

นิเวศวิทยาการเติบโตของนกแอ่นร้างขาว *Aerodramus fuciphagus* (Thunberg)  
ที่อาศัยในโรงเรือนและในธรรมชาติ

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BREEDING ECOLOGY OF THE WHITE-NEST SWIFTLET  
*Aerodramus fuciphagus* (Thunberg) IN MAN-MADE AND  
NATURAL HABITATS

Miss Supaluck Viruhpintu

A Dissertation Submitted in Partial Fulfillment of the Requirements  
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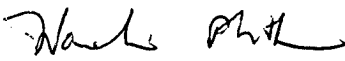
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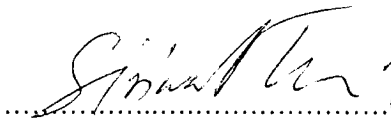


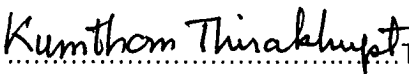
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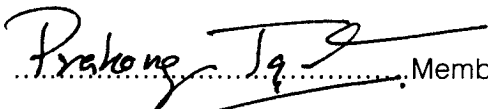
  
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ได้ทำการศึกษาขนาดประชากร อาหาร พื้นที่หากิน และชีววิทยาการสืบพันธุ์ของนกแอ่นรังขาว ที่วัดสุทธิวาตวราราม จ.สมุทรสาคร ตั้งแต่เดือนสิงหาคม พ.ศ. 2543 ถึงเดือนตุลาคม พ.ศ. 2544 และได้ทำการศึกษาเปรียบเทียบสัณฐานวิทยาของรังและลักษณะของพื้นที่สร้างรังกับนกแอ่นรังขาวที่อาศัยในถ้ำ บนเกาะสี่เกาะห้า จ.พัทลุง ในปีพ.ศ. 2544

ขนาดประชากรในปีที่เริ่มศึกษามีจำนวน 2,702 ตัว โดยนกมีการสืบพันธุ์ตลอดทั้งปี ระยะเวลาเฉลี่ยที่ใช้ในการสร้างรัง  $29.83 \pm 6.3$  วัน กกไข่  $23.63 \pm 1.6$  วัน และเลี้ยงลูก  $40.25 \pm 3.0$  วัน โดยเว้นระยะห่างระหว่างครอก  $15.94 \pm 10.5$  วัน โดยทั่วไป นกวางไข่รังละสองใบ โดยวางไข่ใบที่สองห่างจากใบแรก  $3.36 \pm 3.0$  วัน การวางไข่ความสำเร็จในการฟัก และความสำเร็จในการสืบพันธุ์ มีค่าสูงสุดในเดือนเมษายน

พ่อและแม่นกทำหน้าที่ในการกกไข่ และเลี้ยงลูก ไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติซึ่งนกจะจับคู่กันและใช้พื้นที่สร้างรังที่เดิมตลอดระยะเวลาการศึกษา อาหารหลักของลูกนกได้แก่แมลงในอันดับDiptera อันดับHomoptera และอันดับHymenoptera ซึ่งลูกนกได้รับอาหารโดยเฉลี่ยวันละ 5.35 ก้อน อัตราการป้อนอาหารขึ้นอยู่กับจำนวนและอายุของลูกนก นกแอ่นรังขาวหากินเหนือบริเวณพื้นที่สีเขียว เช่นทุ้งนา สวนผลไม้ สวนมะพร้าว และพื้นที่น้ำขังตามธรรมชาติ โดยมีระยะทางที่หากินไกลที่สุด 25 กิโลเมตรจากที่อาศัย

ความสำเร็จในการสืบพันธุ์ ขึ้นอยู่กับคุณภาพของพื้นที่สร้างรัง ซึ่งทำให้พ่อแม่มีอัตราการผลิตลูกนกเท่ากับ  $3.55 \pm 2.3$  ตัว/คู่/ปี สำหรับสัณฐานวิทยาของรังนกจากถ้ำพบว่ามีความหนา ความกว้าง และน้ำหนักมากกว่ารังนกจากวัดสุทธิวาตวราราม การทดลองใช้พื้นที่สร้างรังเทียมกับนกในวัด ซึ่งสร้างขึ้นโดยเลียนแบบพื้นที่สร้างรังของนกในถ้ำ ประสบความสำเร็จ ซึ่งจะเป็นประโยชน์อย่างยิ่งในการเพิ่มประชากรและผลผลิตของนกแอ่นรังขาวในบ้านเลี้ยงในอนาคต

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SUPALUCK VIRUHPINTU : BREEDING ECOLOGY OF THE WHITE-NEST SWIFTLET  
*Aerodramus fuciphagus* (Thunberg) IN MAN-MADE AND NATURAL HABITATS.

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The population size, diet, foraging area and breeding biology of White-nest Swiftlets *Aerodramus fuciphagus* were studied at Suthiwararam Temple, Samut Sakhon Province during August 2000 and October 2001. The nest morphology and nest-site characteristics were compared to those living at Si-Ha Islands, Phatthalung Province.

The population size of White-nest Swiftlets was 2,702 individuals at the beginning of the study period during which they performed continuous breeding pattern. Average times of nest building, incubation and nestling feeding were  $29.83 \pm 6.3$ ,  $23.63 \pm 1.6$  and  $40.25 \pm 3.0$  days, respectively, with  $15.94 \pm 10.5$  days for subsequent brood. The two-egg clutch was the normal clutch size with the laying interval of  $3.36 \pm 2.5$  days. The highest percentages of egg laying, hatching success and breeding success at fledging was in April.

Parental investments in egg incubation, brooding and nestling feeding were not significantly different between sexes. Breeders paired and had nest-site fidelity throughout the study period. Nestlings were fed mainly with dipterans, homopterans, hymenopterans with the average of 5.35 food-balls/day and the rate was influenced by the brood size and the age of nestlings. Adults were frequently seen foraging over rice fields, orchards, coconut plantations and swamps with the longest distance of 25 km from their breeding sites.

The breeding success at fledging was affected by the quality of nesting sites, leading to the average production of  $3.55 \pm 2.3$  fledglings/pair/year. Nests from caves were thicker, wider and heavier than those from the temple. The experiment on the use of artificial nest-sites by swiftlets living in the sacred building, in which the nest-site characteristics at caves were imitated, was successful. The application of the artificial nest-site model would be useful to increase the production in cultivated houses in the future.

Department : Biology..... Student's signature.....  
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# CHAPTER 1

## INTRODUCTION

The White-nest Swiftlet is renowned as an important species due to its valuable white nests. Some of its ecology and breeding biology were studied in Vietnam, Malaysia, Singapore and Indonesia. In Thailand, only few studies existed. Despite the fact that the right to harvest nests under the official permission was evident in the reign of King Taksin the Great (BE 2312, 1769 AD), neither concessionaires nor local administrators who issued the harvesting rules, have a true understanding of the ecology of these birds.

Generally, the White-nest Swiftlet is a cave dweller. Its habitat is usually inaccessible for human and is located at completely dark sites in limestone caves. However, the White-nest Swiftlet is occasionally found to breed in abandon houses or man-made buildings (Wildash, 1968; King and Dickinson, 1975, Langham, 1980; Kang, Hails, and Sigurdsson, 1991). In this regard, there is a good opportunity to conduct the ecological study as well as to develop the population for economical purposes.

This study focused on a small isolated breeding colony of the White-nest Swiftlet that has established its colony naturally for more than 30 years in a sacred building at Suthiwatwararam Temple, Samut Sakhon Province. The unique characteristic of this colony is that it is the only colony found in Samut Sakorn and nearby Provinces and is located at the northern most part of its species' distribution range in Thailand. It is estimated that the nearest breeding colony of the same species is located at Phetchaburi Province which is around 100 km away. This isolated population produces high quality nests and is very well adapted to live and breed in the environment under strong disturbances from human activities of which this type of environment almost totally differs from those in caves or abandoned houses. Hence, this population is expected to have a high potential to be *developed for farming in larger scale. The detailed ecological study in terms of its* population characteristics, breeding biology, feeding habits including nest-site

characteristics and nest sizes in comparison to the population of the same species in the natural habitat at Si-Ha Islands, Phatthalung Province would provide a crucial information for the conservation and the management of this population. In addition, the study on the use of artificial nest-sites, designed from the knowledge of nest-site characteristics in nature, was conducted. The information from the study would pave the way on the development of cultivated houses in the future.

### Objectives

1. To study the population size, diet and foraging areas of White-nest Swiftlet nesting in the sacred building, Suthiwatwararam Temple, Samut Sakhon Province.
2. To study its breeding biology including parental investment and reproductive success in the sacred building.
3. To study the nest-site characteristics and nest sizes of the White-nest Swiftlet, living in the sacred building and in the caves at Si-Ha Islands, Phatthalung Province.
4. To conduct the study on the use of artificial nest-sites by White-nest Swiftlets, living in the sacred building.



## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Classification of Edible-nest Swiftlets

Edible-nest Swiftlets are classified within the taxonomic order as follows :

Superorder Apodimorphae

Order Apodiformes

Family Apodidae

Genus *Aerodramus*

*Aerodramus fuciphagus* produces white nest so it is commonly called the White-nest Swiftlet whereas *A. maximus*, producing black nest, it is called the Black-nest Swiftlet. Another species, *A. unicolor*, produces nest with saliva incorporate with moss, is called the Indian Swiftlet

#### 2.2 General description of Family Apodidae

Within the Family Apodidae, all species are small and medium birds, the bill is short and broad with a deeply cleft gape and nostrils that open vertically, saliva glands are large and the sizes increase during the breeding season (Chantler and Driessens, 2000). Apodidae species are resemble swallows, but have longer, thinner, usually crecent-sharped wing, fly with rapid wing beats, interspersed with long glides. Many species have screamly call and *Aerodramus* species have ability to ecolocate. They are aerial insectivores. They never perch on trees or wires like swallow but with their short claws can only hang from the vertical surface. Normally, birds spend much of their time on the wing. The large species are among the fastest flying birds in the world. Swiftlets nest in group and sexes are similar. There are 80 species around the world and 4 species, White-nest Swiftlet; Black-nest Swiftlet ; Himalayan Swiftlet *Aerodramus brevirostris* (McClellant,1840) and Glossy Swiftlet *Collocalia esculenta* (Linnaeus,1758) are found in Thailand (Lekagul and Round,1991).

For genera *Aerodramus* and *Collocalia*, birds have small and medium sizes and fluttering flight on bowed wings. Their tails are slightly notched rather than forked, appearing almost squar-ended. They nest in huge numbers in caves or sometimes in buildings. Edible-nest species build cup nests incorporating hardened saliva, and other species build nests using saliva with other materials (Lekagul and Round, 1991; Eve and Guigue, 1996; Chantler, 1999; Wells, 1999; Chantler and Driessens, 2000)

*A. fuciphagus* builds wholly nest from its saliva, so it is renowned as an important species regarding its valuable nest, which is most highly prized. *A. maximus* uses saliva mixed with its feathers and *A. unicolor* uses saliva incorporated with vegetable matters for its nest (Kang and Lee, 1991; Rodelphe, 1992; Chantler, 1999; Wells, 1999).

### 2.3 Morphology of the White-nest Swiftlet

White-nest Swiftlet is medium size with body length of 110-120 mm and its body mass ranges between 10-15 g. It has glossy plumage, almost black-brown on upper parts with slightly greyer on the rump, underpart of the throat is paler and greyer. Upperwing is blackish with strong gloss while underwing is paler. The tail covert is blackish. It has naked-tarsi. The color of the rump shows variation throughout its range (Smythies, 1975; Well, 1999).

### 2.4 Composition of the white nest

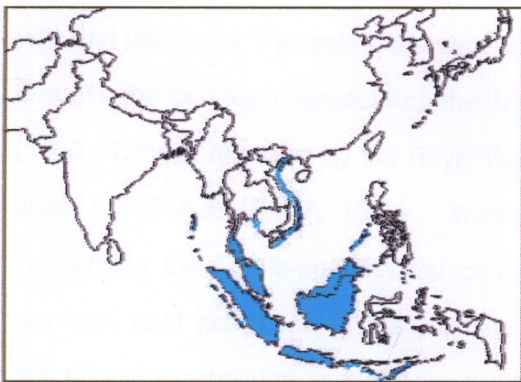
Nests of the White-nest Swiftlet compose mainly of pure saliva. This saliva is a kind of mucin-like glycoprotein, composing of 50-60% protein, 25% carbohydrate, 10% water with small amounts of minerals, mainly calcium, phosphorus, potassium and sulphur (Kang et al, 1991; Lau and Melville, 1994)

### 2.5 Habitat and distribution of the Edible-nest Swiftlet

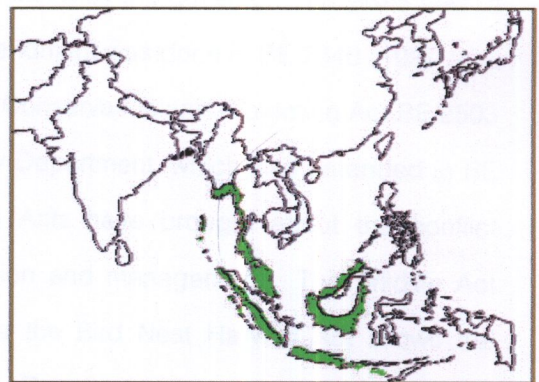
White-nest Swiftlet is common and resides mainly in limestone caves on islands or on the mainland coast. Its distribution is in the oriental region, ranging from the Andaman and Nicobar Islands in the Indian Ocean to South East Asia (Myanmar, Thailand, Peninsular Malaysia, Vietnam, and extending to Sumatra, Java, Bali, Sarawak,

Sabah, Borneo) and the Lesser Sunda Islands. The Black-nest Swiftlet is also found along this distribution line. For the Indian Swiftlet, it is abundant in caves of western Ghats on the islands off Malabar coast. This species is restricted to the southwest coast of the Indian Subcontinent and Sri Lanka (Glenister, 1971; Smythies, 1975; Medway, 1962; Cranbrook, Somadikarta, and Kartikasari, 1996; Chantler, 1999; Kenneth, 1999). The distribution lines of these three species are shown in Figure 2.1.

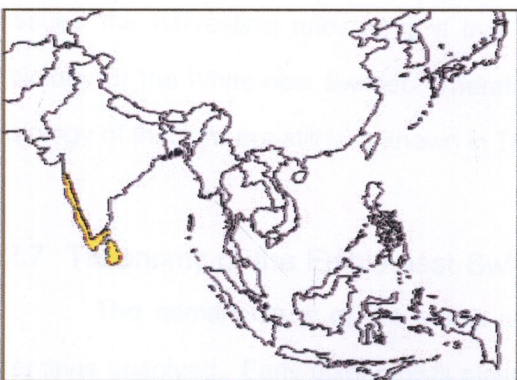
*A. fuciphagus* and *A. maximus* are residents in Thailand, living in sea caves, islands offshore along the coastlines in Prachuap Khiri Khan, Chumphon, Surat Thani, Phatthalung, Satun, Trang, Phuket, Phang-nga and Trat Provinces ( Lekagul and Round, 1991; Royal Forestry Department of Thailand, 1999).



(a)



(b)



(c)

**Figure 2.1** Distribution map of the Edible-nest Swiftlet : (a) *A. fuciphagus*; (b) *A. maximus*; and (c) *A. unicolor* . The map was modified from Chantler, 1999.

## 2.6 History of nest trade and the Act.

Saliva cement of birds' nests has been used for nest soup and Chinese cuisine since Ming Dynasty (1318-1644 AD) (Cranbrook et al., 1996; Kenneth, 1999). The Edible-nest birds have provided an enormous income to the local and countries across their ranges.

A history of edible-nest harvesting in Thailand dated back to the reign of King Taksin the Great. It was recorded when his majesty went down to Songkhla Province (BE 2312, 1769 AD). At that time, his majesty gave the unofficial permit to the governor to collect edible nests at See-Ha Islands (or Ko Si Ko Ha) (Giles, 1963). Dunlap (1907) stated that the official permit to collect nests on the islands probably was first released in the reign of King Rama the third (BE 2367, 1824 AD). After 115 years, the Bird Nest Harvest Act BE 2482 (1935 AD) was first announced by the governor. Ten years later, it was first improved. Thereafter, the second amendment was done in BE 2540 (1997 AD). Besides the Bird Nest Harvest Act, the Wildlife Conservation and Protection Act BE 2503 (1960 AD) was released by the Royal Forestry Department, which was amended in BE 2535 (1992 AD) (RFDT, 1999). These two Acts have brought about the conflict concerning the Edible-nest Swiftlet conservation and management. The Wildlife Act provides total protection to the swiftlets while the Bird Nest Harvest Act allows the granting of concession to the highest bidder. Despite the fact that nests have been harvested for many decades, neither concessionaires nor the government sector who issued the harvesting rules have a true understanding of the ecology and breeding biology of the White-nest Swiftlet. Therefore, the information on ecology and breeding biology of this bird are still less known in Thailand.

## 2.7 Taxonomy of the Edible-nest Swiftlet

The nomenclature of the edible-nest species has created many debates and remains unsolved. Early taxonomists classified birds producing edible nests in a group of "the swallow" (now is known in Family Hirundinidae), using the Genus *Hirundo* (Cranbrook et al., 1996). From the zoological explorations and bird collections in the 19<sup>th</sup> and 20<sup>th</sup> centuries, the distinguished characters between the swift and the swallow



were revealed. The two groups differ in the material and structure of the nests. The swallow uses mud and straws with a little of its saliva for the construction of the nest but the edible-nest species mainly uses the saliva to build nest. For this reason, the ornithologist later placed swiftlets in Subfamily Chaeturinae in Family Apodidae.

Gray (1840) separated members of the Indo-pacific group (including Edible-nest species) from other swifts and placed in the Genus *Collocalia*. He selected *Hirundo esculenta* Linnaeus as the type species (Peter, 1940), after that Wallace (1863, cited in Cranbrook et al., 1996 : 4) indicated that *C. esculenta* did not produce edible nests, therefore *C. esculenta* should not be in the same Genus with other edible-nest species.

In 1906, Oberholser divided the genus *Collocalia*, selecting *Collocalia innominata* Hume as a type of Genus *Aerodramus* that was characterized by the presence of tarsal feathers ( Peter,1940).

Brooke (1972, cited in Cranbrook et al., 1996 : 5) suggested that the Glossy Swiftlets including *C. esculenta* (Linn.) and the dull, gray-brown plumaged swiftlets (e.g. *A. innominata*) should belong to the Genus *Aerodramus* Oberholser. Based on the nesting behavior, nest types and the echolocation ability, he split *Collocalia* Gray into three genera as follows: *Collocalia* Gray; *Aerodramus* Oberholser; and *Hydrochous* Brooke, of which *C. fuciphaga* (Thunberg), *C. fuciphaga germani* Oustalet and *C. maxima* Hume were classified to Genus *Aerodramus*. This classification was supported by Pratt (1986, cited in Kenneth, 1999 : 5) with additional suggestion that these species also exhibited the same characteristics of using salivary cement for their nests (Medway,1962; Kang and Lee,1991; Lee and Kang, 1994).

Based on molecular genetics study, Sibley and Monroe (1990) regrouped all species in Genus *Aerodramus* Oberholser and in Genus *Hydrochous* Brooke under the Genus *Collocalia* Gray. They listed the name of Edible-nest Swiftlets as *C.[fuciphaga] fuciphaga* (Gmelin) 1789. In 1993, they named the Edible-nest Swiftlets as *C. fuciphaga* and listed these subspecies of edible-nest birds as *C. (f.) inexpectata* : Edible-nest

Swiftet; *C. (f.) vestita* : Brown-rumped Swiftlets; *C. (f.) fuciphaga* : Thunberg's Swiftlets and also elevated *C. fuciphaga germani* to *C. germani*.

Cranbrook et al. (1996) proposed that Edible-nest Swiftlets should be classified in the Genus *Areodramus* Oberholser and considered *C. fuciphaga germani* as a subspecies of *Areodramus fuciphagus* (Thunberg, 1812). This was on the basis of the geographical isolation, differences in morphology and behavior among the species and the new evidence from the molecular study. By the analysis and enzyme assay, Lim (1993, cited in Cranbrook et al., 1996 : 7) also showed that the Edible-nest Swiftlet was closer to *Areodramus* Oberholser than *Collocalia* Gray.

Lee, et al. (1996) using 406-bp cytochrom b mt DNA analysis, showed that *Collocalia* Gray was not monophyletic and *Areodramus* Oberholser and *Collocalia* Gray were not sister taxa.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) pointed out that Edible-nest Swiftlets were in the Genus *Collocalia* Gray 1840. It listed the four species producing edible nests as follows : the White-nest Swiftlets *C. fuciphaga* (Gmelin) and *C. germani* Oustalet, the Black-nest Swiftlets *C. maxima* Hume, and the Indian Swiftlet *C. unicolor* (Jerdon) (Cranbrook et al., 1996).

Dunlap (1907) called birds produced white nests in See-Ha islands, Phatthalung Province as "*Collocalia* species" while the same population was called as "*Collocalia francica*" by Quate (1952), *C. fuciphaga* Thunberg 1812 by Medway (1963) and *C. francica germani* by Brandt (1966). Boswell and Kanwanich (1978) reported that the Edible-nest Swiftlet in Phi Phi Le was *Aerodramus fuciphaga*. Lekagul and Round (1991) named edible-nest species as *A. fuciphagus*. RFDT (1999) called *C. fuciphaga* (Gmelin) and *C. germani* Oustalet for edible-nest species and *C. maxima* for black-nest species. Wells (1999) called the Edible-nest Swiftlet as *A. fuciphacus* (Thunberg) 1812 and the Black-nest Swiftlet as *A. maximus* (Hume) 1878, this concordant to the report of

Chantler (1999) who called Edible-nest Swiftlets as *A. fuciphagus* and the Black-nest Swiftlets as *A. maximus*.

Chantler and Driessens (2000) retained *C. germani* as a subspecies of *C. fuciphaga* and named Edible-nest Swiftlets as *C. fuciphaga* (Thunberg) 1812. Robson (2000) listed the birds produced white-nests as *C. fuciphaga* and *C. germani* and he noted that the latter distributes extreme south of Thailand, Malaysia and Singapore.

In this study, the studied species will be named as *A. fuciphagus* (Thunberg, 1812) as recognized by Lekagul and Round (1991); Chantler (1999) and Wells (1999).

## 2.8 Population size of the Edible-nest Swiftlet

Population size is defined as the number of individuals that live together in one place at one period of time. The population size of White-nest Swiftlets has been indirectly estimated from the amount of harvesting. Banks (1935, cited in Er et al., 1997 : 2) estimated *C. maxima* number from the harvested yield of the Niah Cave in Sarawak. Lau and Melville (1994) used an average of 8 g per nest to estimate the amount of exported nests. Er et al. (1997) estimated the population size of the Edible-nest Swiftlet in South East Asia (i.e. Malaysia, Indonesia, Thailand, Vietnam and Myanmar) at 50.6 million birds and gave the average recruitment of 12.2 %. The accuracy of this method is subject to the variation brought about by the harvested yield report.

Unlike the previous method, the use of bird censusing techniques such as direct bird count, direct nest count and capture-mark-recapture method to estimate the population size of this species has not been popular with fieldworks. Good (1993, cited in Er et al., 1997 : 3) used for *C. maxima* in Niah Cave, where an observer counted the number of birds flying out of the cave entrance at fixed time interval. This method is subject to the variation brought about by the movements of swiftlets in and out of the caves in the evening and morning, the multiple entrances to some caves; and the different species (e.g. bat) inhabiting the caves. Basir et al. (1996) also reported the use of capture-mark-recapture method. However, they did not elaborate on its effectiveness.

## 2.9 Diet and foraging area of the Edible-nest Swiftlet

White-nest Swiftlets are insectivores. Aerial insects are main items of prey. Adults feed on wings and nestlings are fed at the nest with "food-balls" or "food bolous". The food-ball consists of a mass of insects bound together by saliva. The parents catch preys, keep in mouths, and return to their nests to feed directly to their young, one by one. Langham (1980) analyzed food items in 13 regurgitated food-balls collected from nestlings and adults of Edible-nest Swiftlets in shop house at Penang, Malaysia. He found that the mean weight of food-balls was  $0.57 \pm 0.09$  g with a range of 0.13 to 1.08g. Almost half of the prey items in food-balls were hymenopterans especially chalcidoid wasps, followed in numerical importance by mayflies (Order Ephemeroptera), Homopteran bugs and true flies (Order Diptera). Chantler and Driessens (2000) indicated that these insects are important preys for swiftlets in both temperate and topical regions.

Foraging areas are the area that birds find and catch preys. Birds exit from the roost sites at dawn and return at dusk, they feed on wings and forage over all kinds of open and forest areas, rice fields or other wetland types, including crop and coastal areas (Mardiastuti and Mranata, 1996). Comparing to other swifts, White-nest Swiftlets fly at the middle height, lower than *Apus* and *Hirundapus* species (Wells, 1999). Waugh and Hails (1983, cited in Kenneth, 1999 :17) found that this species was commoner in primary forest than open habitats such as plantations and agricultural fields. To date, there is no research on the distance between the foraging areas and the nesting sites of White-nest Swiftlets.

## 2.10 Breeding season and breeding duration of the Edible-nest Swiftlet

Breeding season of a population is a time period from the first day the nest is built to the last day when the last nestling is fledged. Breeding time of a breeding pair is indicated by the appearance of breeding activities, for instance, the activities of nest building, incubation, nestling feeding and other signs such as nest defense. A time period, which covers all of breeding activities (from nest buiding to fledging), is defined as the breeding duration

The literature on the breeding biology of the White-nest Swiftlet has been reviewed (e.g. Medway, 1962; Langham, 1980; Francis, 1987; Kang et al., 1991; Lau and Melville, 1994; Nguyen, 1994; Er et al., 1997; Mardiasuti and Mranata, 1996; Wells, 1999; Chantler and Driessens, 2000). Many researchers stated that breeding activities of the White-nest Swiftlet coincide with the time of insect abundance in the inter-monsoon dry season (Kang and Lee, 1991; Chantler and Driessens, 2000). However, the breeding time of populations can be varied due to localities, especially when they are under the different environmental conditions. For example, Langham (1980) found that birds in Malaysia, under the harvesting condition, showed two laying peaks, the first was in October to December and the second was in February. In Thailand, under the 3 times harvesting a year, birds started nesting in January and ended up in August (RFDT, 1999). Under the natural condition, birds in Vietnam started nesting activities in December to April and the breeding season was timed by climate (Nguyen, 1994). Breeding activities of birds in Singapore reduced in August to September (Kang and Lee, 1991).

Other studies on the congener for example *Aerodramus spondiopygius* by Busst (1956); Smyth et al. (1980) and Tarburton (1988, cited in Cranbrook et al., 1996 : 9) and *A. salangana* by Medway, 1962 and *A. leucophaeus sawtelli* by Tarburton (1986) showed the same pattern in periods of incubation and fledging. The data also indicated the variation caused by location and climatic conditions.

The incubation period (the number of days from laying to hatching) and the nestling feeding period (the number of days from hatching to fledging) have been reported by many researchers. Medway (1969) studied on other species of this group and showed that it took 93 days for the total hatching-fledging period in the Black-nest Swiftlet *C. maximus* and 71 days for those of the Mossy-nest Swiftlet *C. salangana*. The periods of nest building and incubation of Edible-nest Swiftlets in Vietnam were 31-40 days and 23-30 days, respectively (Nguyen, 1994). Kang and Lee (1991) reported that White-nest Swiftlets in Singapore fed their nestling for 40 days.

The precise knowledge in the periods of nest building, incubation and nestling rearing of the White-nest Swiftlet is crucial important for the management of the sustainable harvesting. Therefore, detailed studies should be carried out for each breeding colony.

## 2.11 Breeding success of the Edible-nest swiftlet

The reproductive success is mostly considered as the number of young that survive to become breeding adults (Weatherhead and Dufour, 2000). However, the measurement of this parameter is often difficult because it takes time and most of fledglings often disperse before they are mature. For example in White-nest Swiftlets, once fledglings leave nests, there is no evidence that they comeback to live with their parents. For this reason, most researchers have to use other parameters (e.g. fledging success) instead of the true reproductive success.

In general, there are several parameters to determine the breeding success for birds and other animals. First is the clutch size (the number of eggs laid in one clutch). Second is the hatching success or hatchability (the number of hatched eggs in a clutch). Third is the fledging success or breeding success at fledging, BSF (the number of fledged chicks in a clutch). Forth is the production or fledgling production (the number of fledgling per pair per year) and the fifth is the nesting success (the number of nests that eggs hatched divided by the number of nests performing nesting attempts throughout the breeding season). To determine the breeding success of a bird species, researchers may select parameters depending on their purposes. For examples, Bukacinska, Bukacinski, and Spaans (1996) collected the data of the fledging success in Herring Gulls *Larus argentatus* in Netherlands to test the patterns of parental care and diet on the breeding success when a given colony was under the food limiting and high predation. Burger et al. (1996) determined breeding success of Roseate Tern *Sterna dougallii* in New York and Massachusetts in relation to the effect of adults' age, food availability and time of breeding using the data of clutch size, hatching success and production. Yogev, Ar, and Yom-Tov (1996) recorded clutch size and hatching success of Spur-winged Plover *Vanellus spinosus* in Israel for the study on the

determination of clutch size and breeding biology. Bennetts et al. (2000) recorded clutch size, brood size and nesting success of Little Egrets *Egretta gazetta* in order to evaluate the influence of environmental and density-dependent factors on the reproductive parameters. Ahumada (2001) measured clutch size, nesting success, time of breeding and renesting attempts to determine the strategy in breeding biology of Neotropical Wrens in an unpredictable environment of Northeastern Colombia. Larison, Layman, and William (2001) used the clutch size and fledging success in the Song Sparrow *Melospiza melodia* to evaluate the quality of the habitat in the restored stand and natural areas in California.

For the White-rumped Swiftlet *Aerodramus spondiopygius* in Fiji. This species is cogeneric to the White-nest Swiftlet. Tarburton (1986) recorded its clutch size, hatching success and fledging success to test for the feeding ability of a breeding pair and demonstrated the inability of this species to raise more young than that was normal.

In the White-nest Swiftlet, Kang et al. (1991) recorded the nesting success to determine the effect of harvesting on the breeding success and reported that the reproductive success of re-nesting in *C. fuciphaga* declined significantly from 71% after the first harvest to 41% after the second harvest. In Vietnam, Nguyen (1996) found that the reproductive success of renesting *C. germani* Oustalet was 71%, in which the range of overall breeding success was between 45-63% after the first harvesting and he suggested that this might be due to marked variation in climate. However, under the natural condition, Langham (1980) found that the breeding success of *C. fuciphaga* did not differ significantly between the three subsequent clutches.

## 2.12 Parental care, loyalty in pair and nest-site fidelity of the Edible-nest Swiftlet

Parental care is the allocation on time and energy for breeding activities (e.g. nest building, incubation, nestling feeding, nest defense, etc.) during the breeding cycle. Many authors claimed that both sexes of the Edible-nest Swiftlets allocating in the nest building and incubation (i.e. Nugroho and Whendrato, 1999; Wells, 1999; Chantler and Driessens, 2000).

The White-nest Swiftlet is monogamous (one male and one female form a pair bond and breeding activities are shared by both sexes). It is also believed that the White-nest Swiftlet is faithful to its nest-site, which is called "nest-site fidelity", and its pair which is called as "royalty in pair" (Nugroho and Whendrato, 1999). This manner has been found in other swifts such as Common Swifts *Apus apus* (Chantler and Driessens, 2000). However, There has been little information on the parental care in the White-nest Swiftlet and the previous assumptions remain untested.

## 2.13 Nest-site characteristics of the Edible-nest Swiftlet

White-nest Swiftlets are cave dwellers, roosting and nesting in the dark or totally dark places in limestone caves off the mainland coast. Somewhere inland, this species can be found living in houses (i.e. abandoned or cultivated houses in Malaysia, Indonesia and Thailand) and in other man-made buildings (e.g. tunnels in Sentosa, Republic of Singapore). Wells (1999) reported that the White-nest Swiftlet preferred to choose higher and inner nest-site in caves than the Black-nest Swiftlet. However, he did not mention in more detail between the two species. A few researchers have been trying to reveal the nest-site characteristic of cave swiftlets (i.e. Robiah, 1998; Risman, 1996, cited in Mardiasuti, 1999 : 4 ) examined the habitat and the morphology of the Black-nest Swiftlet at Misiu Cave, West Sumatra. However, this study did not concentrate on the nest-site characteristics. Therefore, the information of nest-site characteristics is less known.



## CHAPTER 3

### STUDY SITE AND STUDY SPECIES

#### 3.1 Study sites

The field study took place in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province and nearby areas. Some parts of the study were conducted at Si-Ha Islands, Phatthalung Province and at Chulalongkorn University. The study was carried out during the year 2000 and 2001.

##### 3.1.1 The sacred building of Suthiwatwararam Temple

The sacred building of Suthiwatwararam Temple is the breeding site of White-nest Swiftlets (Figure 3.1). It is located at approximately 100 m from the mouth of Tha Chin River ( $13^{\circ}31'41''\text{N}$ ,  $100^{\circ}16'12''\text{E}$ ). There are 3 temples nearby namely Wat Ling Chon, Wat Lang San Prasit, and Wat Bang Ya Phraek at approximately 0.7, 1.5, and 1.7 Km away to the north, west and south of the sacred building (Figure 3.2), but these temples are not colonized by swiftlets.

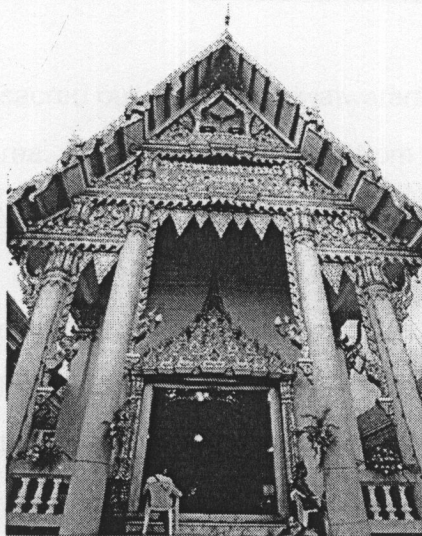


Figure 3.1. The sacred building of Suthiwatwararam Temple, Samut Sakhon Province.

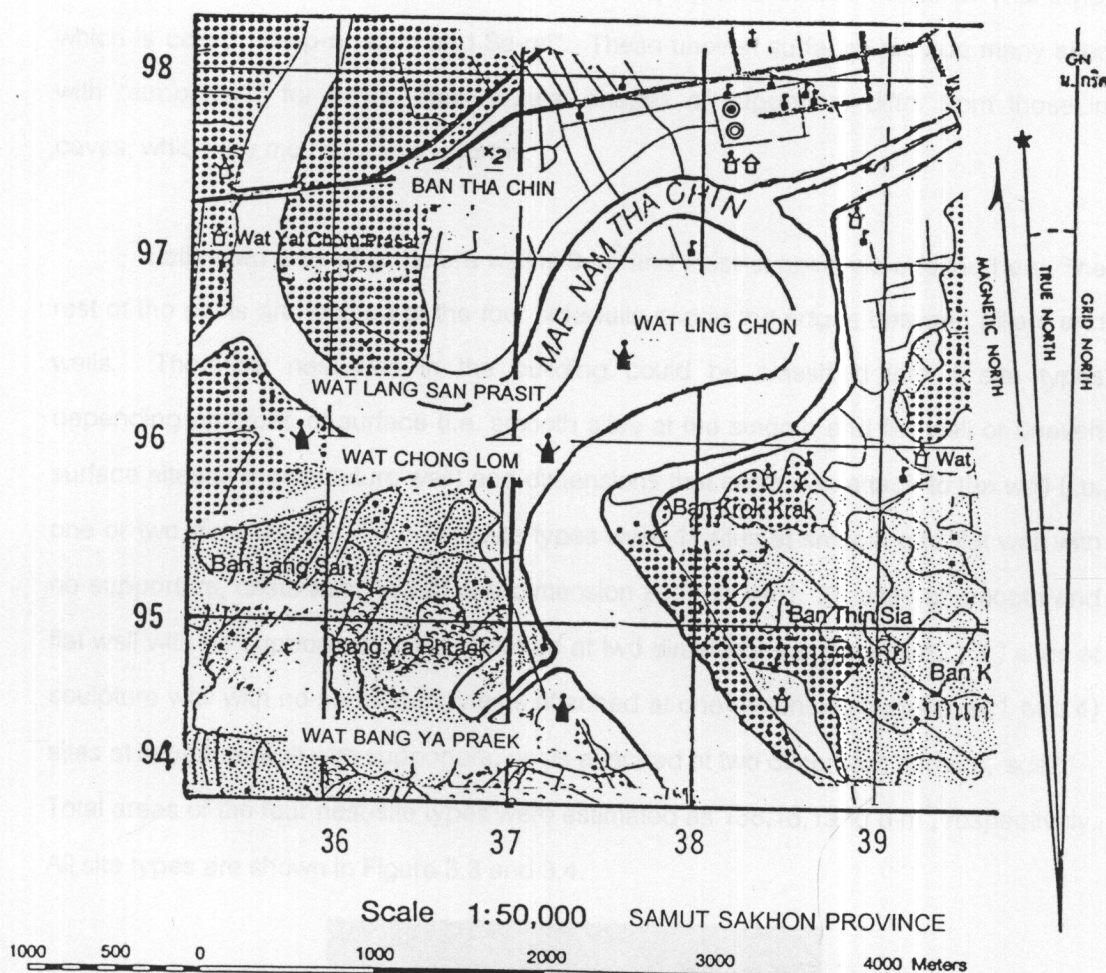


Figure 3.2. Location of the sacred building of Suthiwatwararam Temple (or Wat Chong Lom) and its surrounding area. The map was adapted from the topographic map with the scale of 1 : 50,000, provided by the Royal Thai Survey Department.

The main entrance of the sacred building faces toward the east. It is a rectangular building containing the altar of the golden coffin of the late abbot. The altar is located at the end of the nave section against the back wall. The building has a saddle-shaped roof where nesting or roosting sites of around 1,000 breeding pairs are inside. The remaining birds live in the hall of which four sidewalls were made by bricks and covered with lime-based plaster. The walls are slightly high (~7 m) which allow more ventilation. The walls were constructed on each side of 10 pillars. The altar section was partitioned from the nave section by the sculptural wall hanging from the ceiling. This sculptural wall,  $3.0 \times 3.0 \times 0.2 \text{ m}^3$  in length, width and thickness, respectively, was



made by cement and was decorated with moulding and stucco motifs of Thai-style, which is called "Thep-pa-nom and Sa-rai". These uneven surfaces provide many sites with "supporters" for nests. The irregular shapes of supporters differ from those in caves, which are mostly U-shape forms.

Estimated area of sculpture wall is  $9 \text{ m}^2$  and most of nests were found here. The rest of the nests are located at the four sidewalls and at the edges between pillars and walls. Therefore nest-sites in the building could be classified into 4 site types depending on types of surface (i.e. smooth sites at the smooth and flat wall or uneven surface sites at the sculpture wall) and dimensions that nests can attach to the wall (i.e. one or two dimensions). Four nest-site types were 1) sites at smooth and flat wall with no supporters, nests attached at one dimension surface, sm1; 2) sites at smooth and flat wall with no supporters, nests attached at two dimensions surface, sm2 ; 3 ) sites at sculpture wall with no supporters, nests attached at one dimension surface ,sc1 and 4) sites at sculpture wall with supporters, nests attached at two dimension surface, scs2. Total areas of the four nest-site types were estimated as 138,18,1 and  $8 \text{ m}^2$ , respectively. All site types are shown in Figure 3.3 and 3.4.

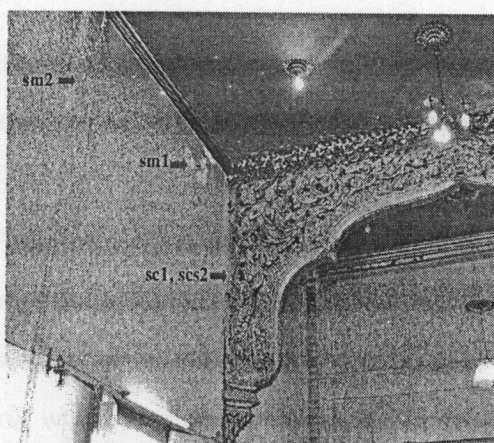
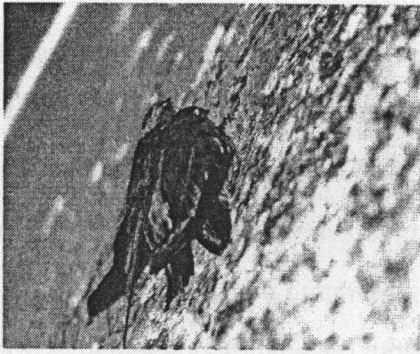
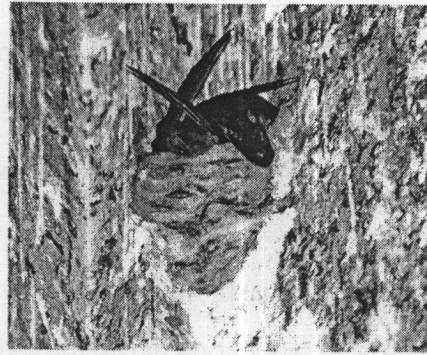


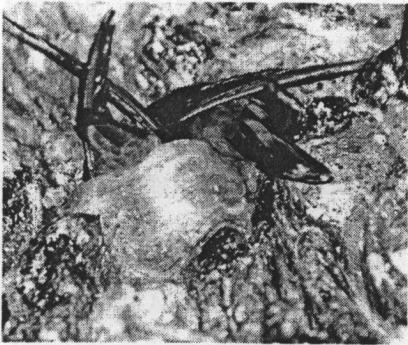
Figure 3.3. Nest sites of White-nest Swiftlets in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province. Sm1 and sm2 are sites at the smooth and flat wall with no supporter, nests attached at one and two-dimension surface; sc1 and scs2 are sites at the sculpture wall with no supporter, nests attached at one and two-dimension surface and without and with supporter.



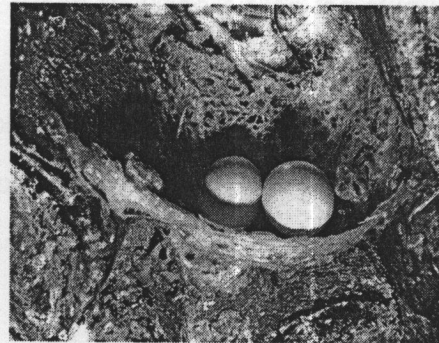
(a)



(b)



(c)



(d)

Figure 3.4. Nests of White-nest Swiftlets at different sites in the sacred building : (a) nest at sm1 site; (b) nest at sm2 site; (c) nest at sc1 site and (d) nest at scs2 site.

Samut Sakhon Province is located in the northern part of the gulf of Thailand, with the area of 872 km<sup>2</sup> at latitude 13° 24-44' N and longitude 100 ° 11-44' E. The northern and eastern borders connect to Nakhon Pathom Province and Bang Khun Thian District of Bangkok while the western side connects to Ratchaburi and Samut Songkhram Provinces. Tha Chin River is the main river of this province, running down from Nakhon Chaisi District in Nakhon Pathom Province, passing the middle area of the province and emerging to the gulf of Thailand at Tha Chalom Subdistrict where the sacred building is located. The south of the province is surrounded by intertidal mud, sand or salt flats, salt marshes with degraded mangrove communities. The land are used for salt field, shrimp and fish ponds. Fisheries are operated at the shallow coastal area and the open sea.

The inner areas of the province comprise of plantations, fish and shrimp ponds, natural swamps and ditches, rice and other crop fields. Most of these lands line at the northwest, west and southwest of the province and are about 15-30 km from the breeding site of the White-nest Swiftlet. The swamps and ditches that joint the Tha Chin river are parts of the irrigation system that are important to the cultivated areas. There are some lands used for the ornamental tree farm (i.e. orchids) and fresh water fisheries (i.e. prawns, fishes and softshelled turtles). Other are urban and industrial areas.

The average annual rainfall at Samut Sakhon Province during the study period was 1,420.8 mm in which the average annual rainfall during November 2000 and April 2001 was 50.22 mm and during May and October 2001 was 211.1 mm. By the amount of rainfall, the period of November 2000 - April 2001 and May - October 2001 were classified as dry and wet seasons, respectively. Data of the monthly rainfall were obtained from Thai Meteorological Department.

The ambient temperature and relative humidity measured at the sacred building during daytime were  $31.23 \pm 1.06$  °C,  $61.05 \pm 5.15$  % in dry season and  $29.82 \pm 0.92$  °C,  $57.57 \pm 5.19$  % in wet season.

### **3.1.1.1 Human activities in the sacred building**

Since the sacred building is built for keeping the coffin of the late abbot therefore, the building is open everyday for the public. There are many people coming to the sacred building to offer food and flowers to the image of the late abbot. Candles and incense sticks are always lit during paying respect.

### **3.1.2 Si-Ha Islands, Phatthalung Province**

Si-Ha Islands (Ko Si Ko Ha) is named for a group of islands, comprising of Ko Kan Tang, Ko Khem, Ko Na Thewada, Ko Ru Sim, Ko Thai Tham Kham, Ko Ran Kai, Ko Poi, Ko Ta So and Ko Yai So. The islands are located in Songkhla Lake ( $7^{\circ}25'N$ ,  $100^{\circ}15'E$ ), of Phatthalung Province, southern Thailand( Figure 3.5).



Si-Ha Islands, elevation ca 63-100 m above sea level has limestone caves of various sizes which are roosting and nesting habitat of sympatric species such as White-nest Swiftlets *A. fuciphagus*, Black-nest Swiftlets *A. maximus*, bats, rats, snakes and invertebrates. At some cave entrances, there are a few nesting sites of Glossy Swiftlets *Collocalia esculenta*.

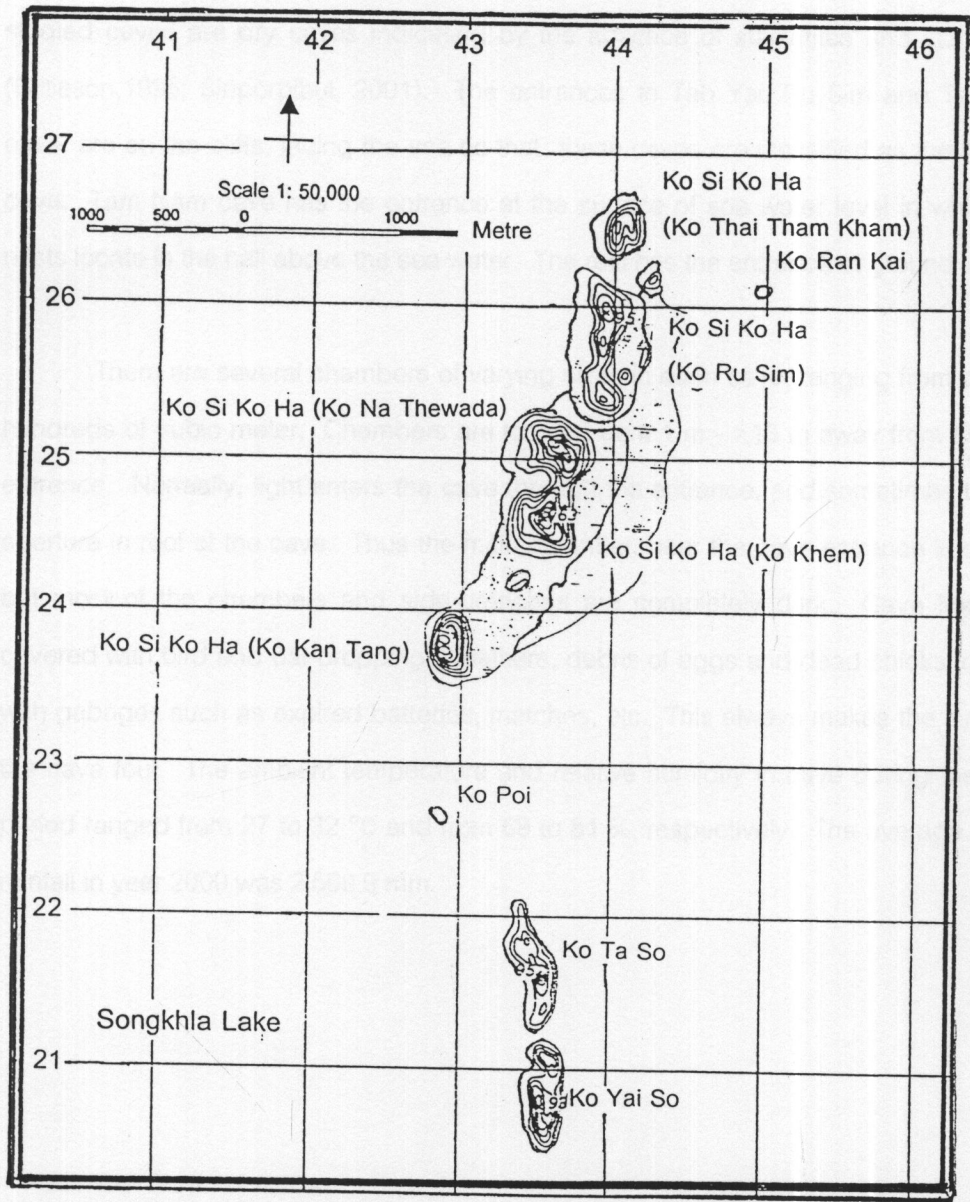


Figure 3.5. Map of Si-Ha Islands in Songkhla Lake, Phatthalung Province. The map was adapted from the topographic map with the scale of 1: 50,000, provided by the Royal Thai Survey Department.

The examination of harvested nest morphology was carried out at the Headquarters of Rung Nok Lam Thong (Siam) Company Ltd., the concessionaire which are constructed on Ko Na Thewada in March, April and August 2000. The study on nest-site characteristics of White-nest Swiftlets living in caves was carried out in 8 caves of 3 islands ( Nong Kwai and Aai Chick caves on Ko Ta So; Tab Yai, Tam Mod and Ru Fin caves on Ko Na Thewada; Tam Nam, Ru Sim and Rang Wauw caves on Ko Ru Sim). All studied caves are dry caves indicating by the absence of stalactites and stalagmites (Gillieson, 1996; Siriporbibul, 2001). The entrances to Tab Yai, Ru Sim and Tam Mod cave, are on the cliffs, facing the sea so that these caves are classified as the hanging cave. Tam Nam cave has the entrance at the surface of sea water level in which bird nests locate in the hall above the sea water. The rest has the entrance at ground level.

There are several chambers of varying sizes in each cave, ranging from a few to hundreds of cubic meter. Chambers are located from 1 m - >10 m away from the cave entrance. Normally, light enters the cave through the entrance, and sometimes through aperture in roof of the cave. Thus the main chamber, near the cave entrance is dimly lit but most of the chambers and side-branches are completely dark. Cave floors are covered with bird and bat droppings, feathers, debris of eggs and dead chicks together with gabages such as expired batteries, matches, etc. This always makes the air inside the cave foul. The ambient temperature and relative humidity in cave during the study period ranged from 27 to 32 °C and from 69 to 81 %, respectively. The average annual rainfall in year 2000 was 2,569.9 mm.

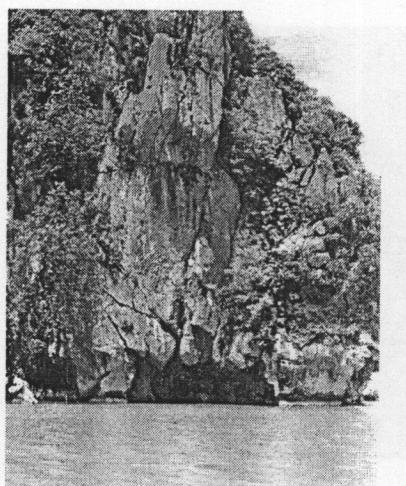


Figure 3.6. Ru Fin cave, one of the nesting site of White-nest Swiftlets at Si-Ha Islands in Songkhla Lake, Phatthalung Province.

### 3.2 The study species

The study species was the White-nest Swiftlet living in the sacred building and in the cave of Si-Ha Islands, Phatthalung Province. The population in the sacred building has established for more than 30 years. There are more than 2,000 breeding pairs living in this building (Figure 3.7 and 3.8) during the study period.

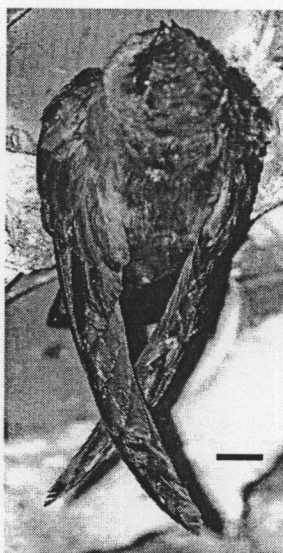


Figure 3.7. An adult of White-nest Swiftlets in the sacred building, Suthiwatwararam Temple, Samut Sakhon Province. Bar = 10 mm.





Figure 3.8. White-nest Swiftlets at the sculpture wall in the sacred building, Suthiwatwararam Temple, Samut Sakhon Province.

## CHAPTER 4

### METHODOLOGY

#### 4.1 Determination of morphology and scientific name of the study species

##### 4.1.1 Morphology

Morphological measurements of birds at Si-Ha Islands, Phatthalung Province were conducted in June 2000. Birds were captured using mist net under the permission of the concessionaire, measured and released. Two individuals were collected as specimens. At Samut Sakhon Province, it was studied in October and November 2000 and January 2001 by the same above method. Morphology of birds from the two sites were compared using *t*-test.

##### 4.1.2 Scientific name

To determine the scientific name of the study species, morphological characters of birds (wing length, tarsus length, tail length, and body weight) at two study sites were measured and compared with reference specimens at Raffle Museum of Biodiversity Research, Department of Biodiversity Science, The National University of Singapore, Republic of Singapore.

The scientific name used in the study was from Lekagul and Round (1991); Eve and Guigue (1996); Chantler (1999) and Wells (1999).

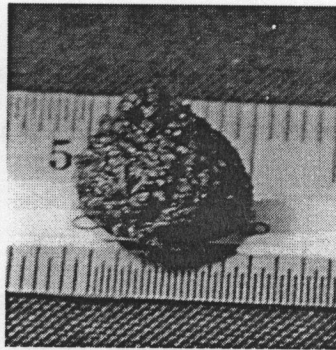
#### 4.2 Determination of population size, diet of nestling and foraging area of the White-nest Swiftlet at Samut Sakhon Province

##### 4.2.1 Population size

Bird census was carried out every two months during April 2000 to February 2001 by counting the number of birds from photographs taken at all nesting and roosting sites in the building. Photographs were taken after dusk when all birds returned to their nest-sites.

#### 4.2.2 Diet of nestling

To determine the diet of nestling, 15 food-balls from the returned feeders were collected. The collection was done in March, July and October 2001. Food-balls were preserved in 70% ethanol and all preys in each food-ball were identified into Orders or Families using a compound microscope at Thai turtle Lab., Chulalongkorn University. The following literatures : Clausen,1940; Bland,1978; Borror, De Long, and Triplehorn, 1981 were used for identification. The amount of each food item was recorded and the percentage of occurrence was calculated. A food-ball is shown in Figure 4.1.



**Figure 4.1.** A food-ball which was collected from feeder at Suthiwatwararam Temple, Samut Sakhon Province in March 2000.

#### 4.2.3 Foraging area

To determine the foraging area and the foraging distance of this population, vehicle surveys through all accessible areas by road in Samut Sakhon and nearby provinces were conducted. These areas comprised of urban and industrial areas, coastal areas (e.g. mangrove forests, salt fields, aquaculture areas) and agricultural areas (e.g. paddy fields, coconut plantations, orchards, swamps and etc.). The survey was done at one-month interval during March 2000 and January 2001. Thus, twelve surveys were made. Each trip was started in the early morning until dusk. During a given survey period, the number of birds and the position of birds seen were plotted in the topographic map (scale 1: 50,000) provided by the Royal Thai Survey Department. The map also used to interpret the distances between foraging positions and the breeding site. The average number of birds seen in all areas of Samut Sakhon Province

and the nearby were shown in the map which was modified from the Land Use map of Samut Sakhon Province. Foraging height was also estimated.

### **4.3 Breeding biology**

The data of breeding pattern and breeding biology of White-nest Swiftlets were obtained from 53 breeding pairs at 4 different nest-site types in the sacred building during September 2000 and October 2001.

#### **4.3.1 Breeding pattern**

To determine the breeding pattern, the number of nesting attempts of each breeding pair was recorded. The occurrence of nesting attempts during a given period would indicate the timing and the pattern of breeding.

#### **4.3.2 Breeding activities**

Breeding activities were focused as follows.

##### **4.3.2.1 Time spent for nest building, egg laying, incubation and nestling feeding**

To record the time for nest building, egg laying, incubation, nestling feeding, a brood was recorded through a series of nest checks every one to three-day intervals. The monitoring of 53 breeding pairs was carried out for 14 months. During the nest status monitoring, the periods of nest building, egg laying, incubation and nestling feeding were noted. The appearance of the first egg indicated that nest building period was complete and indicated time of egg laying. To avoid any disturbance to either incubating breeders or feeders, the nest checking was done in the early morning (0700-0830) when the feeding activity was low. Since nesting White-nest Swiftlets are less sensitive to the disturbance from nest checking, the missing nestling at a particular check would be considered that it was fallen or fledged.



For the analysis, the mean difference between two different clutches and seasons including among the subsequent brood were tested using *t*-test and ANOVA-DUNCAN. Nest checking is demonstrated as in Figure 4.2.

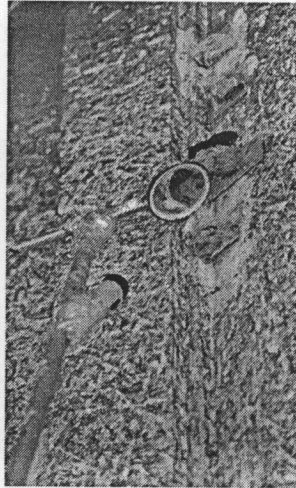


Figure 4.2. Nest checking, using a long stick binding one end with a mirror and a touch light.

#### 4.3.2.2 Breeding success

The parameters for the breeding success were clutch size, hatching success(%) and fledging success (which was used in term of breeding success at fledging,BSF (%)) and production (number of fledging per pair per year). The parameters were recorded during brood monitoring. Fledging success was determined either by observing or by nest checking. Nests were checked in the day around the expected date of fledging. The check was done before dawn (0500-0600) when all members were roosting at the nest. Another evidence was the presence or absence of the nest. The entire clutch of eggs or broods of young that suddenly disappeared was considered that they were fallen and that clutch was considered as unsuccessful clutch. The breeding successes of 262 clutches performed by 53 breeding pairs were pooled and analyzed using ANOVA-DUNCAN.

### 4.3.2.3 Morphology of eggs

The mean difference of egg morphology within/between clutches during the breeding time was conducted by measuring the dimension of the eggs (length and breadth) with a vernier caliper, 0.01-mm accuracy (Figure 4.3,a). Eggs also were weighed using digital balance at nearest to 0.01 g (Figure 4.3,b). The difference was tested by ANOVA-DUNCAN

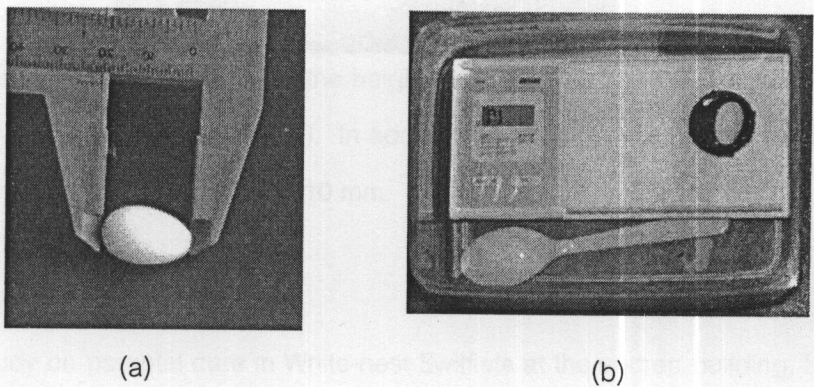


Figure 4.3. Egg measurements : (a) egg length, using vernier caliper; (b). weighing, using digital balance

### 4.3.2.4 Morphology of nests

Nests from Samut Sakhon Province were compared to those of White-nest Swiftlets from caves at Phatthalung Province. All nests harvested were white-nests which were collected in March, April and August 2000 for the first, second and third harvesting, respectively. All nests were weighed using a digital balance at nearest to 0.01g. Height, width and thickness was measured using vernier caliper (Figure 4.4). Data were compared using ANOVA-DUNCAN.



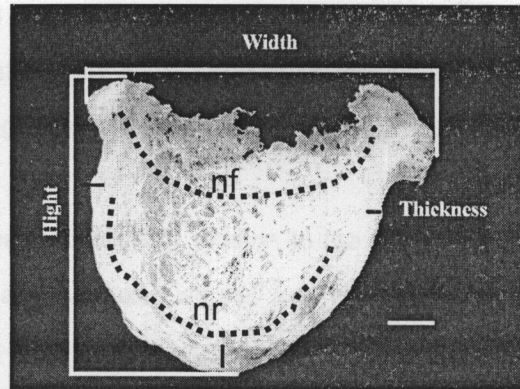


Figure 4.4. Nest morphology, showing the height, width and thickness. Thickness was measured at 3 points as indicated by (-). In addition areas of nest feet (dot line,nf) and nest rim (dot line,nr) were shown. Bar= 10 mm.

#### 4.4 Determination of parental care

The study on parental care in White-nest Swiftlets at the sacred building, Samut Sakhon Province was carried out during November 2000 and October 2001. Focuses of the study were as following;

- 4.4.1 Parental investment for egg incubation
- 4.4.2 Parental investment for nestling incubation
- 4.4.3 Parental investment for nestling feeding
- 4.4.4 Equitability of parental care

The parental investment in incubation (egg and nestling incubations) and nestling feeding were recorded from pairs that were in the stages of incubation and nestling feeding by continuous watching. Each observation day started from 0500 to 1930 (equally 870 min). The equitability of care was recorded from 15 tagged pairs by the same above method.

For the analysis, the breeding cycle was partitioned into 16 age classes (ac). The laying day was equal to "egg day 1" and the hatching day was equal to nestling day1. Sixteen age classes were ac1 (egg day 1); ac2 (egg day 2-5 ); ac3 (egg day 6-10 ); ac4 (egg day 11-15 ); ac5 (egg day 16-20); ac6 (egg day 21-25); ac7 (nestling day 1); ac8 (nestling day 2-5); ac9 (nestling day 6-10); ac10 (nestling day 11-15); ac11

(nestling day 6-20); ac12 (nestling day 21-25); ac13 (nestling day 26-30); ac14 (nestling day 31-35); ac15 (nestling day 36-40) and ac16 (nestling day 41 or more). The nest contents in different stages are shown in Figure 4.5.

All activities were recorded in relation to the age of nest contents. Data of all clutches were pooled and analyzed across age classes of the nest content. ANOVA-DUNCAN and *t*-test were used to test whether the incubation and nestling feeding times and the feeding rate varied between clutch sizes and across the age classes.

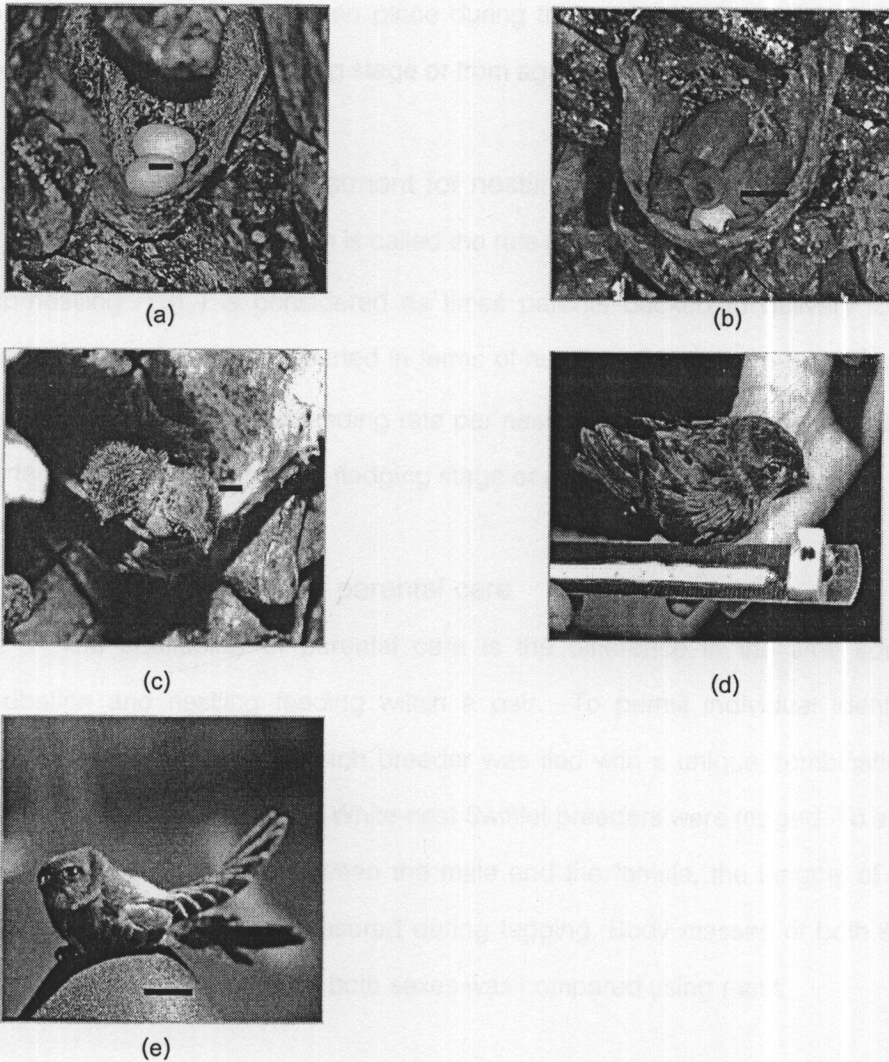


Figure 4.5. Stages of the nest content, showing : (a) egg stage, age class 1-6; (b-e) nestling stages at different age classes and; (e) fledging stage, age class 16.

Bar=10 mm.



#### 4.4.1 Parental investment for egg incubation

Egg incubation time was considered as a period of time a breeder sat or presented on its nest during 0500 and 1930 of each observed day. This activity started from the egg laying stage to the hatching stage or from the age class 1 to the age class 6.

#### 4.4.2 Parental investment for nestling incubation

Nestling incubation was considered as a period of time a breeder sat or covered on its nestling which was taken place during the rearing periods. This activity started from hatching stage to fledging stage or from age class 7 to age class 16.

#### 4.4.3 Parental investment for nestling feeding

Nestling feeding which is called the rate per nestling feeding ( $\text{trip} \cdot \text{nestling}^{-1} \cdot \text{h}^{-1}$ ) is considered as times parents backed to delivery food to their nestlings. The data were reported in terms of number of daily food-ball, feeding rate or feeding trip ( $\text{trip} \cdot \text{h}^{-1}$ ), and feeding rate per nestling ( $\text{trip} \cdot \text{h}^{-1} \cdot \text{nestling}^{-1}$ ). This activity started from hatching stage to fledging stage or age class 7 to age class 16.

#### 4.4.4 Equitability of parental care

The equitability of parental care is the difference in the time spent for the incubation and nestling feeding within a pair. To permit individual identification, a primary feather of wings of each breeder was tied with a unique combination of color bands. Fifteen pairs out of 53 White-nest Swiftlet breeders were tagged. To examine the morphological difference between the male and the female, the lengths of right wing, right tarsus and tail were measured during tagging. Body masses of both sexes were recorded. The morphology of both sexes was compared using *t*-test.

Watching were carried out during 0500 and 1930 of each observed day from November 2000 to August 2001 (at the beginning of tagging to the time of tag lost, due to molting). Times that the male/female presented on the nest and times they took turn including times they returned to feed were recorded. By tagging, the sex of the parents

were distinguished by their behaviours ( the female would sit on the nest before the onset of laying period for 1 to 3 days). The time of incubating breeder leaves nest in any uncertain cause was considered as "temporary leave" and was excluded from the analysis. The stages of nest content were also divided to 16 age classes as above. The data were analyzed using *t*-test and Chi-square test.

#### **4.5 Test for the loyalty in pair and nest-site fidelity**

By observing the tagged breeders, the royalty in pair and nest-site fidelity can be investigated. Times that the breeders bond pair could indicate the type of the mating system (e.g.monogamous, polygamous etc.). To investigate the royalty in pair (pair bonded for a long period of time or for life) of the White-nest Swiftlet, the duration of the association of each tagged pair from the beginning of tagging and the last day that tag lost were recorded.

The evidence of nest-site fidelity indicated by a new nest has been built subsequently at the same site by the same pair after the previous nest was absent. Normally, if nest is built at the suitable site, the nest will survive for a long time and will be reused by the same pair for its subsequent brood.

#### **4.6 Determination for nest-site characteristics of White-nest Swiftlets in caves and in the sacred building.**

##### **4.6.1 Nest-site characteristics of White-nest Swiftlets in the sacred building, Samut Sakhon Province and the effect of nest-site quality on the breeding success**

Because the environment of the nesting site in the building differs from those in caves, therefore, the different method was used. The parameter measured as following,

#### 4.6.1.1 Determination of the preferred nest-site

To determine the preferred nest-site, all nests settled at each nest-site type were counted. The preferred nest-site was indicated by the density of nests at each nest-site type.

#### 4.6.1.2 Determination of the effect of nest-site quality on the breeding success of nests at 4 nest-site types

To examine the effect of nest-site quality on the reproductive success, the breeding success at fledging, BSF(%) of 53 White-nest Swiftlet breeders at 4 different sites (1 at sm1; 12 at sm2; 15 at sc1 and 25 at scs2) were monitored by nest checking. The detail of nest checking and breeding success monitoring were described in 4.3.2.1 and 4.3.2.2. The data presented in the result section were for all given nests that displayed nesting attempts during this study. The number and causes of nesting failures were recorded during the observation of breeding activities. The issue concerning the nest-site quality is whether suitable nest-sites are optimal in term of yielding higher reproductive success. Furthermore, if the nesting site in the building is limited, new breeders will accept the artificial nest-site.

#### 4.6.2 Determination for nest-site characteristics of White-nest Swiftlets in caves

The study was conducted after the nests were collected by commercial collectors in October 2000. The study focused on the nest-site characteristic of White-nest Swiftlets which nest in group. Each nesting area on the wall was called a nest-patch whereas a nest-site was defined as the area on the cave wall to which a single nest-cup was attached. Nest patches of at least 20 nest-sites with the height of < 10 m from the cave floor were examined. For this study, 25 nest-patches, ranged from 1 to 80 m<sup>2</sup> (average =  $10.52 \pm 18.34$  m<sup>2</sup>), were study of which 3 nest-patches were on ceiling and 22 nest-patches were on inward-inclining wall. The angle of nest-patch surface were classified as : 1) the vertical wall with an angle of approximately 90° to the horizontal line, 2) the outward-inclining wall with the angle > 90°, 3) the inward-inclining wall with the angle of < 90° (Figure 4.6).

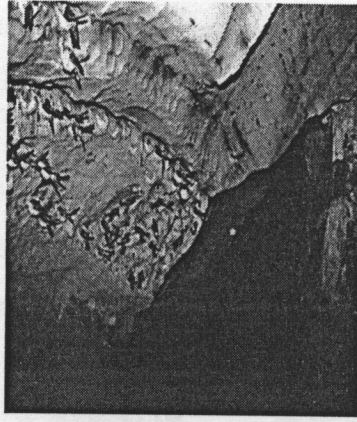


Figure 4.6. A nest-patch on the inward-inclining wall with the angle of  $<90^\circ$  in the Nong Kwai cave, Ko Ta So, Phatthalung Province.

#### 4.6.2.1 Nest-site characteristics

Nest-site characteristics were examined from 5 nest-sites of each 25 nest patches which were selected systematically, starting with one nest-site at the center of each patch and four others at approximately 1 m away at right angles to the center (Figure 4.7).

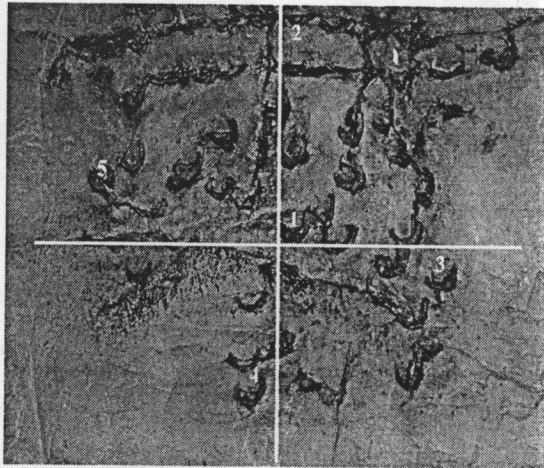


Figure 4.7. Demonstration of the systematic sampling, showing 5 sampling nest-sites selected from the patch.

Nest-site characteristics recorded were the surface of the cave-wall. The surface to which the nests of *A. fuciphagus* were attached was noted as smooth or rough, concave or flat; and with or without supporter (Figure 4.8). A supporter is a protruding rock of U-shaped form on the wall surface (Figure 4.8, d). The number of supporters and the number of nest-sites in each of 25 nest patches were counted in order to examine whether there was any correlation between them.

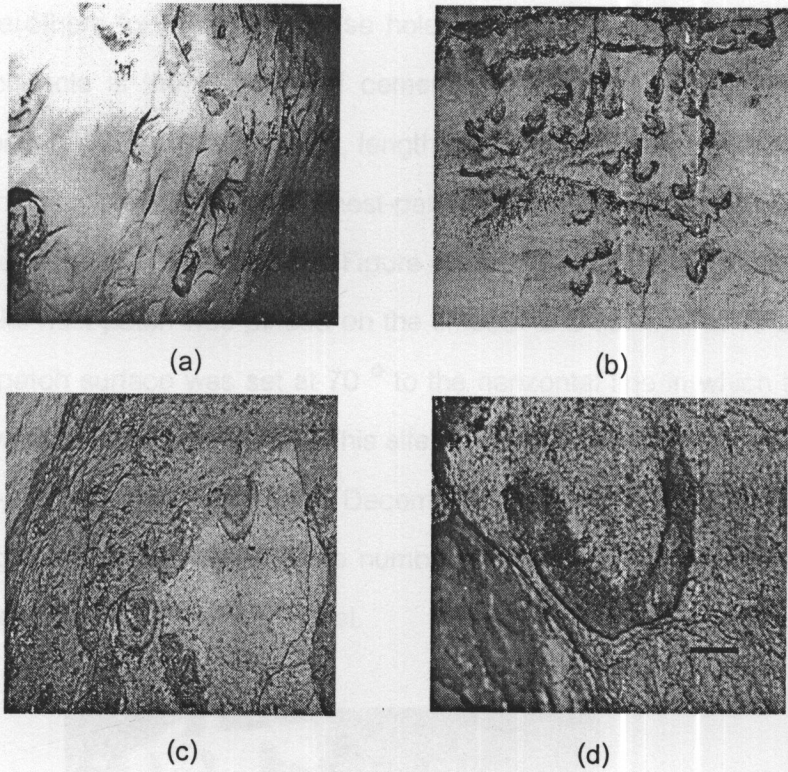


Figure 4.8. Types of nest-sites in the caves of Si-Ha Islands, Phatthalung Province, (a) smooth and concave with no supporter sites, (b) smooth and flat with supporter sites, (c) rough and concave with supporter sites, (d) rough and flat with supporter site, focusing the protruding U-shaped rock. Bar=10 mm.



#### 4.7 Experiment on the use of artificial nest-sites by White-nest Swiftlets living in the sacred building

The model of the nest patch with 30 nest-sites was build to imitate the characteristics of nest-site in the natural caves that correspond to the preferable sites in the sacred building. An artificial nest-patch was made on 30-cm width, 100-cm length and 0.20-cm thick of plywood. The nest-patch consists of thirty 3-cm radius holes. One hole closes to the others for 3–10 cm. These holes imitated as a concave wall. The lower line of each hole is the U-shape of cement molding with the wire inside for strength. The molding,  $3 \times 10 \times 3 \text{ cm}^3$  in width, length, and thickness, presumably plays a role as supporter. The characters of the nest-patches are smooth and concave with supporter sites, comprising of 30 nest-sites (Figure 4.9 and 4.10).

The artificial nest-patch was placed on the smooth and flat wall at 10 cm under the ceiling. The patch surface was set at  $70^\circ$  to the horizontal line in which the lower line of the patch was attached to the wall. This site is located behind the sculpture wall. The artificial nest-patch was hung up on 11 December 2000. The first day that the bird has seen roosting at the nest-patch and the number of nests built at the artificial nest-site would indicate the efficiency of the model.

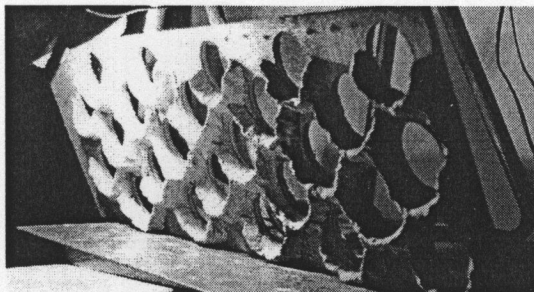


Figure 4.9. A model of artificial nest-patch comprising of 30 nest-sites and the angle of the patch was set at  $70^\circ$  to the horizontal line, imitating the inward-inclining wall of the natural caves.

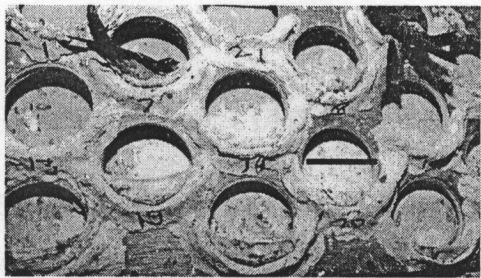


Figure 4.10. Artificial nest-sites in one artificial nest-patch showing the inter-nest site distance that was set at 3-10 cm. Bar=6 cm.

4.8 Data analysis

All variables were reported in term of means  $\pm$  sd. Analyses were conducted with SPSS version 10.0. Chi-square, *t*-test and ANOVA-DUNCAN multiple-test were used, after checking for normality of the data. Results were considered significant differences if  $P \leq 0.05$ .

Measurements	Localities	N	Mean	SD	P
Wing length(mm)	Samsat Sakon	50	113.52	2.71	.212
	Phnomlong	43	118.20	1.51	
Beak length(mm)	Samsat Sakon	50	5.06	0.47	.483
	Phnomlong	43	5.08	0.34	
Tarsus length(mm)	Samsat Sakon	50	14.67	0.53	.242
	Phnomlong	43	14.62	0.45	
Tail length(mm)	Samsat Sakon	50	48.53	2.56	.368
	Phnomlong	43	48.20	2.12	
Weight(g)	Samsat Sakon	50	12.77	1.31	.248
	Phnomlong	43	11.40	1.63	

In general, birds of these two populations are indistinguishable in the morphological appearance. They are similar in color pattern and body form. In addition, both have naked tarsi and produced pure white nests which are different from the Black-nest Sittalet *A. melanus*. The results from the measurement shows no significant different in beak, tarsus and tail lengths as well as the weight. However, there was significantly different in wing length of birds between the two localities, indicating a morphological variation between the two populations.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Morphology and Scientific name of the study species

5.1.1 Morphology of birds of Samut Sakhon and Phatthalung Provinces.

The results of the morphological character comparison are shown in Table 5.1. Other characters such as the body color and characteristics of their nests were also investigated.

Table 5.1. Morphological measurement comparison of birds at Phatthalung and Samut Sakhon Provinces, showing sample sizes (N), means, sd and results of *t*-test with significant difference at  $P \leq 0.05$ .

Morphological measurements	Localities	N	Means	SD	<i>P</i>
Wing length(mm)	Samut Sakhon	50	113.52	2.74	.012
	Phatthalung	43	118.20	1.94	
Beak length(mm)	Samut Sakhon	50	5.05	0.47	.983
	Phatthalung	43	5.19	0.33	
Tarsus length(mm)	Samut Sakhon	50	11.60	0.59	.142
	Phatthalung	43	11.62	0.46	
Tail length(mm)	Samut Sakhon	50	48.53	2.57	.355
	Phatthalung	43	48.30	2.09	
Weight(g)	Samut Sakhon	50	12.70	1.34	.245
	Phatthalung	43	11.40	1.66	

In general, birds of these two populations are indistinguishable in the morphological appearance. They are similar in color pattern and body form. In addition, both have naked tarsi and produced pure saliva nests which are different from the Black-nest Swiftlet *A. maximus*. The results from the measurment shows no significant different in beak, tarsus and tail lengths as well as the weight. However, there was significantly different in wing length of birds between the two localities, indicating a morphological variation between the two populations.



Since the above morphological comparison could not give the clear distinction between birds of Phatthalung and Samut Sakhon, it is possible that the White-nest Swiftlets at two localities are in the same species.

### 5.1.2 Scientific name of the study species

The scientific name of the White-nest Swiftlet used in this study was determined from the recent publications and from the comparison of specimens collected from Phatthalung and Samut Sakhon Provinces to the reference specimens stored at the Raffle Museum, Republic of Singapore. Specimens from Phatthalung and Samut Sakhon Provinces had size range within the range of *Collocalia fuciphagus amechana*, the reference specimens collected from Malacca, Malaysia and Singapore (Table 5.2). This subspecies had been reported as *Aerodramus fuciphaga amechana* by some authors, (i.e. Medway, 1966; Lekagul and Round, 1991; Robson, 2000). The bird reported that was found from the upper Gulf of Thailand to the extreme southern part of Thailand. Recently, Chantler and Driessens (2000) and Robson (2000) retained *C. f. amechana* as one race of *C. fuciphaga* (Thunberg) 1812.

Lekagul and Round (1991) listed two subspecies of Edible-nest Swiftlets in Thailand, the first was *Aerodramus fuciphagus germani*, in which the authors reported that it was the most widespread. The second was the extreme southern subspecies *A. f. amechana*. This was reaffirmed by Chantler (1999) and Wells (1999).

Since the considerable confusion still exists on the taxonomic status of edible-nest species, the scientific name of the White-nest Swiftlet *A. fuciphagus* (Thunberg, 1812) used in this study was from Lekagul and Round (1991); Eve and Guigue, 1996; Chantler(1999) and Wells (1999). This name is used on the basis of the ability of ecolocation of *Aerodramus* group, the production of pure saliva nests and the distribution range as described by many authors above. However, comparative studies on the ecology, morphology and molecular genetics of these birds in different localities that cover the whole distribution range of them are necessary, before the proper taxonomic status can be made.

Table 5.2. The morphology of reference specimens in the Raffle Museum of Biodiversity Research, Department of Biodiversity Science, The National University of Singapore, Republic of Singapore.

List No	Catalogue No.	Scientific name	Wing (mm)	Tarsus (mm)	Localities	Date of collections	Collector
313	9371	<i>Collocalia fuciphaga amechana</i>	112	12.5	Malaca	1953/04/23	E.H. Bromley
315	9373	<i>Collocalia fuciphaga amechana</i>	112	11.5	Malaca	1953/04/23	E.H. Bromley
316	9374	<i>Collocalia fuciphaga amechana</i>	113	10.1	Malaca	1953/04/23	E.H. Bromley
327	9385	<i>Collocalia fuciphaga amechana</i>	117	11.7	Singapore	1931/01/14	
336	9394	<i>Collocalia fuciphaga amechana</i>	115	11.0	Singapore	1935/01/14	
338	9396	<i>Collocalia fuciphaga amechana</i>	107	11.0	Singapore	1935/01/15	
339	9397	<i>Collocalia fuciphaga amechana</i>	113	11.0	Singapore	1935/01/15	
340	9398	<i>Collocalia fuciphaga amechana</i>	113	11.0	Singapore	1935/01/16	
341	9399	<i>Collocalia fuciphaga amechana</i>	106	11.0	Singapore	1939/12/13	
		Means	112.0 ± 3.5	11.2 ± 0.7			

5.2 Population size, diet and foraging area of White-nest Swiftlets in Samut Sakhon Province.

5.2.1 Population size

Results of the population size estimation during April 2000 and February 2001 are shown in Figure 5.1, indicating that the population size increased from 2,702 to 3,486 within one year. The average rate of population increase was 65.33 individuals per month or 29 % per year, which was a very high rate. The increasing numbers of each two-month interval were 138, 188, 112, 127, 219 individuals in June, August, October and December 2000 and February 2001, respectively.

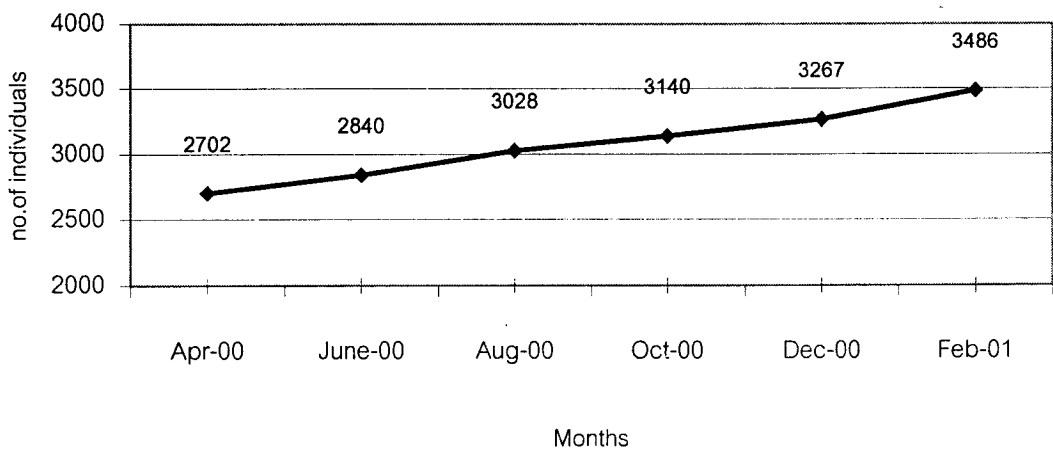


Figure 5.1. Number of individuals of the White-nest Swiftlet at the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during April 2000 and February 2001.

Normally, a population that has been in a suitable environment will increase in numbers. By the fact that population growth cannot occur continuously through time in the natural environment, the number of individuals in a population in a limited space or resource will eventually be stabilized at the carrying capacity level. Therefore, one would expect that the population of the White-nest Swiftlet that has established in the sacred building for more than 30 years should have its population size at the stationary phase.

In this study, it can be concluded that the White-nest Swiftlet has very high potential to increase if suitable nest-sites are available. The factors involved with the population increase could be from several causes. The main causes should be due to the addition of supporters (Figure 5.2) and the addition of artificial nest patches onto the barely smooth walls (Figure 5.3). Predation by other species, disease, starvation, low emigration rate and high survival rate of fledglings may also affected the growth rate of this species.



Figure 5.2. The supporting wood (dark arrows) attached on the smooth wall under the ceiling in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province.

In 1999 or about one year before censusing, 8 rows of supporters made from long pieces of solid wood,  $0.03 \times 0.03 \times 4.00 \text{ m}^3$  each, were nailed on the smooth and flat wall at about 15-30 cm below the ceiling. The reason behind this was because the abbot would like to increase the population size and expected that these long pieces of wood would function as supporters that would provide better nest-sites to new breeders.

The result showed that supporting woods have higher potential, comparing to the smooth and flat wall. However, there were evidences of nest fallings at high rate and the accumulation of droppings on the lower row of the wood.

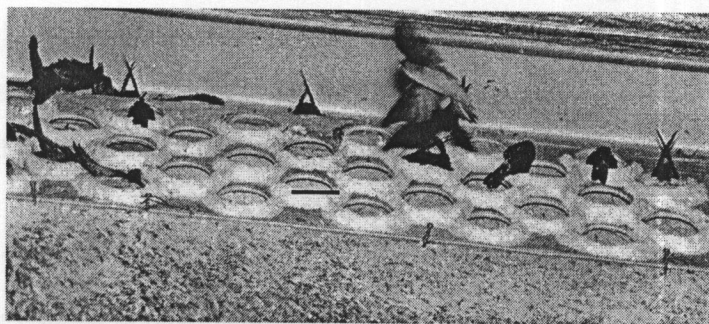


Figure 5.3. An artificial nest-patch in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province. Bar=6 cm.

In December 2000, artificial nest-patches were placed on some areas of the remaining smooth wall. It was found that, four floaters attended on the patch on the following day. Five days after, the first pair started to occupy at one nest-site of the nest-patch, followed by several others later on. This indicated the competition for suitable space in the building. Therefore, addition of supporting woods and artificial nest patches into the building should be major factors, leading to the increase of the population size throughout the study period.

Predators such as a Japanese Sparrow Hawk *Accipiter gularis*, a Barn Owl *Tyto alba* and a Golden Tree Snake *Chrysopelea ornata* were observed on hunting adult birds in the building. However, the incident was seen only a few times. Once a predator was found it would be chased or executed. Thus, the effect of predators on the population change during the study was rather low.

Disease and starvation may have a little effect on the death of adults and chicks since there was no evidence of infected birds or carcasses at the nest or on the floor of the building. Most nestlings died from fallings rather than starvation. Therefore, disease and starvation should not be the major problem for this population.

White-nest Swiftlets are subject to emigration and establishment of a new colony. This behavior was first observed in the 1880s and was documented by Nugroho and Whendrato (1999). The increase of cultivated houses in many countries at present such

as Thailand, Malaysia and Indonesia is also being an evidence. In Thailand, many new buildings are being under construction as cultivated houses such as at Pak Panang District, Nakhon Si Thammarat Province and at Narathiwat, Pattani, Satun and Trang Provinces.

Other causes of emigration may be due to the limitation of nesting site and the disturbance from human (i.e. nest harvesting).

In this population, there has been no evidence of emigration and immigration. However, the dispersal may be occurred and the cause of the movement and where they move to, are interesting to be studied.

White-nest Swiftlets have a high survival rate, approximately at 90% (Fogden, 1972; Francis, 1984; IUCN species Survival Commission, 1994, cited in Kenneth, 1999 : 15). Therefore, breeders have long life and can produce many fledglings before they die. In this study, the breeding success at fledging was high at 33.46% (see Table 5.10). Therefore, the number of recruitment to the population would be ready at any time to replace the number of old adults.

Direct count from photograph was the proper technique for censusing the White-nest Swiftlet in the sacred building because it could be done after dark when all birds returned to the roosting sites. Although birds often flushed out from their sites when the photographer appeared, the photographs can be taken when the exciting birds resumed to their sites and calmed down. Therefore, the reliable data could be obtained. This method is also suitable for the other populations that live in the accessible sites and the photographs can be taken with the aid of flashlight.

Population monitoring provide a picture of birds' tendency to grow as well as the density in relation to the space of nesting sites that is crucial in the prediction on the carrying capacity of the building. Furthermore, the population data are important for management and development to the maximum yield for the cultivated house.

### 5.2.2 Diet of nestling

Diets from fifteen food-balls were analyzed and the result is shown in Table 5.3. The average weight of food-balls was  $0.4 \pm 0.14$  g with the range of 0.2 - 0.6 g. Food-balls consisted of small flying insects and small arachnids, in the average of 350 individuals per one ball. Sizes of food items ranged between 0.5-10.0 mm in length, of which the sizes of 1.0 - 2.5 mm were the most abundance.

Dipterans (e.g. true flies, mosquitoes, 37.82 %) were the prime items most frequently found in food-ball while homopterans (e.g. plant hoppers, 35.09%), hymenopterans (e.g. reproduction form : flying ants and chalcids, 16.26%), hemipterans (e.g. true bugs, 4.69%), arachnids (spiders, 3.79%) and other flying insects (e.g. coleopterans, psocids, thysanurans, psilids, etc., 1.74%) were found in respective order of incidence.

Dipterans caught by White-nest Swiftlets were small flies, not more than 10 mm long, species number of in Suborder Brachycera and Suborder Cyclorrhapha were highest in number (53.08%), while the remainders were the group of long-horned flies such as mosquitoes (Culicidae). The numbers of dipterans found in food-balls were higher in July and October than in March.

Delphacids (plant hoppers) and aphids (plantlice) were the majority in the homopteran group. Some small plant feeders considered as economic important pests and important disease vectors, were commonly found in food-balls collected in March and July.

Formicids (e.g. flying ants) and chalcidoid (e.g. fig wasps) were found more than other hymenopterans. Formicids had solid bodies and most of them were blackish in color. They were larger in length than other insects found in food-balls but their masses were lesser than the masses of arachnids. They were caught in great number in March leading to highest of the average weight of food-balls in this month (0.44 g) while the means in July and October were 0.42 g and 0.34 g, respectively. The winged ants were



queens and drones. Chalcids were the tiny flying insects (0.5-3.0 mm), their color and bodies were paler and softer than the formicids. Fig wasps were the most common taxa comparing to the other chalcidoids, found in nestling diets of March and July.

Hemipterans found in food-balls as follows, the viliids, corixids (water boatmans), tingids (lace bugs), lygaeids (seed bugs), saldids (shore bugs), reduviids (threaded-legged bugs), pleidae (pigmy blackswimmers) and mesovliids (water treaders). They were included in both terrestrial and semiaquatic bugs that feed on plant juices. Some are pests such as lace bugs. Bugs were caught at the similar proportion within three months.

Spiders caught by swiftlets varied in sizes, ranging from 0.5-7.0 mm, assuming that they lived on trees and were dispersed by strong wind.

**Table 5.3.** Food items of 15 food-balls collected from the White-nest Swiftlet feeder at Suthiwatwararam Temple, Samut Sakhon Province in March, July and October 2001, showing the prey size, the total number of preys and the percentage of occurrence.

Orders	Suborders	Families	Common name	Prey sizes (mm)	Total number of individual preys				Occurrence (%)
					Mar.	Jul.	Oct.	Overall	
Diptera	Nematocera	Others		0.5-3.0	79	333	412	824	15.83
Diptera	Nematocera	Culicidae	Mosquitoes	0.5-3.0	14	50	4	68	1.31
Diptera	Anisopodidae	Psychodidae		0.5-3.0	2	0	0	2	0.04
Diptera	Anisopodidae			0.5-2.5	0	2	0	2	0.04
Diptera	Brachycera			0.5-2.5	132	194	596	922	17.72
Diptera	Cyclorrhapha	Drosophilla	Pomance fly	0.5-2.5	11	8	0	19	0.37
Diptera		Muscidae		1.0-4.0	0	3	0	3	0.06
Diptera		Cecidomyiidae		0.5-4.0	0	2	0	2	0.04
Diptera		Ceratopogonidae		0.5-2.5	0	13	0	13	0.25
Diptera		Chironomidae	Marsh fly	7.0-10.0	0	78	0	78	1.50
Diptera		Syrphidae	flower fly	1.5	0	5	1	6	0.12
Diptera		Agromyzidae		0.5-2.5	0	0	1	1	0.02
Total				0.5-10.0	239	689	1014	1942	37.32
Homoptera		Delphacidae		2.0-4.0	602	566	67	1235	23.73



Table 5.3 (Continued)

Orders	Suborders	Families	Common name	Prey sizes (mm)	Total number of individual preys				Occurrence (%)
					Mar.	Jul.	Oct.	Overall	
Homoptera		Aphididae	Aphid, plantlice	1.0-1.5	99	360	61	520	9.99
Homoptera		Typhlucybinae		2.0	18	17	0	35	0.67
Homoptera		Derbidae	Plant hopper	1.0-3.0	2	3	2	7	0.13
Homoptera		Cicadellidae		1.0-2.5	0	0	1	1	0.02
Homoptera		Others		2.0-2.5	18	10	0	28	0.54
Total				1.0-4.0	739	956	131	1826	35.09
Hymenoptera		Torymidae		1.0-2.5	71	56	16	143	2.75
Hymenoptera		Formicidae		2.5-10.0	439	35	1	475	9.13
Hymenoptera		Chalcidae	Fig wasps	0.5-2.0	65	65	4	134	2.57
Hymenoptera		Eupelmidae		0.5-2.5	89	0	0	89	1.71
Hymenoptera		Phyllidae	Psyllid	0.5	2	0	3	5	0.10
Total				0.5-10.0	666	156	24	846	16.26
Hemiptera		Others		1.0-2.5	0	1	0	1	0.02
Hemiptera		Corixidae	Water Boatman	1.5	3	23	1	27	0.52
Hemiptera		Viliidae		1.5-2.0	4	56	71	131	2.52
Hemiptera		Tingidae	Lace Bugs	2.5	2	1	0	3	0.06
Hemiptera		Mesoviliidae	Water Treaders	1.5	0	1	0	1	0.02
Hemiptera		Lygaeidae	Seed Bugs	1.5	0	2	1	3	0.06
Hemiptera		Reduviidae	Tread-legged Bugs	2.5-3.0	0	2	1	3	0.06
Hemiptera		Pleidae	Pigmy blackswimmer	2.0	0	2	0	2	0.04
Total				1.0-3.0	46	106	92	244	4.69
Arachnida				0.5-7.0	58	134	5	197	3.79
Coleoptera		Others		2.5-4.0	19	10	7	36	0.69
Coleoptera		Pleidae		2.0	12	5	1	18	0.35
Coleoptera		Staphylinidae	Rove Beetle	2.0	0	0	1	1	0.02
Coleoptera		Bostrichidae	Bistrichid beetle	1.0-2.0	1	0	1	2	0.04

Table 5.3 (Continued)

Orders	Suborders	Families	Common name	Prey sizes (mm)	Total number of individual preys				Occurrence (%)
					Mar.	Jul.	Oct.	Overall	
Coleoptera		Curculionidae	Snout weevil	1.5	1	0	1	2	0.04
Total				1.0-4.0	33	15	11	59	1.13
Psocida		Lepidopsocidae	Potato phyllid	0.5-2.0	7	9	2	18	0.35
Psocoptera				1.0-2.0	3	7	1	11	0.21
Thysanoptera		Phlaeotripidae	Thrips	1.0	3	2	1	6	0.12
Lepidoterata		Oecephoridae		4.0	3	0	0	3	0.06
Lepidoterata		Bittacidae	Caddisfly	3.0	0	1	0	1	0.02
Unidentified		Lepidopsocidae		0.5-5.0	22	22	7	51	0.98
Overall				0.5-10.0	1819	2097	1288	5204	100.00

From Table 5.3, it can be concluded that food-ball compose mainly of the tiny aerial insects and some arthropods. It is found that size of prey ranging about 0.5-10.0 mm. This minute size may be appropriate to the size of the feeder's beak, which is  $5.05 \pm 0.5$  mm. Therefore, the small flying insects, between 0.5–10.0 mm long, such as true flies, mosquitoes, plant hoppers, bugs, flying ants and chalcids are the most common items foraged by swiftlets. However bigger insects, 10.0-15.0 mm, such as large flies and damselflies were also observed in the diet of a nestling (the diet fallen down from the mouth of nestling during the feeding at 1830 in November 2000). Since large insects such as damselflies are reported to fly at lower elevation and they are often found near the streams, ponds and small swamps (Borror et al., 1981). Therefore, they should not be the main food of White-nest Swiftlets. For this case, the preys may be caught during twilight hour in which birds usually forage at low elevation around the surrounding of nesting sites before returning to their nests. Although insects of larger sizes are not the common preys of White-nest Swiftlets, birds may catch them if they have opportunity.

The size of preys of some species of swiftlets had been reported. The studies indicated that swifts have diet preference for prey size. Large dipterans and

hymenopterans of 10.0 to more than 12.0 mm long were the preys of the Pallid Swift while Common Swifts fed on smaller insects and the size of preys did not exceed 12.0 mm. Eighty seven percents of preys of Spot-fronted Swifts were insects 1.0-5.0 mm long while White-chinned Swifts ate insects at 10.0 -12.0 mm up to 38.4% and Black Swifts chose prey sizes between 8.0–11.0 mm around 82.5% (i.e. Finlayson, 1979; Cucco, Bryant, and Malacarne, 1993; Marin and Stiles, 1992, cited in Chantler and Driessens, 2000 : 33).

The species and number of flying insects caught by White-nest Swiftlets *A. fuciphagus* depended on seasons that they foraged. The results from this study shows the difference in species and the number of flying insects at different time of the year.

Several authors had reported the proportion of the prey species of this bird and the results demonstrated that kinds of preys vary by spaces and times as well. For example, the diet of Edible-nest Swiftlets *Collocalia fuciphaga germani* in Binh Dinh, Vietnam had the ratio of homopterans, coleopterans and hemipterans differed from that in Khanh Hoa (Nguyen, 1996). In Penang, Malaysia, the proportion of hymenopterans and chalcidoid wasps was highest in the food contents, followed by the great number of mayflies, homopteran bugs and dipterans (Langham, 1980). Ali and Ripley (1970) noted that preys of Black-nest Swiftlets *C. maxima* and Himalayan Swiftlets *Aerodramus brevirostris* were dipterans and hymenopterans, while mango-hoppers, hemipterans, coleopterans, damselflies and dragonflies, hymenopterans, dipterans and trichopterans were preys of the Indian Swiftlets *Collocalia unicolor* (Harrison, 1974). Furthermore, the studies on the stomach contents of *C. maxima* from the Niah caves indicated that during the wet season in November, flying ants and termites were the major food items (89%) and the percentages increased to 99 % in March (Kenneth, 1999). This confirmed the report of Medway in 1962.

Langham (1980) pointed out that Edible-nest Swiftlets *A. fuciphaga* selected mayflies and fig wasps as their main diets and birds used the acute visual sense. He

also suggested that mayflies were the swarming insects, easily to be seen and digestible. Therefore, mayflies would be suited for nestlings.

From the reports of Francis (1987, cited in Kenneth, 1999 : 16), the different in foraging areas could lead to the difference in numbers and species of food items. For example, at Gomantong cave, the preys of *Collocalia esculenta* (Linnaeus), *C. maxima* Hume and *C. fuciphaga* (Gmelin) made up by flying ants and termites. The different result was found by Langham who studied the food items of *A. fuciphaga* in the urban environment. He confirmed that mayflies were the commonest item in food-balls while flying ants and termites contained as 6 % and 0.1 %, respectively of all total items found. Edible-nest Swiftlets *Collocalia fuciphaga* in Hainan Island, China foraged on beetles, aphids, hymenopterans and dipterans (Zhiyong and Fenqi, 1996). Indian Swiftlets *C. unicolor* fed shiefly on flies, bugs, wasps and bees (Rodelphe, 1912). Furthermore, Waugh and Hails (1983, cited in Kenneth, 1999 : 17) suggested that the primary forests provide a higher abundance of food than the open habitats

In addition, Cucco et al. (1993, cited in Chantler and Driessens, 2000 : 32) remarked that hymenopterans (bees, wasps and ants); dipterans (flies); hemipterans (bugs) and coleopterans (beetles) were the common preys of tropical and temperate swifts.

In this study, dipterans, homopterans, hemipterans and hymenopterans are the main food items. Birds forage over the areas of plantations, mangrove forests and paddy fields. Comparing to the the population at Phatthalung Province, the preliminary study on the diet showed that the percentages of termites and mayflies were up to 90% in food-balls collected in April 2000. These cave swiftlets forage over the tree canopy on the islands and along the water body of Songkhla Lake including the plantations and rice fields on the main land.

The result shows the role of White-nest Swiftlets in pest control since some of their food items are pests of some economic plants. The result also provides the

knowledge which will lead to the development of food to feed the fallen nestling as well as the development of supplementary food for adult birds.

### 5.2.3 Foraging area

From the observation, White-nest Swiftlets left their nests to forage at dawn. The time of leaving depended on the local time of sunrise, normally around 10 min before the first light appeared. They flew out, swooped around the sacred building for approximately 30-60 min, before dispersing to the foraging areas. In the evening, all of them returned to their nest-sites, did not land immediately but again swooped around the building for about 30 min, screaming and performing erratically flight. Within one hour after dusk, they already roosted at their nests and at this time, the last nestling feeding often occurred. Non-breeding birds probably foraged all day, landed only for roosting at night or during bad weather but the breeding birds often returned for nestling feeding during daytime.

The results of the foraging area and the foraging distance of White-nest Swiftlets are demonstrated in Table 5.4 and Figure 5.4. It was found that members of this population foraged only over Samut Sakhon areas. None was found feeding over the areas of nearby provinces. The longest foraging distance observed was approximately 25 km from the breeding site.

The areas of 872 Km<sup>2</sup> of Samut Sakhon Province is divided into three Districts : Mueang, Krathumbaen and Ban Phaeo in which the major types of land use in each District are different. The number of foraging birds seen varied by locality ranging from 0-100 individuals per one observation. The averages were 2.4, 7.5 and 4.9 individuals per observation over the urban and industrial areas, the green areas and the coastal areas, respectively. This can be interpreted that the paddy fields, crop fields, orchard plantations (e.g. coconut, mango, etc.), irrigation areas (i.e. ditches and canals having small shrubs and grasses growing along the edges) and natural swamps located in the northwest and the west of the province are potential foraging areas comparing to areas

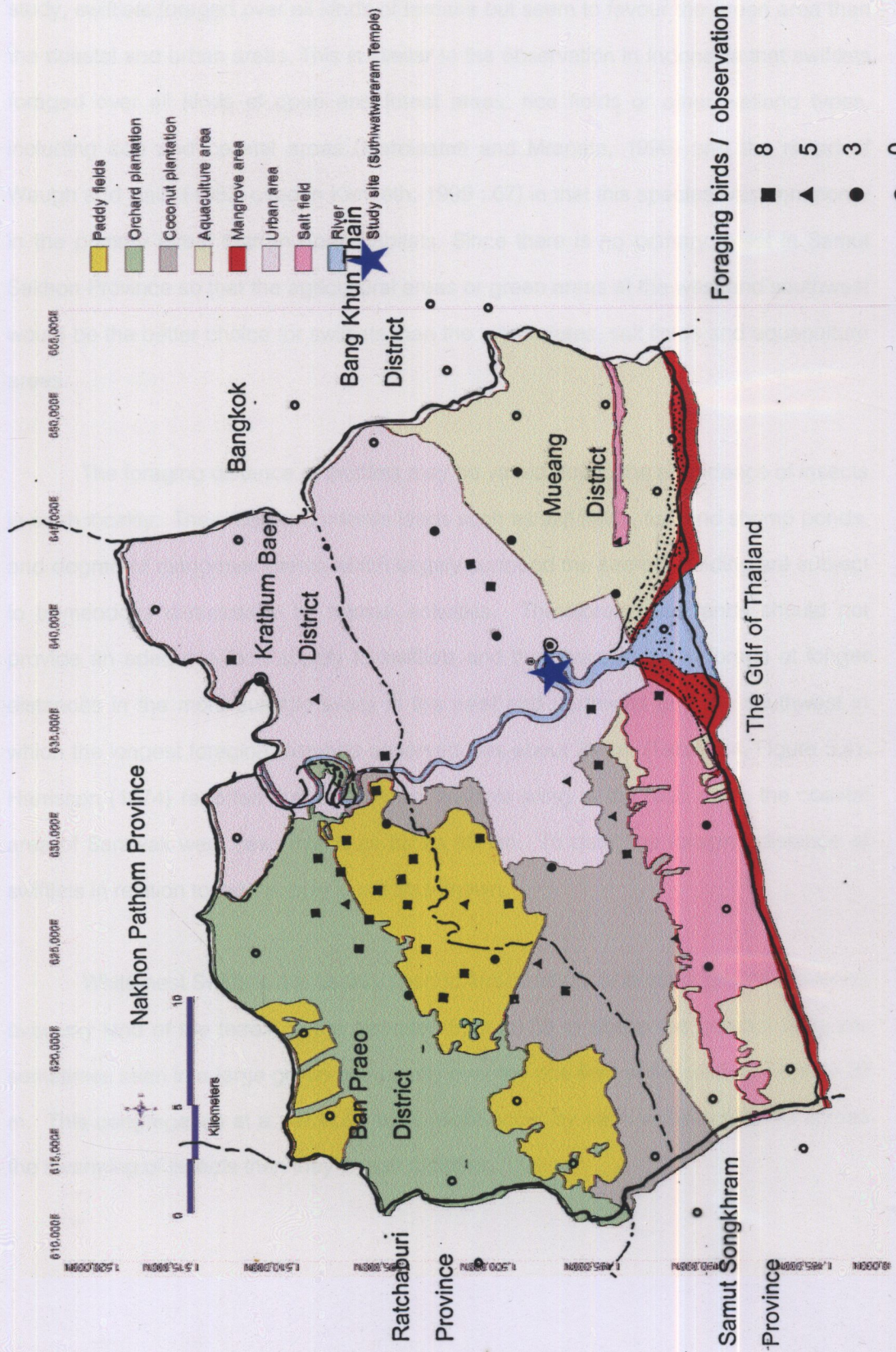


of other directions which are salt fields, fish and shrimp ponds, degraded mangrove forests and urban areas. These green areas are about one third of the total area of Samut Sakhon Province and are very important to the White-nest Swiftlet's population. If these habitats are changed or devastated, it must have the strong effect on the fate of this population. Therefore, to maintain the population of White-nest Swiftlets or to enhance the population for economic purpose, these green areas should be preserved.

**Table 5.4.** Average number of foraging White-nest Swiftlets seen at 3 locations of Samut Sakhon Province. Data were obtained from 183 observation during March 2000 and January 2001.

Locations	Major types of land use	Directions from breeding site	Foraging distances from breeding site (km)	Average number of foraging birds per observation (no. of observations)
Krathumbaen District, Maung District	urban and industrial areas	central, north, northeast	0 – 15	$2.4 \pm 7.7$ (80)
Ban Phaeo District	green areas (orchards, coconuts, rice fields, crop lands, swamps and ditches)	northwest, west	5 – 25	$7.5 \pm 17.0$ (84)
Mueang District	coastal areas (aquaculture, degraded mangrove forests, salt fields)	south, southeast, southwest	12 – 17	$4.9 \pm 12.4$ (15)





**Figure 5.4.** Map of the land use in Samut Sakhon Province. Foraging distances, foraging direction and average numbers of foraging birds are shown on the transparent sheet. This map was modified from the map produced by The Land Use Department. (Available from



The aerial insects in the tropical zone do not fluctuate drastically like those in the temperate zone ( Stutchbury and Morton, 2001). Generally, they are abundant all year but quite unpredictable that where and when insects will be available in great number. Therefore, the foraging distance of swiftlets can be varied from time to time. From this study, swiftlets foraged over all kinds of terrians but seem to favour the green area than the coastal and urban areas. This is similar to the observation in Indonesia that swiftlets foraged over all kinds of open and forest areas, rice fields or other wetland types, including cop and coastal areas (Mardiastuti and Mranata, 1996) and the report of Waugh and Hails (1983, cited in Kenneth, 1999 : 67) in that this species was commoner in the primary forest than in open habitats. Since there is no primary forest in Samut Sakhon Province so that the agricultural areas or green areas at the west and southwest would be the better choice for swiftlets than the urban areas, salt fields and aquaculture areas.

The foraging distance of swiftlets may be varied due to the abundance of insects in each locality. The urban and infertile lands such as salt fields, fish and shrimp ponds, and degraded mangrove forests which largely surround the sacred building are subject to tremendous disturbance by human activities. Therefore, these lands should not provide an adequate food supply to swiftlets and they have to go to forage at longer distances in the more suitable areas in the west and northwest and the southwest in which the longest foraging distance observed was about 25 km (Table 5.4, Figure 5.4). Harrison (1974) reported that Edible-nest Swiftlets living at the Niah cave, the coastal area of Sarawak were seen inland as far as 40 km. To date, the foraging distance of swiftlets in relation to food supply is still less known.

White-nest Swiftlets are usually seen to forage singly or in small groups, hovering over any kind of the terrain at the elevation from 20-50 m above the ground. They are sometimes seen in a large group particularly over the rice field at the elevation below 20 m. This congregation at a particular area might occur by each individual came across the swarming of insects then they forage together.

Over some habitat types of the study area, Pacific Swifts *Hirundo tahitica*, Barn Swallows *H. rustica* and White-nest Swiftlets are observed to forage together but White-nest Swiftlets tended to use higher level to forage than other species. Wells (1999) reported that White-nest Swiftlets *Aerodramus fuciphagus* foraged at lower height than the typical swifts *Apus* spp. and the needletails *Hirundapus* spp. The foraging height of other species have been reported. For example, Black-nest Swiftlets *C. maxima* and Crested Treeswifts (Family Hemiprocnidae) at Borneo fed over the canopy level, never under tree-covering. The Mossy-nest Swiftlet *C. salangana natunae*; Black-nest Swiftlet *C. maxima* and other species such as *C. vestita* in Baram basin were seen at the level of 75 m or more above the canopy (Harrison, 1974). The Mascarene Swiftlets *C. francica* (Gmelin, 1788) and Seychelles Swiftlets *C. elaphra* foraged at the level over 20 m above the ground and were reported that they fed at lower elevation over fresh water lakes (Diamond, 1987).

The level of the feeding height of each species may depend on the availability of the aerial insects and the specific level that each species usually forages would benefit to them in the way that they can avoid the interspecific competition. However, the foraging height is also determined by the weather condition. White-nest Swiftlets are observed at the height of 20-50 m or more when the weather is fine, but come down when it is cloudy. In addition, they swoop around the building not only in the morning and evening but also on the rainy day.

5.3 Breeding biology of the White-nest Swiftlet in Samut Sakhon Province.

5.3.1 Breeding pattern

Population of the White-nest Swiftlet in the sacred building showed pattern of continuous reproduction (Figure 5.5). Nesting attempts were observed every months from August 2000 to October 2001. Percents of nesting attempts were relatively high in December-January 2001, April 2001 and June-July 2001 which were indirectly correlated with the amount of rainfall (Pearson correlation,  $r = -0.587$ ,  $P = 0.015$ ,  $n = 15$ )

In average, the percentage of nesting attempts during October 2000 and October 2001 was  $7.3 \pm 3.1\%$ . Of which, more than half of them were unsuccessful clutches (60.34%). Most of unsuccessful clutches suffered from nest and/or nest content falling before the clutch completion. As a result, most of nestling hatched and fledged during April to July or at the time between summer and the beginning of wet season.

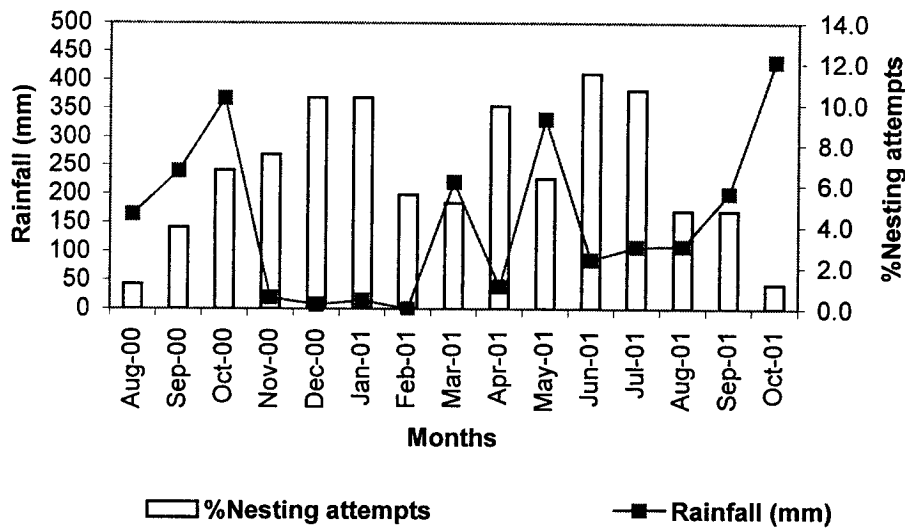


Figure 5.5. The monthly rainfall and the percentage of nesting attempts of 53 White-nest Swiftlet breeders during August 2000 and October 2001 at the sacred building of Suthiwatwararam Temple, Samut Sakhon Province.

The White-nest Swiftlet's population at Samut Sakhon Province shows continuous breeding pattern. Results from the nest status monitoring for 14 months indicates asynchronous nesting performance in that some pairs built their subsequent nests after their previous nests failed, while other pairs laid eggs in reused nests at the second time. At the end of observation, at least 25 active nests were on the process of breeding cycle. Similar results were reported for birds in Malaysia (i.e. Langham, 1980) that laid their eggs year round, but laying peaks were different.

### 5.3.2 Breeding activities

#### 5.3.2.1 Time spent for nest building, egg laying, incubation and nestling feeding.

##### 5.3.2.1.1 Time period of nest building

From the observation, White-nest Swiftlets built their nests entirely with mucilaginous secretion, which is called "nest cement". The nest cement was retched from mouth of the breeder and was placed directly to the substrate. Nest pad was first built adhering to the wall, then nest cements were added subsequently to form a rim of nest foot. The rim gradually widened until cup-shaped nest was formed. A nest would be completed with both nest feet reinforced with more saliva.

Both breeders in a pair built nest both at day and nighttime. The bout of nest cement smearing on the rim of the nest was around 30 seconds to 2 minutes. Breeders might spend longer time if it was at the beginning of the nest building. Breeders took  $30.64 \pm 6.07$  days in dry season ( $n=88$ ) and  $28.35 \pm 7.09$  days in wet season ( $n=48$ ) with overall  $29.83 \pm 6.31$  days ( $n=136$ ) to build a nest.

*At the end of the nest-building period, breeders laid and incubated their eggs.* They often placed trades of saliva on the top of the rim as well as at both sides of nest feet during the incubation period. Normally, the same breeding pair would reuse its nest for the second and third times but if the nest was harvested or absent, they would build



a new nest immediately. The time of nest construction was not difference among the first to the third clutch, taking  $30.71 \pm 5.09$ ,  $30.19 \pm 4.54$ , and  $26.83 \pm 9.06$  days, respectively. However, the nest building performance tended to be faster at the fourth nest ( $20.00 \pm 11.31$ days), indicating by the significant difference between the 4<sup>th</sup> and the first three clutches (ANOVA-DUNCAN,  $F_{3,130}=3.602$ .  $P = .015$ ).

5.3.2.1.2 Time period of egg laying

This population showed three peaks of egg laying. The first peak was in December to January, the second was in April and the latter was in June to July. The highest peak was April. However, laying was found every month with an average of  $7.7 \pm 4.5\%$  for all observed nests from September 2000 to 2001. During November 2000 and September 2001, the time of laying was directly correlated with nesting attempts (Pearson correlation,  $r = 0.613$ ,  $P=.013$ ,  $n =15$ , Figure 5.6)

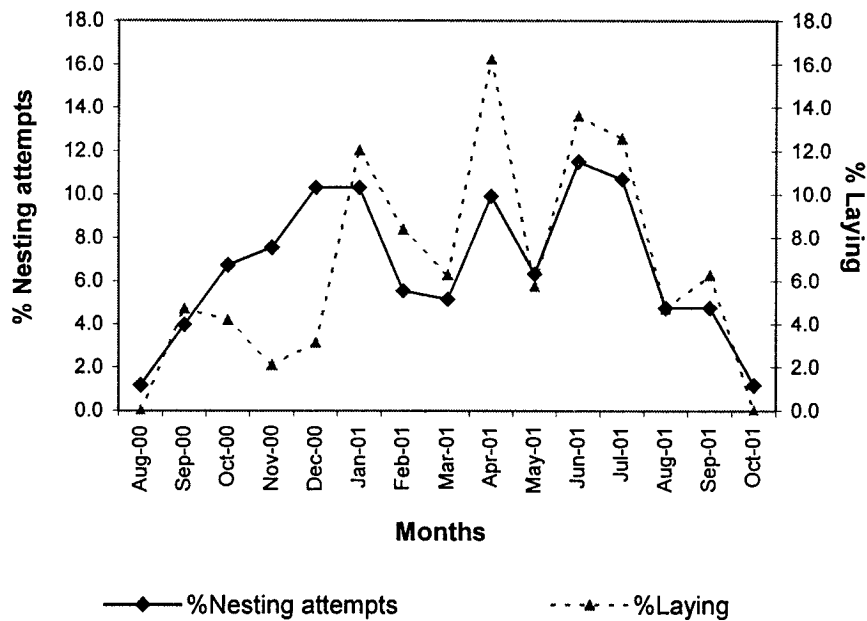


Figure 5.6. The percentages of nesting attempts and egg laying of 53 White-nest Swiftlet breeders at the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during September 2000 and October 2001.

The laying time of populations can be varied due to localities, especially when they are under the different environmental conditions. For example, Langham (1980) found that birds in Malaysia, under the harvesting condition, showed two laying peaks, the first was in October to December and the second was in February. Under the natural condition, birds in Vietnam started nesting activities in December to April and the breeding season was timed by climate (Nguyen, 1994).

White-nest Swiftlets in the sacred building, under the non-selective harvesting condition (the monk randomly collected a few empty nests from time to time), showed three laying peak in which concordant to the peaks of nesting attempts.

#### 5.3.2.1.3 Time period of egg incubation

Periods of egg incubation were determined from the 53 breeding pairs. Egg incubation occurred after the first egg was laid and lasted  $23.63 \pm 1.59$  days ( $n=142$ ). The range of incubation period was 17– 31 days with the laying interval of  $3.36 \pm 2.50$  days and hatching interval of  $2.31 \pm 1.92$  days. Overall, breeders of 1- egg and 2 -egg clutches took  $24.30 \pm 1.41$  days ( $n=10$ ) and  $23.58 \pm 1.59$  days ( $n=132$ ), respectively. There were no significant differences of egg incubation periods between the two clutch types ( $t$ -test,  $P = .087$ ).

Since White-nest Swiftlets had continuous breeding. Breeders started the successive clutches after their young fledged, a few laid egg immediately and the average of subsequent interval was  $15.59 \pm 10.48$  days (ranged 0 – 53 days,  $n=105$  clutches).

Considering the egg incubation period within clutch (based on the 2-egg clutches), the period of the first and the second eggs were  $23.53 \pm 1.73$  and  $23.65 \pm 1.97$  days, respectively ( $n=141$ ) and significant difference was not found ( $t$ -test,  $P = .296$ ). Similar results were found between the successive clutches, the first and the second egg incubation periods did not vary among the first clutch to the later clutches. In addition, the first and the second egg incubation periods of the four successive clutches did not differ (Table 5.5).

**Table 5.5.** Comparison on egg incubation periods of 53 White-nest Swiftlet breeders in the sacred building between dry and wet season, order of clutches and the egg of the same clutch during September 2000 and October 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test and ANOVA with significant difference at  $P \leq 0.05$ .

Test for		Egg incubation periods (days)			<i>P</i>
		Overall (142)	1 <sup>st</sup> egg	2 <sup>nd</sup> egg	
Season	Dry season	23.72 $\pm$ 1.21	23.68 $\pm$ 1.28(74)	23.68 $\pm$ 1.75(67)	.496
	Wet season	23.54 $\pm$ 1.92	23.35 $\pm$ 2.12(67)	23.61 $\pm$ 2.25(52)	.264
	<i>P</i>	.135	.423	.255	
Order of clutch	1 <sup>st</sup>	23.76 $\pm$ 1.44	23.65 $\pm$ 1.46(64)	23.74 $\pm$ 1.88(58)	.391
	2 <sup>nd</sup>	23.57 $\pm$ 1.39	23.60 $\pm$ 1.67(41)	23.31 $\pm$ 1.34(35)	.202
	3 <sup>rd</sup>	23.32 $\pm$ 2.13	23.10 $\pm$ 2.42(28)	23.68 $\pm$ 2.94(19)	.233
	4 <sup>th</sup>	24.06 $\pm$ 1.54	23.62 $\pm$ 1.18(8)	24.57 $\pm$ 2.22(7)	.157
	<i>P</i>	.582	.563	.152	

The range of incubation period of individual eggs was between 23-25 days with time of laying interval of 3-4 days and hatching interval of 2-3 days. The similar pattern in number of days from egg laying to hatching was found both in the same clutches and different clutches. Langham (1980), Nguyen (1994), Kang et al. (1991) and Wells (1999) had reported similar results for birds in Malaysia and Vietnam. Unlike other species that were sensitive to the effect of season and other environmental factors. White-nest Swiftlets exhibited consistency in egg incubation periods.

There are several factors that can be related to the consistency of egg incubation period.

First, it may be due to the incubating behavior of this species. By observation, breeders share the incubation task continuously till the last egg hatched. Therefore, the optimum temperature is transferred to eggs regularly along the period of egg developing. This could be advantage for eggs and parents in order to bring about the higher hatching success.

The second factor is the suitable site that directly involves with the constant incubation period. Eggs of ground species (e.g. gulls) and other opened-nest species (e.g. ducks) have problems of overheating from sunlight and cooling from rainfall when their parents are away. Therefore, the time of hatching is prolonged or shortened than the usual period. Unlike those of ground species, nests of White-nest Swiftlets are built in safety place, for example in the buildings or caves that should provide eggs and nestlings with better protection from either sunlight or precipitation.

The third factor is the weather at nesting site, Samut Sakhon Province. It is situated in the climate of tropical zone that has less variation in temperature. Temperature at the nesting site during the study was  $29.82 \pm 0.96$  °C in wet season and  $29.11 \pm 1.06$  °C in dry season. Therefore, eggs were incubated under the mind weather condition.

From the possible suggestions above, this study suggests that the consistency of the incubation period of White-nest Swiftlets should be due to the low variation of egg temperature during incubation.

#### 5.3.2.1.4 Time period of nestling feeding

After hatching, parents reared nestlings for  $40.25 \pm 3.01$  days, range 32-54 days, (n=98). There was no significant difference between the average of nestling feeding between 1-chick clutches ( $39.60 \pm 2.90$  days, n=5 ) and the 2-chick clutches ( $40.28 \pm 3.20$  days, n=91) ( *t*-test , *P* = .311).

The data in Table 5.6 shows that the second nestlings tended to have longer nest-life than the first ones, especially in dry season. The younger sibling leave the nest after the older one for  $2.48 \pm 2.50$  days (range 0-8 days, n= 40 clutches). From the observation on the order of clutches, periods of nestlings remained with their parents did not vary among the successive clutches and times that two nestlings live with their parents did not differ, except at the 2<sup>nd</sup> clutch. The difference might be due to the variation in food availability

Table 5.6. Comparison on nestling feeding periods between dry and wet seasons, order of clutches and the nestling of the same clutch of 53 White-nest Swiftlet breeders in the sacred building during September 2000 and October 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test and ANOVA with significant difference at  $P \leq 0.05$ .

Test for		Nestling feeding periods (days)			<i>P</i>
		Overall(102)	1 <sup>st</sup> nestling	2 <sup>nd</sup> nestling	
Season	Dry season	39.63 $\pm$ 2.81	39.14 $\pm$ 2.5(59)	40.71 $\pm$ 3.87(39)	.007
	Wet season	41.15 $\pm$ 3.09	41.29 $\pm$ 3.77(43)	41.96 $\pm$ 3.24(27)	.223
	<i>P</i>	.007	.000	.082	
Order of clutch	1 <sup>st</sup>	40.52 $\pm$ 3.37	40.48 $\pm$ 3.88(43)	41.54 $\pm$ 3.76(31)	.122
	2 <sup>nd</sup>	39.48 $\pm$ 2.88	38.98 $\pm$ 2.54(33)	40.61 $\pm$ 4.20(21)	.040
	3 <sup>rd</sup>	40.63 $\pm$ 2.28	40.54 $\pm$ 2.69(21)	41.10 $\pm$ 2.68(10)	.299
	4 <sup>th</sup>	41.75 $\pm$ 2.17	41.20 $\pm$ 2.68(5)	42.25 $\pm$ 1.70(4)	.260
	<i>P</i>	.582	.144	.750	

The period of nestling feeding in White-nest Swiftlets is relatively long since it take about 40 days to reach a post fledging stage. According to reports of birds in various regions such as in Malaysia by Langham (1980), in Singapore by Kang and Lee (1991) and Kang et al. (1991) and in Vietnam by Nguyen (1994), periods of nestling feeding were not much different across the distribution lines. *A. fuciphagus* shows long nestling feeding period similarly to other related species, for example *A. maximus* (Medway, 1962), *A. spodiopygius* (Tarburton, 1986), and *A. salangana* (Medway, 1962) but not similar to other small altricial birds of the same size (Kang and Lee, 1991). Langham (1980) noted that the slow growth rate would be advantage for this species when food abundance is depended on the fluctuation of rainfall. In addition, it might be a function of the need for the fledgling to be ready before fledging (Chantler and Driessens, 2000) since there is no post-parental care in this species, therefore the young should be well feathered and able to fly and forage by their own after leaving the nests.

5.3.2.2 Breeding success

5.3.2.2.1. Clutch size

Nests of White-nest Swiftlets in the sacred building contained one to two eggs, but the 2-egg clutch was common. From the observation, it was found that some breeders occasionally laid one egg. One egg was observed both in the first nest of the new breeder and in the renesting nest of the older breeder. The proportion of 2-egg clutch to 1-egg clutch was 1 : 0.15 and the average of clutch sizes was  $1.87 \pm 0.34$  eggs (Table 5.7). Laying interval between two eggs was  $3.36 \pm 2.50$  days (n=82, based on the successful clutches). Overall, there was no significant difference in the mean of clutch sizes among months during the study period (ANOVA-DUNCAN,  $F_{11,70}=1.181$ ,  $P = .316$ ).

The result is concordant with report of Langham (1980) and Kang et al. (1991). They did not find the differences in clutch size between the first and the successive clutches whether under natural or harvesting condition.

Table 5.7 Difference in clutch size, sample sizes (N), avearge and sd of clutches in each month. Data were recorded from 82 successful clutches of White-nest Swiftlets in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during November 2000 and October 2001.

	Study period												Total (clutches)	%
	Year 2000						Year 2001							
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct		
1-egg clutches	2	-	-	-	1	1	1	-	1	3	1	1	11	13.41
2-egg clutches	3	5	5	4	8	8	11	6	8	5	7	1	71	86.59
N	5	5	5	4	9	9	12	6	9	8	8	2	82	
Average	1.60	2.00	2.00	2.00	1.89	1.89	1.89	2.00	1.89	1.62	1.87	1.50	1.87	
SD	0.54	0.00	0.00	0.00	0.33	0.33	0.28	0.00	0.33	0.57	0.35	0.70	0.34	



Clutch sizes of other swiftlets, White-rumped Swiftlets *C. spondiopygius* and Australia Swiftlets *C. terracraginae chillagoensis* had been studied by Tarburton in 1986 and in 1993, respectively. He reported the variation in clutch sizes in different localities and found that the later species could not adequately feed the young adding to their 1-egg clutches. This suggested that the quantity of food can determine the clutch size. The suggestion also supported by the study of Skutch (1935, cited in Chantler and Driessens, 2000 : 29) on Chimney Swifts *Chaetura pelagica*.

Food availability has provided an explanation for the variation in clutch size of many bird species. Some species exhibit yearly variation in clutch size response to seasonal difference. For example, in the insectivorous birds, Brown and Brown (1996, cited in Brown and Brown, 1999 : 470) noted that the clutch size of Cliff Swallows will depend on food supply that is highly sensitive to temperature and rainfall. They also added that clutch size of swallow may reflect energetic constraints associated with egg production early in breeding season when food is reduced by cold weather. In Little Egrets and herons, the mean clutch size is positively associated with rainfall in which the rainfall increases the foraging area and prey for these birds (Bennetts et al., 2000). Clutch size of Roseate Terns *Sterna duagallii* also decline during the breeding season (Burger et al., 1996).

Several hypotheses have explained the clutch size in bird species as following :

- 1) the egg-formation hypothesis (the ability of female to produce egg may be limited), 2) the incubation-ability hypothesis (parents are limited by their ability to cover egg and incubate them efficiently, 3) the parental-care hypothesis (clutch size is limited by the parental ability to protect egg and nestling ( i.e Perrins and Birkhead, 1983; Szekely et al., 1994; Safriel, 1995, cited in Yogev et al. 1996 : 68; Thomson, Monaghan and Forness, 2002). However, age of adult female can also influence the clutch size as well. This phenomenon has been reported in Roseate Tern by Burger et al. (1996) in that the young birds (two to three year old) had lower clutch size than the older ones.

The clutch size in White-nest Swiftlets is remarkably stable, most breeders had two eggs and the clutch of two eggs had higher breeding success than the clutch of one egg (see Table 5.7 and 5.9). However, breeders of the two groups invested the time for incubation and rearing similarly (see 5.3.2.1.3 and 5.3.2.1.4). Clearly, the clutch of two give more advantage to the population of White-nest Swiftlets and on the evolutionary process, the clutch of two would be favorable. The question on what are the limiting factors affecting the clutch size of White-nest Swiftlets is interesting to be investigated.

#### 5.3.2.2.2 Hatching success and breeding success at fledging

The result in Table 5.8 shows that hatching success and breeding success at fledging varied throughout the year. Hatching success was low during October and December 2000 and was high during January and August 2001. It was peaked in April 2001 which was coincided with the breeding success at fledging (Pearson correlation,  $t = 3.98$ ,  $F = 0.002$ ,  $r = 0.569$ ).

All breeding parameters between one and two clutches were significantly different. The hatchability and breeding success at fledging of 1-egg clutches was lower than 2-egg clutches by 37% and 30%, respectively. This indicated that the clutch of two eggs achieves more advantage than the clutch of one egg (Table 5.9)

Number of eggs, nestlings, fledglings and breeding success at fledging among the 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> clutch from new breeding pairs were not significantly different. Most variables in the 1<sup>st</sup> clutch were significantly lower than the latter clutches (Table 5.10).

Table 5.8. Breeding success of 53 White-nest Swiftlet breeders in the sacred building in different months during September 2000 and October 2001, showing mean percentages  $\pm$  sd of hatching success and breeding success at fledging with number of clutches in parentheses and results of mean comparison(ANOVA-DANCAN). The different superscript alphabet means there is significant difference.

Months	Breeding success parameters	
	Hatching success (%)	Breeding success at fledging (%)
Aug-00	66.66 $\pm$ 57(3) <sup>b</sup>	16.61 $\pm$ 28.86(3) <sup>a</sup>
Sep-00	60.00 $\pm$ 51(10) <sup>bc</sup>	45.00 $\pm$ 49.72(10) <sup>b</sup>
Oct-00	25.00 $\pm$ 47(16) <sup>a</sup>	18.75 $\pm$ 40.31(16) <sup>a</sup>
Nov-00	34.21 $\pm$ 47(19) <sup>a</sup>	13.15 $\pm$ 32.66(19) <sup>a</sup>
Dec-00	26.42 $\pm$ 45(26) <sup>a</sup>	19.23 $\pm$ 37.62(26) <sup>a</sup>
Jan-01	59.61 $\pm$ 49(26) <sup>bc</sup>	44.23 $\pm$ 49.65(26) <sup>b</sup>
Feb-01	64.28 $\pm$ 49(14) <sup>bc</sup>	42.85 $\pm$ 47.46(14) <sup>b</sup>
Mar-01	65.21 $\pm$ 48(23) <sup>bc</sup>	36.36 $\pm$ 44.13(22) <sup>b</sup>
Apr-01	84.00 $\pm$ 34(25) <sup>c</sup>	70.00 $\pm$ 38.18(25) <sup>c</sup>
May-01	59.37 $\pm$ 49(16) <sup>bc</sup>	37.54 $\pm$ 46.43(16) <sup>b</sup>
Jun-01	53.44 $\pm$ 48(29) <sup>bc</sup>	31.03 $\pm$ 43.12(29) <sup>b</sup>
Jul-01	53.70 $\pm$ 49(27) <sup>bc</sup>	33.33 $\pm$ 41.60(27) <sup>b</sup>
Aug-01	50.70 $\pm$ 52(12) <sup>b</sup>	29.16 $\pm$ 45.01(12) <sup>b</sup>
Sep-01	45.83 $\pm$ 45(12) <sup>b</sup>	8.33 $\pm$ 28.86(12) <sup>a</sup>

Table 5.9. Comparison on breeding success in different clutch sizes of 53 White-nest Swiftlet breeders in the sacred building during September 2000 and October 2001, showing sample sizes (N), means  $\pm$  SD of number of eggs, nestlings, fledglings, and mean percentage of hatching success and breeding success at fledging,BSF. The different superscript alphabet means there is significant difference.

Clutch sizes	N	No.of eggs	No. of nestlings	No. of fledglings	Hatching Success (%)	BSF (%)
1-egg clutch	24	1.00	0.42 $\pm$ 0.05 <sup>a</sup>	0.29 $\pm$ 0.46 <sup>a</sup>	41.64 $\pm$ 50.36 <sup>a</sup>	39.17 $\pm$ 46.43 <sup>a</sup>
2-egg clutch	161	2.00	1.60 $\pm$ 0.76 <sup>b</sup>	1.03 $\pm$ 10.89 <sup>b</sup>	78.88 $\pm$ 38.58 <sup>b</sup>	50.00 $\pm$ 44.86 <sup>b</sup>

Table 5.10. Comparison on breeding success in different seasons and order of clutches of 53 White-nest Swiftlet breeders in the sacred building during September 2000 and October 2001, showing means  $\pm$  SD of number of eggs, nestlings, fledglings, and mean percentages  $\pm$  SD of hatching success and breeding success at fledging, BSF with number of clutches in parentheses. The different superscript alphabet means there is significant difference.

Test for	No.of eggs	No. of nestlings	No. of fledglings	Hatching Success(%)	BSF (%)
Season					
Dry season	1.35 $\pm$ 0.90(128) <sup>a</sup>	1.13 $\pm$ 0.96 (128) <sup>a</sup>	0.78 $\pm$ 0.89(128) <sup>a</sup>	56.06 $\pm$ 49.05(132) <sup>a</sup>	38.54 $\pm$ 45.38(131) <sup>a</sup>
Wet season	1.36 $\pm$ 0.85(128) <sup>a</sup>	1.00 $\pm$ 0.95(128) <sup>a</sup>	0.56 $\pm$ 0.81(128) <sup>a</sup>	48.83 $\pm$ 48.59(124) <sup>b</sup>	28.29 $\pm$ 41.85(124) <sup>b</sup>
Order of clutch					
1 <sup>st</sup>	1.16 $\pm$ 0.94(149) <sup>a</sup>	0.83 $\pm$ 0.96(149) <sup>a</sup>	0.49 $\pm$ 0.80(149) <sup>a</sup>	43.58 $\pm$ 49.23(148) <sup>a</sup>	25.83 $\pm$ 41.52(147) <sup>a</sup>
2 <sup>nd</sup>	1.55 $\pm$ 0.82(58) <sup>ab</sup>	1.32 $\pm$ 0.90(58) <sup>ab</sup>	0.96 $\pm$ 0.89(58) <sup>ab</sup>	59.37 $\pm$ 47.87(64) <sup>a</sup>	43.75 $\pm$ 5.86(64) <sup>b</sup>
3 <sup>rd</sup>	1.68 $\pm$ 0.57(38) <sup>b</sup>	1.26 $\pm$ 0.86(38) <sup>b</sup>	0.84 $\pm$ 0.85(38) <sup>b</sup>	68.42 $\pm$ 44.14(38) <sup>a</sup>	43.42 $\pm$ 3.76(38) <sup>b</sup>
4 <sup>th</sup>	1.82 $\pm$ 0.40(11) <sup>b</sup>	1.63 $\pm$ 0.80(11) <sup>b</sup>	0.90 $\pm$ 0.94(28) <sup>b</sup>	77.27 $\pm$ 41.01(11) <sup>b</sup>	40.90 $\pm$ 49.08(11) <sup>b</sup>
Overall(262)	1.35 $\pm$ 0.87	1.04 $\pm$ 0.95	0.67 $\pm$ 0.85	52.49 $\pm$ 48.88	33.46 $\pm$ 43.88

### 5.3.2.2.3 Production

During September 2000 and October 2001, 53 breeding pairs had 281 nesting attempts, 19 clutches were in progress when the observation ceased and were excluded in the analysis. Therefore, 262 clutches were examined. On average, birds produced 4.94 clutches/pair during the study period. The output of 53 breeding pairs was 172 fledglings, in which the maximum potential of the production could be up to 10.66 individuals/pair/year but 159 out of 262 clutches were failed by several factors. Falling was clearly the main cause of nest failure. Eggs, nestlings and nests fell down during the incubation and rearing stages were at high rate (82.80%). Unhatched and infertile eggs were found but were not important factor (17.2%). No clutch failed because of starvation and depredation. At the end of the study, only 103 clutches (39.31%) were successful. The fledgling production ranged between 0-8 individuals per pair. The average of annual production of fledglings was  $3.55 \pm 2.32$ , ranging between 0 - 7.6 fledglings/pair/year ( $n = 53$  pairs). Overall, breeding success at fledging of 53 breeding pairs was  $33.46 \pm 43.88\%$  ( $n=262$  clutches)

The results of hatching success and breeding success at fledging showed that breeders with the clutch of two eggs have more advantage in breeding success than breeders with the clutch of one egg. Therefore, natural selection should favor the higher traits with reproductive output this species.

Since it takes around three months and a half for any one set of clutch to complete, the new breeding pairs can have approximately four clutches a year. In this study, the first, second, third and fourth clutch were taken in October to December, December to February, March to May and June to August, respectively. The overall breeding success of the 2<sup>nd</sup> to 4<sup>th</sup> successive clutches was similar. From the result, breeding success of the first clutch was lowest, probably due to the high rate of nest and nestling fallings. On the other hand, the latter three broods had higher reproductive outputs, especially at the 3<sup>rd</sup> and 4<sup>th</sup> clutch, suggesting that more experience breeders would have better performance. Furthermore, the food availability and the weather

condition at different times of the year may be other important factors for breeding performance.

From the study, nesting, laying and fledging were indirectly correlated with the amount of rainfall. Birds showed enormous of nesting attempts between the period of dry to early wet season (December-January, March-April and June-July see Figure 5.5), but only a few nests were successful.

Several factors may be involved in the high percentage of nesting failure. The first factor can be the quality of nest-site. Second, the falling occurred more in the first clutch built during November-December 2000 by the first year breeders and this is probably because the new breeders have less experience than the older ones both in nest-site selection and nest-building performance. Therefore, the first nests of the new breeding pairs had fallen in higher rate. This effect contributed to lower laying activities, hatchability and breeding success at fledging of the 1<sup>st</sup> clutches. The third can be from the effect of climatic change on the property of nests. Dry season is the time of the year that has lowest rainfall (average 50.22 mm, ranged 0 - 220.4 mm from November 2000 to April 2001), lowest temperature (27.98°C in November 2000 and 27.91°C in December 2000) and strong wind blowing from the sea to the mainland. Nests built during this time would be drier and more fragile than those in the wet season. Hence, nests especially at sites without supporters are prone to be damaged and fallen in dry season than those in the wet season. Since most of new breeding pairs had built their first nests during November and December 2000 (based on 53 breeding pairs) and most of the nests fell, this leads to the lower and breeding success, comparing to the successive clutches (see Table 5.10).

The effect of wind blowing on nests of White-nest Swiftlets was reported in Vietnam by Nguyen in 1994 in which birds in caves with the opening oriented towards the north were strongly affected by cold northeastern wind. They performed nesting activities later than the birds lived in caves that the entrance opens to different



directions. Therefore, the cold wind may be one of the causes that involve with the breeding success.

Other biological factors such as ectoparasite (s), predation and starvation seem to be less responsible for unsuccessful clutches as well as physical factors such as sun light and temperature.

#### 5.3.2.3 Egg morphology

The egg of White-nest Swiftlets at Samut Sakhon was blunt and subelliptical in shape and white in color. For the entire sample of eggs, the means of length and breadth of 89 eggs were  $20.29 \pm 0.93$  mm and  $13.33 \pm 0.39$  mm, respectively with the weight of  $1.91 \pm 0.25$  g. Egg morphology of the 1-egg clutch and the 2-egg clutch were compared and results from *t*-test are shown in Table 5.11.

Although means of length and breadth of eggs between clutch types were not significantly different, eggs of 1-egg clutches were significantly lighter than those of the 2-egg clutches. All variables of the egg size were compared among months and there were no significantly difference for weight and length of eggs, except that the breadth of egg laid in May 2001 was less than the breadth of egg laid in other months (Table 5.12).

Table 5.11. Comparison on the egg morphology of White-nest Swiftlets in the sacred building collected from two clutch sizes during November 2000 and October 2001, showing sample sizes (N), means  $\pm$  sd of the weight, the length and the breadth of the egg. The different superscript alphabet means there is significant difference.

Morphology	Clutch sizes	N	Means
Weight(g)	1-egg clutch	5	1.40 $\pm$ 0.50 <sup>a</sup>
	2-egg clutch	26	1.91 $\pm$ 1.7 <sup>b</sup>
Length(mm)	1-egg clutch	5	20.04 $\pm$ 1.24 <sup>a</sup>
	2-egg clutch	26	19.93 $\pm$ 0.88 <sup>a</sup>
Breadth(mm)	1-egg clutch	5	12.83 $\pm$ 0.78 <sup>a</sup>
	2-egg clutch	26	13.47 $\pm$ 0.37 <sup>a</sup>

Table 5.12. Comparison on the egg morphology of White-nest Swiftlets in the sacred building collected in different months during November 2000 and October 2001, showing sample sizes (N), means  $\pm$  sd of the weight, the length, and the breadth of the egg. The different superscript alphabet means there is significant difference.

Months	N	Egg morphology		
		Weight (g)	Length (mm)	Breadth (mm)
Jun-00	13	1.77 $\pm$ 0.29	19.61 $\pm$ 0.96	13.50 $\pm$ 0.40 <sup>a</sup>
Jul-00	12	1.90 $\pm$ .0.36	20.50 $\pm$ 0.70	13.35 $\pm$ 0.47 <sup>a</sup>
Jan-01	12	2.06 $\pm$ 0.13	20.21 $\pm$ 0.79	13.42 $\pm$ 0.30 <sup>a</sup>
Feb-01	7	1.80 $\pm$ 0.21	20.34 $\pm$ 0.35	13.37 $\pm$ 0.37 <sup>a</sup>
Mar-01	10	1.93 $\pm$ 0.26	20.17 $\pm$ 1.26	13.44 $\pm$ 0.36 <sup>a</sup>
May-01	20	1.90 $\pm$ 0.21	20.40 $\pm$ 1.07	13.06 $\pm$ 0.43 <sup>b</sup>
Jul-01	15	1.96 $\pm$ 0.16	20.60 $\pm$ 0.76	13.40 $\pm$ 0.21 <sup>a</sup>
Total	89	1.91 $\pm$ 0.25	20.26 $\pm$ 0.93	13.33 $\pm$ 0.39 <sup>a</sup>

Similar results of the study on size of eggs were found in the study of Langham (1980) and Kang et al. (1991) who found no statistical differences in size, dry mass and the composition of egg of the congeneric Black-nest Swiftlets *C. fuciphaga* between the successive clutches. However, they found the variation in weight of eggs between the population.

From the result of this study, it can be concluded that under the nonselective harvesting, eggs of White-nest Swiftlets *A. fuciphagus* are similar in size among months.

#### 5.3.2.4 Nest morphology

Measurement of harvested nests from the caves and the sacred building (Figure 5.7, a,b), showed that the former were heavier and larger than the latter. The data on morphology of nests are described in Table 5.13.



(a)



(b)

**Figure 5.7.** Nests of White-nest Swiftlets at : (a) Phatthalung Province; (b) Samut Sakhon Province. Bar = 10 mm.

Table 5.13. Comparison on nest measurements of White-nest Swiftlets from Phatthalung and Samut Sakhon Provinces in the year 2000 and 2001, showing sample sizes (N) and means  $\pm$  sd of the weight, the width and the height of the nest. The different superscript alphabet means there is significant difference.

	Phatthalung nests			Samut Sakhon nests
	1 <sup>st</sup> harvesting	2 <sup>nd</sup> harvesting	3 <sup>rd</sup> harvesting	
N	70	42	76	86
Weight(g)	14.41 $\pm$ 3.36 <sup>a</sup>	12.28 $\pm$ 3.56 <sup>b</sup>	9.78 $\pm$ 3.09 <sup>c</sup>	7.12 $\pm$ 2.64 <sup>d</sup>
Width(mm)	75.20 $\pm$ 21.86 <sup>a</sup>	73.77 $\pm$ 11.64 <sup>bc</sup>	78.77 $\pm$ 11.64 <sup>c</sup>	71.25 $\pm$ 11.57 <sup>b</sup>
Height(mm)	51.92 $\pm$ 9.23 <sup>a</sup>	51.94 $\pm$ 10.52 <sup>a</sup>	50.18 $\pm$ 11.78 <sup>a</sup>	35.32 $\pm$ 10.23 <sup>b</sup>
Thickness(mm)	3.57 $\pm$ 0.73 <sup>a</sup>	2.67 $\pm$ 0 .49 <sup>b</sup>	2.96 $\pm$ 0.63 <sup>b</sup>	3.49 $\pm$ 1.31 <sup>a</sup>

Considering the morphology of nests of White-nest Swiftlets in caves, there were different between nests of subsequent harvesting (1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> harvesting). Harvested nests in all groups were pure in saliva, without or with a few of incorporating materials (i.e. birds' down feathers). The nest was white, except at the nest feet which were yellowish or redish. The first harvested nest was cleanest whilst the third lot was dirtiest with birds' droppings. These droppings made the nest color become grayish and these nests were classified as the lowest quality in economic value.

Nests of birds in the sacred building, Samut Sakhon Province also made up with wholly saliva, white and a little mixed with down feathers. The nests were cup-shaped with irregular nest feet, of which both sides were thicker than middle of the rim of the cup. The nests from Samut Sakhon Province were more fragile and drier than those from cave swiftlets.

Harvested nests of cave swiftlets from Phatthalung Province normally differ from nests of birds living in Samut Sakhon Province in weigh and size. The variation may be related to several factors such as the time of nests built, the period (number of days) for

nest construction, the age and weight of breeders and the time that breeders are forced to build nest.

For the cave swiftlets, at the beginning of the breeding cycle, birds usually have longer time to build their first nests than any other time. Generally, the bird begin to build the first nest in dry season from late January to late of March. This season will be suitable for nest building since it has low rainfall and birds will meet their energy requirement for nest construction. Traditionally, the first nests are harvested in late March. Breeders will rebuild nests immediately if they lost the nest before the onset of laying period. They take about 30 days for the construction of the second nest. When the second nests are nearly complete, the nests will be harvested again. The second harvesting is occurred in the late April of the year. The third nests are built to replace the second if breeders have not yet laid eggs before the second harvesting. After the second harvesting, birds take about four months to build nest, incubate and rear their offspring. The third harvesting is occurred on the expected day that most of the young fledged, usually in late August. After the third task of nest collecting, birds are unguarded by cave owners. There is no document to confirm whether birds have nesting attempts during non-harvesting period (September to January).

Under the harvesting regime, birds have a long time for their first nest construction (60days), 30 days for the second and the third. Therefore, the first nests observed were somewhat pure in saliva and heavier than the later groups. The second was smaller and lighter than the first group but no distinct difference in color and form. The third nests were collected after nests had been used to rear young. So nests were fouled and contaminated with droppings and other materials. Some nests changed in color from white to yellowish or grayish, the third nests were smaller than the former and are classified as the lowest quality nests. Difference in morphology of harvested nests indicates that there was the effect of harvesting on the breeding biology of White-nest Swiftlets. Kang et al. (1991) reported that under the harvesting regime, birds built the second and the third nests slower than the first nests and the successive nests were



also smaller. They suggested that birds might have limited resource of nest building such as nest cements.

Morphology of nests at Samut Sakhon Province were quite different from those of cave swiftlets at Phatthalung Province. Nests were quite dry and fragile, small and irregular forms. A few had cup-shaped forms whilst all nests of cave swiftlets were cup-shaped forms, more durable, bigger and heavier than the nests from Samut Sakhon Province.

The above differences are unclear, probably due to the climatic factor and the characters of substrate. Since the sacred building is located at the river mouth of Tha-Chin River and the entrance faces to the sea. It was built on the area of strong wind, blowing directly from the sea to the building all year especially in dry season (this area is called "the wind channel"). This phenomenon provides inside of the building with more ventilation in which this condition is totally different from the cave environment. Therefore, nest-sites of the birds faced to the wind and nests should be drier and more fragile than nests built in caves that have high relative humidity and less wind flow.

Morphology and size of nests in Samut Sakhon Province may be shaped by the characteristics of the nest-site. Nests at uneven surface of Thai-style motifs are often small in size. Moreover, birds built their nests within a short period of time, taking only 10 days in some pairs for their nest building (range 10-42 days,  $n=159$  clutches). This suggests that birds might have limited area above the supporter provided by the Thai-style motifs.

However, the tendency to build a small nest remains unclear. The further study such as the comparative study on nest-building period between birds inhabiting in houses and caves are needed.

5.4 Parental care

The study on parental care in White-nest Swiftlets was focused on the investment of time for incubation and nestling feeding. It was found that egg incubation began immediately after the first egg was laid and continued until hatching date. Investment of time for egg incubation was high and was quite consistent along the egg incubation period (age class 1 to age class 6). Investment of time on nestling incubation was decreased when nestling developed pin feathers on its body. The incubation was unnecessary when the chick grew up to post fledgling. The pattern of incubation time from egg laying through fledging is demonstrated in Figure 5.8 and Table 5.14.



Figure 5.8. Pattern of incubation time of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001. The scattered plots showing the average of incubation times in relation to age classes of the nest content, averaged of 12 month observations.

**Table 5.14.** Comparison on incubation times in different ages of nest contents of 53 White-nest Swiftlet breeders in the sacred building, showing sample sizes (N) means  $\pm$  SD, maximum and minimum values. Data were recorded during 0500-1930 of each observed day, from November 2000 to October 2001.

Age classes	Nest contents	N	Incubation times (min)		
			Means	Max.	Min.
1	Egg day 1	58	599 $\pm$ 236	870	120
2	Egg day 2-5	120	724 $\pm$ 202	870	90
3	Egg day 6-10	179	791 $\pm$ 136	870	90
4	Egg day 11-15	179	817 $\pm$ 95	870	330
5	Egg day 16-20	147	829 $\pm$ 69	870	480
6	Egg day 21-25	104	802 $\pm$ 157	870	90
7	Nestling day 1	46	653 $\pm$ 209	870	90
8	Nestling day 2-5	105	491 $\pm$ 219	840	90
9	Nestling day 6-10	150	292 $\pm$ 86	780	60
10	Nestling day 11-15	146	211 $\pm$ 141	660	60
11	Nestling day 16-20	140	150 $\pm$ 111	600	60
12	Nestling day 21-25	139	111 $\pm$ 67	720	60
13	Nestling day 26-30	121	106 $\pm$ 50	480	90
14	Nestling day 31-35	144	105 $\pm$ 44	330	90
15	Nestling day 36-40	114	95 $\pm$ 20	240	90
16	Nestling day 41 up	57	107 $\pm$ 58	450	60
	Overall	1949	437 $\pm$ 335	870	60

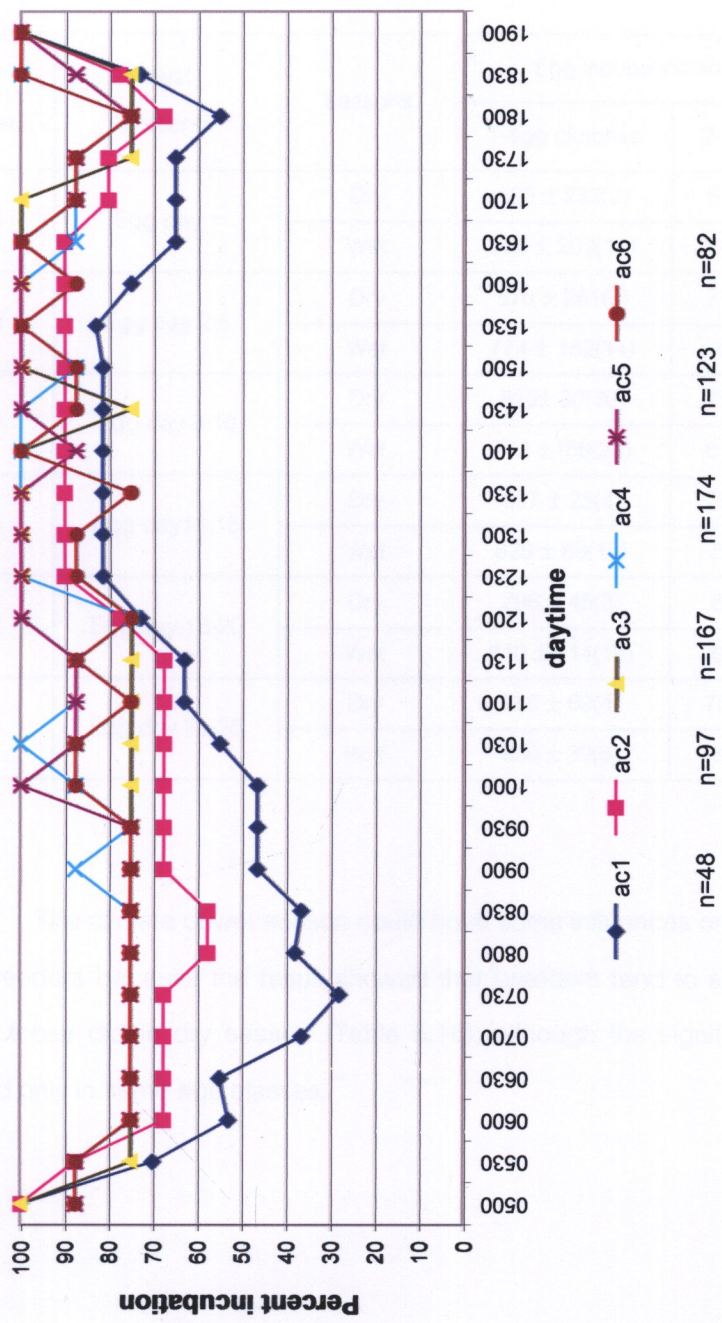
### 5.4.1 Parental investment for egg incubation

Both parents incubated the eggs by taking turn during the daytime and doing together at nighttime. Form the observation, one parent would leave the nest to forage in the early morning, between 0500-0600, while its mate was on the duty. At least 30 min, it would return to the nest to replace its mate. From the daytime observation during 0500-1930, a parent went out and returned to its nest about one to two times a day. The length of time for one turn varied day by day, ranging from 30 min up to 10 hours and a

half. Therefore, during the egg incubation period, all incubating breeders took in part of the asynchronous in-and-out marching between foraging area and breeding site.

Occasionally, during the egg incubation period, breeders were observed to leave their nests due to the disturbances by human activities or the coming of predators into the sacred building. Most breeders would resume their nests within 2 min after the disturbance was over. However, sometimes without any disturbance, both breeders were also observed to disappear from their nest. Most of the absence occurred in early morning or in the late afternoon. The presence of one or both incubating breeders at the nest during daytime is shown in Figure 5.9.

Considering on the egg incubation time of each age class, it was found that egg at the age of 1 day (ac1) received the lowest incubation time from their parents. The average incubation time in age class 1 was 520 and 645 min in dry and wet season, respectively. The mean of incubation time increased gradually from age class1 to age class 5 when eggs were older. In addition, the egg incubation times among clutch sizes (one and two eggs) were compared and the significant difference was not found (Table 5.15). Therefore, the breeders of two-egg clutches took incubation period similarly to those of one-egg clutches.



**Figure 5.9.** Percentage of incubating breeders of White-nest Swiftlets. Each spot on the line showing the percentage of one or both breeders found sitting on the nest during 0500-1930. Data presented in relation to the age class (ac) of the nest content, averaged of 12 month observations. The study was conducted in the sacred building of Suthiwararam Temple, Samut Sakhon Province. (ac1=egg day 1; ac2=egg day 2-5 ; ac3=egg day 6-10; ac4= egg day 11-15; ac5= egg day 16-20; ac6= egg day 21-25.)

**Table 5.15.** Comparison on egg incubation times in different clutch sizes of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test with significant difference at  $P \leq 0.05$ .

Age classes	Nest contents	Seasons	Egg incubation times (min)		<i>P</i>
			1-egg clutches	2-egg clutches	
1	Egg day 1	Dry	525 $\pm$ 233(2)	516 $\pm$ 270(17)	.964
		Wet	635 $\pm$ 209(12)	565 $\pm$ 288(17)	.798
2	Egg day 2-5	Dry	570 $\pm$ 261(3)	711 $\pm$ 211(33)	.280
		Wet	774 $\pm$ 182(14)	767 $\pm$ 166(47)	.892
3	Egg day 6-10	Dry	810 $\pm$ 30(30)	750 $\pm$ 156(47)	.514
		Wet	783 $\pm$ 159(23)	813 $\pm$ 123(67)	.350
4	Egg day 11-15	Dry	697 $\pm$ 25(4)	797 $\pm$ 104(52)	.060
		Wet	839 $\pm$ 69(19)	834 $\pm$ 91(69)	.836
5	Egg day 16-20	Dry	796 $\pm$ 45(3)	818 $\pm$ 71(48)	.606
		Wet	810 $\pm$ 114(16)	848 $\pm$ 43(56)	.202
6	Egg day 21-25	Dry	780 $\pm$ 69(4)	787 $\pm$ 157(29)	.928
		Wet	850 $\pm$ 39(5)	837 $\pm$ 96(44)	.774

The climate of wet season could have some influences on the incubation activity of breeders because the result showed that breeders tend to sit on their nests longer than those did in dry season (Table 5.16), although the significant differences were found only in some age classes.



**Table 5.16.** Comparison on egg incubation times in different seasons of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test with significant difference at  $P \leq 0.05$ .

Age classes	Nest contents	Clutch sizes	Egg incubation times (min)		<i>P</i>
			Dry season	Wet season	
1	Egg day 1	1-egg	525 $\pm$ 233(2)	635 $\pm$ 209(12)	.508
		2-egg	516 $\pm$ 270(17)	565 $\pm$ 228(17)	.122
2	Egg day 2-5	1-egg	570 $\pm$ 261(3)	774 $\pm$ 182(14)	.120
		2-egg	711 $\pm$ 211(33)	767 $\pm$ 166(47)	.192
3	Egg day 6-10	1-egg	810 $\pm$ 30(3)	783 $\pm$ 82(22)	.964
		2-egg	750 $\pm$ 156(47)	813 $\pm$ 123(67)	.024
4	Egg day 11-15	1-egg	697 $\pm$ 75(4)	839 $\pm$ 47(47)	.000
		2-egg	797 $\pm$ 104(52)	834 $\pm$ 91(69)	.040
5	Egg day 16-20	1-egg	796 $\pm$ 45(3)	810 $\pm$ 114(16)	.484
		2-egg	818 $\pm$ 71(48)	848 $\pm$ 43(56)	.012
6	Egg day 21-25	1-egg	780 $\pm$ 69(4)	850 $\pm$ 39(5)	.138
		2-egg	787 $\pm$ 157(29)	837 $\pm$ 96(44)	.090

The results in Table 5.15 and 5.16 indicated that incubation times varied across age classes. Breeders did not incubate the 1<sup>st</sup> egg all day. On the day when 1<sup>st</sup> egg was laid, it was left in the nest for a period of time when both parents went out to their foraging areas, normally at dawn. The female came back to incubate the 1<sup>st</sup> egg in the late morning or sometimes in the late afternoon and her mate returned later to changeover. This manner may be determined by the need in energy compensation of the female after the first egg is laid as well as the energy demanded for the 2<sup>nd</sup> egg formation that it would be laid out 3-4 days later on. By the above reason, female can not incubate her 1<sup>st</sup> egg immediately after egg is laid but the following days after (egg at age of 2-25 days), female and her mate keep the consistency of all day incubation by regularly changing over on the duty. For the reason that why male do not incubate the 1<sup>st</sup> egg immediately after it was laid is not known.

Sharing in the incubation and feeding is common in the group of swifts and swiftlets (Chantler and Driessens, 2000) as well as other monogamous species (Gill, 1990; Ehrlich, Dobkin and Wheye, 1988; Krebs and Davies, 1993; Stutchbury and Morton, 2001). This behavior provides the advantage for parents and their eggs, in which parents can feed themselves while the incubation is not interrupted. Unless the alternation, the parents may not survive well until the end of the breeding cycle due to the energy shortage during the breeding season that higher energy is required than in non-breeding time (Gill, 1990). This limit seems likely for many small birds, which have to spend at least two-thirds of the daytime on incubation and the rest of the time for feeding. This is because small birds have high metabolic rate and very fast burning of the fat reserves (Ehrlich et al., 1988).

Occasionally, both parents were observed to leave their nests during the egg incubation phase. Most absences occurred in the morning and in the late afternoon. The factor that influences the disappearance could be the energy demanded by both parents. After the starvation time at night, breeders would rush out to feed themselves at dawn. The reason for leaving in the late afternoon may be because of the need to store an adequate food to support them during the night hours.

The absence of parents during egg incubation was reported in the Common Swift that left their eggs for up to six hours and a half. Lack (1956, cited in Chantler and Driessens, 2000 : 28 ) suggested that this issue was related to the higher abundance of food.

Breeders which nested in wet season tended to spend more times in egg incubation than those in dry season. It may be because the climate in wet season decreases amount of aerial insects and it would be difficult for birds to catch preys during the heavy rain, therefore, swiftlets often delay the leaving. On the cloudy day, some birds were observed to swoop around their breeding sites or nearby areas and if it was heavy rain most of them would return earlier and roost at their nests.

#### 5.4.2 Parental investment for nestling incubation

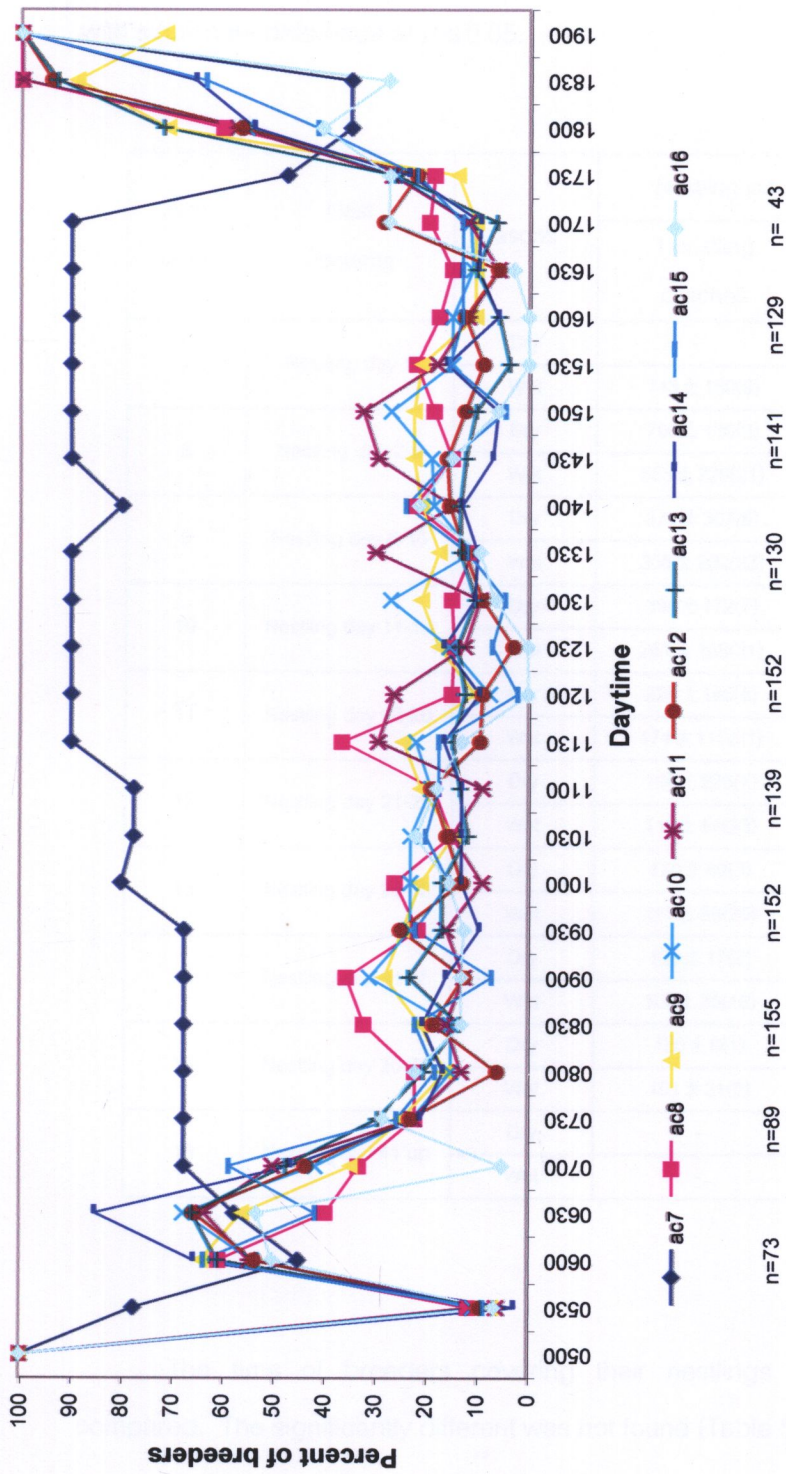
Nestlings of the White-nest Swiftlet are the altricial young that hatched with eyes closed, naked and incapable of departing (Figure 5.10).



Figure 5.10. Nestlings of White-nest Swiftlets at the age of 2 days (left) and of 1 day (right).

From the observation, nestling incubation at the first few days after hatching was performed all day. Breeders kept the naked nestlings warm by covering them all the time after feeding. The longest time that one parent incubated nestling was 7 hours and 30 min. The incubating time decreased continuously when nestlings got older. Nestling incubation was at minimum when the chicks had the full set of feathers covering the bodies in which they became post fledglings( referred to Figure 5.8 and Table 5.14). Percent of breeders appeared on the nest during the nestling feeding period is shown in Figure 5.11.

The number of nestlings within a brood affected to the nestling incubation time as well. The data showed that breeders of two-nestling broods tended to spend lower times than those of one-nestling broods although there were no significant difference (Table 5.17).



**Figure 5.11.** Percentages of White-nest Swiftlet breeders. Each spot on the line showing the percentage of one or both breeders found sitting on the nest during 0500-1930. Data presented in relation to the age class (ac) of the nest content, averaged of 12 month observations. The study was conducted at the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during November 2000 and October 2001. (ac7=nestling day 1; ac8=nestling day 2-5; ac9=nestling day 6-10; ac10=nestling day 11-15; ac11= nestling day 16-20; ac12= nestling day 21-25; ac13=nestling day 26-30; ac14=nestling day 31-35; ac15= nestling day 36-40; ac16=nestling day 41 up)



**Table 5.17.** Comparison on nestling incubation times in different clutch sizes of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test with significant difference at  $P \leq 0.05$ .

Age classes	Nest contents	Seasons	Nestling incubation times(min)		<i>P</i>
			1-nestling clutches	2-nestling clutches	
7	Nestling day 1	Dry	-	607 $\pm$ 225(20)	-
		Wet	743 $\pm$ 150(9)	598 $\pm$ 220(44)	.066
8	Nestling day 2-5	Dry	700 $\pm$ 135(3)	424 $\pm$ 197(27)	.270
		Wet	555 $\pm$ 226(21)	420 $\pm$ 193(32)	.024
9	Nestling day 6-10	Dry	375 $\pm$ 307(6)	298 $\pm$ 178(62)	.348
		Wet	358 $\pm$ 202(23)	263 $\pm$ 178(64)	.038
10	Nestling day 11-15	Dry	398 $\pm$ 172(7)	172 $\pm$ 107(62)	.050
		Wet	261 $\pm$ 168(21)	216 $\pm$ 140(62)	.236
11	Nestling day 16-20	Dry	225 $\pm$ 166(8)	124 $\pm$ 99(49)	.138
		Wet	174 $\pm$ 116(21)	151 $\pm$ 106(61)	.420
12	Nestling day 21-25	Dry	198 $\pm$ 226(7)	113 $\pm$ 58(54)	.634
		Wet	115 $\pm$ 54(23)	120 $\pm$ 94(68)	.802
13	Nestling day 26-30	Dry	130 $\pm$ 69(3)	140 $\pm$ 42(45)	.400
		Wet	117 $\pm$ 89(20)	112 $\pm$ 54(62)	.874
14	Nestling day 31-35	Dry	100 $\pm$ 17(3)	110 $\pm$ 51(44)	.692
		Wet	105 $\pm$ 35(19)	102 $\pm$ 44(75)	.756
15	Nestling day 36-40	Dry	120 $\pm$ 0(1)	98 $\pm$ 20(53)	.308
		Wet	101 $\pm$ 31(8)	94 $\pm$ 20(61)	.408
16	Nestling day 41 up	Dry	-	106 $\pm$ 39(43)	-
		Wet	-	-	-

The time of breeders covering their nestlings in different seasons were compared. The significantly different was not found (Table 5.18)

Table 5.18. Comparison on nestling incubation times in different seasons of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test with significant difference at  $P \leq 0.05$ .

Age classes	Nest contents	Clutch sizes	Nestling incubation times (min)		<i>P</i>
			Dry season	Wet season	
7	Nestling day 1	1-nestling	-	743 $\pm$ 225(9)	-
		2-nestling	607 $\pm$ 225(20)	598 $\pm$ 220(44)	.882
8	Nestling day 2-5	1-nestling	700 $\pm$ 135(3)	555 $\pm$ 197(21)	.298
		2-nestling	424 $\pm$ 197(27)	420 $\pm$ 193(32)	.944
9	Nestling day 6-10	1-nestling	375 $\pm$ 307(6)	358 $\pm$ 178(23)	.872
		2-nestling	298 $\pm$ 178(62)	263 $\pm$ 178(64)	.284
10	Nestling day 11-15	1-nestling	398 $\pm$ 175(7)	261 $\pm$ 21(107)	.074
		2-nestling	173 $\pm$ 107(61)	216 $\pm$ 140(62)	.058
11	Nestling day 16-20	1-nestling	225 $\pm$ 166(8)	174 $\pm$ 99(21)	.360
		2-nestling	124 $\pm$ 99(49)	151 $\pm$ 106(61)	.174
12	Nestling day 21-25	1-nestling	196 $\pm$ 22(7)	115 $\pm$ 58(23)	.428
		2-nestling	114 $\pm$ 58(54)	120 $\pm$ 94(68)	.636
13	Nestling day 26-30	1-nestling	130 $\pm$ 69(3)	117 $\pm$ 42(20)	.812
		2-nestling	104 $\pm$ 42(42)	112 $\pm$ 54(62)	.400
14	Nestling day 31-35	1-nestling	100 $\pm$ 17(3)	105 $\pm$ 51(19)	.792
		2-nestling	110 $\pm$ 51(44)	102 $\pm$ 44(51)	.366
15	Nestling day 36-40	1-nestling	120 $\pm$ 0(1)	101 $\pm$ 20(8)	-
		2-nestling	98 $\pm$ 20(53)	94 $\pm$ 61(20)	.294
16	Nestling day 41 up	1-nestling	-	-	-
		2-nestling	106 $\pm$ 39(43)	140 $\pm$ 12(7)	.354

Intensive nestling incubation was commonly found in the altricial species because hatchlings were born with naked bodies, therefore they need the warmth from their parents until the time that they can regulate body temperature. Gill (1990) stated that for the small passerines, their altricial young will develop the homeothermy during the development and can generate metabolic heat within six to seven days after hatching. This was concordant with the behavior observed in White-nest Swiftlets in that breeders often covered their nestlings just after feeding and neglected nestling incubation when nestlings had a full set of adult feathers.

The number of nestlings in a nest would reduce the time of nestling incubation. Gill (1990) stated that the bigger brood would achieve functional homeothermy earlier than those of small brood size. He also reported the relationship between the number of brood and the homeothermy in other passerines such as starlings and quail. This might be explained in White-nest Swiftlets as well.

From the result, it can be concluded that in the egg incubation period, breeders spent nearly all day to incubate eggs. Time for nestling incubation would decrease directly along the development of nestlings. The time of incubation bout could determine by the internal factor of breeders as well as the external factors such as food availability and climatic condition.



### 5.4.3 Parental investment for nestling feeding

From the observation, feeding activities were performed during the period of 0530-1930, therefore, the data that reported in terms of  $\text{trip} \cdot \text{h}^{-1}$  and  $\text{trip} \cdot \text{h}^{-1} \cdot \text{nestling}^{-1}$  were the average number of trips that breeders delivered food-balls to their young within 14 hours. One trip of feeding was equally to one food-ball delivery.

#### 5.4.3.1 Feeding behavior

At the stage of nestling feeding, one parent would be go out to forage at dawn and return to the nest with a food-ball in the mouth. A food-ball was the mass of tiny aerial insects weighing between 0.2-0.6 g ( $n=15$ ). When a parent arrived the nest, it clung at the rim of nest while its mate, if still on the nest, slowly moved backward to hang at the rim and flew out. At this moment, nestling would respond by erecting its head, squeaking, shaking its body, opening the mouth and swallowing some part of parent's head. After that food was regurgitated and was sent directly to nestling's mouth, one by one. Sometimes nestling neglected the feeding by closing its eyes and kept quiet on the nest even though the parent tried to encourage it. The parent would draw nestling's attention by banging it and moving backward to the rim of the nest until the nestling respond. If there were two nestlings in a nest, only one or both would be fed at that time. The feeding was quite slow when the nestling was very young in which the food-ball must be split to a few small ones. The feeding was faster when the brood was older because a whole food-ball could be swallowed by one nestling at one time. A parent often kept the naked young warm after the feeding and delayed the leaving until its mate returned to changeover. Occasionally, both parents departed at the same time and returned to the nest at nearly the same time and the feeding would be on the order of arrival. The nestling at the age of more than 16 days might be bigger than its nest and it often clung at the rim of the nest. When the parent returned to feed, the parent might cling at its back, then the young turned its neck backward and swallowed food-ball from the mouth of parent. After the feeding, the parent flew out at once or stayed at the nest for awhile.

There were low feeding rates when nestlings were young. The rate would increase when nestlings were at the stage of rapid growth and decrease when nestlings grew up to the post-fledgling stage at the age of 35 days or more. Occasionally, fledgling left the nest when parents were away. Hence, when parents returned to feed they found the vacant nest.

The unattended older nestling had many activities in the nest during one feeding trip duration. It spent the time with the series of relaxing activities, for example closing the eyes or napping, excreting, exercising its wings, preening, and hanging at the rim of the nest. The last three activities were observed when nestling was at the age of more than 15 days.

At the late evening, the time when a parent arrive at the nest was the noisy time with the rattle calling including the squeaking, screaming and chirping of all members, not only the adults but also the chicks. This time was the critical time for the survival of the nest. Since nests were built closely together, the interaction between neighborhood often happened and could cause the nest to fall down, leading to eggs and the helpless young died. When the last feeding was done, parents might cling at the rim of the nest for awhile. After that all members were crammed inside the nest.

#### **5.4.3.2 Duration of feeding trip**

Duration of feeding trip was the period of time between the previous and the current feeding. For example, if the first feeding was at 0630 and the second feeding occurred at 0830 then the feeding trip duration was 120 min or 2 hours. From this study, the range of duration of single feeding trip was 20 min to 450 min (equally 7 hours and a half). The duration of feeding trip varied day by day and across the nestling ages and brood sizes.

#### **5.4.3.3 The occurrence of feeding activities**

The feeding activity varied according to the time of the day. Most activities were concentrated in an hour after dawn (0600-0730) and an hour before dusk when all

parents returned to the nests (1800-1900). However, the activity occurred all day but was low during the late morning and late afternoon. The occurrence of feeding activities is shown in Figure 5.12.

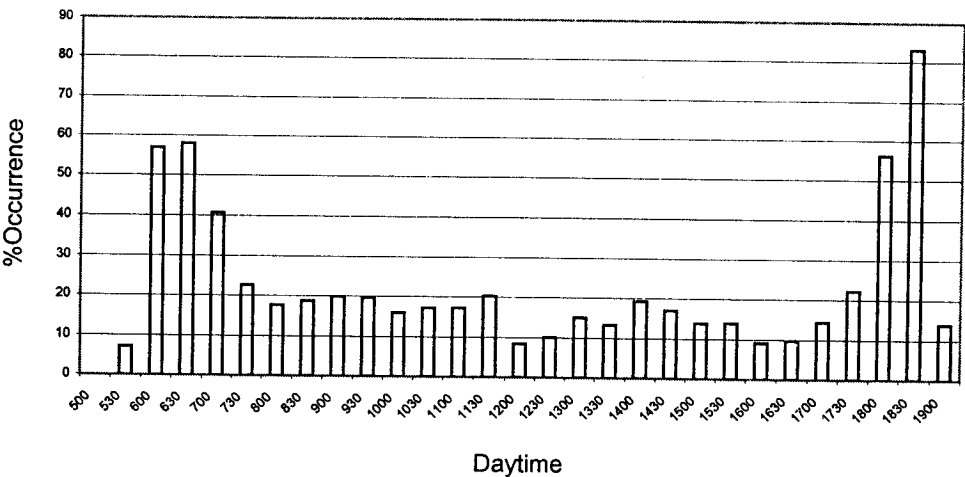


Figure 5.12. The occurrence (%) of feeding activities during 0500-1930 of 53 White-nest Swiftlet breeders in the sacred building of Suthiwatwararam Temple, averaged of 12 month observations.

5.4.3.4 The daily number of food-balls

The daily number of food-balls delivered to nestlings depended on the nestling age and brood sizes, ranging between 0-16 food-balls per day and the average was 5.35 food-balls per day (n=1162, Table 5.19).

Calculation of the feeding rate ( $\text{trip} \cdot \text{h}^{-1}$ ) in Table 5.19, showed that the average was  $0.38 \pm 0.20 \text{ trip} \cdot \text{h}^{-1}$  (n=1162), with the maximum and minimum values of  $1.14 \text{ trip} \cdot \text{h}^{-1}$  and  $0 \text{ trip} \cdot \text{h}^{-1}$ , respectively. Results showed that when nestling at the age of 1 day and 35-41 days were fed at lower rate of which parents often returned to the nests without feeding. On the other hand, when nestlings were at the age of 2-30 days old, parents worked harder by feeding the young more than other stages, providing chicks met the optimum energy requirement for the development. Parents of two chicks may work harder than those of the one chick.

The evidence of the feeding rate between two brood sizes showed the tendency of higher rate in the brood of two chicks. However, the significant differences were found only in some age classes (Table 5.20).

Table 5.19. The daily number of food-balls for nestlings of different age classes of 53 White-nest Swiftlet breeders, showing sample sizes(N), means  $\pm$  SD, maximum and minimum values. The different superscript alphabet means there is significant difference. The study was conducted in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during November 2000 and October 2001.

Age classes	Nest contents	N	Daily number of food-balls		
			Means	Max.	Min.
7	Nestling day 1	46	4.02 $\pm$ 2.40 <sup>a</sup>	10	0
8	Nestling day 2-5	105	6.24 $\pm$ 2.39 <sup>b</sup>	14	2
9	Nestling day 6-10	150	6.89 $\pm$ 2.21 <sup>b</sup>	14	2
10	Nestling day 11-15	140	6.90 $\pm$ 2.74 <sup>b</sup>	15	1
11	Nestling day 16-20	140	6.02 $\pm$ 2.37 <sup>b</sup>	13	1
12	Nestling day 21-25	139	5.42 $\pm$ 2.50 <sup>c</sup>	16	0
13	Nestling day 26-30	121	4.81 $\pm$ 2.57 <sup>c</sup>	13	0
14	Nestling day 31-35	144	4.15 $\pm$ 2.45 <sup>a</sup>	13	0
15	Nestling day 36-40	113	3.50 $\pm$ 2.72 <sup>a</sup>	15	0
16	Nestling day 41 up	57	2.68 $\pm$ 2.54 <sup>d</sup>	12	0
	Overall	1162	5.35 $\pm$ 2.80	16	0

**Table 5.20.** Feeding rate ( $\text{trip} \cdot \text{h}^{-1}$ ) for nestlings of different age classes and brood sizes of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001, showing means  $\pm$  SD with number of clutches in parentheses and results of *t*-test with significantly different at  $P \leq 0.05$ .

Age classes	Nest contents	Wet season		<i>P</i>	Dry season		<i>P</i>
		1-nestling clutches	2-nestling clutches		1-nestling clutches	2-nestling clutches	
7	Nestling day 1	-	.25 $\pm$ .14(14)	-	.21 $\pm$ .19(9)	.34 $\pm$ .17(23)	.081
8	Nestling day 2-5	.36 $\pm$ .01(3)	.49 $\pm$ .18(31)	.28	.41 $\pm$ .17(22)	.44 $\pm$ .17(49)	.494
9	Nestling day 6-10	.40 $\pm$ .01(4)	.47 $\pm$ .15(58)	.32	.45 $\pm$ .15(25)	.53 $\pm$ .15(63)	.054
10	Nestling day 11-	.39 $\pm$ .07(8)	.49 $\pm$ .23(58)	.03	.45 $\pm$ .12(26)	.53 $\pm$ .17(54)	.020
11	Nestling day 16-	.35 $\pm$ .20(9)	.42 $\pm$ .19(45)	.28	.41 $\pm$ .12(29)	.45 $\pm$ .16(57)	.164
12	Nestling day 21-	.30 $\pm$ .00(12)	.38 $\pm$ .19(37)	.00	.37 $\pm$ .15(30)	.39 $\pm$ .17(54)	.784
13	Nestling day 26-	.34 $\pm$ .10(10)	.42 $\pm$ .19(35)	.32	.26 $\pm$ .15(33)	.35 $\pm$ .19(43)	.028
14	Nestling day 31-	.24 $\pm$ .01(24)	.29 $\pm$ .40(25)	.00	.17 $\pm$ .00(32)	.24 $\pm$ .14(33)	.000
15	Nestling day 36-	.20 $\pm$ .19(24)	.29 $\pm$ .40(25)	.00	.17 $\pm$ .00(32)	.24 $\pm$ .14(33)	.024
16	Nestling day 41	.14 $\pm$ .12(23)	.32 $\pm$ .22(18)	.00	.01 $\pm$ .00(10)	.21 $\pm$ .16(6)	.074

Similar results were found between season in that feeding rates were tend to higher in the wet season than in dry season especially when nestlings at the age between 6-20 days, although there was no statistical difference. However the result was converted when nestlings at the age between 26-41 days to more (Table 5.21).

**Table 5.21.** Feeding rate (trip·h<sup>-1</sup>) in different seasons of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test with the significantly different at  $P \leq 0.05$ .

Age classes	Nest contents	Feeding rates		<i>P</i>
		Dry season	Wet season	
7	Nestling day 1	.25 $\pm$ .14(32)	.30 $\pm$ .18(32)	.340
8	Nestling day 2-5	.48 $\pm$ .17(34)	.43 $\pm$ .17(71)	.164
9	Nestling day 6-10	.47 $\pm$ .15(62)	.51 $\pm$ .15(88)	.110
10	Nestling day 11-15	.48 $\pm$ .22(66)	.51 $\pm$ .17(80)	.310
11	Nestling day 16-20	.41 $\pm$ .18(54)	.44 $\pm$ .16(86)	.266
12	Nestling day 21-25	.39 $\pm$ .19(55)	.39 $\pm$ .17(84)	.894
13	Nestling day 26-30	.41 $\pm$ .18(45)	.30 $\pm$ .18(45)	.004
14	Nestling day 31-35	.35 $\pm$ .18(47)	.27 $\pm$ .17(97)	.012
15	Nestling day 36-40	.31 $\pm$ .25(49)	.21 $\pm$ .13(84)	.014
16	Nestling day 41 up	.22 $\pm$ .19(41)	.12 $\pm$ .13(16)	.068

#### 5.4.3.5 Feeding rate per nestling

Since the feeding rate per nestling was calculated from the number of trip per hour divided by the number of nestlings in a brood, the result was concordant with those of other related activities in that feeding rate per nestling was low at the age of 1 day and high when nestling growing up until 35 days old and low again after the chick was 35 days to more.

Although the larger brood seems to be the main factor influencing the higher feeding rate per day, but the feeding rate per nestling in a brood of two was lower than

those of one chick. Statistical difference were confirmed between age class 8 to 13 in dry season and extending to age class 15 in wet season (Table 5.22).

The external factor such as weather condition and the availability of food items in the air would partly involved in daily number of the feeding rate per nestling. The activities within brood size comparing between seasons showed the difference in that parents provided higher number of feeding rate per nestling in wet season. Particularly, when the nestlings were on the stage of highest growth rate (at the age of 6-20 days). After that the rate was decreased and less than those in dry season when nestlings came to the age of 36-41 days. However, statistical differences were found in some age classes, but the tendency of higher rate can be seen in age class 7 to 12 (see Table 5.23).

The factors influencing feeding activities can be divided into two variables, the internal factors related to the species itself such as the nestling ages, brood sizes and growth rate of nestlings, and the external factors such as weather condition and food availability. The internal factor seems to be the major cause. This was concordant to the results from Univariate tests, which detected the effect of nestling ages and brood sizes on the feeding frequency (age classes,  $F=33.48$ ,  $df = 9$  and  $P = 0.000$ ; brood size,  $F = 28.75$ ,  $df = 1$ ,  $P = .001$ )



Table 5.22. Feeding rate per nestling ( $\text{trip} \cdot \text{h}^{-1} \cdot \text{nestling}^{-1}$ ) in different brood sizes of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001, showing means  $\pm$ SD with number of clutches in parentheses and results of *t*-test with significant difference at  $P \leq 0.05$ .

		Feeding rate per nestling									
Age classes	Nest contents	Overall		P	Dry season		P	Wet season		P	
		1-nestling clutches	2-nestling clutches		1-nestling clutches	2-nestling clutches		1-nestling clutches	2-nestling clutches		
7	Nestling day 1	.21 ± .18(9)	.15 ± .01(37)	.142	-	.13 ± .01(14)	-	.21 ± .18(9)	.16 ± .01(23)	.316	
8	Nestling day 2-5	.40 ± .16(25)	.23 ± .01(80)	.000	.36 ± .01(3)	.25 ± .8(31)	.040	.41 ± .17(22)	.22 ± .01(49)	.000	
9	Nestling day 6-10	.45 ± .14(29)	.25 ± .01(121)	.000	.40 ± .00(4)	.24 ± .01(58)	.000	.46 ± .15(25)	.27 ± .01(63)	.000	
10	Nestling day 11-15	.44 ± .11(68)	.26 ± .11(12)	.000	.39 ± .01(8)	.24 ± .12(58)	.002	.45 ± .12(26)	.27 ± .01(54)	.000	
11	Nestling day 16-20	.40 ± .11(38)	.22 ± .01(102)	.000	.35 ± .10(9)	.21 ± .01(45)	.000	.41 ± .12(29)	.23 ± .01(57)	.000	
12	Nestling day 21-25	.36 ± .14(42)	.20 ± .01(97)	.000	.30 ± .00(12)	.21 ± .10(43)	.000	.37 ± .15(30)	.20 ± .01(54)	.000	
13	Nestling day 26-30	.28 ± .11(43)	.19 ± .01(78)	.000	.34 ± .10(10)	.21 ± .01(35)	.000	.26 ± .15(33)	.17 ± .01(43)	.006	
14	Nestling day 31-35	.23 ± .13(60)	.17 ± .01(84)	.012	.24 ± .01(10)	.19 ± .01(37)	.122	.22 ± .14(50)	.16 ± .01(47)	.012	
15	Nestling day 36-40	.18 ± .12(56)	.15 ± .11(57)	.232	.20 ± .15(24)	.20 ± .14(25)	.888	.17 ± .01(32)	.12 ± .01(33)	.016	
16	Nestling day 41 up	.12 ± .11(23)	.15 ± .10(24)	.234	.14 ± .13(27)	.16 ± .11(18)	.634	.01 ± .01(10)	.11 ± .01(6)	.236	

Table 5.23. Feeding rate per nestling ( $\text{trip} \cdot \text{h}^{-1} \cdot \text{nestling}^{-1}$ ) in different seasons of 53 White-nest Swiftlet breeders in the sacred building during November 2000 and October 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test with significant difference at  $P \leq 0.05$ .

Age classes	Nest contents	Feeding rate per nestling									
		Overall		P	1-nestling clutches		P	2-nestling clutches		P	
		Dry season	Wet season		Dry season	Wet season		Dry season	Wet season		
7	Nestling day 1	.13 ± .01(14)	.18 ± .12(32)	0.104	-	.21 ± .18(9)	-	.13±.01(14)	.17 ± .01(23)	.106	
8	Nestling day 2-5	.26 ± .01(34)	.28 ± .14(71)	0.406	.36 ± .01(31)	.40 ± .17(32)	.270	.25±.01(31)	.22 ± .01(49)	.188	
9	Nestling day 6-10	.25 ± .01(62)	.32 ± .13(88)	0.000	.40 ± .01(8)	.46 ± .15(25)	.426	.24±.01(58)	.27 ± .01(63)	.048	
10	Nestling day 11-15	.26 ± .12(68)	.33 ± .13(80)	0.002	.39 ± .01(9)	.45 ± .12(26)	.156	.24±.12(58)	.27 ± .01(54)	.236	
11	Nestling day 16-20	.23 ± .10(54)	.29 ± .13(86)	0.010	.35 ± .10(9)	.41 ± .12(29)	.198	.21±.01(45)	.22 ± .01(57)	.304	
12	Nestling day 21-25	.23 ± .10(58)	.26 ± .14(84)	0.142	.30 ± .00(12)	.38 ± .16(30)	.010	.21±.10(43)	.20 ± .01(54)	.494	
13	Nestling day 26-30	.24 ± .11(45)	.21 ± .13(76)	0.168	.34 ± .10(10)	.26 ± .15(50)	.098	.21±.01(35)	.17 ± .01(17)	.070	
14	Nestling day 31-35	.20 ± .01(47)	.19 ± .13(97)	0.718	.24 ± .01(10)	.22 ± .14(50)	.692	.19±.01(37)	.16 ± .01(47)	.160	
15	Nestling day 36-40	.20 ± .14(49)	.15 ± .01(84)	0.022	.20 ± .15(24)	.17 ± .01(32)	.478	.20±.14(25)	.12 ± .01(32)	.010	
16	Nestling day 41 up	.14 ± .11(41)	.01 ± .01(16)	0.036	.14 ± .13(23)	.01 ± .01(10)	.080	.15±.10(18)	.11 ± .01(16)	.304	

The external factors would influence the daily number of food-ball, feeding rate, feeding rate per nestling, as well as the feeding trip duration.

The hatchling of White-nest Swiftlets likes other passerines, which is an altricial young. It hatches with naked body, eyes closed, lowest reserved nutrient in its huge belly and unable regulate the metabolic heat by itself at just after hatching. It requires more care and feeding by its parents than the precocial young (those with ready to leave the nest not too long after hatching).

At the age of 1 day, the nestling was served with 0 -10 food-balls a day leading to the low average feeding rate. The manner that parents have to spend most of the time incubating the newborn and the second egg would reduce the foraging time and food supply for the hatchling. The period that nestlings are 2-35 days old, parents must bring food as much as they can to help nestlings meet the daily energetic demands. At this period, nestlings were fed at highest rate because they must develop the body mass, have feathers and regulate the metabolic heat. This could be the explanation why parents increased the feeding rate at this period. When the nestling grew up to the stage of post-fledgling with the body had a full set of adult feathers, wing length nearly to 110 mm and weight about 10 g, parents decreased food to them. They left post-fledglings at the nest nearly all day while the chick had been practicing wing exercises, hanging and preening. The reason behind this could benefit the flying efficiency of the young that would be good for the first foraging trip when they leave the nest (Kang and Lee, 1991).

Brood sizes had also been influencing the feeding rate. The broods of two were fed in higher rate than the broods of one and the feeding rate per nestling was lower in the former than the latter. This confirms the need of higher feeding rate in the bigger size in which unless the more feeding, nestling will not survive to fledgling because they do not meet the minimum requirement. This will decrease the parents' fitness as well.

Although the two chicks received lower food, they could survive until fledgling unless there was no case of nest failure (i.e. nest falling and chick, itself, falling). This indicated that the lowest feeding rate that the two-chick brood received was the minimum food supply that would be adequate for the growth of the chick.

Growth rate of nestling are depended on their parents, their energy demands, the rate of food delivery require of the parent and the length of time they are exposed to the predator (Lack,1968; Bosque and Bosque,1995; Halupka,1998, cited in McCarty, 2001 : 176).

Since White-nest Swiftlets feed mainly on aerial insects and the abundance of food items fluctuated by the time of day and season. This strongly affected the feeding rate and growth rate of nestlings.

The feeding rate in White-nest Swiftlets was very low, ranged between 0.22-0.55 trip  $\cdot$  h<sup>-1</sup> comparing to the other tropical passerines which preformed an average of 5 trip  $\cdot$  h<sup>-1</sup> (Stuthbury and Morton, 2001). Therefore, growth rate of nestling was very slow comparing to the small altricial birds of the similar size. Kang and Lee (1991) suggested that the slow growth rate would be advantage for this species in which the development was limited by food availability. Therefore, the unpredictable food abundance would be determined the pattern of growth in this species and this rate would be favored and be selected.

Besides the amount of food delivery, the energy demands and physical constraints on growth of nestling would determine the pattern of growth as well. From all day observation for 12 months, the information on the behavior of nestlings were observed and the results would be confirmed the limit in the growth rate of nestling, in that although the good weather allowed the parents to catch more preys than the usual condition, the brood might neglect the exceeding food if they were fed for several times in that day. For example, the chick, age of 27 days, paid no attention to the sixth food-ball after having 5 food-balls within five hours and a half (0559-1146). Two chicks, age

of 15 days, neglected the third food-ball after receiving a couple of food-balls within 4 min and the post fledgling, age of 39 days, did not response to the arrival of parent coming with food, even though that was the first feeding trip of that day.

These evidences suggested that feeding capacity could be constrained by the internal factor in that when nestlings met the maximum of energetic demands they will ignore the exceeding food. This manner could be advantageous for this species and would be favored by the natural selection leading to the consistency in fledging time and the proper time for learning while remaining with parents in White-nest Swiftlets.

The other external factors that related to the growth rate of nestling was climatic condition. As mentioned in 5.4.1 that microclimate at the given day would involve with the feeding trip duration and the daily number of food-ball. Heavy rain could reduce the aerial insects and make birds difficult to catch preys, then parents would delay the departure. In addition, seasonal change could directly related to the amount of aerial insects. Wet season in tropical zone is the time of highest insect abundance (Eve and Guigue, 1996). Therefore, the number of daily food-balls would be higher in wet season than in dry season. However, the insects in tropical area do not reach the highest peak significantly as in the temperate zone summer, but were available all year (Stutchbury and Morton, 2001). Therefore, birds would have enough food for rearing their young all year leading they able to breed all year as well.

For the predation factor, its seems that predator did not affluent the growth rate of nestling in White-nest Swiftlets due to the fact that this species have the well protected nesting sites (i.e. inbuildings and caves) and less predator, therefore the this factor would be excluded.

#### 5.4.4 Equitability of parental care between sexes

By tagging fifteen breeding pairs, the parental efforts in incubation and feeding displayed by each individual were possible to observe. White-nest Swiftlet is monogamous, both sexes are similar in color and size (Figure 5.13). There is no brood-patch in the female during the breeding season in this species. Therefore, after tagging the careful observation on which individual laid the egg was necessary. The observation revealed clearly distinguishable behavior of the female in which it had the laying bout (times that a female spent on the nest before the onset of egg laying), so that the sex of nine pairs out of fifteen tagged could be identified.



**Figure 5.13.** A breeding pair of White-nest Swiftlets at the sacred building, Suthiwatwararam Temple, Samut Sakhon Province.

The morphological data of males and females were compared and the result showed that both sexes were similar in body color pattern and size. Males and females' wing lengths ranged between 110-119 mm, with the averages of  $114.57 \pm 2.57$  mm for females and  $113.43 \pm 2.07$  mm for males. The rumps of both sexes were pale than the back and the tail, with dark shaft stripes. The tarsi were naked with a range of 10.8-11.7 mm. The tail slightly forked at the end. The shortest rectrix ranged 40-48 mm and the longest rectrix ranged 48-52 mm, respectively. The weight ranged between 11.0-13.0 g with the averages of  $12.43 \pm 0.54$  g for females and  $12.57 \pm 0.92$  g for males. There

were no significant differences on the average weight ( $t$ -test ,  $P = .732$ ) and the average wing length ( $t$ -test ,  $P = .378$ ).

Within a pair, both sexes involved in the breeding activities. After a pair was bonded, both sexes built a nest. When the nest was complete, the female would sit on the nest for 30-60 min, once or twice each day, for a period of 1-5 days before the egg laying actually occurred. When the first egg was laid, both sexes performed the incubation task by changing over during daytime but did together at nighttime. The time of each incubation bout varied day by day, ranging from 26-720 min and 34-870 min for females and males, respectively. After hatching, both sexes also took turn in nestling feeding activities and nestling incubation. Similarly to the incubation task, nestling feeding allocated by females and males varied by time of the day. Females allocated to the young ranged between 0-0.57 trip per hour while the males did between 0-0.86 trip per hour. To keep the naked nestlings warm, one parent often covered the nestlings for a period of time and often did after feeding. It would delay the leaving till its mate returned to the nest. In this study, females incubated nestlings for 26-768 min per day while males did between 34-618 min per day.

During the study period, all observed pairs performed nesting at least 2 clutches and the data of all pairs were pooled. Overall, females and males allocated times to incubate eggs and feeding similarly ( $\chi^2 = 12.88$ ,  $df=19$ ,  $P = .844$  for egg incubation and  $\chi^2 = 10.15$ ,  $df=15$ ,  $P = .810$  for feeding ). The results also confirmed by  $t$ -test (Table 5.24 and 5.25).



**Table 5.24.** The times spent for egg incubation, nestling incubation, total feeding trip and the percentages of investment by the tagged female and the tagged male of White-nest Swiftlets in the sacred building during November 2000 and August 2001, showing means  $\pm$  sd with number of clutches in parentheses and results of *t*-test with significant difference at  $P \leq 0.05$ .

	Tagged breeders		<i>P</i>
	Females	Males	
Egg incubations (min)	2892 $\pm$ 1192(20)	2572 $\pm$ 1064(20)	.378
%investment in egg incubation	45.33 $\pm$ 11.79(20)	42.73 $\pm$ 10.42(20)	.464
Nestling incubations (min)	1063 $\pm$ 722(19)	1161 $\pm$ 1948(12)	.778
%investment in nestling incubation	51.53 $\pm$ 10.24(12)	48.47 $\pm$ 10.24(12)	.472
Total feeding trips	39.35 $\pm$ 27.03(20)	39.63 $\pm$ 24.36(20)	.972
% investment in feeding trip	47.36 $\pm$ 12.94(20)	50.27 $\pm$ 18.08(20)	.392

Table 5.25. The investment in incubation and nestling feeding by the tagged female and the tagged male White-nest Swiftlets in the sacred building during November 2000 and August 2001, showing means,SD and results of *t*-test with significant difference at  $P \leq 0.05$ .

Age classes	Nest contents	%Incubation investments						%Feeding investments					
		N	Tagged females		Tagged males		P	N	Tagged females		Tagged males		P
			Mean	SD	Mean	SD			Mean	SD	Mean	SD	
1	Egg day 1	11	63.64	20.75	36.92	17.10	.000						
2	Egg day 2-5	26	59.19	19.94	47.11	21.30	.040						
3	Egg day 6-10	38	53.14	18.07	51.76	18.00	.740						
4	Egg day 11-15	36	53.95	11.60	51.98	12.40	.480						
5	Egg day 16-20	32	55.00	12.16	50.04	15.10	.160						
6	Egg day 21-25	24	54.83	12.92	50.21	13.20	.220						
7	Nestling day 1	16	53.39	18.22	47.52	16.00	.340	16	48.12	16.30	45.62	15.74	.662
8	Nestling day 2-5	15	55.41	18.20	44.59	18.20	.115	15	47.01	8.48	52.89	8.42	.067
9	Nestling day 6-10	34	52.19	14.34	47.68	14.42	.200	34	49.26	24.00	50.77	9.33	.507
10	Nestling day 11-15	40	53.63	13.27	47.07	14.01	.035	40	51.56	11.00	48.47	11.03	.218
11	Nestling day 16-20	26	44.74	13.87	55.25	13.87	.000	26	51.64	14.77	48.35	14.80	.427
12	Nestling day 21-25	23	48.17	14.21	53.50	14.05	.213	23	51.75	15.82	48.62	16.11	.514
13	Nestling day 26-30	31	55.58	10.82	44.42	10.82	.000	31	53.24	10.73	46.76	10.73	.021
14	Nestling day 31-35	30	50.80	12.42	49.19	12.40	.620	39	51.56	11.00	48.5	11.03	.500
15	Nestling day 36-40	30	52.05	9.20	47.94	9.20	.100	26	51.64	14.80	48.4	14.80	.500
16	Nestling day 41 up	14	53.75	9.88	46.24	9.88	.055	12	67.25	42.87	7.75	14.67	.000

However, when each age class was focused, the percentages of investment in incubation and nestling feeding allocated by both sexes were not all equal. The results in Table 5.25 showed that females invested significantly more than males in age class 1,2,10,11 and 13. Similar results were found in the nestling feeding in that females spent more time than males and the significant differences were found in age class 13 and 16. Females invested more times for incubation and feeding than males did by 7.51 % and 6.91 %, respectively.

The test for equitability of parental care leads to the understanding of the incubation and feeding strategies and of the effort making by both sexes to incubate eggs and raise their young. From the study on the feeding rate of this species, the result showed that White-nest Swiftlets had lower feeding rate either per day or per nestling, comparing to other species (Kang and Lee, 1991). This may be due to the tiny food items that breeders need more times to catch them as well as the food availability that fluctuates by the time of the day and the season. This can be implied that food do not exceed for nestlings all the time and females require help in the nestling rearing and there would not be success at all unless the help from males. These evidences were supported partly by the data of breeding success in 53 breeding pairs in which there was no nest failed by the starvation of nestlings. In addition, the data from six tagged breeders out of nine pairs had at least one chick fledged and the unsuccessful nests were failed by other causes, not by the starvation.

This could be stated that the allocation in incubation and feeding sharing by both parents would provide greater fitness for both of them. The unsuccessful pairs may be linked to the inexperienced breeders, involving with the nest-site selection, leading to the lower reproductive success than the experienced birds (i.e. Nol and Smith, 1987; Smith, 1988; Sher, 1990, cited in Larison et al., 2001 : 439).

The strategy that males and females share the incubation and feeding tasks in White-nest Swiftlets could be concluded that sexes' roles of this species are similar.

Although males tend to share in the incubation and feeding tasks less than females, males might respond in other duties (e.g. nest building and nest defense) more than females and those duties would be important to the breeding success.

Monogamous birds are believed that they share the young raising together (Stutchbury and Morton, 2001). At present, the varieties in pattern of parental care in monogamous species are well documented and many reports indicated that both sexes did not share equally in all activities during the breeding cycle. For examples, the Elegant Trogon *Trogon elegans* the number of times females incubated was significantly higher than that for males, but there was no significant difference between the sexes in the amount of time spent on incubation eggs per hour and overall rate and duration of incubation, brooding and nestling feeding were equal between both sexes (Hall and Karubian, 1996). The Yellow-bellied Elaenias *Elaenia flavogaster*, a tropical bird, males shared nest building and nestling feeding but not in incubation (Stutchbury and Morton, 2001). Northern Goshawks *Accipiter gentilis* males provided most of food and females generally remained at the nest and protected the young, females would leave and hunt prey when the young were about 3 weeks old (Dewey and Kennedy, 2001). Herring Gulls *Larus argentatus* males spent significantly more times alone on territory than females (Bukacinska et al., 1996). However, besides the pair quality, the local condition such as predation and feeding condition would influence the behavior of parents in the equitability of care as well (i.e. Burger, 1986; Morris, 1987, cited in Bukacinska et al., 1996 : 306).

## 5.5 Loyalty in pair and nest-site fidelity

After tagging, ten breeders had pair-bonds. They were paired around 30 days before the first and the second tagging were done. Four pairs were bonded within 10 days after the third tagging.

Results from the observation indicated that all of tagged pairs keep in pairing for a long period (Table 5.26). The maximum duration of the association was observed up to 220 days (~ 7 months). However, four pairs had lost their tags within a short time (23 days). All 15 tagged pairs used their first nest-sites permanently as their nest-sites along the period of the observation. They also used the same nests for their subsequent broods (i.e. B59, C5,C3,B57 and B57.1).

By the tagging, it is possible to study the period of breeding performed by a breeding pair and the result showed that both sexes within each pair keep the monogamous relationship for a long period and use the same sites and also the same nests. These manner can be called as loyalty in pair and nest-site fidelity.

Although the monitoring was ceased when the tag lost dued to molting, all pairs were observed living on their same sites and they were on the varied stage of breeding cycle untill the end of this study.

Table 5.26. Monitoring chart for 15 tagged pairs of White-nest Swiftlets in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province, showing the period from tagging date to tag loss date and pairing duration.

No	Tagged pairs' numbers	Time period	Pairing durations (days)
1	A1	22 Oct-13 Nov-00	23
2	A4*	22 Oct-13 Nov-00	23
3	B98*	22 Oct-13 Nov-00	23
4	B62*	22 Oct-13 Nov-00	23
5	B59*	7Nov-00-15 Jun-01	185
6	C5*	7Nov-00-15 Jun-01	185
7	C3*	7Nov-00-15 Jun-01	185
8	B64*1	7Nov-00-15 Jun-01	185
9	B57*	7Nov-00-15 Jun-01	185
10	B57.1*	7Nov-00-15 Jun-01	185
11	B96**	12Jan-4Aug-01	192
12	CV4	12Jan-22Aug-01	220
13	CSOK**	12Jan-22Aug-01	210
14	C32**	12Jan-4Aug-01	192
15	BI**	12Jan-7Aug-01	195

\* bonded a pair 30 days before the tagging

\*\* bonded a pair 10 days after the tagging

In general, living together and having equitability of parental care would be advantageous to both the male and the female in which they can raise more young than a single parent can do, leading to the higher breeding success. The results of the study on the Kittiwakes *Rissa tridactyla* and Manx Shearwaters *Puffinus puffinus* (Coulson, 1966; Brooke, 1978, cited in Krebs and Davies, 1993 : 209) confirmed the above phenomenon. In addition, if either sex deserted, they might have to spend more times and energies searching for a new mate and might be faced with the jeopardized circumstance. Particularly in the White-nest Swiftlet in which the food availability is unpredictable and the good site for nesting is limited, staying together for life would benefit for this species.

Ninety percent of birds are monogamous and the period of pairing varies among species. A few species, such as some raptors and geese and swans, pair for life (Nash, Online, September 21, 2002) as well as the swiftlets ( Corpuz and Leon ,1999) and Chimney Swifts *Chaetura pelagica* (Dexter, 1977, cited in Kang et al., 1991 : 171), this species pairs for one year before the egg laying (Chantler and Driessens, 2000).

Although White-nest Swiftlets show the high fidelity to their nest-sites, the evidence from the observation indicated that a pair might be moved to the new site if its nest was prone to fall. It moved for 5-10 cm from the previous site if the space was available (n=2). However, there were 10 pairs that built nests at the same sites even though they had never succeeded in the breeding.

The manner of the site fidelity was reported in many species. It would be advantageous to the breeders, which occupied the good sites to achieve the highest breeding success. Therefore, this behavior exists in the life-history strategy of the species ( i.e. Badyaev, Martin, and Etges, 1996; Hooge, Stanback, and Koenig, 1999). However, it remains unclear why most pairs at the bad sites do not try to move to the new place. The reason behind this was interesting to be investigated.

The results provide the better understanding on the way of life for White-nest Swiftlets and the information for the comparison with other monogamous species.



5.6 Nest-site characteristics of White-nest Swiftlets in the sacred building at Samut Sakhon Province and in caves at Phatthalung Province

5.6.1 Nest-site characteristics of Wite-nest Swiftlets in the sacred building at Samut Sakhon Province and the effect of nest-site quality on breeding success

5.6.1.1 Preferable nest-sites

The nest-site count of White-nest Swiftlets and estimated areas of 4 different nest-site types in the sacred building are shown in Table 5.27.

Table 5.27. Estimated area of 4 different nest-site types, total number of nests and density of nests of White-nest Swiftlets at each site in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province. Data were recorded in November 2000.

	Sites				
	Overall	sm1	sm2	sc1	scs2
Estimated areas (m <sup>2</sup> )	156	138	8	1	8
Total nests	848	1	13	30	800
Density (nests/m <sup>2</sup> )	5.44	0.001	1.63	30	100

Note: sm1= sites at the smooth and flat wall with no supporter, nests attached at one-dimension surface  
sm2= sites at the smooth and flat wall with no supporter, nests attached at two-dimension surface  
sc1= sites at the sculpture wall with no supporter, nests attached at one-dimension surface  
scs2= sites at the sculpture wall with supporter, nests attached at two-dimension surface

Nest density at smooth and flat wall (sm1, sm2) and sculpture walls (sc1, scs2) were 0.10 and 92.22 nests/m<sup>2</sup>, respectively, showing that sites at sculpture wall were most preferable and birds tend to select nest-sites of two dimensions with supporters. Most of these sites are at sculpture wall where uneven surfaces of Thai-style motifs provide supporters for nests.

Considering sites with no supporters at smooth and flat walls (sm1 and sm2), the study indicates that there were more nests at the angle of pillars (sm2) than nests at smooth and flat wall (sm1). This indicates that the dimension for nest attachment is also important factor for the selection and sm2-sites are more important for the survival of nests than sm1-sites.

Comparing to sc1-sites, it was found that birds at sm2-sites found hard ways to reach the high breeding success since they performed nesting attempts higher than breeders at sc1-sites did by 26.07% but the production was higher only for 10.34%. Comparing the outcome of sm2-nests with that of scs2-nests, the first achieved %BSF lower than the later by 50.01%, although they performed nesting attempts lower only 25.23% (28 clutches lower), ( these figures in this paragraph were calculated from the data in Table 5.28). In this regards, it could be concluded that having the two dimension for nest attachment is inferior important to nest survival when compare to the role of supporters.

#### **5.6.1.2 Nest-site quality and fledging success**

Form the above results, the quality of nest-sites in the sacred building were defined as "good site" and "bad site"( see Figure 3.3 and 3.4). Bad sites were sites with no supporter (sm1, sm2 and sc1) whilst good sites were sites with supporters (scs2). Reproductive success and production of nests at good sites would be higher than that of bad sites.

Overall, 39.31 % of 53 breeding pairs successfully produced at least one fledgling (Table 5.28). The success was shared by the outcome of nests at scs2-sites up to 26.72 %, the rest, 7.25% and 5.34 % came from the nest of sm2-sites and sc1-sites, respectively. On average, birds using sites with no supporters fledged 20.98% lower than those using sites with supporters. They also gave lower production by 16.43 %(these figures in this paragraph were calculated from the data in Table 5.29).

Table 5.28. Nest fate of 53 White-nest Swiftlet breeders at 4 different nest-site types, showing percentages of successful, unsuccessful and uncertain fate clutches with number of clutches in parentheses. The study was conducted at the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during September 2000 and October 2001

Nest fates	Sites				
	Overall	sm1	sm2	sc1	scs2
Successful clutches	39.31(103)	0(0)	7.25(19)	5.34(14)	26.72(70)
100 % BSF	27.10(71)	0(0)	4.20(11)	3.82(10)	19.08(50)
50% BSF	12.21(32)	0(0)	3.05(8)	1.53(4)	7.63(20)
Unsuccessful clutches	60.39(159)	1.15(3)	40.25(64)	32.08(51)	25.79(41)
0 % BSF	60.30(158)	1.15(3)	24.43(64)	19.08(50)	15.65(41)
Uncertain fate clutches	0.09(1)	0(0)	0(0)	0.40(1)	0(0)
Total	100.00(262)	1.15(3)	31.68(83)	24.81(65)	42.37(111)

Note: sm1= sites at the smooth and flat wall with no supporter, nests attached at one-dimension surface  
sm2= sites at the smooth and flat wall with no supporter, nests attached at two-dimension surface  
sc1= sites at the sculpture wall with no supporter, nests attached at one-dimension surface  
scs2= sites at the sculpture wall with supporter, nests attached at two-dimension surface

**Table 5.29.** Reproductive parameters of 53 White-nest Swiftlet breeders at 4 different nest-site types in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during September 2000 and October 2001, showing number of the observed nests, means  $\pm$  SD of total clutches, successful clutches, unsuccessful clutches, number of fledglings and production.

Reproductive parameters	Sites				
	Overall	Sm1	Sm2	Sc1	Scs2
No. of the observed nests	53	1	12	15	25
Total clutches	7.49 $\pm$ 2.00	3 $\pm$ 0	5.85 $\pm$ 2.00	4.36 $\pm$ 1.63	4.44 $\pm$ 1.58
Successful clutches	1.98 $\pm$ 1.23	0 $\pm$ 0	1.29 $\pm$ 0.79	1.06 $\pm$ 1.09	2.80 $\pm$ 0.91
Unsuccessful clutches	2.94 $\pm$ 2.44	3 $\pm$ 0	4.77 $\pm$ 2.34	3.33 $\pm$ 2.46	1.56 $\pm$ 1.38
Number of fledglings	3.25 $\pm$ 2.25	0 $\pm$ 0	1.99 $\pm$ 1.37	1.53 $\pm$ 1.40	4.48 $\pm$ 1.90
Production ( fledglings/pair/year )	3.55 $\pm$ 2.32	0 $\pm$ 0	2.24 $\pm$ 1.47	2.03 $\pm$ 1.87	5.11 $\pm$ 1.88

Note: sm1= sites at the smooth and flat wall with no supporter, nests attached at one-dimension surface

sm2= sites at the smooth and flat wall with no supporter, nests attached at two-dimension surface

sc1= sites at the sculpture wall with no supporter, nests attached at one-dimension surface

scs2= sites at the sculpture wall with supporter, nests attached at two-dimension surface

### 5.6.1.3 The effect of site quality on reproductive success

Since clutch that the young survived to fledging date was considered as successful clutch and clutch that could not produce nestling was considered as unsuccessful clutch. In this population, there was no predation and starvation associated with the nesting failure. Most failures observed were from nest or nest content falling which could occur at any breeding stages. Nest falling occurred highest at bad sites and lowest at good sites by 89.61% and 10.39% of all failed nests, respectively.

Breeding pairs occupied at good sites had lower reneesting and relaying activities than those at bad sites by 92.50% and 83.04%, respectively (these figures were calculated from data in Table 5.30).

The comparison of hatching success and breeding success at fledging of 53 pairs nested at bad sites and good sites are shown in Table 5.31. Significant differences were found, suggested that the breeding success of nests at scs2-sites are higher than those at sm1, sm2, and sc1-sites. On average, nests at scs2-sites also produced fledglings more than the others.

Table 5.30. Causes and percentages of nesting failure with number of clutches in parentheses of 53 White-nest Swiftlet breeders at 4 different sites in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during September 2000 and October 2001, including the averages of renesting and relaying (time/pair).

Causes	Nesting failure(%)	Sites			
		sm1	sm2	sc1	scs2
Nest falling before laying	22.17(58)	-	13.36(35)	6.87(18)	1.91(5)
Egg and nest falling	4.96(13)	0.38(1)	1.15(3)	3.05(8)	0.38(1)
Nestling and nest falling	2.29(6)	-	0.38(1)	1.15(3)	0.76(2)
Egg falling	10.67(28)	0.76(2)	3.82(10)	2.67(7)	3.44(9)
Nestling falling	21.38(56)	-	6.87(18)	4.58(12)	9.92(26)
Egg falling, nestling falling hereafter	0.76(2)	-	-	-	0.76(2)
Infertile egg	3.44(9)	-	0.38(1)	0.38(1)	2.67(7)
Flushing out of post fledgling	0.76(2)	-	-	0.76(2)	-
Harvesting	6.48(17)	-	1.53(4)	1.53(4)	3.41(9)
Total of unsuccessful clutches	72.90(191)	1.15(3)	27.48(72)	20.99(55)	23.28(61)
Total of successful clutches	27.10(71)	0 (0)	4.20(11)	3.82(10)	19.08(50)
Total clutches observed	100.00(262)	1.15(3)	31.68(83)	24.81(65)	42.37(111)
Renesting (time/pair)	4.49	3.00	3.67	2.10	0.68
Relaying(time/pair)	1.98	3.00	1.08	0.4	0.76

Note: sm1= sites at the smooth and flat wall with no supporter, nests attached at one-dimension surface

sm2= sites at the smooth and flat wall with no supporter, nests attached at two-dimension surface

sc1= sites at the sculpture wall with no supporter, nests attached at one-dimension surface

scs2= sites at the sculpture wall with supporter, nests attached at two-dimension surface

**Table 5.31.** Breeding success of 53 White-nest Swiftlet breeders at 4 different sites in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during September 2000 and October 2001, showing means  $\pm$  sd of number of fledgling and mean percentages  $\pm$  sd of hatching and breeding success at fledging with number of clutches in parentheses. The different superscript alphabet means there is significant difference.

Sites	Breeding success		
	No. of Fledglings	Hatching Success(%)	Breeding success at fledging (%)
sm1	0.00 $\pm$ 0.00(3) <sup>a</sup>	0.00 $\pm$ 0.00(3) <sup>a</sup>	0.00 $\pm$ 0.00(3) <sup>a</sup>
sm2	0.33 $\pm$ 0.66(83) <sup>a</sup>	36.74 $\pm$ 47.55(83) <sup>a</sup>	18.00 $\pm$ 36.42(83) <sup>a</sup>
sc1	0.35 $\pm$ 0.69(65) <sup>a</sup>	41.40 $\pm$ 49.24(64) <sup>a</sup>	19.04 $\pm$ 37.49(64) <sup>a</sup>
scs2	1.15 $\pm$ 0.87(111) <sup>b</sup>	72.07 $\pm$ 43.00(111) <sup>b</sup>	54.05 $\pm$ 45.29(111) <sup>b</sup>
Total	0.67 $\pm$ 0.85(256)	52.49 $\pm$ 48.86(262)	33.46 $\pm$ 43.88(262)

Note: sm1= sites at the smooth and flat wall with no supporter, nests attached at one-dimension surface  
sm2= sites at the smooth and flat wall with no supporter, nests attached at two-dimension surface  
sc1= sites at the sculpture wall with no supporter, nests attached at one-dimension surface  
scs2= sites at the sculpture wall with supporter, nests attached at two-dimension surface

Breeders generally selected nest-sites characterized by the wall with supporters. Density of nests at sculpture wall was highest during the study period indicating sites with supporters are preferable. Tendency of White-nest Swiftlets to exhibit poor reproductive success at sites with no supporters is concordant with the result from causes of nesting failure. Nests at the bad sites (sm1, sm2 and sc1) are prone to fall during nesting performance than those at sites with supporters (scs2). This suggests that supporters may play a key role for survival of nests and nest contents. However, observation on parental investment for one year reveals evidence that high density could be the cause of nesting failure due to aggressive interactions between breeders and their neighbors. Therefore, scs2-sites, the area of highest nest density (100 nests/m<sup>2</sup>) of which breeders had more aggressive manners, often lose eggs and nestlings in higher rate.

For this study, the result shows that characteristics of nest-sites influence nest-site selection and reproductive success in White-nest Swiftlets in the sacred building. Other constraints such as interspecific competition for good nest-sites should be observed in the future. The second constraint is a manner, which is called "nest-site fidelity". Once a pair chose one site for nest-site they rarely move to another site even though, their nest have high risk to fall. So breeders at sm1, sm2 and sc1-sites still stay at their first sites and have higher re-nesting rates than those at scs2-sites (see Table 5.30).

It can be concluded that significant ecological and demographic constraints exist on the nest-site selection in White-nest Swiftlets. This result is important implication for the conservation and management of this population. For example, bad area could be adapted through the addition of Thai-style motifs. In addition, providing some artificial nest-sites at the remaining bad sites, such as at the area behind the sculpture wall, will be more likely to enhance the reproductive output of this population. Moreover, this knowledge could provide benefits for the management of swiftlets' houses in nearby area in the future. However, the management should incorporate careful consideration of the environmental and social circumstances.



## 5.6.2 Nest-site characteristics of White-nest Swiftlets in caves

### 5.6.2.1 Nest-site characteristics

From the observation, nest-site characteristics were divided into 8 characters as follows :1) smooth and flat with no supporter; 2) smooth and flat with supporter; 3) smooth and concave with no supporter; 4) smooth and concave with supporter; 5) rough and flat with no supporter; 6) rough and flat with supporter; 7) rough and concave with no supporter; 8) rough and concave with supporter. Number of each nest-site is shown in Table 5.32. Most of the nest-sites (89.4%) were found on the smooth than the rough surface of the wall. Nest-site characterized as smooth and concave with supporter were found in all sampled nest-patches and this site was the highest in numbers and all of them were used by birds.

### 5.6.2.2 Correlation between the number of nest-sites and the number of supporters in each nest-patch

Form the total count of supporters and nest-sites of each 25 nest-patch. Sites with supporters were found scattered in all nest-patches on an average of 49.3 % (range 25.0-75.0%) and all of them were occupied by the breeding pairs. The number of supporters in each nest-patch was significantly correlated with the number of nest-sites in that patch ( $r = 0.95$ , Figure 5.14), suggesting that the supporter plays an important role in nest survival.

Table 5.32 Nest-site characteristics of *A. fuciphagus* were obtained from 25 nest-patches of 8 caves on 3 islands of Si-Ha Islands, Phatthalung Province, showing number and percentages. Data were recorded in October 2000.

Nest-site characteristics	Numbers	%
Smooth and flat with no supporter	3	2.4
Smooth and flat with supporter	28	22.0
Smooth and concave with no supporter	10	8.0
Smooth and concave with supporter	71	57.0
Rough and flat with no supporter	1	0.8
Rough and flat with supporter	2	1.6
Rough and concave with no supporter	5	4.0
Rough and concave with supporter	5	4.0
Total	125	100.0

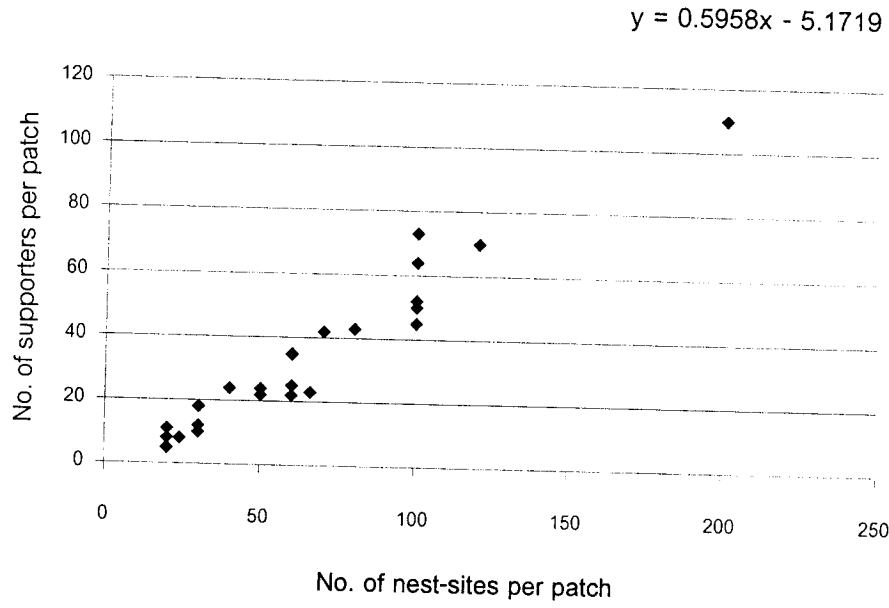


Figure 5.14 Relationship between number of nest-sites per patch versus the number of supporters per patch were obtained from 25 nest-patches in 8 caves of 3 islands on Si-Ha Islands, Phatthalung Province in October 2000. Each point represents one nest-patch.

From Table 5.32, it indicates that *A. fuciphagus* nest at the unique characteristic sites. Since the area of smooth and flat, rough or jagged wall on the outward-inclining wall and vertical wall as well as the wall that covered with water film locating near the entrance have not been observed that there are the nesting site of *A. fuciphagus*. Therefore, it can be concluded that *A. fuciphagus* selected suitable sites for nesting. Site of smooth and concave surface with supporter on the inward-inclining wall seems to be the suitable one.

The height and the angle of the wall may influence the selection in the way that inaccessible sites, such as those that are high up on the vertical wall, on the inward-inclining walls or on the ceiling, may normally prevent predators from gaining access to eggs and nestlings.

In this study, it seems likely site that smooth and concave surface with supporter is insufficient. Once a site is occupied by breeding pair, would not be available for the other unless the first pair dies. Hence, inferior breeders may be forced to occupy the lower quality sites (i.e. smooth or rough and flat sites with no supporters) in the same patch even though those sites lack supporters.

The question of how the supporter or the protruding U-shaped rock appears on the surface of the cave wall remains unclear. Some may be geological phenomena, but the large numbers of them found within nest-patches suggests that they are probably not formed by geological process alone. Most of them are probably formed due to the accumulation of calcium carbonate from the limestone rock at the base of the nest-cup which becomes U-shaped after repeated use by birds over many years.

From the observation on the use of the cave wall by congeners, it seems that *A. fuciphagus* and *A. maximus* have avoided interspecific competition for the nesting space by using different areas of the cave wall. Both species are not found nesting in the same nest-patch. This is concordant with the report of Boswell and Kanwanich

(1978). However, the interaction between the two species is needed to be investigated in the future work. In addition, the correlation between the role of supporter and the breeding success at fledging as well as the formation of the U-shaped supporter are also interesting and worth investigating in the future.

There are several ecological barriers that may constrain the ability to study the nest-site characteristics of cave swiftlets. The first is the sampling nest-patches that used to obtain the data are restricted at the accessible areas. These sites are enable to determine the character of nest-sites with the aid of flashlights and binoculars. Therefore, other inaccessible nest-patches, particularly the ones over 10 meters high are excluded form the analysis. Secondly, the correlation between suitable nest-sites and the breeding success of each nest in the cave could not be investigated.

In order to increase the number of nests by managing their nest-site habitat or by providing them with artificial nest-sites, the information of nest-sites in caves utilized by White-nest Swiftlets is necessary. The result from this study was applied to construct the artificial nest-site model for birds at Samut Sakhon Province. It, also, would be useful for the development of techniques using in cultivated houses.

## 5.7 The study on the use of artificial nest-sites by White-nest Swiftlets in the sacred building.

A few of non-breeders that were called "floaters" attended to the artificial nest-patches within one day after the patches had been placed on the wall. Later on the pair was bonded and the number of breeding pairs increased continuously through time until all sites in the artificial nest-patch were occupied (Table 5.33, Figure 5.15).

One month after the patch had been placed, five breeding pairs started to perform nesting activities. Until October 2001, there were 27 pairs and 2 floaters at the artificial nest-site. The first fledgling was seen in May 2001. During 11 months of the study, at least 13 pairs performed 17 nesting attempts and produced 13 nestlings. When the study was over, there were 56 individuals using the artificial nest-sites and at least 14 pairs were being under the breeding cycle while some pairs were initiating the third clutches. All 30 nest-sites in a nest-patch were used up by November 2001.

The number of birds that utilized the artificial nest-site and the breeding success at fledging indicated the suitability of the sites. The percentages of hatching success and breeding success at fledging of this group were high at 67.80% and 44.12% (Table 5.34) whereas those of 53 breeding pairs were 52.49% and 33.46%, respectively (see Table 5.10). In addition, the number of successful nests was high at 52.94%. It indicated that the artificial nest-sites were appropriate to the birds.

Table 5.33. Number of White-nest Swiftlets participated to one artificial nest-patch, which was set up in the sacred building, Samut Sakhon Province on 11 December 2000. Data were recorded during December 2000 and October 2001.

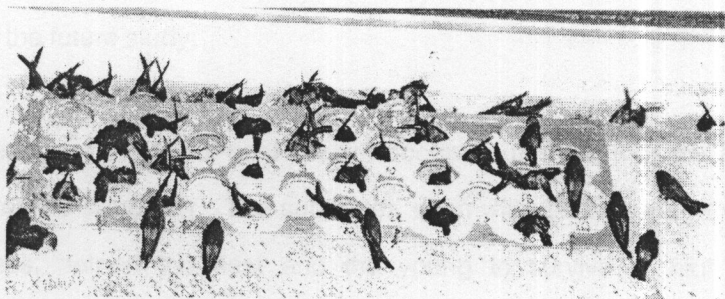
Date	Number of participated birds		
	Floater (individuals)	Pairs	Total (individuals)
12-Dec-00	4	-	4
17-Dec-00	6	1	8
28-Dec-00	3	4	11
1-Jan-01	7	5	17
22-Feb-01	7	9	25
20-Mar-01	7	9	25
29-Apr-01	-	12	24
25-May-01	2	12	26
12-Jun-01	2	12	26
11-Jul-01	2	15	32
5-Aug-01	4	15	34
4-Sep-01	8	15	38
10-Oct-01	8	24	56
30-Oct-01	2	27	56

**Table 5.34.** Breeding success of White-nest Swiftlet breeders nested at the artificial nest-site in the sacred building of Suthiwatwararam Temple, Samut Sakhon Province during December 2000 and October 2001.

Nest number	Observed months	No. of eggs	No. of nestlings	Hatching success(%)	No. of fledging	BSF (%)
25	Apr -01	2	0	100	0	0
24	May-01	1	0	0	0	0
7	May-01	2	2	50	1	50
19	May-01	2	2	100	2	100
17	June-01	1	1	100	1	100
14	June-01	2	2	100	2	100
10	June-01	1	1	100	1	100
27	June-01	2	1	50	1	50
8	July-01	2	0	0	0	0
27	Sep-01	2	0	100	0	0
17	Sep-01	2	0	100	0	0
28	Sep-01	2	0	10	0	0
19	Oct-01	2	0	0	0	0
8	Oct-01	2	0	0	0	0
7	Oct-01	2	1	50	1	50
11	Oct-01	2	2	100	2	100
3	Oct-01	2	2	100	2	100
Average		1.82	0.82	67.80	0.76	44.12
Total		31.00	14.00	-	13.00	-



(a)



(b)



(c)

Figure 5.15. The artificial nest-patch comprised of 30 nest-sites and was set up at the smooth and flat wall on 11 December 2000, showing the number of participants at different time : (a) in January 2001; (b) in October 2001; (c) in August 2002.



The model of the artificial nest-patches, with 30 nest-sites/patch, which imitated the characteristics of preferred nest-sites in natural caves and in the sacred building was proved to be a successful model. The evidence that the model was appropriate came from the result that birds started to occupy one of the artificial nest-sites on the following day after the nest-patch was set up on the wall in the sacred building. The increasing number of breeding pairs that succeeded in producing the young and all of nest-sites were occupied within one year confirmed that the artificial nest-sites were highly acceptable and suitable for nesting. This type of model is reported for the first time and is expected that the higher efficiency output could be improved in the future study.

Breeders of the White-nest Swiftlet accepted the site with the hole, 6 cm in diameter over the supporter. The supporter, each with  $3 \times 10 \times 3 \text{ cm}^3$  in width, length, and thickness, helped the nest and the young to survive at high percentage. Furthermore, the nests at some sites had been used for the subsequent broods at least two times ( $n = 4$  nests).

The area of  $100 \times 30 \text{ cm}^2$  of the nest-patch with 30 nest-sites provided approximately 5 cm inter-nest site distance. This density was proved in this study to be appropriate at one level since the intraspecific interaction between the neighborhood, which often appeared in other areas where the nests were crowded with the inter-nest distance less than 3 cm, was less seen. The optimum number of nest-sites per patch, the appropriate inter-nest distance and the size of the nesting site in the model should be studied more in details for the economic purposes.

The angle of the nest-patch that was set at 20 degrees to the perpendicular line is also proved to be preferable. In nature, nest-patches often found on the inward inclining wall with the angle of less than  $90^\circ$  to the horizontal line. Nesting at the steep and incline wall might be useful not only for the avoidance of some predators but also of droppings from the above nests, keeping the nest clean and avoiding the spread of the disease.

Floater birds were first seen roosting at the nest-sites for several days and later on the pairs were observed. This could be implied that the new generation was looking for the suitable site and at the same time seeking for mate. Whenever they could form the pair, the nesting would start. The floaters and the pairs attended at the artificial nest-sites could be the young that fledged in the year 2000 since the older breeders have nest-site fidelity (see 5.5 loyalty in pair and nest-site fidelity).

The young that could not find the suitable site to nest would have low opportunity to breed and to reach to the breeding success. The artificial nest-site adding to the building must be advantageous for birds themselves and the population. Three advantages of having artificial nest-sites are 1) the opportunity of new pairs to breed; 2) the breeding success of the given pairs would be higher than they nest at the smooth and flat wall; and 3) more new young are recruited to the population.

Further studies are needed to be investigated such as the material and the efficiency of the model, the inter-nest site distance, the angle of the patch and the shape of supporter that would be involved with the enhance of the breeding success.

## CHAPTER 6

### CONCLUSION AND RECOMMENTATION

#### 6.1 Conclusion

The study on the population size, diet, foraging area, nest-size characteristics, breeding biology and the use of artificial nest-sites of White-nest Swiftlets *Aerodramus fuciphagus* were conducted at the sacred building of Suthiwatwararam Temple, Samut Sakhon Province, from August 2000 to October 2001. The nest morphology and nest-sites of White-nest Swiftlets at Si-Ha Islands, Phatthalung Province were also studied and compared to those at the sacred building, Samut Sakhon Province. Based on the results of this study, the following conclusions could be made.

1. The population size of White-nest Swiftlets in the sacred building increased from 2,702 to 3,486 individuals during April 2000 and February 2001. The population growth rate was 29 % per year. The two factors affecting with the population growth rate could be the addition of supporters and the use of artificial nest-sites. Besides, it could be influenced by the adequate food supply, low predation, and low emigration rate. The high rate of increase indicates that this population has potential to be enhanced if it is under favorable conditions.
2. White-nest Swiftlets are insectivores. They feed mainly on air-borne insects with 0.1-10.00 mm in body length. Major insect groups were small dipterans, homopterans and hymenopterans including the small arachnids.
3. All of the green terrians in Samut Sakhon Province are the potential foraging areas for White-nest Swiftlets. They were able to forage at the longest distance of 25 km from their breeding sites.

4. White-nest Swiftlets have continuous breeding pattern. They spent 92-104 days for one breeding cycle from the start of nest building to the end of nestling rearing. Therefore, they can breed approximately 4 times a year. The maximum number of nestlings that one breeding pair could produce was 8 individuals per year with the average of 3.55 nestlings per pair per year.

5. White-nest Swiftlets are monogamous birds. They are faithful to their mates and their first nesting sites. Both sexes share the duty of parental care. The investment of time for incubation and nestling rearing by the female did not differ from the male, leading to the breeding success at fledging of 56.82% (based on tagged pairs). Chicks died from starvation or diseases were not found.

6. The breeding success of White-nest Swiftlets at the sacred building was influenced by the quality of nest-sites. Most nests were found at the sculpture wall in which its uneven surface provided suitable nest-sites for breeders. Nests at these sites normally survived until the chicks fledged and could be reused several times for subsequent broods, leading to the higher breeding success than other nesting areas elsewhere. This area is designated as "good site" while the smooth and flat wall with no supporter as "bad site". Egg, nest and nestling fallings were the major cause of nesting failures and the falling frequently occurred at the bad site. The evidence that the nest is strengthened by the aid of supporter and the dimension of the wall is useful for the design of the interior wall of the cultivated house.

7. Nest-sites of White-nest Swiftlets in the cave were mostly found on the smooth and concave wall with supporters. The position of the nest-site was found mainly on the inward-inclining wall at the completely dark site. All nesting-sites are at the dry areas of the wall. The number of supporters is correlated to the number of nests in the nest-patch, suggesting that the supporter plays an important role in the nest survival. The smooth and concave characteristics with supporters were used as the basis for the construction of the artificial nest-sites.

8. All artificial nest-sites were occupied by new breeders within one year, indicating that the suitable nest-site in the sacred building was limited. Birds nested at artificial nest-sites had higher breeding success than those that nested at the study areas, indicating that artificial nest-sites are appropriate to the birds.

## 6.2 Recommendation

1. Since the considerable confusion on the taxonomy of the Edible-nest Swiftlet still exists, comparative studies on the ecology, morphology and molecular genetics of these birds in different localities of their distribution range are necessary, before the proper taxonomic status can be made.

2. The study on food items of White-nest Swiftlets may lead to the development of food to feed the fallen nestlings as well as the development of supplementary food for adult birds.

3. The knowledge on the breeding biology of White-nest Swiftlets is useful for the arrangement of harvesting times. However, the optimal time for harvesting in different localities may vary due to the climatic conditions. Therefore, the study of breeding biology of swiftlets in each breeding colony should be conducted in order to get the maximum yield from nest harvesting.

4. For the artificial nest-site, the improvement of the paratype is needed. Further studies on the type of materials for the nest-site construction, the inter-nest-site distance, the angle of the patch and the shape of supporter that would be involved with the enhancement of the breeding success should be conducted. The quality improvement of the nest for economic purposes (i.e. in shape, color and weight ) should be of interested as well.

5. Although White-nest Swiftlets contribute to an enormous economic income and every owner would like to increase the population size in the cultivated house, they may spread various diseases to the conspecifics and to the people who live in or nearby area. Thus, the diseases caused by White-nest Swiftlets should be studied in the near future in order to prevent the outbreak and to avoid the collapse of the bird colony as well as the negative effects on human health. Therefore, all the management should incorporate careful consideration of the environmental and social circumstances.

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## **Biography**

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