Timing and variation in the emergence and return of Mexican free-tailed bats, *Tadarida brasiliensis mexicana*. Zoological Studies 40: 309-316.
- Lekagul, B. and McNeely, J.A. 1977. Mammals of Thailand. Bangkok: Association for the Conservation of Wildlife.
- Lima, S.L. 1998. Stress and Decision Making under the Risk of Predation: Recent Developments from Behavioral, Reproductive, and Ecological Perspectives. Ecology 27: 215-290.
- Lima, S.L. and Dill, L.M. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Canadian Journal of Zoology 68: 619-640.
- Loudon, S. and Racey, P. 1987. Reproductive energetics in mammals. New York: Oxford University Press.
- Mares, M.A. and Wilson, D.E. 1971. Bat Reproduction during the Costa Rican Dry Season. BioScience 21: 471-477.
- McAney, C.M. and Fairley, J.S. 1988. Activity patterns of the lesser horseshoe bat *Rhinolophus hipposideros* at summer roosts. Journal of Zoology 216: 325-338.
- McCracken, G.F. and Wilkinson, G.S. 2000. Bat Mating Systems. In Krutzsch, P.H. (ed.), Reproductive Biology of Bats, pp. 321-362. London: Academic Press.

- Mello, M.A.R., Kalko, E.K.V., and Silva, W.R. 2013. Effects of moonlight on the capturability of frugivorous phyllostomid bats (Chiroptera: Phyllostomidae) at different time scales. Zoologia (Curitiba) 30: 397-402.
- Meyer, C.F.J., Schwarz, C.J., and Fahr, J. 2004. Activity Patterns and Habitat Preferences of Insectivorous Bats in a West African Forest-Savanna Mosaic. Journal of Tropical Ecology 20: 397-407.
- Mickleburgh, S.P., Hutson, A.M., and Racey, P.A. 2002. A review of the global conservation status of bats. Oryx 36: 18-34.
- Molur, S., et al. 2002. Status of South Asian Chiroptera: Conservation Assessment and Management Plan (CAMP) Workshop Report, 2002. Zoo Outreach Organisation, CBSG South Asia and WILD, Coimbatore, India, CD-Rom 1: 1-320.
- Mould, A. 2012. Cave bats of the central west coast and southern section of the Northwest Panay Peninsula, Panay Island, the Philippines. Journal of threatened taxa 4: 2993-3028.
- Nanayakkara, R.P., Vishvanath, N., and Kusuminda, T.G.T. 2012. Re-discovery of Pouch bearing sheath tailed bat *Saccolaimus saccolaimus* Temminck (Chiroptera: Emballonuridae) from Sri Lanka after 75 years. Asian Journal of Conservation Biology 1: 134-137.
- Nowak, R. 1991. Order Chiroptera. In (ed.), Walker's Mammals of the World, pp. 190-194. Baltimore: Johns Hopkins University Press.
- O'Farrell, M.J. 1974. Seasonal Activity Patterns of Rodents in a Sagebrush Community. Journal of Mammalogy 55: 809-823.
- O'Shea, T.J., Bogan, M.A., and Ellison, L.E. 2003. Monitoring Trends in Bat Populations of the United States and Territories: Status of the Science and Recommendations for the Future. USGS Staff Published Research.
- O'Shea, T.J., Ellison, L.E., and Stanley, T.R. 2011. Adult survival and population growth rate in Colorado big brown bats (*Eptesicus fuscus*). Journal of Mammalogy 92: 433-443.

- O'Donnell, C.F.J. 2000. Conservation status and causes of decline of the threatened New Zealand Long-tailed Bat *Chalinolobus tuberculatus* (Chiroptera: Vespertilionidae). Mammal Review 30: 89-106.
- O'Farrell, M.J. and Bradley, W.G. 1970. Activity Patterns of Bats over a Desert Spring. Journal of Mammalogy 51: 18-26.
- Palmeirim, M. and Rodrigues, L. 1995. Dispersal in colonial animals —the case of *Miniopterus schreibersii*. In Racey, P.A. and Swift, S.M. (ed.), Ecology, evolution and behaviour of bats, pp. Newyork: Oxford: Oxford University Press.
- Papadatou, E., Butlin, R.K., Pradel, R., and Altringham, J.D. 2009. Sex-specific roost movements and population dynamics of the vulnerable long-fingered bat, *Myotis capaccinii*. Biological Conservation 142: 280-289.
- Payne, J., Francis, C.M., and Phillipps, K. 1985. A field guide to the mammals of Borneo. Kota Kinabalu, Sabah, Malaysia: Sabah Society ;.
- Pearson, O.P., Koford, M.R., and Pearson, A.K. 1952. Reproduction of the Lump-Nosed Bat (*Corynorhinus rafinesquei*) in California. Journal of Mammalogy 33: 273-320.
- Podlutzky, A.J., Khritankov, A.M., Ovodov, N.D., and Austad, S.N. 2005. A New Field Record for Bat Longevity. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 60: 1366-1368.
- Polis, G.A. and Farley, R.D. 1980. Population Biology of a Desert Scorpion: Survivorship, Microhabitat, and the Evolution of Life History Strategy. Ecology 61: 620-629.
- Pryde, M.A., O'Donnell, C.F.J., and Barker, R.J. 2005. Factors influencing survival and long-term population viability of New Zealand long-tailed bats (*Chalinolobus tuberculatus*): Implications for conservation. Biological Conservation 126: 175-185.
- Purohit, A., Soni, P., Kaur, A., and Ram, H. 2012. First record of *Taphozous melanopogon* in the Barmer area of the Thar Desert, Rajasthan, India. Vespertilio 16: 241-242.

- Racey, P.A. and Entwistle, A.C. 2000. Life-history and Reproductive Strategies of Bats. In Krutzsch, P.H. (ed.), Reproductive Biology of Bats, pp. 363-414. London: Academic Press.
- Racey, P.A. and Swift, S.M. 1981. Variations in gestation length in a colony of pipistrelle bats (*Pipistrellus pipistrellus*) from year to year. Journal of Reproduction and Fertility 61: 123-129.
- Rautenbach, I.L., Kemp, A.C., and Scholtz, C.H. 1988. Fluctuations in Availability of Arthropods Correlated with Microchiropteran and Avian Predator Activities. Koedoe; Vol 31, No 1 (1988).
- Ricklefs, R.E. and Wikelski, M. 2002. The physiology/life-history nexus. Trends in Ecology & Evolution 17: 462-468.
- Russo, D. and Jones, G. 2003. Use of Foraging Habitats by Bats in a Mediterranean Area Determined by Acoustic Surveys: Conservation Implications. Ecography 26: 197-209.
- Russo, D., Jones, G., and Migliozi, A. 2002. Habitat selection by the Mediterranean horseshoe bat, *Rhinolophus euryale* (Chiroptera: Rhinolophidae) in a rural area of southern Italy and implications for conservation. Biological Conservation 107: 71-81.
- Rydell, J., Entwistle, A., and Racey, P.A. 1996. Timing of foraging flights of three species of bats in relation to insect activity and predation risk. Oikos 76: 243-252.
- Rydell, J. and Speakman, J.R. 1995. Evolution of nocturnality in bats: Potential competitors and predators during their early history. Biological Journal of the Linnean Society 54: 183-191.
- R Core Team. 2016. R: A language and environment for statistical computing (Version. 3.3.2) Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <http://www.R-project.org/>.
- Sapkal, V.M. and Khamre, K.G. 1983. Breeding habits and associated phenomenon in some Indian bats. Part 8 - *Taphozous melanopogon* (Temminck) - Emballonuridae. Journal of The Bombay Natural History Society 80: 303-311.

- Shirley, M.D.F. 2001. Assessing the impact of a music festival on the emergence behaviour of a breeding colony of Daubenton's bats (*Myotis daubentonii*). Journal of Zoology 254: 367-373.
- Sinha, Y.P. 1981. New record of Black-bearded tomb bat, *Taphozous melanopogon melanopogon* Temminck from Rajasthan. Geobios, Jodhpur 8: 225-226.
- Speakman, J.R. 1991. The impact of predation by birds on bat populations in the British Isles. Mammal Review 21: 123-142.
- Speakman, J.R. and Racey, P.A. 1987. The energetics of pregnancy and lactation in the brown long-eared bat, *Plecotus auritus*. In Fenton, M.B., Racey, P.A., and Rayner (ed.), Recent advantages in the study of bats, pp. 367-393. Cambridge UK: Cambridge University Press.
- Swift, S.M. 1980. Activity patterns of Pipistrelle bats (*Pipistrellus pipistrellus*) in north-east Scotland. Journal of Zoology 190: 285-295.
- Temminck, C.J. 1841. Monographies de mammalogie. Vol. 2 has imprint: Leiden, C. C. van der Hoek. French: Paris, G. Dufour et E. d'Ocagne
- Thies, W., Kalko, E.K.V., and Schnitzler, H. 2006. Influence of environment and resource availability on activity patterns of *Carollia castanea* (phyllostomidae) in Panama. Journal of Mammalogy 87: 331-338.
- Vaughan, T., Ryan, J., and Czaplewski, N. 2000. Mammalogy. 4. Toronto: Brooks Cole.
- Vaughan, T.A. 1980. Opportunistic Feeding by Two Species of *Myotis*. Journal of Mammalogy 61: 118-119.
- Voigt, C.C., et al. 2008. Songs, Scents, and Senses: Sexual Selection in the Greater Sac-Winged Bat, *Saccopteryx bilineata*. Journal of Mammalogy 89: 1401-1410.
- Walter, H., Harnickell, E., and Mueller-Dombois, D. 1975. Climate-diagram maps of the individual continents and the ecological climatic regions of the earth. Springer-Verlag.
- Wei, L.. 2008. Wing morphology, echolocation calls, diet and emergence time of black-bearded tomb bats (*Taphozous melanopogon*, Emballonuridae) from southwest China. Acta Chiropterologica 10: 51-59.

- Welbergen, J.A. 2006. Timing of the evening emergence from day roosts of the grey-headed flying fox, *Pteropus poliocephalus*: the effects of predation risk, foraging needs, and social context. Behavioral Ecology and Sociobiology 60: 311-322.
- Welbergen, J.A. 2008. Variation in twilight predicts the duration of the evening emergence of fruit bats from a mixed-species roost. Animal Behaviour 75: 1543-1550.
- Wickham, H. 2009. ggplot2: Elegant Graphics for Data Analysis. New York: Springer-Verlag.
- Wickham, H. and Francois, R. 2016. dplyr: A Grammar of Data Manipulation (Version R package version 0.5.0). Retrieved from <https://CRAN.R-project.org/package=dplyr>.
- Wilkinson, G.S. and McCracken, G.F. 2003. Bats and balls: sexual selection and sperm competition in the Chiroptera. In (ed.), Bat ecology (TH Kunz and MB Fenton, eds.). University of Chicago Press, Chicago, Illinois, pp. 128-155.
- Wilkinson, G.S. and South, J.M. 2002. Life history, ecology and longevity in bats. Aging Cell 1: 124-131.
- Zar, J.H. 1999. Biostatistical Analysis. Prentice Hall.



APPENDIX

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

Capture and recapture history of adult *T. melanopogon* at the Kham colony from January 2015 to April 2016. Grey boxes represented individual from the Changkleua colony.

		Capture time (Sampling period)															
Time of last captured	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	
Jan-15		0	1	0	0	0	0	0	0	0	0	2	1	0	0	0	
Feb-15			1	0	1	0	0	0	0	0	1	0	0	0	0	0	
Mar-15					0	0	0	0	0	0	0	1	0	0	0	0	
Apr-15					0	0	0	2	0	0	0	0	0	1	0	0	
May-15						0	0	0	0	0	0	0	1	1	2	0	
Jun-15							0	0	0	0	0	0	0	0	0	0	
Jul-15								0	0	0	0	0	0	0	0	0	
Aug-15									0	0	0	0	0	0	0	0	
Sep-15										0	0	0	1	0	0	0	
Oct-15											0	0	0	0	0	0	
Nov-15												1	0	0	0	0	
Dec-15													1	0	2	0	
Jan-16														0	0	0	
Feb-16															0	0	
Mar-16																0	
Apr-16																	
Total marked	0	0	2	0	1	0	0	2	0	0	1	4	4	2	4	0	
Total unmarked	47	21	17	8	7	24	30	17	26	20	23	27	17	20	11	9	
Total caught	47	21	19	8	8	24	30	19	26	20	24	31	21	22	15	9	

Capture and recapture history of adult *T. melanopogon* at the Changkleua colony from January 2015 to April 2016. Grey boxes represented individual from the Changkleua colony.

Capture time (Sampling period)																
Time of last captured	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16
Jan-15		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Feb-15			0	0	0	0	0	0	0	0	0	0	0	1	0	0
Mar-15					0	0	0	0	0	0	0	0	0	0	0	0
Apr-15					0	0	0	0	0	0	0	0	0	0	0	1
May-15						0	0	0	0	0	0	0	0	0	1	0
Jun-15							0	0	0	0	0	2	0	0	0	0
Jul-15								0	0	0	0	0	0	0	0	0
Aug-15									0	0	0	1	0	0	0	0
Sep-15										0	0	0	0	0	0	0
Oct-15											2	0	0	0	0	0
Nov-15												0	0	0	0	0
Dec-15													0	0	0	0
Jan-16														0	0	0
Feb-16															0	0
Mar-16																0
Apr-16																
Total marked	0	0	0	0	0	0	0	0	0	0	2	4	0	1	1	1
Total unmarked	21	19	0	3	6	7	28	25	14	14	22	18	25	16	7	3
Total caught	21	19	0	3	6	7	28	25	14	14	24	21	25	17	9	4

Reproductive and developmental stage compositions of *T. melanopogon* in each capture sessions at the Kham colony during studied period

Month	adult male	adult female				Juvenile	late juvenile	total
		non reproductive	pregnancy	lactation	total adult female			
		January 2015	28	19	0			
February 2015	11	10	0	0	10	0	0	21
March 2015	4	15	0	0	15	0	0	19
April 2015	2	6	6	0	12	0	0	14
May 2015	4	4	4	4	12	0	0	16
June 2015	5	19	0	8	27	2	0	34
July 2015	8	22	0	0	22	4	0	34
August 2015	5	14	0	0	14	10	1	30
September 2015	7	19	0	0	19	0	5	31
October 2015	5	15	0	0	15	0	12	32
November 2015	13	11	0	0	11	0	4	28
December 2015	16	15	0	0	15	0	2	33
January 2016	10	11	0	0	11	0	0	21
February 2016	12	10	0	0	10	0	0	22
March 2016	5	10	0	0	10	0	0	15
April 2016	4	5	5	0	10	0	0	14
total	139	205	15	12	232	16	24	411

Reproductive and developmental stage compositions of *T. melanopogon* in each capture sessions at the Changkleua colony during studied period

Month	adult male	adult female				Juvenile	late juvenile	total
		non reproductive	pregnancy	lactation	total adult female			
January 2015	11	10	0	0	10	0	0	21
February 2015	13	6	0	0	6	0	0	19
March 2015								0
April 2015	1	2	3	0	5	0	0	6
May 2015	4	2	2	2	6	0	0	10
June 2015	4	3	0	4	7	4	0	15
July 2015	14	14	0	0	14	3	0	31
August 2015	7	18	0	0	18	12	3	40
September 2015	5	9	0	0	9	0	5	19
October 2015	5	9	0	0	9	0	7	21
November 2015	10	14	0	0	14	0	1	25
December 2015	11	10	0	0	10	0	4	25
January 2016	14	11	0	0	11	0	0	25
February 2016	10	7	0	0	7	0	0	17
March 2016	2	7	0	0	7	0	0	9
April 2016	2	2	5	0	7	0	0	9
total	113	124	10	6	140	19	20	292

VITA

Mr. Kasidit Rison was born on 14 February 1991. After completing his high-school study at Princess Sirindhorn's College, Nakhon Pathom in 2008. He enrolled in Silpakorn University for a Bachelor's degree from Department of Biology, Faculty of Science and graduated this program with first-class honors. He has got an academic scholarship from Development and Promotion for Science and Technology talents project (DPST). In 2013, he continued his study in Zoology program for Master degree at Department of Biology, Faculty of Science, Chulalongkorn University and completed the program in 2016.

In the academic year, he presented the poster presentation in 3rd International Southeast Asian Bat Conference at Sarawak, Malaysia from 14-17th August 2015, the 5th International Symposium on Asian Vertebrate Species Diversity on December 16– 8th, 2015 at Chulalongkorn University. In addition, he published his work and presented the oral presentation in 11th Conference on Science and Technology for Youths at Bangkok International Trade and Exhibition Center (BITEC), Bangkok, Thailand during June 10-11th (proceeding book, pp. 47–54).

