ROOSTING ECOLOGY OF THE EDIBLE-NEST SWIFTLET IN THE ANDAMAN ISLANDS

Thesis Submitted to the

BHARATHIAR UNIVERSITY

For the award of

DEGREE OF DOCTOR OF PHILOSOPHY

In

ZOOLOGY

By

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Sâlim Ali Centre for Ornithology and Natural History

Coimbatore, India

August 2017

CERTIFICATE

This is to certify that the thesis, entitled "**Roosting ecology of the Edible-nest Swiftlet in the Andaman Islands**" submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original work done by **Ms. Mane Akshaya Mohan** during the period of September 2012–August 2017 of her research in the Department of Zoology at Sálim Ali Centre for Ornithology and Natural History (SACON), under my supervision and guidance and the thesis has not formed the basis for the award of any Degree /Diploma /Associateship /Fellowship or other similar title to any candidate of any University.

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I, **Mane Akshaya Mohan** hereby declare that the thesis, entitled **"Roosting ecology of the Edible-nest Swiftlet in the Andaman Islands"** submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original and independent research work done by me during the period of September 2012–August 2017 under the supervision and guidance of **Dr. Manchi Shirish S.**, Senior Scientist at Sâlim Ali Centre for Ornithology and Natural History (SACON) and it has not formed the basis for the award of any Degree /Diploma /Associateship /Fellowship or other similar title to any candidate of any University.

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4	Name of the Supervisor	DR. MANCHI SHIRISH S.
5	Department / Institution/ Research Centre	Dept. of Conservation Ecology Salim Ali Centre for Ornithology and Natural History, Coimbatore
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Acknowledgements

A doctoral thesis is often described as a solitary endeavour. However, the long list that proves the opposite.

In the beginning, I express my indebtedness to India's great conservationist, the pioneer and the father of Edible-nest Swiftlet Conservation Programme, *Late Dr Ravi Sankaran*. He germinated the seed of swiftlet conservation in his mind and everyone's heart in Andaman Island. His stories from field always motivated me to achieve this work. Secondly, I acknowledge the efforts & the determinations of *Dr Manchi Shirish S* who truly carried forward the conservation work and nurture it till it became a huge fruiting tree. I am very much pleased & grateful to him for involving me in swiftlet conservation family and providing resilient support for implementing the conservation and research of Andaman Edible-nest Swiftlet (AENS). I feel delighted for being a first student of him. He is a teacher, a boss, a colleague, a friend & a guardian for me.

I thank *Dr B Anjan Kumar Prusty* (Senior Scientist, Environmental Impact Assessment Division, Gujrat Institute of Desert Ecology, Bhuj) for giving me his complete unconditional support as a co-guide and motivating me for timely completion.

My sincere acknowledgement to Ministry of Environment, Forests & Climate Change, Govt. of India for funding this project. I acknowledge the Department of Environment and Forests, Andaman and Nicobar Islands for initiating such an important conservation program with SACON and also for providing funds. I thank the Chief Wildlife Wardens for their support during the period of this research. *Mr N S Negi* (PCCF), *Mr D V Negi* (PCCF), *Dr Shashikumar* (CWLW) & *Mr Ajai Saxena* (Add. PCCF), *Mr Ravi Chandran* (CCF), *Mr Shaji Abraham* (ACF, WL) have taken special interest in the progress of this study. It was a pleasure to work in the Andaman Islands and I would not have had this feeling of freedom to work without the active participation of the Wildlife Division, Mayabunder & Forest Division, Baratang especially *Mr Ashok Kumar Paul, Mr C R Malik, Mr S K Thomas and Mr Sajan Paul* who held the chair of the DFO during the work. Their support, interest & encouragement were my mainstays during the tribulation of fieldwork.

The Swiftlet Protection Team at Interview Island, Chalis-ek and Baratang (*Late Saw Alexander, Anil Dumdum, Justin Barwa, Senthil Kumar, Kuldeep, Mangal, Saw Loren, Tercius Barla, Jerom Khujur, Ingnecius Khujur, Parimal Roy, Gabril Khujur, Chittaranjan Biswas, Shivpado Bairagi, Sunil Ninj, Mansit Barwa, Paresh Das, Domnik Lakra, Duijit Khujur, Santosh Barla, Simon Khujur, James Kindo, Rajender Lakra, Noel Surin, Thomus Kindo, Sukra Barla, Prabhusahay Ashisan, Nicodimus Kindo, Vinod Baa, Pawal Kullu, Dilbar Surin, Martin Guria, Rakesh Surin, Fabianus Digga, Ranjan Uraon, Baiju Uraon, Sumit Kullu*) deserve much more than an acknowledgement. Without their true dedication to the conservation of the AENS, this work would not have been possible. All my exposure to the cave exploration without any modern equipment in such inaccessible areas was due to these protectors. I thank all the protectors for their wholehearted involvement & participation in the conservation of the AENS and also for assisting, training & sometimes troubling me in the field. Receiving such dedicated protection & research assistance from a group of ex-poachers with little education is part of luck. I hope that the hard work they have put in for the past so many year's yields them good returns in future. They are a splendid team.

I thank *Dr K Thiyagesan* (Rtd. Professor, AVC College, Mayiladuthurai) for his logical inputs & excellent guidance in applying statistical tools to the ecological datasets, which reinvigorated this thesis. I would also like to thank *Mrs Thiyagesan* for delicious homemade food & her kind nature.

I thankfully acknowledge *Dr P A Azeez* (former Director, Senior Principal Scientist (I), SACON) for his boundless encouragement at every stage of the project, his logical insights, moral support & illimitable backing at every stage of the study. I sincerely thank *Dr Ram Pratap Singh* (Scientist) *& Dr. Goldin Quadros* (Senior Scientist), SACON, *Dr Percy Erach Avari* (Assistant professor, BVC, Mumbai), *Dr Girish Jathar* (Senior Scientist, BNHS), *the Earl of Cranbrook* (the pioneer of swiftlet research, Saxmundham, England) and *Aasha Dinkarrao Mudrale* (my aunt, Associate professor, Willingdon college, Sangli) for reading through the manuscripts from thesis draft and giving valuable suggestions and comments.

I am thankful to Director, Sálim Ali Centre for Ornithology and Natural History (SACON), Coimbatore for the institutional support. I thank SACON staff from Library, Finance & Administration for their logistic support. I also thank Doctoral Committee (*Dr P R Arun* (Principal Scientist) and *Dr P Balasubramanian* (Senior Principal Scientist), at SACON and

Dr S Jayraj (Dept. Zoology, Kongunadu Arts & Sci. Collage, Coimbatore)) for critically analysing my work and giving positive encouragement during all committee meeting.

I extend my heartfelt gratitude to *Dr Shirish & Harshada Pethe* (Coimbatore), *R Rajalakshmi & P Selvakumar* (Coimbatore), *Eunicy & Nelson-II* (Kadamtala), *Senti Kullu & Rajender Lakra* (Wrafter's creek), *Sandhya & Parimal Roy* (Pattilevel), *Paval Kullu* (Nayadhera), *Neelmani Kiro & AnandPrakash Tuti* (neighbor at Mayabandar), *Jasenta & Thomas Kindo* (Katta-khari), *Vinod Baa* and family (Wrafter's creek) for being my local guardian, supporting me in every way and making me feel part of their family, for all their support and love, for innumerable delicious home-cooked meals and for making me a part of their joys and sorrows. Their lovely house was a home-away-from-home for me. I thank all Ranchi-Bengali families of Naya Dhera, Rafter's Creek at Baratang and Patti-level for their help, love and support.

I especially thank *Nelson II* (CO, WL Camp, Kadamtala) for giving his kind, cheerful support at Pattilevel and Baratang. I remember the days when we caught the *edible-nest* thief who was about to enter the cave at Pattilevel, in 2012. Because of no proof, the person got free with an only warning. However, no such incidence has happened till date, is indeed an achievement. He helped us in making strong, lively protection work and the team at Pattilevel and Baratang.

I also thank *Saundra Pandiyan* (RO, Kalara range)*; Fransis Zaviar Runda* (Forester), *Cain* & *John Chrisostom* (FG, Interview Is.)*; Dhanraj Tirkey* (Forester, Nilambur Range) & *Ishakh Ali* (FG, Baratang); *Peter Bara* (Forester) & *Gangadhar Singh* (ASK), Mayabandar; and all the field and office staff of Wildlife Division, Mayabunder and Forest Division, Baratang for their support.

I would like to thank and mention courageous *Late Saw Alexander*, he was not only a boatman but also a key person at Andamans, without whom a single boat trip to Interview Island was not possible and agreeable. Notwithstanding few disagreements, the time he has devoted for the swiftlet conservation progranne is certainly worth mentioning. I also thank *Ravi Bonik*, *Krishna Mazi, Sanica Gudhiya & Sandeep Tete,* (boatman) and *Vallabh Rao* (Sai Ram PhotoStudio) for timely help in transportation throughout Islands. I also thank Anuj Trivedi (MSc student FRI, Dehradoon) who helped me in collecting data for predators at Baratang Island during his MSc dissertation. I also thank all my friend fellow researchers (especially: *Arijit, C Ramesh, Ganesh, Jins, Joydeep, Lalal, Manikanthan, Nishadh, P Nehru, Prakash, Prathamesh, Zaibin, Zeeshan, Punyamurthi*) at SACON for helping me in different ways. I thank *Shirish, Ashwin HP, Anuj* for providing beautiful pictures for this document.

Thank you does not seem sufficient but it is said with appreciation and respects for the support, affection and friendship to only my best friend Prashant Anand Khot (Environmental Officer, Godrej, Mumbai) whose enthusiasm, love and support have helped me a lot especially during my hard time with subjective management. I am much indebted to my friends, *Dr Varad B Giri & Dr Percy Erach Avari* (for being always there for help), *Avadhoot D Velankar* (teaching me many things).

Moreover, most of all, I would especially like to share this moment of happiness with my loving, supportive, encouraging, family (*mom, dad, sister and niece*) where the most basic source of my life energy resides. The support of my parents and sister has been unconditional all these years, without their encouragement, prayers and understanding, I would not have made it this far, I love them so much. My sister has been my best friend all my life, and I love her dearly and thank her for all her advice and support. I know I always have my family to count on when times are rough. I owe every thing in my life to them and seek their blessings for all my future endeavours.

I received guidance, affection and support from my aunts, friends, a significant number of people, some of whom I have mentioned and many others who have inadvertently slipped out of this admiration. Please accept my sincere gratitude.

- *Akshaya Mohan Mane*

Summary

In colonial birds, roosting timings and period of roost depend on the biology of the colony, external cues, and the environmental conditions. Among Apodidae, roosting patterns of the Chimney Swift *Chetura pelagica* are relatively well explored. However, studies examining the effects of biological or environmental factors on the roosting patterns are lacking.

The Andaman Edible-nest Swiftlet (AENS) *Aerodramus fuciphagus inexpectatus* is endemic to the Andaman and Nicobar (A & N) Islands. The species is known for their inimitable nest (exclusively made up of saliva) of high value, believed to have medicinal properties. Most studies focused on the species, were related to its echolocating ability, breeding biology, foraging ecology, nest material and nest trading. Until now, two studies by Medway (1961) and Ramji *et al.* (2012) explored the study of the roosting ecology of the AENS in caves and the farmed population in Sarawak respectively. However, neither of these studies examined the roosting habitat and effect of biotic and abiotic factors on the roosting patterns and behaviour of the species. As a step in furthering the existing knowledge about this fascinating species, the present study attempts to address certain questions relating to the roosting ecology of the cave dwelling populations of AENS in the Andaman Islands.

The aim of this study was to understand more about the species habits and habitats towards strengthening the ongoing *in-situ* and *ex-situ* conservation of the AENS. This study was initiated and conducted to 1) understand the roosting patterns and behaviour of the AENS, 2) identify the biological factors affecting roosting patterns of the AENS and 3) determine the environmental factors influencing roosting patterns of the AENS.

A&N Islands, in the northeastern Indian Ocean, are the peaks of a submerged continuous mountain ridge arching from Arakan Yoma in the north to Sumatra in the south, between latitude 6°45’ and 13°41’N and longitudes 92°12’ and 93°57’E. The caves in the A&N Is fall into two broad categories; (a) those formed by underground drainage and erosion in limestone formations and (b) those formed in sea cliffs by marine erosion of rocks. Seventy percent caves (n = 204) on Interview Island (12° 51' 54'' N, 92° 40' 12'' E), Chalis-ek, North Andaman Island (13° 2' 55'' N, 92° 59' 13'' E) and Baratang Island (12° 5' 20'' N, 92° 44' 48'' E) of North and Middle Andaman Districts were surveyed for the study.

Data were collected during 2012 - 2015. Round the clock (24h) Roost Counts were made repetitively at different caves at all study sites to know the roosting population and roosting movements/patterns of the AENS. Focal animal sampling was done to understand the time-activity budget during the roosting period. To understand the breeding biology of AENS, the nests in various caves at three sites were marked for daily monitoring. Breeding and non-breeding populations were estimated by nest and roost count methods. The potential predators and their abundance inside and outside the caves were recorded through Visual Encounter Survey and Point Count Method. The roost-site characters (Rock Surface Texture, Slope at the Roost-site, Inclination of the Wall, Presence of Wall Support, Distance to Nearest Nest, Adjacent Light and Distance to Cave Opening) at active, inactive roost sites and random sites on the cave walls and ceilings were collected. Simultaneously, other information related to the micro and macro roosting habitat (Temperature, Humidity, Light intensity and Wind Speed inside and outside the cave along with the Cloud Cover, Lunar Phase, Day length, Sunset time, Sunrise time, Cave Openings, Cave Dimensions, Cave Opening Direction, Cave Types and Cave Sizes) were collected. Finally, an attempt was made to discuss the effects of the biological and environmental factors on the roosting patterns of the species.

The study revealed that more than 98% AENS individuals arrive for roosting between 17:00-20:00 h (Peak Roosting Hours; PRH) and all of them leave the roost between 05:00-08:00 h. AENS depicted spatio-temporal variations in the arrival roosting movements and the average roosting period between caves, sites, hours and months ($p<0.001$). The roosting activities of the AENS were divided into 11 states and eight events. The nest construction was observed only during night hours while roosting. AENS were observed constructing the nest between 17:00h to 02:00h and rarely during pre-emergence after 03:00h till 5:00h; therefore the resting period is less during nest construction stage. The active period and the activities varied significantly between the hours of the day and the breeding stages (active period $p<0.001$; activities $p<0.001$). With this approach, the conclusion is drawn that the AENS does follow a certain pattern in the roosting movements and depicts significant spatio-temporal variations in the existing patterns.

AENS colonies in the study caves had various proportions of breeding and non-breeding populations. The big colonies with non-breeding population showed variation in daily movements at the time of roosting ($p<0.01$). The breeding seasonality and chronology of the

AENS were similar at all three study sites; but, the population at West coast, Interview Island found delaying breeding by two weeks than East coast population at Baratang Island and Chalis-ek. The AENS colony size affected the average roosting period, hatching, fledging and breeding success of the colony ($p<0.001$). The breeding stages showed significant ($p<0.05$) influence on the roosting movements of birds in the Andaman Islands. From this study, the conclusion can be drawn that the breeding chronology does influence the arrival time of roosting birds and the night roosting period of the AENS in the Andaman Islands.

All the study sites have caves with various physical characters. It was found that the big caves with multiple wide openings regulate presence and population of the AENS in caves. The total height of roost, rough Surface Texture, inwardly inclined Wall and presence of Roost/Nest Support (74.70%, E=0.63) were found a significant effect ($p<0.05$) on the selection of roosting sites. Roost site combination of slope $<45^{\circ}$ at the height of 200-400 cm, with or without support on the inwardly inclined wall (E=0.29, 75.30%) of rough and slightly rough surface texture were preferred (rough: E=0.97 & slightly rough: E=0.93) by birds suggesting important role in successful nesting and breeding success. Environmental humidity showed slight correlation ($R^2=0.049$) with average roost time spent by AENS. Unlike most diurnal foraging birds including many non-echolocating swifts and swiftlets, more than 92.68 ± 9.03 SD percentage of individuals of the AENS returned to their roosting caves after sunset. The variation ($p<0.001$) was seen in different day length and after sunrise and before sunset movements possibly due to different breeding duties. The fewer birds returned to roost during 17:00-20:00 h on full moon nights than new moon nights ($Z=10.063$, $p<0.0001$). Amongst all the environmental variables, environmental humidity and lunar phase affected the average roosting period of the AENS. With these findings, it is concluded that the environmental factors affect the roosting patterns and night roosting period of the AENS in the Andaman Islands.

An attempt was also made to explore the combined effect of the biological and environmental factors on the roosting patterns of the species, which suggests the lunar phase and breeding chronology to be the key factors influencing roosting decisions by the AENS in the Andaman Islands.

Echolocating ability makes the cave dwelling AENS, a unique species among Aves. Exploring its ecological dynamics makes every study essential for providing additional information. This study was first of its kind to the lunarphilic nature of any member of the Apodidae family. The study was designed to explore the roosting patterns of the AENS and the factors affecting the roosting population and patterns. Since the study was conducted as a part of the ongoing *in-situ* and *ex-situ* conservation of the AENS in the islands, the outcomes of the study were expected to improve the present knowledgebase about the species for improving the management strategies. Counts of absolute numbers will be most useful if combined with other estimates of population health. Observations of >98% birds arriving for roosting during 17:00-20:00 h with the spatio-temporal variations and the factors causing those variations, provides an alternative non-invasive method for estimating the approximate population inside the caves in different circumstances, without entering the cave. It will help in providing insights for proper management of the fragile subterranean ecosystems. The most active time of the AENS while roosting indicates the time to be avoided for entering the caves during night hours. One of the significant findings of absence of non-breeding populations in some colonies directed us to review the populations of the AENS estimated in the region. Moreover, the role of cave characters playing a vital role in the presence of the AENS inside explained to us the non-existence of the AENS populations in some caves. The study findings will help in prioritising *in-situ* conservation sites and designing of *ex-situ* houses of AENS. The study conducted will enhance and strengthen the ongoing *in-situ* and *ex-situ* conservation of the cave dwelling Aves, especially swiftlets in India.

Chapter 1: Introduction

1.1. BACKGROUND

Aggregations of roosting individuals are widespread in mammals, birds and insects (Eiserer 1984, Pearson & Anderson 1985, Lewis 1995, Wilkinson 1995, Anderson 1998, Finkbeiner 2012). Avian communal roosting is thought to exchange benefits in various terms and knowledge of the ecological associates, which could help solve issues about the origin and conservation of the trait in birds. Roosting in fearfulness relative to other times of day influence the potential survival values of communal roosting include thermoregulation (Du Plessis & William 1994), protection from predation (Rolland *et al.* 1998), information centre for feeding grounds, population regulation and arrangements for migration (Ward & Zahavi 1973, Beauchamp 1999). The information centre hypothesis (Ward & Zahavi 1973) is applicable when food is unpredictable in space and time, such as with the insect prey of Andaman Edible-nest Swiftlet (AENS). All these factors probably have numerous advantages of communal roosts. Future research attempts might lucratively focus on impacts of roosts on survival success of the species, ecology and on the use of bird roosts as tools to study distinct facts in ornithological research (Eiserer 1984). Roosting movements and behaviour in colonial birds is governed by illumination level but various other factors like breeding biology, day length, temperature, wind flow, a distance of foraging grounds, and so forth also plays a major role in evolved roosting strategies in different species (Ward & Zahavi 1973, Eiserer 1984, Beauchamp 1999). The large accessible congregations and easy species identification techniques using the morphological characters may have resulted in more communal/colonial roosting studies in different species (Galef & Laland 2005, Bijleveld *et al.* 2010). Beauchamp (1999) reviewed the gregarious birds for the roosting habits including around 85% of 432 gregarious bird species from 42 families. In birds and other animals, the adaptive value of communal roosting is not clearly understood (Beauchamp 1999). Communal roosting appears to be an ancestral state that has persisted in several families and also emerged more recently in families with no genetic tendencies like Raptors (Beauchamp 1999). It appears that the association with body mass trait often weakens once communal roosting has evolved, such as swallows (Hirundinidae), swifts (Apodidae), and shorebirds (Charadriiformes; Beauchamp 1999).

The cave dwelling Apodides are the colonial birds, studied scarcely for their roosting ecology. The present study is an attempt to explore the roosting pattern of the species of an Edible-nest Swiftlet known from the caves of the A & N Islands.

1.2. SYSTEMATICS OF SWIFTLETS

The swiftlets belong to the order Caprimulgiformes, superorder Apodimorphae, family Apodiformes, the most difficult of all groups of birds have been controversial and predominantly uncertain phylogeny and taxonomy, (Peters 1940, Sibley & Ahlquist 1999). The DNA-DNA hybridization analysis (Sibley & Ahlquist 1999) broadly considered the owls (Strigiformes), the nightjars (Caprimulgiforms), the swifts and the hummingbirds (Apodeformes) to form a monophyletic congregation. The family Apodidae (swifts & swiftlets) and Hemiprocnidae (tree swifts) have normally been grouped along with their most closely allied Trochilidae (hummingbirds; Chantler & Driessens 1995). Swifts and swiftlets belong to 19 genera, 275 taxa and 96 species including five threatened species (Chantler & Driessens 1995, Chantler 2017). Apodidae consists two sub-families: Cypseloidinae and Apodinae and three tribes: Collocaliini (with four genera), Chaeturini (containing the seven genera) and Apodini (with six genera) (Figure 1). All except the needletails (*Hirundapus*) from these three tribes use saliva in nest-building (Chantler 2017). Brooke (1970) split *Collocalia* into three different genera: *Collocalia* (non-echolocating swiftlets), *Hydrochous* (non-echolocating giant swiftlets) and *Aerodramus* (echolocating swiftlets), which is well supported by recent phylogenetic studies within the *Collocaliini* (Chantler 2017). However, subsequent studies proposed that these three genera should either be combined into a single genus, *Collocalia*, (Salmonsen 1983, Chantler

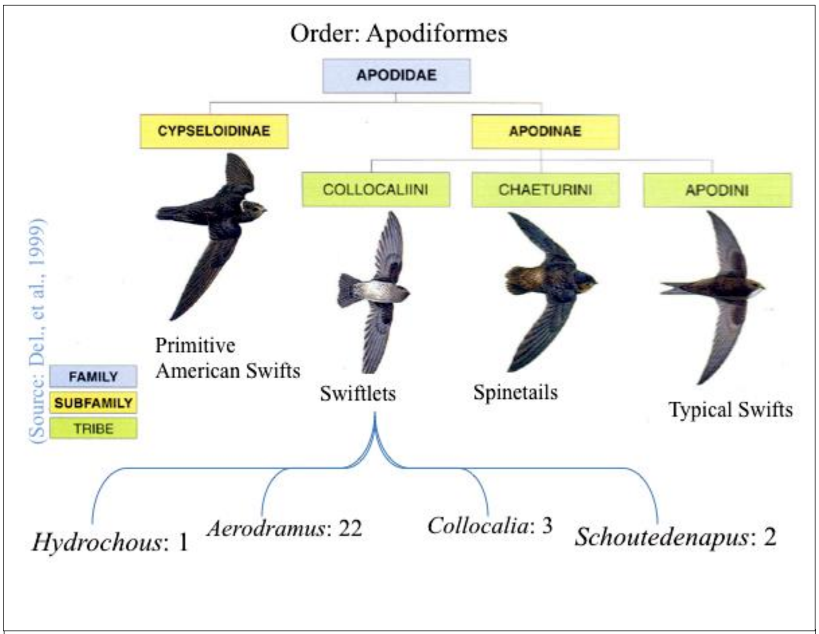

Figure 1: Systematics of Swiftlets

& Driessens 1995) or incorporate new sister groups, Chaeturini and Apodini to the pre-existing genus based on various morphological and behavioural characteristics (Sibley & Ahlquist 1990). The present document follows the classification by Brooke (1970) in Chantler & Boesman (2017) and refers the echolocating, swiftlets under genus *Aerodramus*. The very recent study by Cranbrook *et al.* 2013 suggested that, the variation in size and plumage coloration and the possibility of spontaneous immigration from wild to house-farm population and or hybridization in house-farms of White-nest swiftlets. The taxonomy of this group has proved challenging as of limited size and plumage coloration which needs to be resolved with modern techniques.

1.3. DISTRIBUTION OF SWIFTLETS

Swiftlets are found in the oriental region from the western Indian Ocean to southern continental Asia, Indonesia, northern Australia and New Guinea to islands of the west and south Pacific (Figure 2). The range extends from the Himalayas and Szechwan in China to North up to Mauritius in the Indian Ocean and Queensland, Australia to the south. The eastern range extends to New Caledonia in the southwestern Pacific region (Lim & Cranbrook 2002).

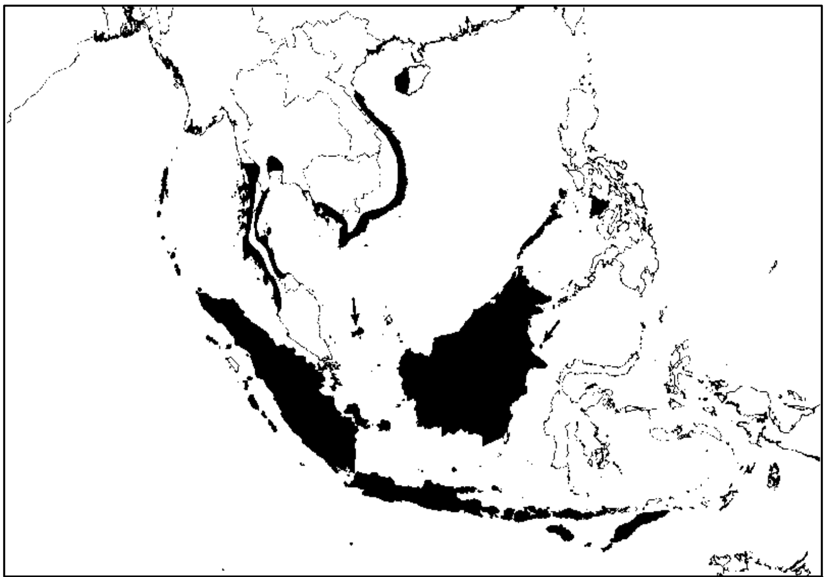

Figure 2: Distribution of Edible-nest Swiftlet *Aerodramus sp.* (source: Chantler, P. & Boesman, P. (2017)

India has four swiftlet species: (a) Indian Swiftlet *Aerodramus unicolor*, distributed in the Western Ghats, makes a black nest using saliva and own feathers (Mahabal *et al.* 2007). This species is endemic to the Western Ghats in India and Sri Lanka; (b) Himalayan Swiftlet *Aerodramus brevirostris* from North-eastern region of India, might be a migrant to the Northern parts of A & N Islands (Osmaston 1906, Ali & Ripley 1970, Sankaran 1998). Himalayan Swiftlet uses less saliva to bind mostly plant material to make the nest; Further, (c) Glossy Swiftlet *Collocalia esculenta*, is widespread in the A & N Islands uses moss, twigs, leaves, flowers to construct the nest using saliva as the binding material and to attach the nest to the rock surface; (d) Economically most important species is the Edible-nest Swiftlet *Aerodramus fuciphagus,* which makes nest exclusively using saliva, and in India it is found only in the A & N Islands (Sankaran 1998, 2001), an endemic *Aerodramus fuciphagus inexpectatus* (Chantler & Boesman 2017).

1.4. EDIBLE-NEST SWIFTLETS

The intriguing biological trait of making its nests' with saliva is threatening the survival of the Edible-nest Swiftlet *Aerodramus fuciphagus* since Tang (907 AD) and Sung (960–1279 AD) dynasties when it has been considered a precious food in China (Lau & Melville 1994, Lim & Cranbrook 2002). By the early 18th century, due to its rising demand in Chinese cuisine and pharmacy, edible-nest production and trafficking became one of the biggest trades. Today, edible nest is ranked as the world's most expensive natural products resulting in its extensive exploitation and sharp decline in populations of Edible-nest Swiftlets across their range, some as much as 80% - 90% and led to local extinction in some cases (Medway 1963, Sankaran 1998, 2001, Lim & Cranbrook 2002, Nguyen *et al.* 2002, Hobbs 2004). According to Nguyen *et al.* (2002), the population of the Edible-nest Swiftlets is not declining in Indonesia, where the species is cultured in houses, and in Vietnam where the wise management policies for nest collection are under strict governmental control. All the commercially valuable, edible nest producing swiftlet species are in the least concern category of IUCN Red list, may be because of their huge populations in swiftlet farms and the enormous scale of the economic turnover of the legal trafficking in South-east Asia. The regions in South-east Asia currently involved in commercial trading of the edible nests are: A & N Islands in India, Hainan Island in China, Palawan Island in the Philippines, the coasts and islands of Vietnam, Cambodia, Thailand, Myanmar, Malaysia and Singapore, and the Indonesian archipelago including Sumatra, Java, the Lesser Sunda Islands, and Borneo regions (Lim & Cranbrook 2002, Nguyen *et al*. 2002). The Edible-nest Swiftlet *Aerodramus fuciphagus* has eight recognised subspecies. Sexes are alike in the group. These gregarious birds are known to breed in big colonies, as significant as thousands of breeding pairs in a single colony and are known for nest site fidelity (Lau & Melville 1994, Lim & Cranbrook 2002, Nguyen *et al.* 2002). The Edible-nest Swiftlet species that exclusively use saliva for nest building are also known as White-nest Swiftlet. This glue (saliva) is composed largely of glycoproteins that, according to the Chinese pharmacy, hold remarkable medicinal properties.

1.5. EDIBLE-NEST SWIFTLET IN ANDAMAN AND NICOBAR ISLANDS

Figure 3: Andaman Edible-nest Swiftlet

The AENS are common in Andamans, roost and nest in caves or cavern-like places, where they cling to the surface of walls and ceilings or on self-supporting bracket-shaped nests (Ford & Cullingford 1976, Langham 1980, Lim & Cranbrook 2002, Manchi 2009). The general body of Edible-nest Swiftlet *A. f. inexpectatus* (Figure 3) measures 115–125mm; the tail is 49-53mm 13–18gm medium size bird, black brown under part and slightly grey rump with tail-fork 10–19% of the tail length (Chantler 2017). A little population is found breeding in few human-made buildings as well (Manchi & Mane 2012). *A. fuciphagus* occurs over a range of habitats, cleared and forested, coastal and interior, from sea-level to highlands. These birds are seen hovering over forest, mangroves and cultivation (Ali & Ripley 1970, Manchi & Sankaran 2010), possibly for food, i.e. aerial insects. Calls are less documented. The most distinctive calls are metallic 'zwing', a dry "chi-chit" and rapid clicking series of echolocating sound audible at breeding sites, which they use to navigate in the dark (Chantler & Driessens 1995, Manchi 2009, Manchi & Mane 2012). Edible-nest Swiftlet mainly breeds during March-April (Chantler & Driessens 2000). In Andaman, *A. f. inexpectatus* breeds from December through August (Manchi 2009).

1.6. CONSERVATION OF THE ANDAMAN EDIBLE-NEST SWIFTLET

The nest collection started in the A & N Islands during late 17th or early 18th century by Burmese and Thai poachers. The knowledge then came to the local settler communities like Karen, Bengali and Ranchis' (Sankaran 1998). The populations of the *A. f. inexpectatus* were identified to be under threat with more than 80% of population declining in a decade in the A & N Islands. Recently, the species has been described as *Aerodramus inexpectatus* and believed to be endemic to the A & N Islands (Cranbrook *et al.* 2013).

Given the alarming situation, researchers from Sàlim Ali Centre for Ornithology & Natural History (SACON) and managers from Andaman Forest Department (AFD) during 1999 collaborated towards formulation and implementation of *in- situ* and *ex-situ* management strategies to conserve this species. Simultaneously, with the conservation efforts, breeding and foraging ecology of the species was studied to improve the basic conservation strategy (Sankaran & Manchi 2008). With the inputs from species research and transformation of the nest collectors into nest protectors, the conservation program depicted continuous significant success in population recovery of the wild Andaman Edible-nest Swiftlet. During 2002 the species was included in the Schedule-I of the Indian Wildlife (Protection) Act, 1972. With the successful population recovery through participatory conservation and required research, the species was recommended for removal from the Schedule-I of the Wildlife (Protection) Act (WPA), 1972 (Sankaran & manchi 2008).

By the successful results of the conservation program in A & N Islands, during November 2009 National Board for Wildlife, India recommended conditional delisting of *A. fuciphagus* from Schedule – I of the WPA (1972) for three years, i.e. till 2012 to develop the ex-situ population of the species for house ranching. Further research about the breeding and roosting ecology of the species contributed significantly to strengthening of the house ranching and cave protection systems. Considering the later achievements of the program and plan of livelihood generation with economic growth of people SACON and AFD recommended removal of the species from the Schedules of the WPA, 1972 (Manchi & Mane 2012). On this basis, the amendment was made on 6th December 2013 by the Minsitry of Environment, Forest and Climate Change (MoEF&CC), and the Edible-nest Swiftlet *A. fuciphagus* was removed from the schedules of the Wildlife (Protection) Act, 1972 (Gazette of India 2013).

1.7. RESEARCH HISTORY AND ROOSTING STUDIES

The sustainable nest harvesting and trade was always in focus, considering value commodities of edible-nest (Chasen 1933, Cranbrook 1984, Lau & Melville 1994, Nugroho & Whendrato 1996, Mardiastuti 1996, Lim 1999). The studies on the Edible-nest Swiftlets in their natural caves were much related to breeding biology of the species for executing the sustainable harvesting strategies. Several researchers (Medway 1962a & 1962b, Langham 1980, Kang & Lee 1991, Nguyen 1992, Manchi 2009) have studied the breeding biology, breeding ecology and moulting of different swiftlets to understand the natural history and biology of the species. The economic importance of this species propelled for well documentation of populations of the Edible-nest Swiftlets across their distribution range (Medway 1962a, 1962b & 1967, Lim 1999 & 2000, Lourie & Tomkins 2000, Thomassen 2005, Manchi & Mane 2012). Usage of the edible-nest in Chinese pharmacy attracted the researchers across the globe to study the nest cement, its nutritional value and other components (Wang 1921, Marshal & Folley 1956, Howe *et al.* 1960-61, Kathan & Weeks 1969, Kong *et al.* 1987, Lim 1999). Other than bats, echolocation among swiftlets was studied to understand the movement mechanism, sensitivity and evolution (Medway 1959, Cranbrook & Medway 1965, Griffin & Suthers 1970, Fenton 1975, Medway & Pye 1977, Smyth *&* Roberts 1983, Fullard *et al.* 1993). Ecological studies on the Andaman Edible-nest Swiftlet *A. f. inexpectatus* were initiated in India with the population surveys (Sankaran 1995, 1998) to understand the impact of nest collection on AENS population in A & N Islands. Once the threat to the species was recognised, conservation efforts along with the research (breeding and foraging ecology) were initiated and implemented (Manchi 2009, Manchi & Sankaran 2009, 2010 & 2014). Simultaneously, strategies for sustainable nest harvesting were also established in the Andaman Islands (Sankaran & Manchi 2008, Manchi & Mane 2012, Manchi & Sankaran 2014).

Roosting studies in Apodidae were not much addressed due to limitations of the huge colony size of the species in inaccessible big caves. So far around 25 species of the Apodidae have been studied among which 50% were swifts and needletails known to studied briefly for the roosting habits (Baldwin & Hunter 1963, Stager 1965, Palomeque *et al.* 1980, Zammuto & Franks 1981, Fischl & Caccamise 1985, Pettigrew & Wilson 1985, Marin & Stiles 1992, Tarburton 1993b, Beauchamp 1999). Less literature is available for ecology and behaviour of birds in this group.

Of the scarce studies documented about the roosting ecology of the swiftlets, few were conducted in the wild, as studies in the swiftlet house are comparatively feasible to perform. The first natural history observations on the roosting pattern of the Black-nest swiftlet *A. maximus* and Mossy-nest Swiftlet *A. salangana* were made by Medway (1962b) on arrival and departure of the individuals in a single cave at Niah, Sarawak. Later, Sankaran and Manchi (2008) and Manchi (2009), adapted the same method to study the Edible-nest Swiftlet population in the caves of the North and Middle Andaman Islands. Recently, Ramji *et al.* (2014) studied the roosting behaviour of swiftlet by using night vision recording in houses at Sarawak where the only behaviour at nest was studied.

As a further contribution to the knowledge regarding roosting ecology, the present study was designed. This study is the first of its kind related to the roosting ecology of any swiftlet species in its natural habitat which address the roosting patterns of the Andaman Edible-nest Swiftlet (AENS) about various biotic and abiotic factors.

1.8. AIM AND OBJECTIVES

The study was designed with the aim of understanding more about the species habits and habitats towards strengthening the ongoing *in-situ* and *ex-situ* conservation of the Andaman Edible-nest Swiftlets (AENS). The study was initiated and conducted to accomplish the following major objectives:

1. To understand the roosting pattern and behaviour of the AENS,
2. To identify the biotic factors influencing roosting patterns of the AENS and
3. To determine the environmental factors influencing roosting patterns of the AENS.

1.9. ORGANISATION OF THESIS

This PhD thesis is organised into six chapters described asunder:

Chapter 1 briefly introduces the subject and the study species along with current state-of-art (research) in the field and in the area along with the aim and objectives of the study.

Chapter 2 describes the study region, i.e. the A & N Islands, it’s geography, climate and geology. Further, it briefly describes the number and location with the classification of caves in the islands, vegetation in the study area.

Chapter 3 focuses on the roosting pattern and behaviour of AENS. The detailed roosting habits are described with the spatio-temporal variations in the roosting patterns. The roosting behaviour was described using the ethograms and the time-activity budget while the species was at its roost.

Chapter 4 is focused on understanding the breeding chronology and seasonality of the AENS and the related biotic factors, viz., breeding population, colony size, breeding success and potential predators inside and outside the caves. Further, the role of biotic factors in roosting decisions is also explained in details.

Chapter 5 reports the roosting habitat inside & outside the caves along with the related environmental factors. Factors such as roost site characters (rock surfaces texture, presence of nest supports, wall inclination, height from the ground and slope of the rock), physical characters inside/of the roosting caves (cave size, cave openings, limestone type, light intensity, cave structure, temperature, humidity, wind speed, distance from light source to roosting/nesting site). This chapter also described the role of meteorological parameters outside cave (temperature, humidity, rainfall, sunrise and sunset timings, moon phase, day length) in deciding the roosting patterns / timings and population of the species in the caves of the Andaman Islands.

Chapter 6 concludes the impact of all biotic and abiotic factors on the roosting behaviour and populations of the Andaman Edible-nest Swiftlets in the Andaman Islands. Finally, the important outcomes of the research are compiled and presented a detailed action plan for furthering the further species and habitat research, and strengthening of the *in-situ* and *ex-situ* conservation strategies in the A & N Islands.

Chapter 2: Study area

2.1 THE ANDAMAN AND NICOBAR ISLANDS

The Andaman-Nicobar archipelago, believed to have originated during Late-Pliocene to Pleistocene from a single eruption, extends from the southern strip of Burma to the northeastern strip of the Java-Sumatra trench between latitudes 6°45' and 13°41'N and longitudes 92°12' and 93°57'E (Kumar 1990). The region of the Burmese arc from Arakan including the A & N Islands to Sumatra and beyond is characterised by highly seismic, seismic and aseismic zones with earthquake segments of shallow to intermediate foci in the earth crust (Kumar 1981, 1990). Ten-Degree Channel separates the A & N groups of islands. The length between the extremities is about 355km, while the maximum width is about 60km. The islands have a coastline of 1,962km (Figure 2.1) (Kumar 1981, Saldanha 1989, Sankaran 1998, Andrews & Vasumati 2002, Jayaraj & Andrews 2005, Sankaran *et al.*2005).

The islands are under the influence of both the southwest and northeast monsoons; they receive rain from April to December. The mean annual precipitation is around 3100 mm, unevenly distributed and maximum rain occurring from May to December. The average relative humidity ranges from 68 to 86%. The islands receive north-eastern winds between November and March and south-western winds between May and October. Cyclone winds and gales are usually common with a change of monsoons and sudden depressions in the sea around. The maximum daily sunshine experienced in the islands during the dry months is of 8-10 hours and in rainy season clouds restrict this to 3-8 hours. The solar radiation is intense at the peak of the day, due to fairly dust-free and clean sky. The Islands are endowed with year-round true humid, tropical coastal climate with least variation of temperature between 20°C and32°C. Temperatures during May-December are moderated by rain with maximum temperatures observed during the dry season between January-April (Saldanha 1989, Andrews & Vasumati 2002, Jayaraj & Andrews 2005).

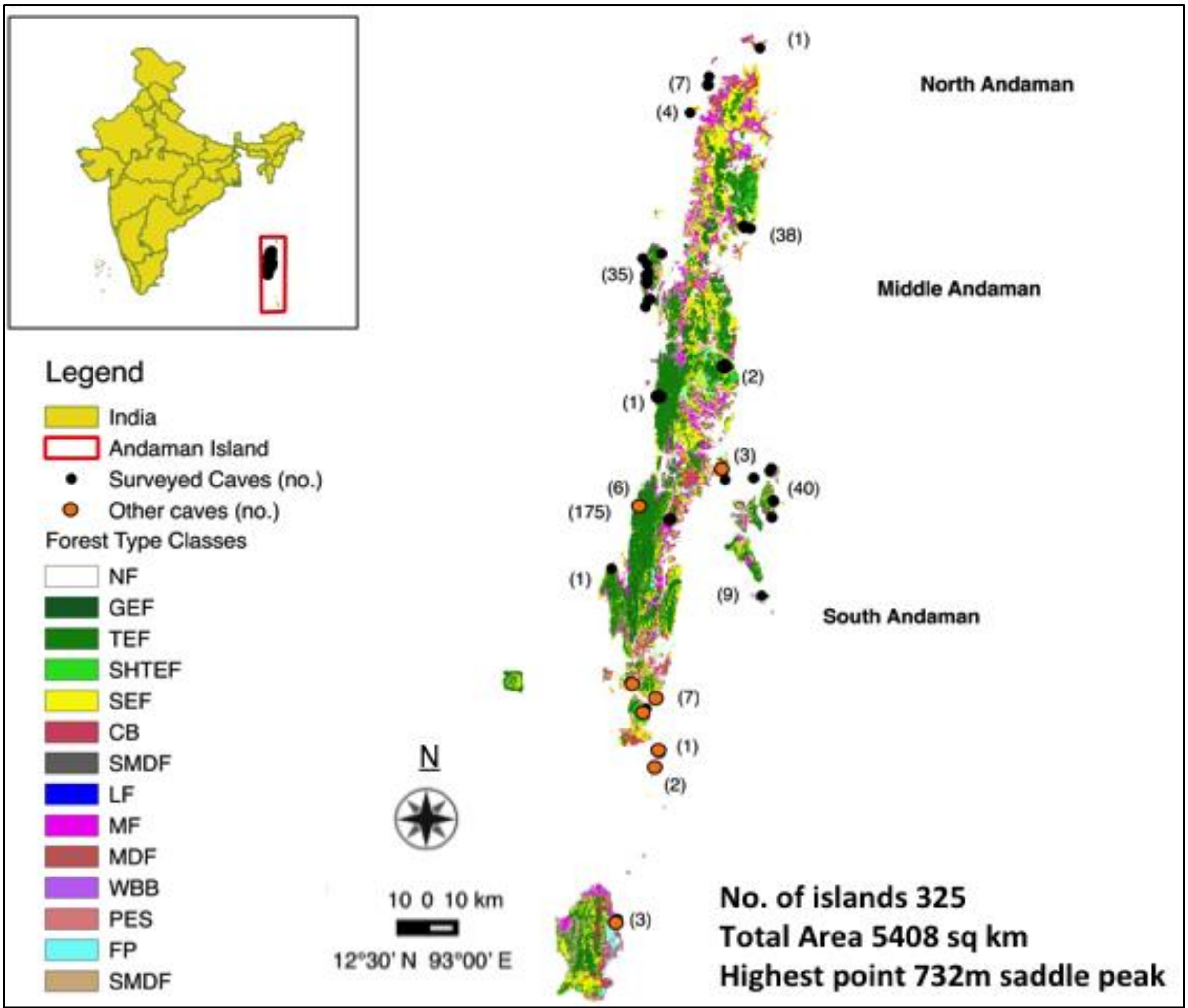

Figure 2.1: Caves of the Andaman Islands distributed in different forest habitats
NF: Non Forest, **GEF**: Giant Evergreen Forest, **TEF**: Andaman Tropical Evergreen Forest, **SHREF**: Southern Hilltop Tropical Evergreen Forest, **SEF**: Andaman Semi-Evergreen Forest, **CB**: Cane Brakes, **SMDF**: Andaman Secondary Moist Deciduous Forest, **LF**: Littoral Forest, **MF**: Mangrove Forest, **MDF**: Andaman Moist Deciduous Forest, **WBB**: Wet Bamboo Brakes, **PES**: Pioneer Euphorbiaceous Scrub, **FP**: Forest Plantation, **SMDF**: Secondary Moist Deciduous Forest

2.2. CAVES IN THE ANDAMAN & NICOBAR ISLANDS

The caves are human enterable cavities on earth (>0.6m in width; Poulson & White 1969), large enough to get the surveyor fully inside, turn around and exit without damaging the attached flora and fauna (Poulson & White 1969). All the caves enterable by human were classified as macro cavern by Howarth (1983). The classification indicates that all the AENS caves explored in the Andaman islands are the macro caverns. Sankaran (1998) located and surveyed 384 caves on 37 islands to understand the impact of nest collection on the population of AENS. Then, during 2013 surveyed additional ten caves and mapped all the

394 caves in the Andaman Islands (Mane & Manchi 2017, Figure 2.1). At the Nicobar Islands, Sankaran (1998) located and surveyed total 60 caves on nine islands. Most caves in the A & N Islands fall into two broad categories, a) those formed by underground drainage and erosion in limestone formations and b) those formed in sea cliffs by marine erosion of the rocks (Challinor1986, Sankaran 1998).

2.3. CLASSIFICATION OF CAVES

In total 314 caves were surveyed during February and March 2013. Following Allen (2008) and Pal (2005), the caves were classified based on lithology of the region: i) Mithakhari group, i.e. lentoid conglomerate and sandstone beds in dominantly shale facies (trench sediments; Chakraborty *et al.* 1999); ii) Ophiolite group, i.e. tectonic (ultramafic)-cumulate (layered mafic and ultramafic) plagiogranite diorite suite basalt pelagic sediments (fossilized oceanic crust; Gass *et al.* 1990); iii) Archipelago, i.e. a thick pile of pyroclastic deposits, limestone, sandstone and shale (Ray 1982); and iv) Flysch, i.e. a thick sedimentary pile of sandstone and shale representing classic turbidites (Karunakaran *et al.* 1964). Caves were further distinguished according to their location and approach (Sankaran 1998 & 2009a, Manchi 2015) as; A = On coast, approachable on foot; B = On coast, entrance partially submerged and access by swimming into cave; AB = On coast, approachable on foot after swimming ashore; BD = Cave above sea level on cliff face towards the sea; Ci = In the forest, at the origin of a stream; Cii = In the forest, cavern below the ground; Ciii = In the forest; D = Midway on inland cliff; and E = Japanese bunker (manmade tunnel). The length and height of the cave were measured manually using bamboos and Freeman's measuring tape. Accordingly, the caves were further classified as: Very big (>40m in length), Big (30-40m length), Medium (20-30m length), Small (10-20m length) and Very small (<10m length); cave Height: High (>10m), Medium (5-10m) and Short (1-5m). Some cave openings and their shapes (Figure 2.2) with height and width were recorded using Freeman's measuring tape. Caves were classified as dry or wet according to the presence of water inside the cave. Following

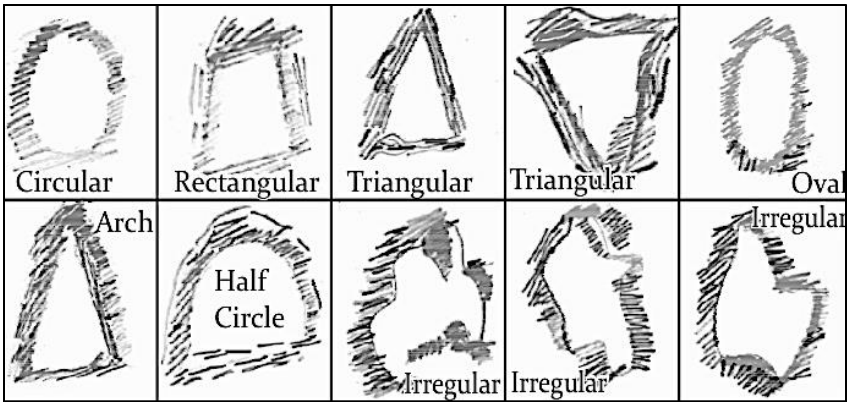

Figure 2.2: Shapes of the openings in the Andaman Islands

Howarth (1993), by presence of light and its intensity, caves were divided into different zones: light zone (LZ; light intensity >50 up to 1800lux), Dim Light Zone (DLZ; light intensity >0 to <50lux) and Dark zone (DZ; No light zone), Digital Lux-Light Meter was used to measure the light intensity. Vegetation types in the areas were classified following Champion and Seth (1968).

Table 2.1 Vegetation types surrounding the caves surveyed in the Andaman Islands

Forest type combination	**Forest type class**	**# of Caves**
Moist Deciduous	MD	1
Moist Deciduous, Secondary Moist Deciduous	MDSMD	4
Moist-Deciduous, Tropical Evergreen	MDTE	20
Moist Deciduous, Secondary Moist Deciduous, Semi-evergreen	MDSMDSE	4
Secondary Moist Deciduous	SMD	24
Secondary Moist Deciduous, Tropical Evergreen	SMDTE	9
Secondary Moist Deciduous, Semi-evergreen	SMDSE	13
Semi-evergreen	SE	11
Southern Hilltop Tropical Evergreen	SHTE	5
Southern Hilltop Tropical Evergreen, Tropical Evergreen	SHTETE	197
Southern Hilltop Tropical Evergreen, Semi-evergreen	SHTESE	35

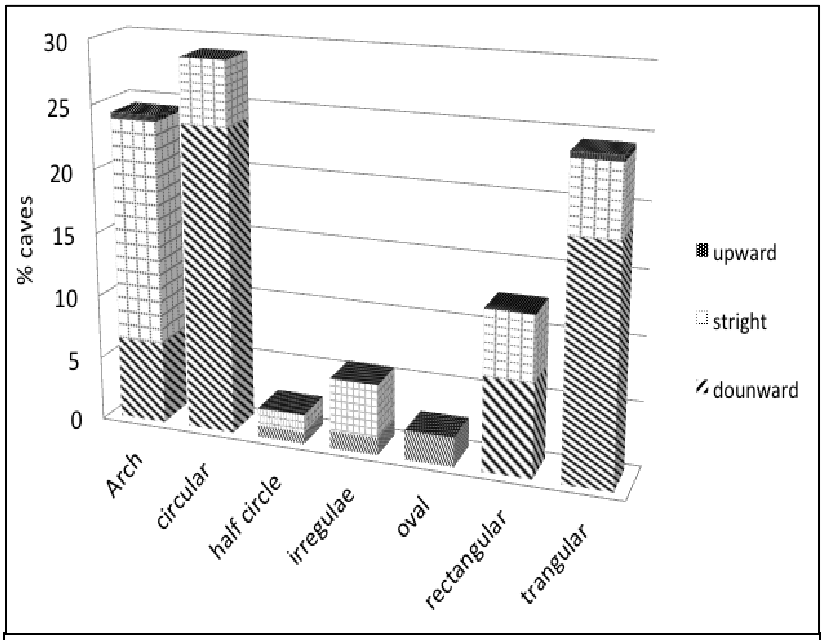

Figure 2.3: Cave structure-showing cave opening shape & length direction of different size cave at Andaman Island

Around 66% of surveyed caves had Archipelago (33%) and Flysch group (33%) of rock layers, and the rest had Ophiolite (19%) and Mithakhari (15%) types. All the surveyed caves were spread in seven different types of forests (Figure 2.1, Annexure 2.1, Table 2.1) among which >60% in Southern Hilltop Tropical Evergreen and Tropical Evergreen Forests. Around 66.45% of the caves were found located inland while the rest 30.97% were in the coastal areas. Of the total surveyed caves, 61.49% were of Cii-type (in the forest and below ground) followed by 23.58% of B-type (on the coast, entrance partially submerged and access by swimming into the cave).

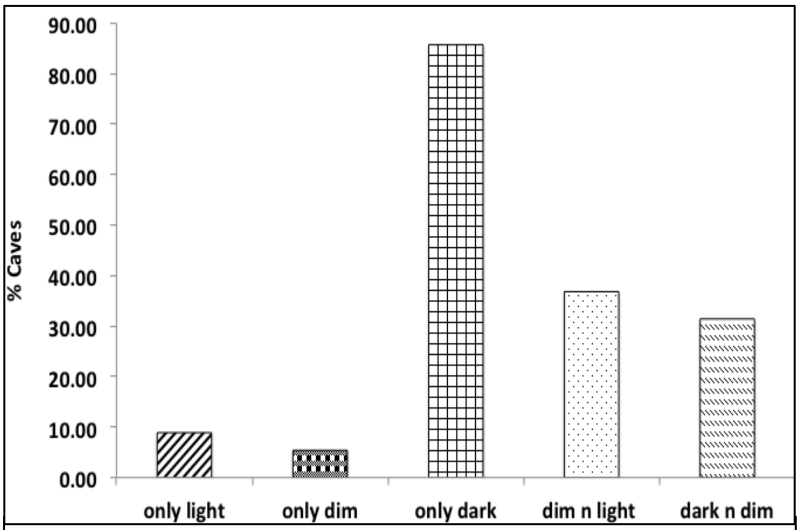

Figure 2.4: Zonation of the caves Andaman Is.by presence & intensity of light
Note: dim n light=lim zone and light zone presence in caves, dark n dim= dark and dim zone presence in caves

The size of the caves varied with the cave type (χ^2=45.77,df=8, p<0.001, N=334), forest type around the cave (χ^2=82.75,df=12, p<0.001, N=319) and the type of rock layer in the region (χ^2=116.58, df=12,p<0.001,N=335). Of the total, 28.90%, 24.31% and 24.31% caves had Circular, Arch and Triangular shape of openings respectively (Figure 2.3). Maximum caves (86.24%) had a single opening than two (10.09%) and three openings (3.67%). Immediately after the openings, 60% caves extend downward, and 38.53% caves extend in a horizontal direction, while very few (0.92%) had an upwardly extending cavern (Figure 2.3 & 2.5). More than 80% of the were dark, where as less than 10% were of an open type having dim light zones inside (Figure 2.4). Multiple regression models with all variables depicted that the formation of different sizes of caves is highly influenced by the type of rock layer existing in various regions followed by dim light zone and number of cave mouths (Table 2.2).

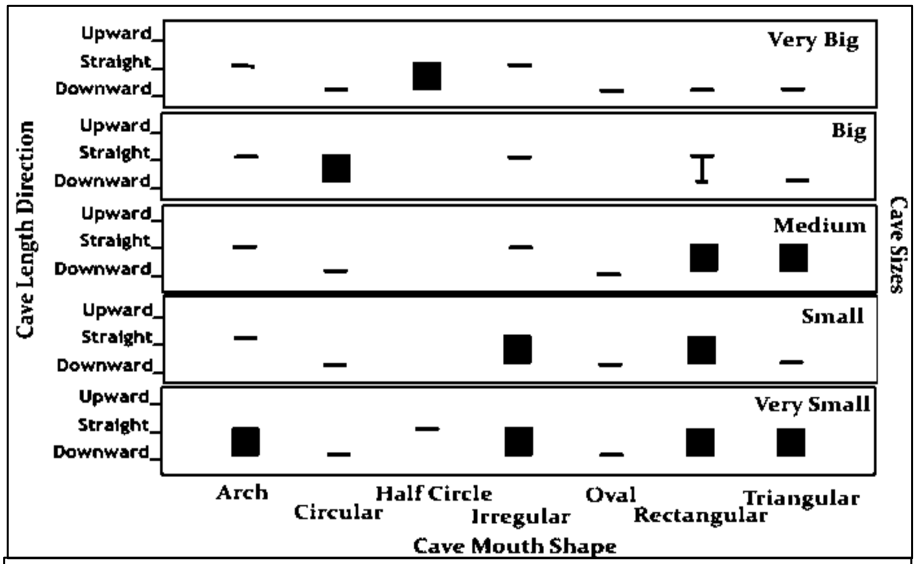

Figure 2.5: Cave site, opening shape and direction of the length inside the caves at Andaman Island

Table 2.2 Result of multiple regression analysis (Forward type) for predicting the size of the caves

Multiple regression equation: Cave size = -2.402 + 1.106 (Rock layer) - 2.387 (cave mouth (CM) 3:door shape) - 0.525 (cave mouth (CM) 9: circular shape) - 0.186 (cave mouth (CM) width in meter) + 0.429 (dim light zone) + 0.524 (number of cave mouths (CM)); Adj R^2= 0.280; F=14.774; $p< 0.001$

Model	Unstd Coeff.	Unstand. Coeff.		t	Sig.	95.0% Conf. Intr. for		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	-2.40	0.86	--	-2.78	0.01	-4.10	-0.70	--	--	--	--	--
Rock layer type	1.11	0.20	0.35	5.64	0.00	0.72	1.49	0.32	0.37	0.33	0.89	1.12
CM: door shape	-2.39	0.63	-0.23	-3.80	0.00	-3.62	-1.15	-0.24	-0.26	-0.22	0.94	1.06
CM:circular	-0.53	0.19	-0.17	-2.80	0.01	-0.90	-0.16	-0.12	-0.19	-0.16	0.94	1.06
CM width	-0.19	0.08	-0.16	-2.44	0.02	-0.34	-0.04	-0.15	-0.17	-0.14	0.84	1.19
Dim light zone	0.43	0.18	0.15	2.40	0.02	0.08	0.78	0.30	0.17	0.14	0.87	1.14
CMs' No.	0.52	0.19	0.17	2.83	0.01	0.16	0.89	0.29	0.19	0.17	0.92	1.09

2.4. HABITAT AROUND CAVES

Especially in island systems, frequent tectonic and geological processes result in tremendous variations in the substrates (volcanic rocks, limestone and former reef bed). These unique substrates favour only the least number of species to colonise and establish a peculiar vegetation community successfully. In the Andaman Islands, many Islands have limestone areas that are highly heterogeneous regarding climate, soil and biota, leading to a wide range of specific karst environments. The aim was to study the diversity, composition and density of tree vegetation on the karst land in Baratang Island. The karst land area was demarcated with the help of local swiftlet protectors (Sankaran 1998) before the entire habitat was systematically divided into grids of 100×100m size. Sampling plots of 10×10m were established in the centre of each alternate grid for the enumeration of trees (≥10cm dbh; Figure 2.6). GPS was used to search the alternate grids for the plot location. The random walk method (Greig-Smith 1983) was used to determine the compass bearing for laying out the plot. Plot measuring adjustments were made by topography and slope changes (Peters 1996). Within each quadrat, all stems (trees, lianas and palms) with ≥10cm Diameter at Breast Height (DBH) were measured using a Freemans' measuring tape at 1.3m height or above the buttress. For enumeration of saplings (>1m height but <10cm dbh) and seedlings (<1m height), four nested subplots of 3x3m and 1x1m were established at each corner of the survey plots. Voucher specimens were collected for all the species within the study plot and identified with the help of Parkinson (1923) and Hajra *et al.* (1999). Plant specimens were identified and subsequently confirmed with field taxonomists from the Botanical Survey of India (Pune and A & N Islands circles). The voucher specimens were deposited in the herbarium at Sálim Ali Centre for Ornithology and Natural History (SACON), Coimbatore. The plant names were verified at The Plant List, 2013 (http://www.theplantlist.org/).

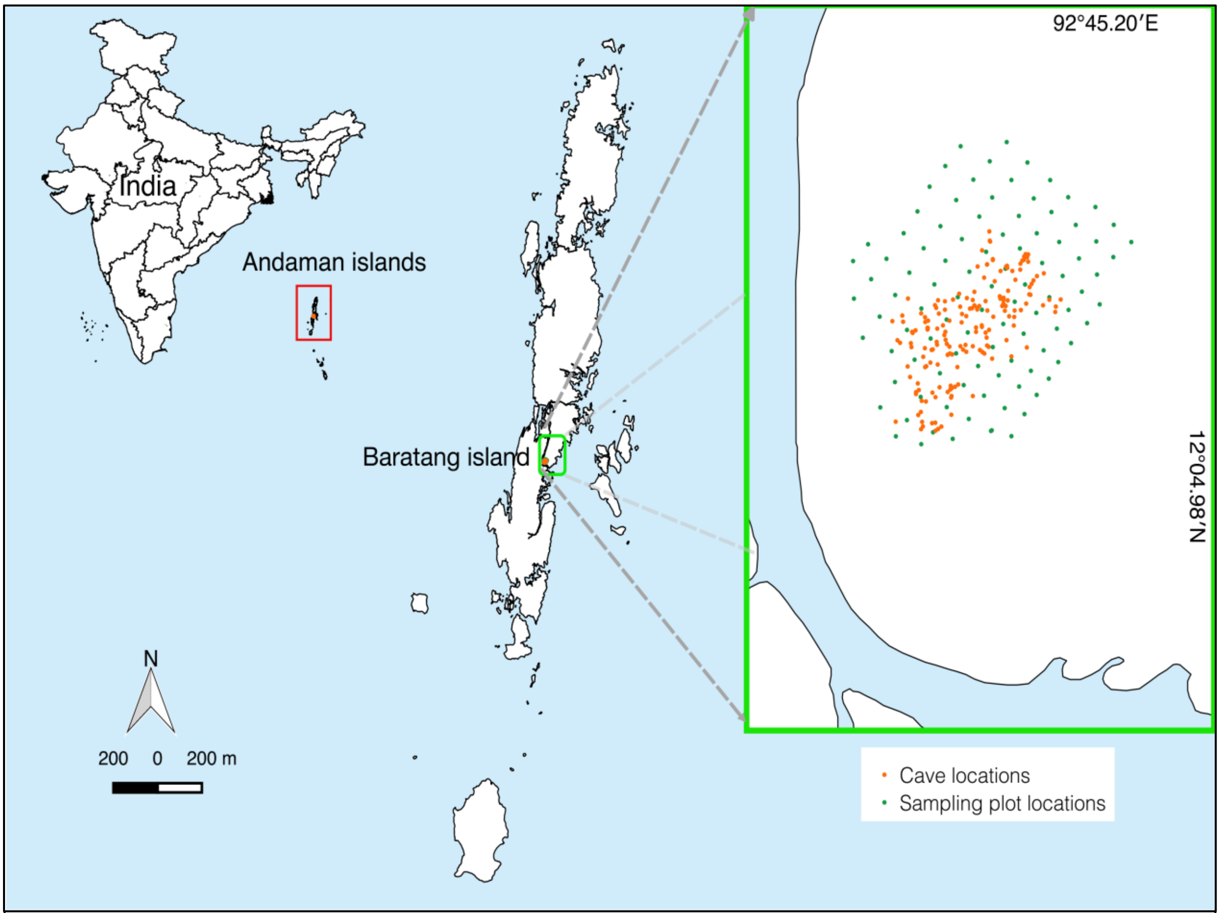

Figure 2.6: Baratang Karst land area with plot location and cave sites at Baratang Island

Table 2.3 Details of study plots and ecological variables observed for different vegetation class

S.No.	Variable	Tree	Sapling	Seedling
1	No. of plots	101	404	404
2	No. of tree individuals	641	2587	812
3	Density / ha.	635	7115	80396
4	No. of species observed	89	57	42
5	No. of species estimated (chao2)	126	67	52
6	No. of species for ‘n’ individuals (*n=640*)	89	42	40
7	No. of genera	64	44	32
8	No. of families	34	28	23
9	Basal area m^2/ ha.	94.18	-	-
10	Cumulative Shannon index	3.75	2.95	2.91
11	Simpson index (1/D)	22.45	12.29	12.46

A total of 90 species belonging to 63 genera and 34 families were recorded, of which 89 species are represented by trees. Saplings were represented by 57 species, 43 genera and 28 families; and seedlings by 42 species, 31 genera and 23 families (Table 2.3). Of the recorded species, 14 are endemic (Annexure 2.2). Anacardiaceae (8 species), Malvaceae (8 species) and Moraceae (5 species) were found to be the families with high species diversity. Meanwhile, *Syzigium* was the genus with more species (4) followed by *Aglaia*, *Diospyros*, *Sterculia* and *Terminalia* (3 each). The non-parametric estimator Chao2 suggested a 53% and 41% more species in trees as compared with saplings and seedlings (figure 2.7a, 2.7b & 2.7c). However, the rarefaction curve established for 640 individuals suggested nearly a similar number of species for sapling (n=42) and seedling (n=40; figure 2.7d), which is 53% and 55%, respectively less than the tree species.

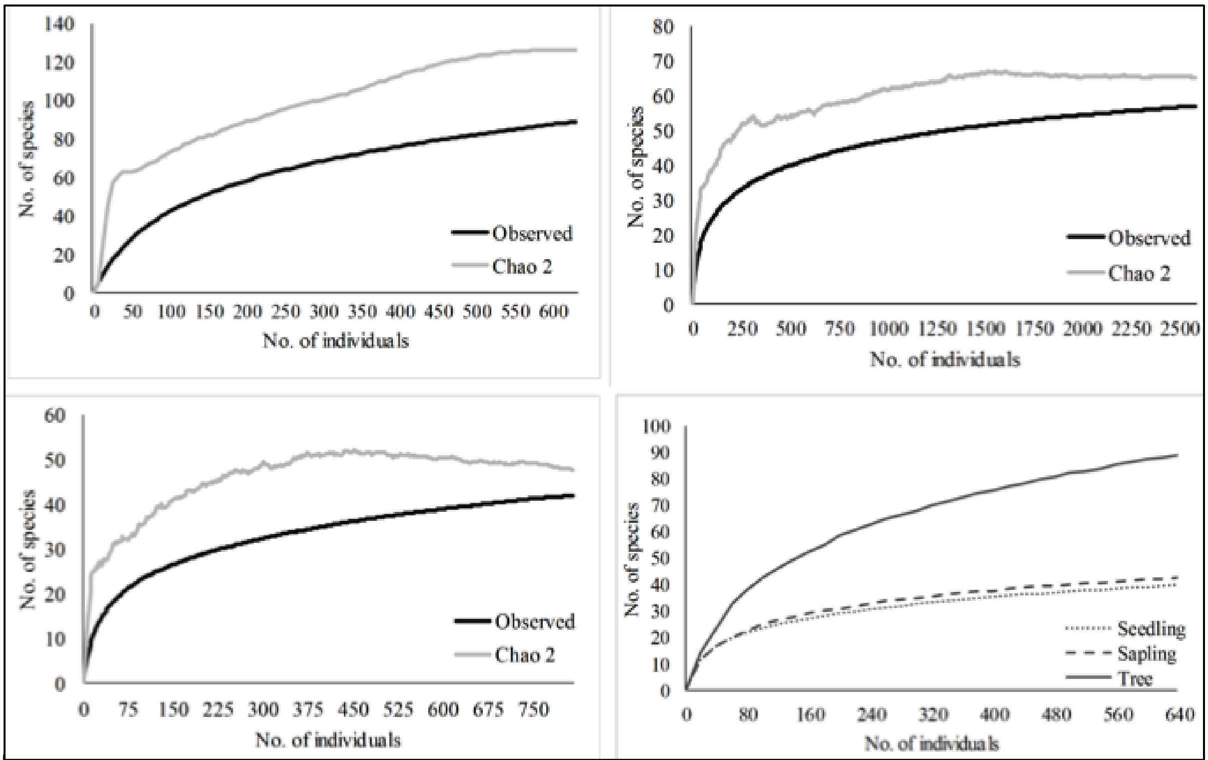

Figure 2.7: Species accumulative curve -established for trees (a), saplings (b) and seedlings (c). The rarefaction curve (d) established for the set number of individuals (*n=640*) indicating species diversity among the vegetation classes

The plot wise Shannon index values have significantly varied among the three vegetation classes (F=320.06, p<0.001). Pair wise comparisons showed a significant difference in species diversity (p<0.0001) among trees, saplings and seedlings. Both cumulative and plot wise diversity indices were high in trees followed by saplings and seedlings (Table 2.3, figure 2.8). The diversity of tree species is positively correlated with the diversity of saplings (Pearson's R=0.32) and seedlings (Pearson's R=0.30) (figure 2.8). However, the coefficient of determination derived from the linear model though showed the positive influence of tree diversity on sapling (R^2=0.081) and seedling (R^2=0.098) diversity, but the low R^2 values indicate that the strength was rather weak.

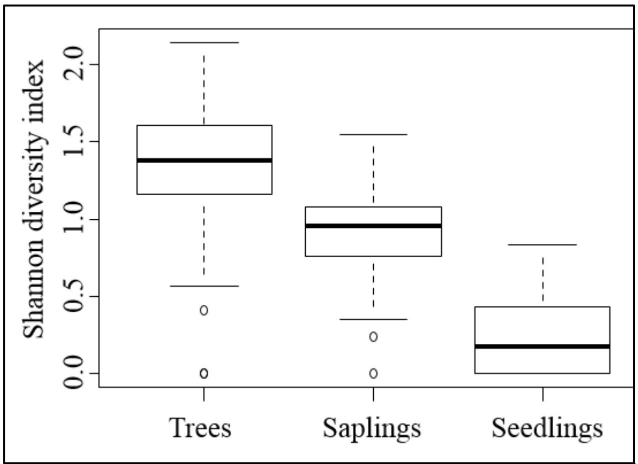

Figure 2.8: Box plot showing the difference in plot wise Shannon index value derived for trees, saplings and seedlings
Boxes represent 25–75 percentiles, lines within boxes represent the median value, & bars indicate the 90th and10th percentiles, & open circles are outliers.

Species composition between and among vegetation classes have varied significantly (A=0.031; $p<0.001$), where the maximum difference was observed for sapling Vs. seedling (Table 2.4). Among trees, 30 species were found in one plot, and 12 were found in two plots; meanwhile, 33 species were represented by one individual and 12 species were represented by two individuals. Therefore, the encounter rate of about 50% of tree species was rare. Meanwhile, 28% of saplings and 38% of seedlings were found to be uncommon in the study area. Among the 90 species recorded, 40 were located in all three vegetation categories, and 32 species were restricted to tree layer; while, 16 species were found only in trees & saplings, and one species each was found in trees & seedlings, and saplings & seedlings.

Table 2.4 Results of the Multi-response permutation procedure (MRPP) indicating the species composition dissimilarities exist among the vegetation classes

Category	**Observed δ**	**Expected δ**	**A value**	**P value**
All groups	0.855	0.882	0.031	0.001
saplingVs seedling	0.822	0.830	0.010	0.001
seedlingVs tree	0.895	0.915	0.022	0.001
saplingVs tree	0.775	0.882	0.038	0.001

The tree layer was dominated by *Celtis philippensis* (IVI=83.6) followed by *Anaxagoreal uzonensis* (IVI=42) and *Aglaia oligophylla* (IVI=30.5). The demography of tree population showed a high number of individuals in less DBH classes and a low number of individuals in higher DBH classes (Figure: 2.9a). The demography of five dominant tree species also showed a similar pattern, except for *Aglaia oligophilla* (Figure 2.9b).

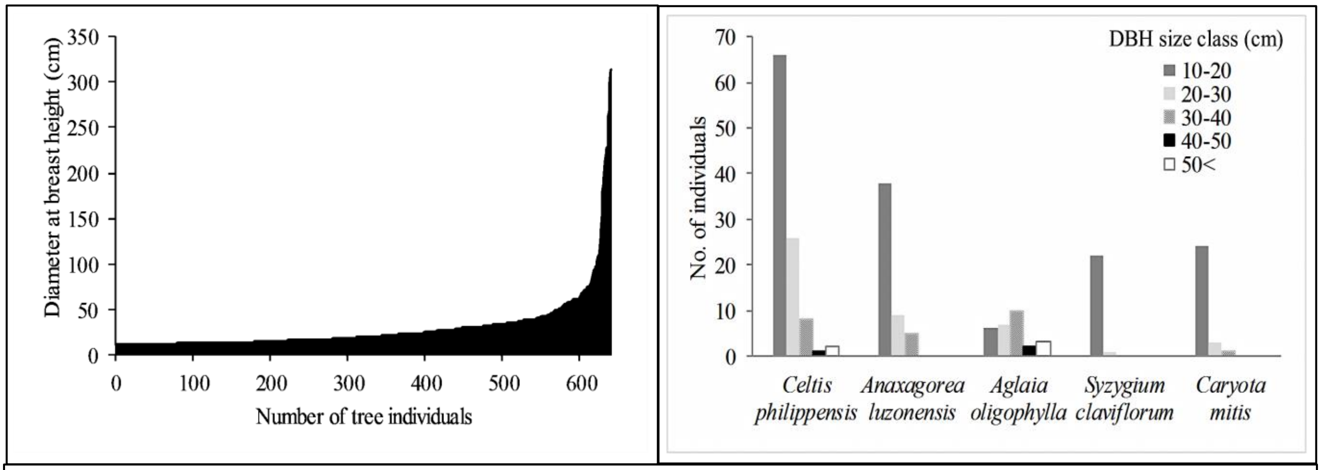

Figure 2.9: Size class distribution of tree densities in the study area; (a) population demography of the whole tree vegetation (b) size class distribution of five dominant tree species present in the study area

2.5. INTENSIVE STUDY AREAS

Roosting ecology of the AENS was studied at three different sites located on three Islands, viz. Interview Island (12° 51' 54" N, 92° 40' 12" E), Chalis-ek, North Andaman Island (13° 2' 55" N, 92° 59' 13" E) and Baratang Island (12° 5' 20" N, 92° 44' 48" E). Interview Island spreads over 133 km^2 and is located in the western part of the Middle Andaman Islands. It has the largest Wildlife Sanctuary in the A & N Islands group. The forest type on this island is characterised as Tropical Evergreen, Andaman Semi-Evergreen, Littoral and Mangrove Forest (Pande *et al.* 1991). The Island has 34 known limestone caves (Sankaran 1998, Mane & Manchi 2012); of which, the AENS occupies 30 caves. Chalis-ek, a limestone hillock bearing 32 known caves (Mane & Manchi 2012, Manchi & Sankaran 2014), falls in the Reserved Forest of Patti level village near Ramnagar in the North Andaman Island and is known for its Semi-Evergreen and Dry-Deciduous Forests. BaratangIsland situated between Wraffter’s Creek and Naya Dhera Village in Middle and South Andaman Islands the southernmost tip of Middle Andaman. This biggest cave complex in the Andaman Islands is spread within 0.77km^2 area. The area is protected as a Reserve Forest and has virgin Evergreen, Semi-evergreen and Mangrove Forests (Manchi & Mane 2012). The terrain here is of jagged rocks, beneath a warren of clefts, crevices, tunnels and a few caverns that are formed by drainage and erosion of limestone. The majority of these clefts and cracks are 1-2m deep and more than 20m long (Sankaran 1998, Manchi & Mane 2012, Manchi & Sankaran 2014). Of the 120 caves occupied by AENS, only 90 were shared with bats.

Chapter 3: Roosting pattern and behaviour of the Andaman Edible-nest Swiftlet

3.1. INTRODUCTION

The large accessible congregations and easy species identification techniques using the morphological characters have resulted in studies on roosting habits of the 85% (n=432) gregarious bird species from 42 families (Beauchamp 1999, Galef & Laland 2005 and Bijleveld *et al.* 2010). Studies so far have explored the communal roosting as an adaptation of life strategies such as thermoregulation mechanism (Plessis and William 1994), security from predators (Rolland 1998), improving foraging efficacy and higher species-specific interactions (Ward & Zahavi 1973, Beauchamp 1999). Spatial and temporal activity patterns are the key factors for determining the relations between biological rhythms and environmental conditions (Medway 1962, Zammuto & Franks 1981, Fleming 1992, Chantler 2017). Spatial distribution of food resources has a substantial influence on niche differentiation and the life strategy of animals.

Several different species of Swallows and Martins, Owls, Raptors and Nightjars were observed roosting in nooks or caverns for a part of their life. However, Oilbird *Steatornis caripensis* of South America, Cave Swallow *Petrochelidon fulva* of North America and Swiftlets *Aerodramus and Collocalia* species of the Eastern region do spend significant phase of their life in the caves or cave-like places. The echolocating swiftlets are unique Aves, being the only echolocating, diurnal foragers (Osmaston 1906). Harrisson (1976) mentioned the Black-nest Swiftlet *Aerodramus maximus* and Mossy-nest Swiftlet *Aerodramus salangana* foraging by night in the bright moonlight. These resident birds roost at their nesting places. Common swifts and other members of the family are known for aerial roosting (Tarburton & Kaiser 2001); sometimes breeding adults, non-breeders as well fledged individuals also recorded roosting at 2000-3000m elevations. Roosting habitat of Common Swift, Vaux's Swift, Chimney Swift and Alpine Swift are well studied (Lack 1951 & 1956, Baldwin & hunter 1963). The length of the roosting period is subject to some variables such as species behaviour, age and climate (Spendelow 1985, Watson 1997) ultimately, related to energetics and diurnal pattern of their prey density (Zammuto & Franks 1978, Rodgers 1987).

In Common Swifts, roosting pairs ruffle their feathers and roost one on top of other. Wingspread behaviour to stop intruders to land near breeding pair was seen in White-collared Swift and Spot-fronted Swift.

The high population, gregarious nature, unique and mostly inaccessible nesting and roosting locations in the dark zones of subterranean caves, may have caused scarce availability of literature among colonial swifts and swiftlets compared to information on the other species (Bent 1940, Lack 1951, Baldwin & hunter 1963, Collins 1968, Ford & Cullingford 1976, Tarburton 1987, Chantler & Driessens 2000). Among the scarce studies, Medway (1962b) initiated the study of the Roosting pattern (arrival and departure) of Black-nest Swiftlet and Mossy-nest Swiftlet at a cave in Niah, Sarawak. Later, Sankaran and Manchi (2008) adapted the same method to study the population of the AENS in the caves of the North and Middle Andaman Islands. Further, as part of the ongoing study Mane and Manchi (2017) studied the effect of the select biotic and abiotic factors on the roosting patterns of the species on the Baratang Island in the Andaman Islands. Recently, Ramji *et al.* (2013) followed a similar method to explore the roosting behaviour of the group living White-nest Swiftlet in a house at Sarawak. This study aims at understanding the roosting patterns and behaviour of the AENS at Baratang Islands. Further, the study also explores the spatial-temporal variations in the roosting movements of the species in the North and Middle Andaman Islands.

3.2.OBJECTIVES

1) To examine the roosting habits of the AENS
2) To understand the spatio-temporal variations in roosting patterns of the AENS
3) To know the time-activity budget of the AENS at roost

3.3.STUDY AREA

Movements of the AENS were studied at the openings of the caves at Interview Islands (n=1), Chalis-ek (n=3) and Baratang Islands (n=6). These ten selected caves were of underground (n=7) and aboveground (n=3) type. Accessible caves were chosen where roosting movements could be observed throughout the breeding season. Roosting behaviour was studied in two caves, viz., Cave I: Is a bellow ground big cave with two openings at Interview Island, among 34 known limestone caves (Sankaran 1998, Manchi & Mane 2012) with big colony (264 individuals) of AENS (Manchi & Mane 2012). Cave II: is an above ground type of big cave with a single opening at Chalis-ek, a limestone hillock (Manchi &

Mane 2012, Manchi & Sankaran 2014) in the North Andaman Island with small colony (64 individuals) of AENS (Manchi & Mane 2012). For further details of the study area, please refer chapter 2.

3.4. FIELD METHODS AND DATA ANALYSIS

3.4.1. Roosting pattern

Roost count method (Medway 1962b, Sankaran & Manchi 2008, Manchi & Mane 2012) was followed to document the roosting movements of AENS at the openings of the ten caves; Baratang Island (n=6), Chalis-ek (n=3) and Interview Island (n=1). Though the AENS is a colonial species, they return to their roosting and breeding caves mostly in single, sometimes in pairs and rarely in a group of three. Accordingly, the observations were taken during dawn-dusk and dusk-dawn segments, wherein for each segment the observation tools were standardized. The observer sitting close to the cave mouth does not disturb the birds' movements (arrival to or departure from the cave). Moreover, it helps in the visual counting of the individuals entering in or exiting out of the caves during the light hours (between 06:00h to 17:00h). Furthermore, the audible echo click sound (frequency between 1.5kHz and 10kHz) produced by each bird helped in navigating and counting them (Medway 1962, Medway & Pye 1977, Thomassen 2005, Manchi & Mane 2012). By listening to these echo-clicks, the birds (entering and exiting) were counted sitting close to the cave mouth during the dark hours (between 17:00h to 06:00h). In total, 18,744 individuals were encountered entering in, and 12,197 individuals were exiting out of the selected caves during 223, round the clock, sampling days between January 2013 and July 2014. During each sampling day, movement (entry and departure) of the birds was recorded continuously for 24 hours. The Indian Standard Time (IST) was followed for recording the observations.

3.4.2. Roosting behaviour

Focal Animal Sampling Method (Altmann 1974) was followed with the Sony Handycam with infrared night vision to observe the roosting habits on the 18 nests from an approximate distance of 8-10feet. As the peak roosting time of AENS starts from 1700h (Medway 1962b) observations (n=387 days=5031h) were made between 1700h and 0600h from January 2012 to July 2014 at two colonies from Chalis-ek and Interview Island. The individuals (adults and chicks) roosting at each selected nest were observed across all breeding stages, a) nest construction, b) egg laying and incubation, c) hatching and nestling, d) fledging and e) post fledging. More than 230 hours were spent to get familiarize with the behaviours of the species before data collection to build an ethogram (Martin & Bateson 1993, Campbel & Lak 2011). Behaviours were classified based on at the time of the day and duration. The terminologies were developed for describing the roosting behaviour of swiftlets. The long-lasting displays (i.e. 15, 100, or >200sec) were classified as a state, whereas the short time displays (i.e. <10-15sec) were classified as events (Winchell & Kunz 1996). All roosting behaviours like resting, preening, crawling, defecation, fluttering, yawning, nest construction, mating, incubation, chick brooding and feeding were recorded during the observations and ethogram was constructed (Table 3.1).

3.4.3. Statistical analyses

The bird counts were converted into proportions (about the total count for a day) for analysis (Mane & Manchi 2017). One-sample T-test, to find temporal (hourly) variations in the movements (entry and exit) of birds was performed for the selected ten caves. Knowing the AENS' wide foraging range and breeding synchrony (Manchi 2009, Manchi & Sankaran 2010), daily movements of the AENS were assumed to be uniform at different roosting sites. Presuming every bird would leave and enter the cave, at least once in a day, the expected proportion of birds roosting in one hour were considered as 100% divided by 24h (i.e. 4.16% per h). Further, the differences in proportionate movement in each hour with expected proportion of birds' roosting in different caves were compared. The time of last bird arrival and first bird departure (119 days observations) were considered to estimate minimum or maximum roosting period of the species. Univariate Analysis of Variance (ANOVA) was performed followed by Tukey's Test for multiple comparisons, to check variation in movement during different hours, months, caves and sites.

Table 3.1 Descriptive ethogram of the observed behaviour of AENS while roosting

Behaviour	Description	Code
Nest construction	Birds spit the saliva by opening and shutting the bill repeatedly. The saliva, in a string form, is then brought out of the mouth and stuck on the rock wall with the help of its tongue. Clinging to the wall, the bird moves its body from side to side to spread the saliva. Once the base of the nest is made, the bird uses it as a perch and continues building the nest. Once the base grows large enough, it starts building the sides of the nest, giving it a cupped shape. The building process consists of chewing, retching and sweeping motion from the open bill with constant jabs on newly added layers. After the curve is built, the individual sits inside the half-built nest or hangs onto the edge of the nest and builds it completely.	NC
Preening	The individual birds arrange, clean and do general maintenance of its plumage using the bill.	PR
Allopreening	It is a preening of one bird by another bird. The pair of swiftlet has allopreening behaviour.	APR
Looking above	Holding the head upward, for a movement. This may be stretching the body.	LA
Head down	Bird sits in the nest with its head downward	HD
Wing spread wing beating	An adult or a chick stretching the wings before fluttering, while on the nest or cave wall.	WSWB
Fluttering	Beating the wings rapidly while hanging on the wall/nest.	FLR
fly (spread) wing	An adult or chick spreads/stretches both the wings at the same time, sometimes only one wing spread/stretched for few seconds.	FWIN
Wing open	An adult or a chick hanging on the nest or cave wall with the wings spread.	WO
Creeping	The bird shifts itself by a small walk on cave wall/nest.	CRWL
Position change	Changing body gesture from one to other position either in/on the nest or wall.	CP
Defecating	An adult or chick sitting in the nest positions itself at any corner of the nest/wall and voids excrement from the bowels through the cloaca, outside the nest.	D
Yawning	Involuntarily opening and closing mouth/Yawning.	MO_C
Calling	The call is a vocalisation. There are calls for covering most aspects of the social behaviour such as threat, courtship, flight, alarm, begging and so on.	CALL
Mating	Bird approaches other bird and lands on its back. The other animal crouches and allows the first bird to climb its back.	OOB
Egg rolling	The incubating bird is sitting in the nest, turning/rolling the egg using its legs.	ER
Begging	On the arrival of the parent bird, the chicks beg for food by opening their gape vertically and fluttering the wings (only after they develop the feathers).	BEGG
Chick feeding	Parent bird feeds the food bolus to the young ones. Here the parent bird inserts its beak into the gape of the chick.	CF
Chick preening	Parent birds preen the chicks in the nest.	CPR
Visibly resting	Sleeping/ birds did not move, and their eyes were closed. Sometimes head taken inside/ conjugative to the body.	SLP

3.5. RESULTS

3.5.1. Roosting pattern of AENS

During 5352 hours of observation, 30,941 individuals were encountered entering in or exiting out of the selected ten caves. Being a diurnal foraging species, the AENS individuals, mostly left the roost at dawn and returned at dusk. However, more than 98 % of the individuals returned to roosts in the dark after sunset. Just before sunset, the birds started gathering above the canopy of nearby roosting caves in several small flocks. With excessive vocalisations, these flocks subsequently get separated while entering the roosting caves, mostly single, sometimes two and rarely three or four individuals together, whereas, individuals left the roosts together in a big group.

3.5.2. Spatio-temporal variation in roosting pattern of AENS

3.5.2.1. Round the clock entry and exit movements: Entry or exit movement of the birds at the cave openings varied significantly ($p<0.05$) according to the time of the day. More than 98% birds arrived between 17:00h and 20:00h. However, Maximum (40.99±18.45%) birds returned to roost between 18:00h and 19:00h followed by 17:00-18:00h (36.8±20.97%) and 19:00-20:00h (6.7±7.31%, Figure 3.1). However, some individuals continued coming until 23:50h. The birds roosted in the caves for minimum 525.20±82.98 min (n=215) and maximum 765.56 ± 66.79 min (n=215). Departure from the roost site began with an individual exiting the cave and surveying by flying for a couple of small rounds just outside the cave opening. Within a minute after this ritual, other birds started leaving the roost. While departure, the birds left in

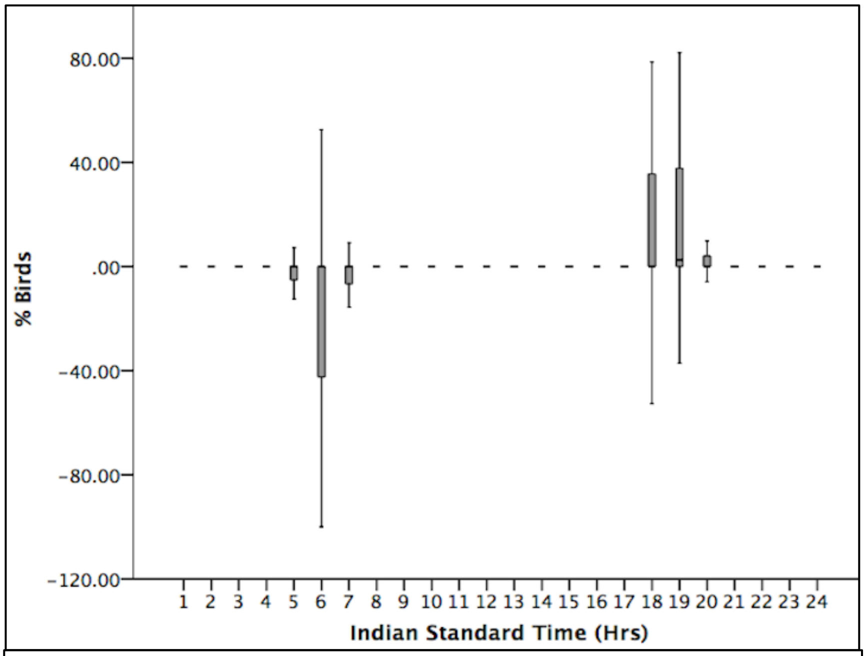

Figure 3.1: Hourly variations in entry and exit movements of the AENS through the cave mouths in the Andaman Islands.
Note: A negative value in figure 3.1 indicates the birds leaving the roosting caves

congregations, within 74.91±35.49min (Range: 20–160min) from 05:00 to 08:00h. Most individuals (45.01±34.21%) left the caves between 05:00–06:00h followed by 4:00-5:00h (21.6±29.11%) and 6:00-7:00h (17.8±26.29%, Figure 3.1).

Table 3.2 Roosting movements of the AENS

Roosting Movements	Months	CN	Sites
Total roost time to enter the caves (min)	$F (6, 201)$ 1.229	$F (9, 198)$ 6.935***	$F (2, 205)$ 20.312***
Roosting starts time at evening	$F (6, 201)$ 9.049***	$F (9, 198)$ 0.625	$F (2, 205)$ 0.621
Total time to leave caves (min)	$F (6, 108)$ 0.717	$F (9, 105)$ 3.487*	$F (2, 112)$ 5.487**
roost leaving time in morning	$F (6, 108)$ 10.4***	$F (9, 105)$ 16.82***	$F (2, 112)$ 30.905***

Note: '***'= $p<0.0005$, '**'= $p<0.005$, '*'= $p<0.05$

3.5.2.2. Variations in entry and exit movements in different months: A two-way ANOVA revealed a significant temporal (monthly) variation in the proportion of birds' entry [$F(6, 3149) = 9.853$, $p<0.001$] and exit [$F(6, 3149)=2.816$, $p<0.001$]. The entry and exit proportion of birds were highest in April. The entry movement of birds in June and July were similar, while it varied between January to May. Exit movement was similar in all the months except April (Figure 3.2). The start and end time when birds come to roost and leave the roost varied significantly within months (Table 3.2). Total time spent to leave the caves was less (Mean=57.70±37.57min SD) in January than other months (February: 64.15±39.53min SD; March: 64.48±26.56min SD; April: 62.18±39.44min SD; May: 86.50±28.72min SD; June and July 99.00±00.00min SD). Whereas, no such difference was found at the time taken to enter caves for roosting (Table 3.2). The average roosting period of the AENS inside caves was 542±128.08 minutes, which, however, varied across the months [$F(6, 121)=10.733$, $p<0.001$)]. In June and July, average

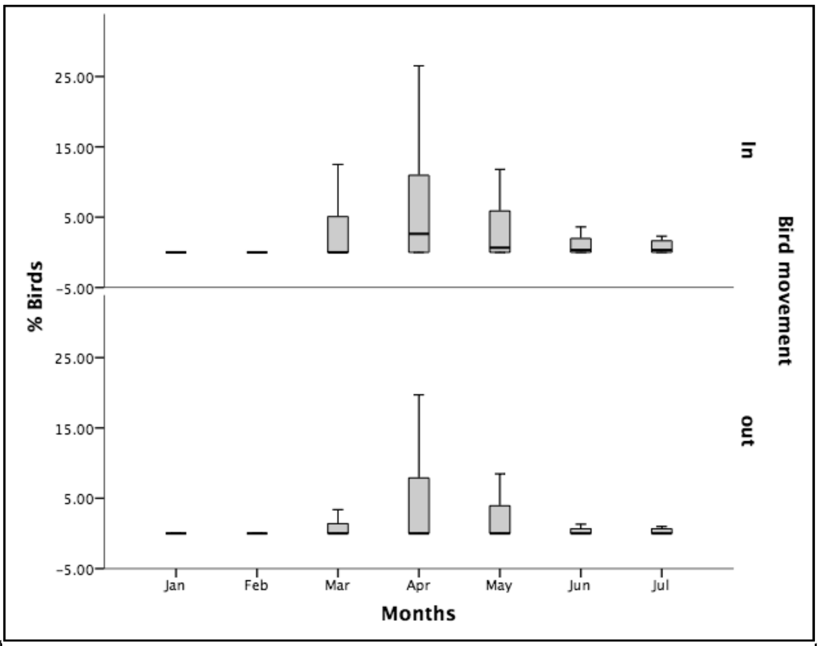

Figure 3.2: Monthly variations in entry and exit movements of the AENS through the cave mouths in the Andaman Islands

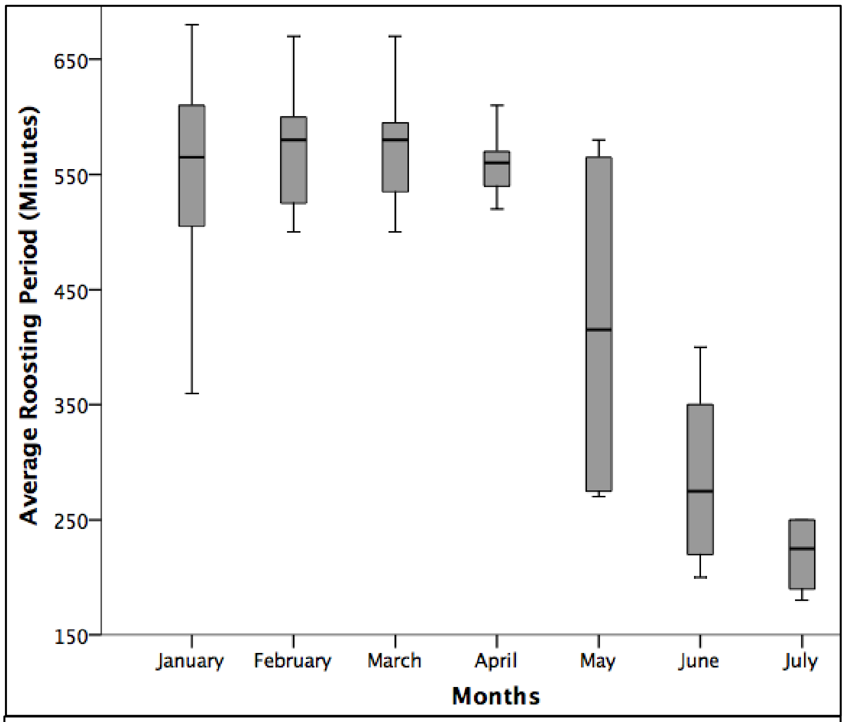

Figure 3.3: Monthly variations in the average roosting period of the AENS in the caves of the Andaman Islands

roosting time spent inside the cave was lesser than in January, February, March and April (Figure 3.3).

3.5.2.3. Variations in entry and exit movements in different caves: The cave wise movement of birds (no of entries into the cave in a day) was compared and found the proportion of AENS coming for roosting significantly variations [$F(9, 3077)=2.541$, $p<0.001$] among the various caves (Figure 3.4), whereas exit movements were similar among the caves, as they leave in the

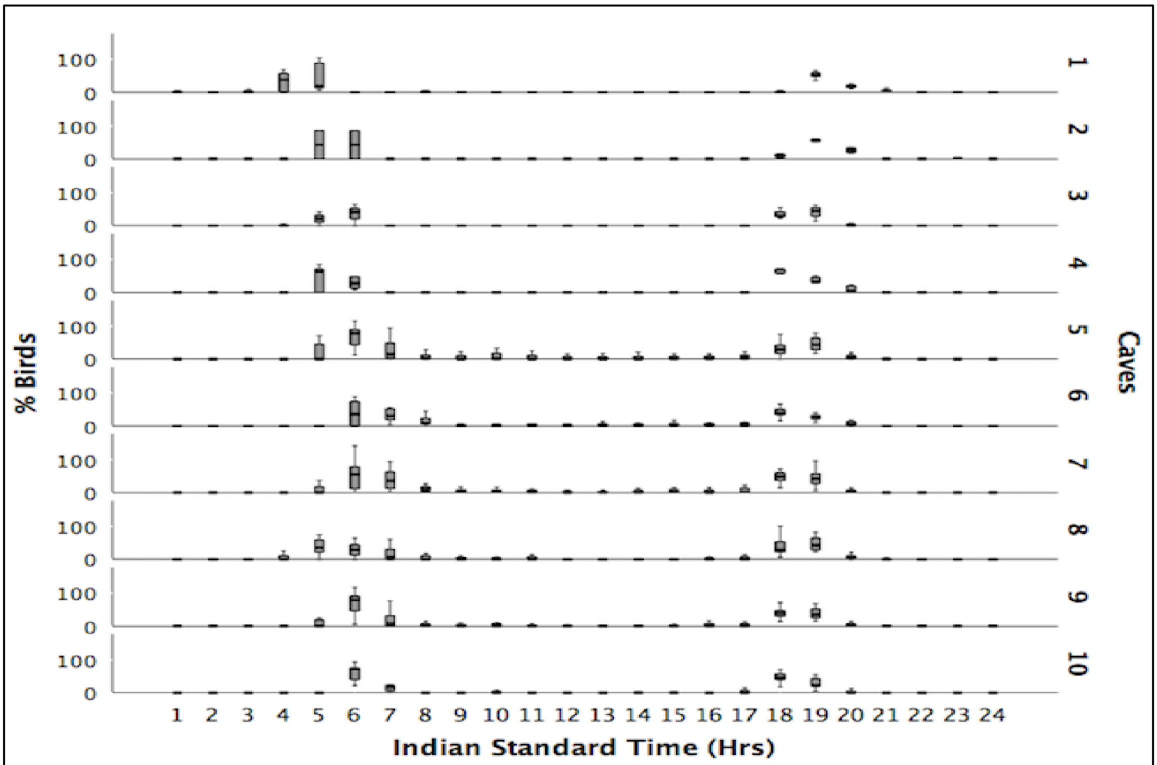

Figure 3.4: Cave-wise variations in entry & exit movements of the AENS in the Andaman Islands

flock. Bird movements at cave no. five at Baratang Island were highest (8.2±16.82% entries), whereas cave no. three at Chalis-ek Island showed least entries in a day (3.3±11.77% entries). Further, Tukey's Test categorised caves with a similar number of entries into three groups, viz. Group 1: (cave number 1, 2, 3, 4, and 10); Group 2:(cave number 1, 2, 4, 6, 9 and 10); Group 3: (cave number 5, 6, 7, 8, 9 and 10). Group three caves were from one site and are subterranean caves. Cave number 10, with 5.9±14.72% entries per day, is common in all three groups (Table 3.2). Time taken to enter the cave for roosting at 'cave 1' is more (Mean=215.00±39.77min SD) than other caves (Mean=129.01±30.28min SD). Time taken by AENS to enter the caves for roosting also varies [at Cave 2 (Mean=129.00±00.00% SD), Cave 3 (Mean=119.00±10.00 % SD), Cave 4 (Mean=115.67±32.14% SD), Cave 5 (Mean=144.24±41.03% SD), Cave 6 (Mean=149.63±36.41% SD), Cave 7 (Mean =133.03±49.88% SD), Cave 8 (Mean=111.52±33.63% SD), Cave 9 (Mean=130.02±38.39% SD) and Cave 10 (Mean=119.00±31.04% SD)]. As well, a daily roosting period of the AENS inside caves also varied between caves [maximum roosting period: $F(9, 205)=6.310$, $p<0.001$ and minimum roosting period: $F(9, 205)=13.226$, $p<0.001$]. The AENS had a comparatively shorter average roosting period in the cave nos. 1 & 2 (Table 3.3).

Table 3.3 Roosting period of the AENS in various caves of the Andaman Islands

Island Name	**Cave ID**	**Average Roosting time (Mean ± SD)**	**Minimum Roosting time (Mean ± SD)**	**Maximum Roosting time (Mean ± SD)**
Interview	1	282.22 ± 58.26	305.3 ± 45.56	679.0 ± 24.49
Chalis-ek	2	393.33 ± 28.86	346.0 ± 30.00	689.0 ± 34.64
Chalis-ek	3	555.00 ± 49.49	513.3 ± 66.58	729.0 ± 0.00
Chalis-ek	4	503.33 ± 181.47	473.6 ± 139.63	741.0 ± 26.83
Baratang	5	572.40 ± 194.25	546.6 ± 54.79	776.4 ± 56.40
Baratang	6	597.14 ± 38.17	566.7 ± 82.97	831.8 ± 98.24
Baratang	7	576.32 ± 39.47	534.9 ± 79.53	790.4 ± 67.38
Baratang	8	537.73 ± 41.74	500.8 ± 66.17	734.3 ± 66.25
Baratang	9	576.82 ± 34.83	536.5 ± 56.71	762.6 ± 46.57
Baratang	10	616.67 ± 49.26	596.7 ± 52.75	769.0 ± 29.54

3.5.2.4. Variations in entry and exit movements at different sites: Roosting and foraging patterns of AENS were observed at three locations (Interview Island, Chalis-ek on North Andaman Island and Baratang Island). Round the clock data showed the hourly entry movement of birds in caves at different sites, which differed significantly [$F(3, 3245)=4.931$, $p<0.001$]. Birds at Baratang Island roosted late compared to the birds on Interview Island and Chalis-ek on North Andaman Island. The sites also depicted significant variation in hour-wise exit movement of birds [$F(3, 3245)=7.710$, $p<0.001$; Figure 3.5]. Between three sites, maximum and minimum roosting time varied significantly [for maximum roosting time: $F (2, 212) = 8.289$, $p<0.001$ and for minimum roosting time: $F (2, 212)= 36.339$, $p<0.001$)]. Roosting time spent by birds from Interview Island (282.22 ± 58.26) was significantly different from those from Chalis-ek (475.00±122.59) and Baratang Island (570.89±102.93; Table 3.3).

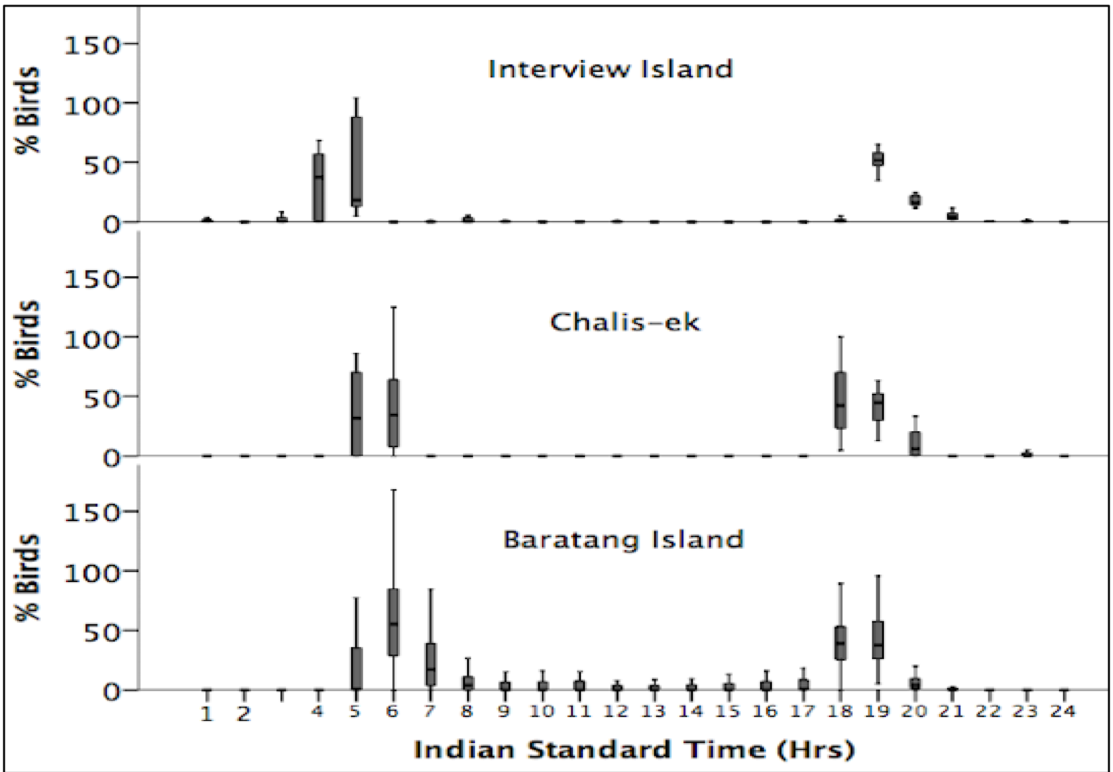

Figure 3.5: Site-wise variations in entry and exit movements of the AENS through the caves in the Andaman Islands

3.5.3. Roosting behaviour of AENS

The 19 discrete behaviours (11 states & 8 events, Table 3.1) and ten positions were identified during the roosting period (Table 3.4). The time of all states and events varied with each other during hours of days [$F(30, 6615)=249.040$, $p<0.001$] (Table 3.5). As well time spent in different body positions significantly different through out the days [F (10, 6635) =44.30,p<0.001] (Table3.4)

Table 3.4 Time budget of different position displayed by AENS while roosting in caves

Position	**Abbreviation**	**# of observations**	**Mean ± SD (sec.)**	**Sum**	**total time spent (min.)**	**maximum time spent in one state/event (min.)**	**% of # observations**
Sitting on nest	**SON**	1585	10.3 ± 28.22	16261	271	4.6	23.8
Hanging on nest	**HON**	1497	6.8 ± 22.85	10109	168.5	6	22.5
Sitting in nest	**SIN**	1178	26.8 ± 59.00	31534	525.6	7	17.7
Hanging on rock	**HORNN**	809	4.5 ± 13.26	3610	60.2	3.8	12.5
Incubating eggs	**SOE**	605	6.2 ± 15.90	3777	63	2.5	9.1
Chick brooding	**SOC**	519	4.5 ± 5.94	2333	38.9	1	7.8
Left from nest	**LFN**	363	1.2 ± 1.55	416	6.9	0.5	5.5
Left from rock/ wall	**LFRNN**	75	1.0 ± 0.00	75	1.3	0	1.1
Sitting on egg/chick	**SOEC**	13	4.2 ± 2.85	54	0.9	0.2	0.2
Landed on nest	**LON**	1	1.0 ± 0.00	1	0	0	0

3.5.3.1. Ethogram states *Visibly Resting / Sleeping:* Birds spent most of the roosting time for resting without any movement with eyes closed or sleeping (Table 3.5). The resting time of the individuals did not vary temporally (hourly) across the roosting period [F(13, 42)=0.862, p>0.05; Figure 3.6]. However, it depicted significant variation between the breeding stages [F(4, 51)=12.103, p<0.001; Table 3.6; Figure 3.7].

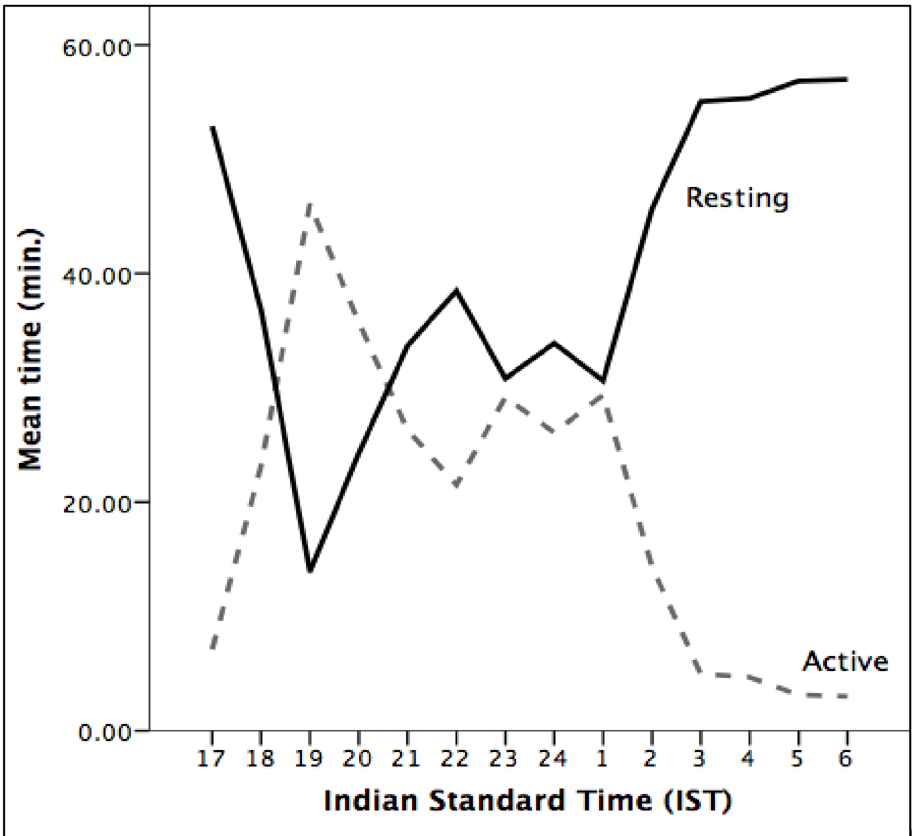

Figure 3.6: Hourly variations in the average time spent by AENS for daily activities and resting while roosting

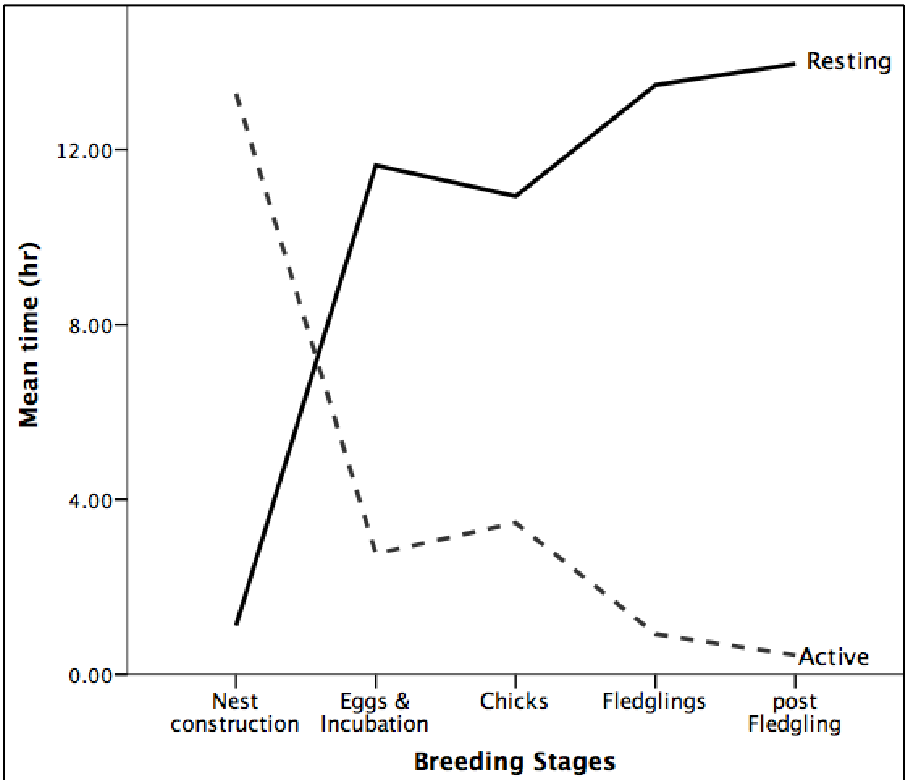

Figure 3.7: Variations in the resting and activity time spent during different breeding stages of AENS

Table 3.5 Temporal variation (hourly) in roosting behaviour of AENS

HOUR		NC	PR	APR	CPR	CRWL	FLR	CP	Other	Act	Rest
1700-1800	Mean	0.5	1.7	0.6	0.1	0.2	0.3	2.7	0.9	7.1	772.9
	±SD	1.06	2.31	1.44	0.15	0.18	0.41	3.32	1.16	7.78	7.78
1800-1900	Mean	10.8	3.4	2.7	0.3	0.3	0.4	3.9	1.2	23.1	756.9
	±SD	18.82	3.52	4.54	0.62	0.18	0.42	3.79	1.28	19.53	19.53
1900-2000	Mean	30.7	3.1	7.5	0.3	0.4	0.2	3.2	0.7	46.1	733.9
	±SD	58.11	3.25	2.74	0.56	0.23	0.23	2.99	0.55	56.34	56.34
2000-2100	Mean	21.2	1.8	7.9	0.7	0.3	0.3	2.4	1.3	35.7	744.3
	±SD	40.79	1.38	7.81	1.3	0.2	0.2	2.01	1.1	44.35	44.35
2100-2200	Mean	17.4	1.5	4.3	1.1	0.2	0	1.5	0.3	26.3	753.7
	±SD	32.94	0.97	4.47	2.21	0.12	0.06	1.3	0.25	33.51	33.51
2200-2300	Mean	12.2	1.7	5.4	0.2	0.2	0.2	1.3	0.3	21.5	758.5
	±SD	22.17	1.83	7.39	0.46	0.13	0.19	1.4	0.32	29.07	29.07
2300-2400	Mean	22.4	2.2	2.6	0.2	0.2	0.1	1	0.5	29.2	750.8
	±SD	37.86	1.75	1.31	0.36	0.08	0.09	1.08	0.53	37.32	37.32
2400-0100	Mean	13.2	1.5	8.4	0.2	0.2	0.3	2	0.4	26.1	753.9
	±SD	26.37	1.16	12.34	0.45	0.24	0.46	2.53	0.26	37.63	37.63
0100-0200	Mean	21.2	1.3	3.7	0.6	0.2	0.4	1.7	0.4	29.4	750.6
	±SD	28.74	1.61	2.04	1.32	0.13	0.37	1.96	0.22	28.79	28.79
0200-0300	Mean	0.8	2.7	7.8	0.8	0.1	0.2	1.5	0.3	14.3	765.7
	±SD	1.44	2.58	6.66	1.46	0.04	0.22	1.3	0.26	12.17	12.17
0300-0400	Mean	1.9	1	0.2	0.3	0.1	0	1.2	0.3	5	775.1
	±SD	2.65	1.5	0.23	0.56	0.12	0.06	1.15	0.17	3.91	3.91
0400-0500	Mean	2.1	1.1	0	0	0.1	0.1	0.9	0.4	4.7	775.3
	±SD	2.46	1.69	0	0.07	0.13	0.17	0.86	0.32	1.89	1.89
0500-0600	Mean	1	0.5	0	0	0.1	0.1	0.7	0.7	3.1	776.9
	±SD	2.01	0.84	0	0	0.09	0.18	0.59	1.03	2.64	2.64
0600-0700	Mean	0	0.5	0	0	0.2	0.3	1.2	0.8	3	777
	±SD	0	0.76	0	0.05	0.05	0.57	0.9	1.04	3.31	3.31

Note: Refer Table 3.1 for abbreviations

Table 3.6 Variation in daily roosting and resting time (in minutes) of AENS during different breeding stages

Breeding Stage		APR	CP	CPR	CRWL	FLR	NC	PR	Other	Activ	Resting
1	Mean	6.2	1.2	0	0.3	0.2	46.2	0.9	0.4	55.3	724.7
	±SD	8.08	0.95	0	0.16	0.26	36.47	0.79	0.36	41.76	41.76
2	Mean	5.1	1.6	0	0.1	0.2	1.9	1.7	0.7	11.5	768.5
	±SD	5.26	1.5	0.09	0.14	0.28	2.3	1.44	0.7	9.35	9.35
3	Mean	2.4	4.4	1.4	0.3	0.5	0.1	4.2	1.3	14.4	765.6
	±SD	3.79	2.54	1.3	0.16	0.32	0.13	2.11	0.89	7.13	7.13
4	Mean	1.2	0.4	0	0.1	0	1.7	0.3	0.1	3.8	776.2
	±SD	1.98	0.4	0	0.09	0.05	2.28	0.23	0.08	3.72	3.72
5	Mean	0.8	0.1	0	0.2	0	0.1	0.6	0	1.8	778.2
	±SD	1.07	0.16	0	0.32	0	0.14	0.87	0.02	2.26	2.26

Note: breeding stages: **1** = nest construction, **2** = egg laying and incubation, **3** = chicks, **4**= fledglings, **5** = post fledgling; for behavioural abreviations refer table 3.1.

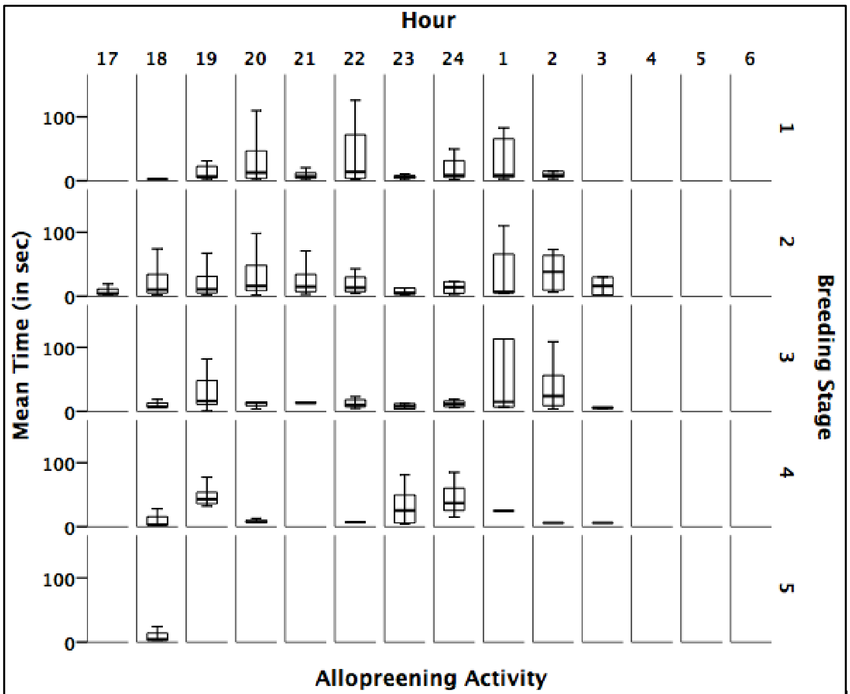

Figure 3.8: Hourly Allopreening activity (in sec) of AENS in different breeding stages

Preening (PR): is the most frequent and common behaviour performed during roosting. Autopreening presumably is a function to remove ectoparasites, clean and arrange the feathers and spread oil over the body from the uropygial gland. These include almost every reachable part of their body including their flight feathers. At roost, the AENS spent 2.2±2.64min/night (Range=0.1–12min/night) in grooming themselves while sitting/hanging on the nest, hanging on the rock surface. This was observed when birds were sitting on eggs/chicks as well. Preening activity was seen more after returning period (18:00-20:00h) and varied temporally [$F(13, 6635) = 46.577$, $p<0.001$; Table 3.5 &3.6]. The preening activity was recorded more during fledgeling stage [$F(4, 6644)=46.577$, $p<0.001$] and variedsignificantly between colonies [$F(1, 6647)=58.823$, $p<0.001$].

Allopreening (APR): This might be considered to be courtship behaviour if it helps in creating or maintaining pair bonds. It is mostly observed in roosting pairs at the time of mating and pre-breeding stage. Birds typically spent several minutes: 4.5±8.99min/night (Range=0–53min) in one allopreening state during roosting. APR was seen more in midnight (24:00-01:00h) and immediately after returning to nest (19:00-21:00 h) in the evening [$F(13, 6635)=7.159$, $p<0.001$; Table 3.5]. Allopreening only occurred between a pair and is more common during the breeding season. APR continues frequently during nest construction intervals [$F(4, 6644)=12.383$, $p<0.001$; Figure 3.8, Table 3.6]. The average daily time spent for APR differed between colonies [$F(1, 6647)=6.214$, $p<0.05$]. One bird approached another within accessible distance, perched facing the same direction, and lowered its head. This behaviour was seen while the bird was hanging on nest or rock near the nest, while sitting on nest, eggs, chicks and while sitting on other bird at the time of copulation. The recipient usually responce by allopreening the soliciting individual or mutual respond, usually on the nape and throat.

Chick preening (CPR): Both parents were found preening their chicks more during mid-night (1:00-3:00h) and after returning to nest (18:00-21:00h) in the evening [$F(13, 6635)=17.462$, $p<0.001$; Table 3.5]. Time spent by AENS for CPR varied between colonies [$(1, 6647)=17.084$, $p<0.001$]. The parents spent 0.44±1.27min/night (Range=0–7min/night) preening their chicks while hanging on nest/rock, chick brooding and incubating the unhatched egg.

Nest construction/repair (NC): This particular behaviour occupied significant hours of the roosting time spent inside the cave during the breeding period. Both mates were involved in this activity. While getting saliva out from the salivary glands, the individuals perform head back, and forth movements repeatedly may be to put pressure on the glands. The saliva is then spat in the form of strings and put on the wall or the previous layer of the saliva on the wall possibly with the help of its tongue. Clinging to the wall, the bird moves its head and body from side to side to spread the saliva on the wall to get the half-cup shape of the nest. Once the base of the nest is made, the bird uses it as a perch and continues building the nest. After the base grows large enough, it starts building the nest from the corners, shaping it into a half-cup form. The building process consists of chewing, retching and sweeping motion from the open bill with repetitive jabs on newly added layers. After the curve is built, the individual sits inside the half-built nest or hangs onto the edge of the nest and builds it completely. The nest construction activity was for 14.5±35.35min/night (Range=1–173min/night). The time spent for nest construction mostly after return (18:00-02:00h) to the nest in the evening till

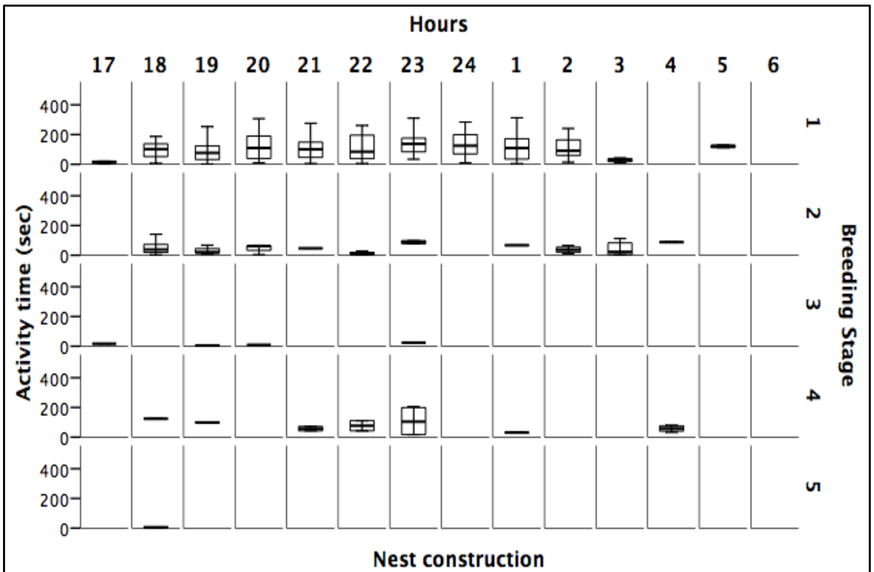

Figure 3.9: Hourly Nest construction activity (in sec) of AENS in different breeding stages

midnight [F(13, 6635)=168.718, p<0.001; Table 3.5]. Bird construct/repair the nest in different positions: with hanging/sitting on the nest, hanging on a rock near the nest, sitting on the nest, sitting on the broods, and also sitting on eggs. The nest repair was observed throughout from egg laying onwards. The time spent on the nest construction varied between colonies [F(1, 6647)=228.983, p<0.001]. This behaviour mostly was seen in early stages of breeding [F(4, 6644)=168.718, p<0.001; Figure 3.9; Table 3.6] and repair work was seen during the mid-breeding stage. Nest building was observed at different times of the night, but two peak activity sessions were apparent immediately after returning to the roost (19:00-21:00h) in the evening and mid-night (23:00-02:00h). It was rare and less frequent to observe birds constructing a nest in the morning before leaving the roost.

Crawling (CRWL): 0.26±0.37min/day (Range=15–37sec). Birds were seen crawling for a very short distance on and around the nest while hanging on the rock/nest and mostly after returning to nest for roosting. CRWL is not differed between hours of the day [F(13, 6635)=1.025, p>0.05] but varied in breeding stage during nest construction and chicks presence stage [F(4, 6644)=20.471, p<0.001; Table 3.4 & 3.5] and between colonies [F(1, 6647)=34.993, p<0.001].

Fluttering (FLR): Birds flapped their wings either to regain balance sitting on the nest and sitting/hanging on the nest/rock or sometimes to stretch their body. The activity was performed for 0.28 ± 0.35 min/day (Range=15–50sec/). Fluttering activity was seen immediately after return to nest in evening (17:00-21:00h) and in mid-night (24:00-02:00h) for short time interval [F(13, 6635)=2.655, p<0.05] mostly when chicks are present in nests [F((4, 6644)=2.655, p<0.05; Table 3.5 &3.6]. FLR did not vary between colonies [F(1, 6647)=3.398, p>0.05].

On other bird/Copulation (OOB): While mating a bird (male) was seen climbing on the other (female). The female raised her tail and shifted it to one side, and the male tucked his tail forward beneath hers. During copulation, the male moved his tail up and down rhythmically while flapping the wings. The copulation lasted for 0.06±0.175min/night (Range=3–10sec/attempt). The bird copulated sitting on the nest and hanging on the nest/rock near the nest. The AENS was seen matting any time in the night without significant variation between the hours [F(13, 6635)=1.897, p>0.05], but did vary significantly between the colonies [F(1, 6647)=9.176, p<0.01]. In early breeding season, birds copulate, so it was seen only in early breeding season.

Head down (HD): 0.0±3.33sec/day (Range=3.33sec). While incubating, brooding and rearing, the parent birds keep their head down. This behaviour can be seen any time throughout the season and didn't show any spatial-temporal variations between hours of the night [$F(13, 6635)=1.907$, $p>0.05$], colonies [$F(1, 6647)=2.298$, $p>0.05$] and breeding stages [$F(4, 6644)=1.952$, $p>0.05$]. Head down could be seen during resting as well.

Egg rolling (ER): 0.12±0.20min/day (Range=7–20sec). During incubation the birds roll the eggs to keep them warm from all the sides. Egg rolling can be seen any time in night hours [$F(13, 6635)=0.810$, $p>0.05$], but varied between colonies [$F(1, 6647)=7.812$, $p<0.05$].

Begging (BEGG): The begging behaviour of AENS is nothing but chicks asking for food. In this state, the juvenile was seen approaching a parent, crouched low with its head drawn close to its body, looked up with its bill open and was seen giving repeated begging calls, which last for 0.06±0.20min/night (Range=3–15sec/call). Chicks exhibited begging while sitting in the nest, which varied significantly between hours of the night [$F(13, 6635)=8.943$, $p<0.001$; Figure 3.10] and between colonies [$F(1, 6647)=1.740$, $p>0.05$]. BEGG activity was also observed sometimes before the parents land on or near the nest and also when the parents of the chicks in nearby nests arrive and land.

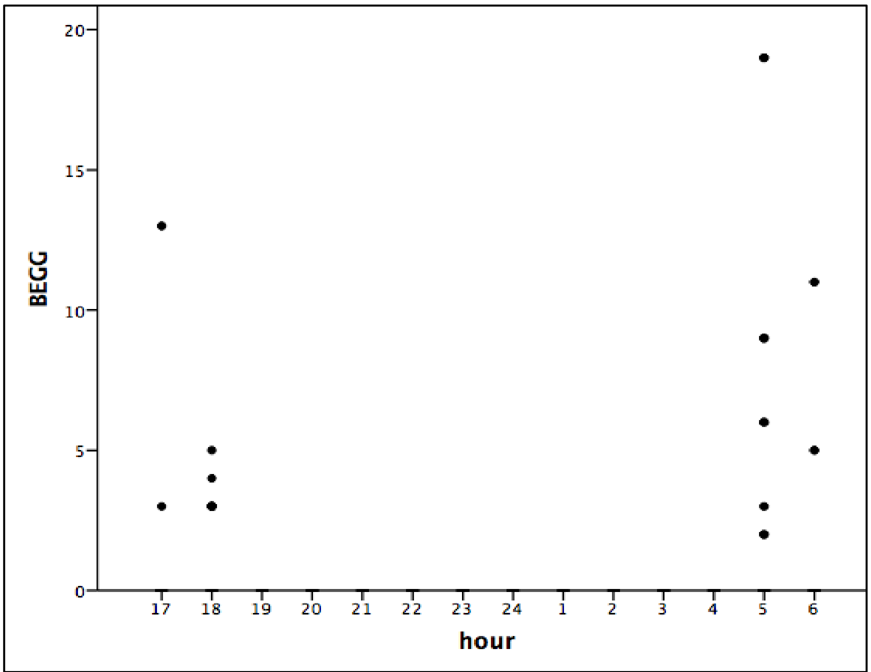

Figure 3.10: Hourly begging activity (in sec) of AENS' chicks

Chick feeding (CF): Both the parent birds of AENS were seen feeding their chicks. Birds were seen feeding chicks only after landing on the nest or the rock near the nest, while in the position of sitting on a nest or hanging on nest/rock near the nest. Once the parent birds land on/near nest the chicks start begging; the parent bird was usually feeding a single chick and sometimes both the chicks. The chicks were fed by parent inserting its beak to the throat of the chick and regurgitate the bolus (it is a small ball of the food, i.e. insects and parents' saliva) into the throat of the chick. Feeding to the chicks was seen lasting for very few seconds only: 0.1±0.14min/session (Range=0.1–1min/day). The timing of chick feeding varied with an hour of the day [$F(13, 6635)=12.154$, $p<0.001$] and colonies [$F(1, 6647)=0.959$, $p>0.05$]. The chicks are fed the most after post-emergence time (0500-0700h) during the morning and pre-roosting time in evening (1700-1900h) hours.

Apart from Allopreening &Nest construction, rest of the behavioural stages were less frequent and witnessed for less time. Some of the behavioural events were for few seconds only & rarely observed (Figure 3.11).

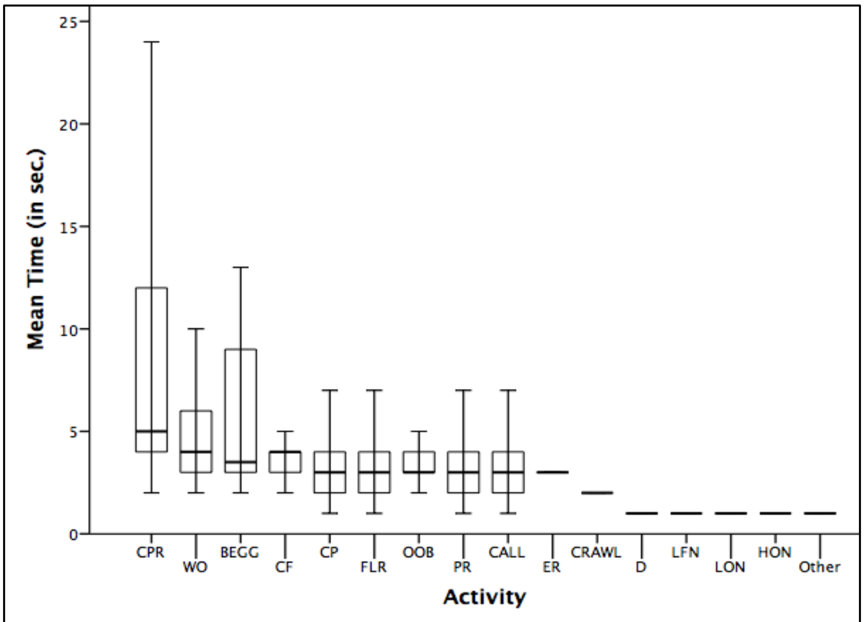

Figure 3.11: Behavioural states and events (Range = <30 seconds) during roosting time of AENS

Note: see table 3.1 and 3.4 for acronyms, other = events observed like chick brooding, Yawning, wing movements, looking above, left from rock/ wall, sitting on egg/chick, incubating eggs, sitting in nest)

3.5.3.2. Ethogram. event

Wing movement: fly (spread) wing (FWIN): 0.05±0.124min/session (Range3–10sec). Birds observed spreading wings in fly position when they are sitting in the nest/ on a rock near and at the time of incubation and parental care while sitting on eggs and chick. Fly (spread) wing behaviour is nothing but stretching of body and did not vary with hours [$F(13, 6635)=1.026$, $p>0.05$], colonies [$F(1, 6647)=1.660$, $p>0.05$] or nor with the breeding stages [$F(4, 6644)=1.026$, $p>0.05$].

Wing spread wing beat (WSWB): 0.0 ± 0.03 min/session (Range=2min). It was a rare event when birds were observed spreading and beating wings, hanging/sitting on the nest. This behaviour can be seen anytime during roosting and does not change with colonies or hours or breeding stages [$F(13, 6635)=0.629$, $p>0.05$] [$F(1, 6647)=1.725$, $p>0.05$] and [$F(4, 6644)=0.629$, $p>0.05$] respectively. *Wing open* (WO): 0.11±0.48min/day (Range=3min). This behaviour event was observed when birds were hanging on wall rock/nest, sitting on/in nest and while incubating eggs stage [$F(4, 6644)=3.541$, $p<0.01$] and varies with hours of a night, mostly after roosting in evening [$F(13, 6635)=3.541$, $p<0.05$] in different colonies [$F(1, 6647)=11.042$, $p=0.001$]. Fly wing, wing spread and wing beat and open wings, are the territory display behaviours seen for 2-3 minutes among the swiftlets in Andaman as well as in farmed colonies at Sarawak (Ramji *et al.* 2013), this behaviour is mostly to stop the intruders to land near /at the nest.

Looking above (LA): 0.04±0.07min/day (Range=7sec). At the time of sitting on nest/egg/chick and hanging on nest position/while resting, these events were seen. This is one type of stretching activity performed at the time of resting or incubating eggs [$F(4, 6644)=4.512$, $p<0.01$] mostly observed in pre-emergence hours (04:00-07:00h) in morning [$F(13, 6635)=4.512$, $p<0.002$] and do not vary between two colonies [$F(1, 6647)=3.678$, $p>0.05$].

Yawning(Y): 0.02±0.04min/day (Range=1-4sec). This event quite frequently observed while the bird is hanging on rock/nest or siting on eggs/chicks. Yawning does not varies in different colonies [$F(1, 6647)=1.392$, $p>0.05$]. Y was mostly seen during pre-emergence hours in morning (04:00-08:00h) [$F(13, 6635)=2.559$, $p<0.05$] and observed mostly in incubation and chick stage [$F(4, 6644)=2.559$, $p<0.05$].

Change position (CP): 2.35±2.52min/day (Range=13min). This is an event observed when birds changing position were seen while sitting on/near the nest, on chick/eggs in the nest and while they left the nest. CP activity was mostly seen immediately after coming to nest in evening (17:00-18:00h), midnight time (24:00-02:00h) and before pre-emergence (06:00-08:00h) in morning [$F(13, 6635)=16.260$, $p<0.001$]. It can be seen mostly during chicks' presence in nests than other breeding stages [$F(4, 6644)=16.260$, $p< 0.001$] but CP did not vary with the colonies [$F(1, 6647)=0.132$, $p>0.05$].

Defecate (D): The frequency of occurrence of this activity is activity was 3.0±2.0times/night but may not be necessary to be seen for all individuals in particular night

(0.08±0.1min/night; Range=4–6sec). While sitting on rock/nest or at the time of incubating/resting, birds lift the tail and defecate outside the nest, which falls on the ground. Defecation is a maintenance activity and can be seen any time in night [$F(13, 6635)=0.437$, $p>0.05$] throughout breeding stages D [$F(4, 6644)=0.437$, $p>0.05$].

Call (CALL): Birds are vocalized when they are hanging/sitting on nest/rock near the nest while sitting on eggs/chick and while leaving the nest as well. Usually, birds call for minimum 0.14±0.24min/night (Range=1min). This is the most aspect of the social behaviour such as threat, courtship, flight, alarm, begging and so on. Swiftlets of genus *Aerodramus* and one species of *Collocalia* utter audible frequency sounds (from 1.5kHz-10kHz), described as the 'echo clicks' (Medway 1967). Birds do not vocalise throughout the day, most calls were heard during the pre-emergence time (04:00-05:00h) and varied in the night [$F(13, 6635)=9.684$, $p<0.001$] and colonies [$F(1, 6647)=18.113$, $p<0.001$]. Most of the calls were recorded during incubation stage and at the time of when chicks were present inside the nests [F((4, 6644)=9.684, $p<0.001$] than other breeding stages (Figure 3.12). Birds make these echo-clicks while navigating in dark caves till they land their nest/roost. Similarly, while leaving roost, they make similar echo-clicks. Apart from this, there are feeding call, flight, begging call, nest call, alarm call which need to be studied in detail.

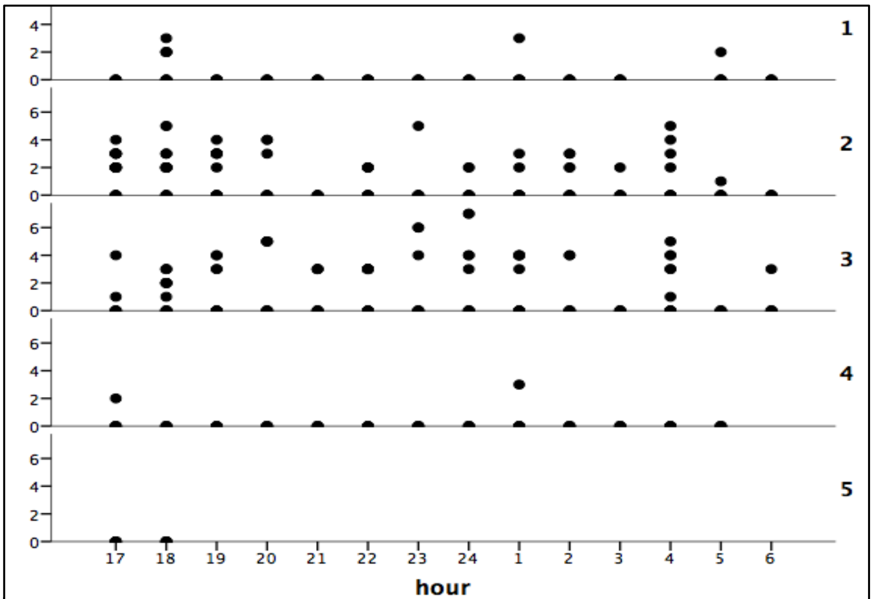

Figure 3.12: Hourly vocalization/calls (in sec) of adult AENS'

3.6 DISCUSSION

The AENS is known to rise from the roosting cave at dawn and return for roosting during dusk (Medway 1962b, Langham 1980, Lim & Cranbrook 2002, Manchi 2009), without exception about the species in the Andaman Islands. Birds' movements at the cave opening were more regular during 18:00h to 19:00h (entry movement) which is similar to the entry movements of swiftlets at houses (Ramji *et al.* 2013). Whereas, the exit movement, when species leave the roost 05:00h to 06:00h is comparatively early than the time recorded at houses (06:00 to 07:00h) by Ramji *et al.* (2013). Fullard *et al.* (2010) documented 18:45h and 19:35h as peak time in the case of Atiu Swiftlet *Aerodramus sawtelli* at Cook Island of Atiu, which is comparatively late to AENS. The variation in the entry and exit time between the caves and sites in the Andaman Islands depict that the roosting movements of the species vary place to place. As mentioned by some previous studies (Medway 1962b, Zammuto & Franks 1981) the further results referred to in chapter 4 & 5 confirm that some biotic and abiotic factors do play a crucial role in these variations. Except for Harrison's (1976) lone observation about night foraging of the Black-nest Swiftlet *Aerodramus maximum* and Mossy-nest Swiftlet *Aerodramu salangana* in Borneo, the echolocating swiftlets are not believed to be foraging in the dark. However, some individuals are known to arrive late to their roosting sites. Medway (1962b) recorded echolocating Swiftlet returning to Niah Cave, Sarawak at 0400 hours Tarburton (1987), documented White-rumped Swiftlets returning to the roost as late as 2230 hours in Fiji. Akin to this, individuals of the AENS were observed returning to their roosting cave on Interview Island at 2350h. These observations regarding the swiftlets foraging late in the evening were presumed as forage strategy of birds till the last light. Further, they take a longer time to return to their roosting sites in the dark. Future studies with satellite tagging may help us confirm the reasons for the delayed arrival of the individuals to the roosting or breeding sites.

Seasonal fluctuations in the number of birds at the communal roosts are typical (Eiserer 1984; Engel and Young 1992). Also, the resting time varied with the breeding stages. Unlike the other breeding stages, during nesting, the AENS built their nests after coming for roosting like swiftlets in Vietnam (Nguyen *et al.* 2002, Manchi 2009). *A. maximus* in Sarawak construct the nest during midnight 1:00h and between 5:00-6:00h in the morning (Kang *et al.* 1991) and *A. fuciphagus* at farmed colonies were recorded to construct their nests between 5:00-6:00h and 18:00-20:00h (Ramji *et al.* 2013). However, in the present study, the AENS were observed constructing the nest between 17:00h to 02:00h and rarely during pre-emergence after 03:00h till 5:00h and therefore the resting period is less during nest construction stage. The time of nest construction is believed to be dependent on digestion and mechanism that regulate saliva from hypertrophied salivary gland (Looi *et al.* 2017).

The study of swallows *Hirundo rustica* suggested that the preening frequency depends on the fitness of the individual and changes with the breeding season. It can be a predictor for breeding success, however exact role is yet to explored (Møller 1991). Apart from cleaning activity for ectoparasites control, preening can act as communication between mates and reduce social stress (Lewis *et al.* 2007). Therefore, when birds are incubating or taking care of the chicks, these behaviours are frequently seen. Tarburton (2009) documented, birds mostly enter and exit the roosting caves only during dawn and dusk. As both parents are involved in the incubation and during March and chick rearing during April and May; much activity was observed at the cave opening during this period of the year. While eggs are in the nest's, parents perform in longer shifts, whereas during nestling period they make multiple visits to feed the chicks in the nest (Manchi 2009), resulting in more activity at the cave opening. Begging for food and chick feeding behaviour varies with the colonies at two sites and hours. The peak in chick feeding was seen just after birds leave the roost and before roosting at the end of the day. Moreover, the begging by chicks was recorded more in the evening before roosting time and post-emergence when the likelihood of being fed by parents is higher (Kouba *et al.* 2014). The variation in two sites is possibly due to the spatial variations in the roosting movements of the parents and also may be due to the food available near colonies. The successful feeding attempt also can be considered for the multiple entries of parent birds.

Wing movement is sort of a warm-up corresponding to maintenance behaviour (Wright *et al.* 2006). Similarly, AENS adjust the body mass to reach aerodynamically appropriate wing placement and balancing of the body on wall/nest or before the flight. The presence of incubating birds in the cave at any given time results in a proportionate decline in the number of birds entering between 17:00h to 20:00h and exiting in between 05:00h to 06:00h during March. Akin to Manchi (2009), new birds were encountered in the populations during June and July months resulted from the philopatric and dispersal nature of the fledgelings of last year from the same or any other cave. Since adult dispersal in the swifts and swiftlets is not yet evident, that possibility is rejected. The change in roosting proportion concerning time, site and behaviour of birds during roosting is surely affected by different biotic and abiotic factors. Details of this are discussed in chapter 4.

Chapter 4: Biotic factors and roosting patterns of the Andaman Edible-nest Swiftlet

4.1. INTRODUCTION

Biotic factors do affect the roosting and foraging habits of animals (Klomp & Furness 1992). Swifts and swiftlets have high nesting success and exceptional reproductive features among birds. They exhibit behavioural and morphological adaptations for unique environments (Chantler & Driessens 1995). They use inaccessible roosting and breeding sites, such as waterfalls, rocky cliffs and caves. This is a strategy that protects them from potential predators (Lim & Cranbrook 2002). It has been seen that the big colonies are more successful with less predation pressure (Kirby *et al.* 2005). Effects of colony size on reproduction have been particularly studied in the Swallows and Martins (Davis & Brown 1999, Brown & Brown 2001, Ambrosini *et al*. 2002). Probably, differences in reproductive parameters such as breeding success related to colony size are more likely to be found in species with a large range of colony size, such as Cliff Swallow (Brown & Brown 2001). Some of the Apodids shows low incubation success e.g. *Streptoprocne rutila* (Vieillot 1817), *Aerodramus salangana* (Streubel 1848), *A.maximus* (Hume 1878), *Chaetura pelagica* (Linnaeus 1758), *C. brachyura* (Jardine 1846) and *Apus apus* (Linnaeus 1758) (Lack & Arn 1947, Weitnauer 1947, Fischer 1958, Medway 1962a, Collins & Landy 1968, Pellantová 1975). Predators may influence the breeding success and colony size of the prey species (Corkhill 1973, Evans 2004, P´eron *et al.* 2010, Bowman & Harris 1980). Similarly, predation risk may also be altered by differences in parental behaviour due to abundance of food for both the parents and chicks in the nest. The food availability therefore may modify their provisioning behaviour (Medway 1962b, Phillips & Hamer 2000, Stevens *et al.* 2008), therefore altering the level of activity at or near the nest, thereby diverge the predation risk of the species (Hamer & Read 1987).

Biotic factors including population, colony size, breeding biology and predators of the most swiftlet species are studied across their distribution (Medway 1962, Langham 1980, Kang *et al.* 1991, Cranbrook & Lim 1999, Lim & Cranbrook 2002, Cranbrook *et al.* 2013). Some also attempted to explore the roosting patterns of these aves (Medway 1962, Ramji *et al.* 2013,).

However, none endeavoured to understand the relation between the roosting movements and other biotic factors of this monogamous species. The present study tried to explore and discuss the biotic factors affecting roosting patterns of the AENS. During the study, the biotic factors studied were: the population, colony size, breeding and nonbreeding population, breeding chronology, breeding biology, breeding success, co-existing species and the presence of predators (Sankaran & Manchi 2008, Manchi 2009, Manchi & Mane 2012, Mane & Manchi 2013, 2017).

4.2. OBJECTIVES

The objective of this study was to identify the biotic factors and understand their role in the roosting decisions of the AENS

4.3. FIELD METHODS AND DATA ANALYSIS

4.3.1. Population

The nest count method (Manchi & Sankaran 2014) was used to estimate the breeding populations of 10 caves; Baratang Island (n=6), Chalis-ek (n=3) and Interview Island (n=1). To estimate the total population, roost count method was followed (Medway 1962b, Manchi & Mane 2012, Manchi 2014) at openings of the ten caves (details are given in chapter 3).

4.3.2. Breeding biology

Following Manchi (2009), breeding chronology/seasonality data was collected from the accessible nests (n=250 nests) in different caves. Each selected nest was visited once in four days to assess the breeding chronology of the species. The Unique Identification (UID) number to all the selected caves and nests were assigned for their identification. Along with nest identity number, the number of eggs and chicks in the nest for each date was also noted (n=250 nests). All the observations were carried out from January to August at Interview Island (n=1 cave), from January to June at Chalis-ek (n=28 caves) and from January to June at Baratang Islands (n=120 caves) between 2012 and 2015. The apparent nest success (Jehle *et al.* 2004, Manchi 2009) of the AENS was determined based on daily observations from the date of egg laying till fledging. As observed in the earlier studies (Medway 1962b), though there is traffic in and out of the roosting/breeding cave during the day, most birds returned to the caves for roosting between 1700–2000 h (Chapter 3). These hours were recognised as

Peak Roosting Hours (PRH) and used for analyses.

4.3.3. Co-existing species inside the caves

The visual encounter & 10 minutes scan twice in a week in 16 caves from 2012 to 2015 were performed to search and document the coexisting species and predator abundance. The subsequent observations by local nest collectors were also considered. Potential predators were estimated according to the species encountered and the literature available from the other ranges of distribution.

4.3.4. Potential predators outside the caves

A non-invasive method of the passive auditory survey at point stations that causes the least disturbance to all birds/fauna was used to know the diversity and abundance of the Owls in the swiftlet and non-swiftlet area (Jathar & Rahmani 2013). Considering the accessibility and extent of area total 17-point stations were identified covering the 8.2km^2 area with four types of forest: 1] Mangroves adjoining Agricultural land (n=4), 2] bamboo brakes forest (n=4), 3] Evergreen forest (n=5) and 4] Teak Plantation (n=4). Each station was kept separated with a minimum distance of 250m. The circular plots (n=17) of the 50m radius were laid. During fieldwork, owls were observed to be highly active after 18:00h. Therefore, the point counts (Sutherland 2006) were taken at 17 stations for three hours (17:30 to 20:30h) between January and May during 2013 to 2015. Total 164 observations were made covering all stations with minimum eight replicates at each point. The area, where human settlement and disturbance were seen, the absence of AENS breeding cave was recorded as the No AENS breeding cave area and forest without any human interference and with AENS breeding caves has been registered as AENS breeding cave area. In the swiftlet and non-swiftlet point, locations were also recorded to study the predator's presence. Also, tree species at point stations, tree GBH, the height of lower and upper branching of a tree, canopy height, canopy cover, weather conditions (temperature, humidity, rain fall, wind speed and light intensity during calls) were recorded for each location. Each observation was of three hours to identify calls and record an approximate number of an individual is around the point area (if one individual calls, at the same time nearby individuals responds to the call at the same time). During the first year of data collection, calls were listened carefully to practice estimating call direction and approximate distance of individuals within 50m. Initially, several nights were spent following the calls of different species to get accustomed to the intensity of calls, identify the species and estimate the distance of the individual calling from the observer. The individuals were sighted quite a few times.

4.3.5. Statistical analyses

The Population classes (class 1=<30 birds, class 2=31-60 birds, class 3=61-90 birds, class 4=91-120 birds, class 5=121-150 birds and class 6=>150 birds) were made to estimate the roosting pattern by performing the Analysis of Variance (ANOVA). Daily nest survey data was used to estimate breeding seasonality, chronology and Success of the AENS. Following Manchi (2009), the period of nest construction was considered till the first egg was laid. The egg-laying period was considered from laying the first egg till the last egg was laid in the colony. The incubation period estimated as the number of days between the laying of the second egg and first hatchling in the nest. The fledgeling period was estimated as the number of days between the hatching of the first egg and fledging of the last chick. These parameters were estimated using data only from the nests where laying date, hatching date and fledging date were recorded. The paired sample t-test was used to show the similarity in breeding stages.

The breeding success was estimated by calculating Apparent Nest Success (Jehle *et al.* 2004). The Analysis of Variance (ANOVA) was performed to check the difference of breeding success among the caves and followed by Tukey's test. The variation in daily roosting movements of birds during different breeding stages was estimated by performing Kruskal-Wallis Test. The ANOVA followed by Tukey's test was carried out to understand the abundance of individuals in various breeding stages and roosting Period and population classes.

The abundance of co-existing species was calculated in different breeding stages with Analysis of Variance (ANOVA). The presence of cave fauna was then correlated with the species abundance by performing the Pearson's co-relation significance. For potential predators outside the caves, the relative abundance was calculated, and Analysis of Variance (ANOVA) was conducted to check the difference in AENS breeding cave area and No AENS breeding cave area, different forest types and weather conditions. Finally, by using all covariant together and performed multiple linear regression (Forward Type) to understand the factors determining the number of Owls present in the area. The IBM SPSS (Ver. 22) was used to perform all the statistical analysis.

4.5. RESULTS

4.5.1. Population

Colony size and roosting pattern: When the population groups (n=6, Table 4.1) were compared with movement of the AENS, the proportion of birds coming for roosting within 24 hours varied significantly [$F(5, 3311)=4.626$, $p<0.001$] among different colonies, whereas exit movements of birds were similar with no significant differences observed among colonies [$F(5, 3311)=1.319$, $p>0.05$]. Daily movements of the smaller colony like cave no. 8 (n=28 birds; 7.7±17.61% entries) at Chalis-ek Island were highest compared to the bigger colony like in cave no. 1 (n=336 birds; 3.8±10.74% entries) at Interview Island (Table 4.1).

Table 4.1 Population and roosting Period of AENS at different caves

Cave ID	Population class	Island Name	Population	Mean % entry	Average Roosting Period (Mean ± SD)
1	6	Interview	336	3.8 ±10.74	282.2 ± 58.26
2	2	Chalis-ek	42	5.8 ±14.11	393.3 ± 28.86
3	4	Chalis-ek	116	5.4 ±14.02	555.0 ± 49.49
4	2	Chalis-ek	47	5.8 ±14.11	503.3 ± 181.47
5	3	Baratang	71	7.4 ±15.68	572.4 ± 194.25
6	3	Baratang	81	7.4 ±15.68	597.1 ± 38.17
7	5	Baratang	130	8.8 ±17.12	576.3 ± 39.47
8	1	Baratang	28	7.7 ±17.61	537.7 ± 41.74
9	3	Baratang	73	7.4 ±15.68	576.8 ± 34.83
10	2	Baratang	39	5.8 ±14.11	616.7 ± 49.26

Further, Tukey's Test categorised colonies with a similar number of entries into three groups, viz. Group 1: (population class 6, 4, and 2); Group 2:(population class 1, 2, 3 and 4); Group 3: (population class 1, 2, 3 and 5). Further, daily roosting period of the AENS of different colonies varied significantly [maximum roosting period: $F(9, 205)=6.310$, $p<0.001$; minimum roosting period: $F(9, 205)=13.226$, $p<0.001$ and total roosting Period $F(9, 108)=8.681$, $p=0.0001$)]. The AENS had a comparatively shorter average roosting period in the cave nos. 1 & 2. The colony size (population class) revealed that big colonies spend less time in roosting

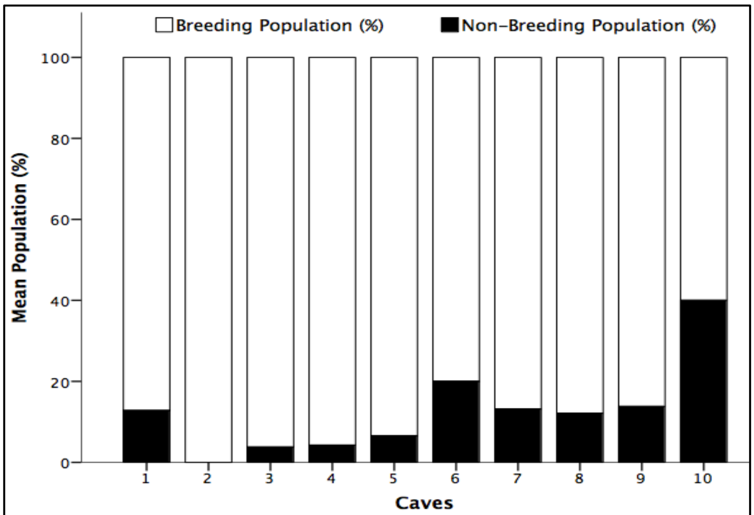

Figure 4.1: Breeding and Non-breeding population of AENS in different caves.

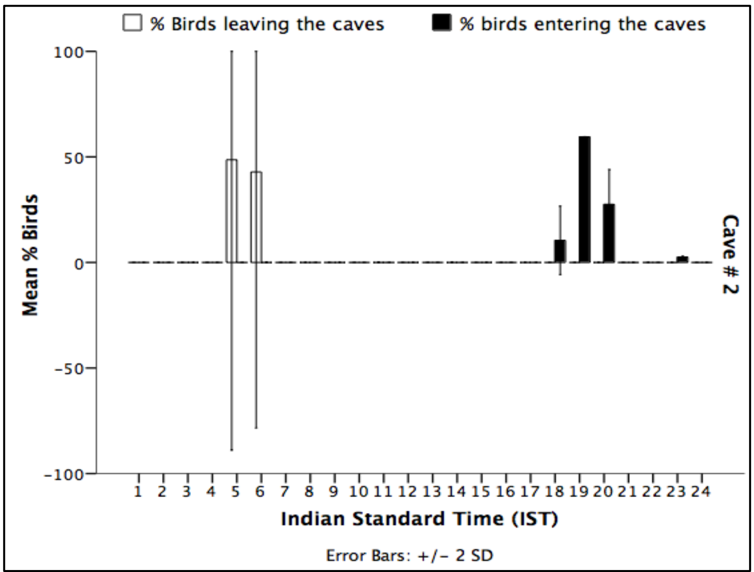

Figure 4.2: Mean (%) birds entering and exiting in 24 h from caves with only Breeding population of AENS.

(Interview Is. cave 1) where as smaller colonies roost for a longer time (some caves at Baratang & Chalis-ek). Multiple comparisons (Tukey's Test) of colony size and daily roosting period of the birds: caves (1, 2); (2, 3, 4, 5, 7, 8, 9); (3, 4, 5, 6, 7, 8, 9, 10; Table 4.1) showed randomly grouping caves of different population classes which possibly could be due to some other factors like cave structure, availability of foraging ground, the breeding status of the colony which is discussed in the subsequent Chapter 5 in detail.

Breeding & non-breeding population: Average non-breeding population in the ten selected colonies was 8.9±7.76% (Figure 4.1). The colonies with only breeding population showed no significant variation in the proportion of birds entering [F(1, 118)=0.000, p>0.05] and exiting [F(1, 162)=0. 092, p>0.05] the caves within 24 hours (Figure 4.2 & 4.3). The colonies with non-breeders showed significant variation in the proportion of birds entering within 24 hours [F(8, 3187)= 2.750, p<0.01] whereas, while leaving the roost no significant variation was seen in the proportion of birds between the colonies [F(8, 3188)=0.887, p>0.05].

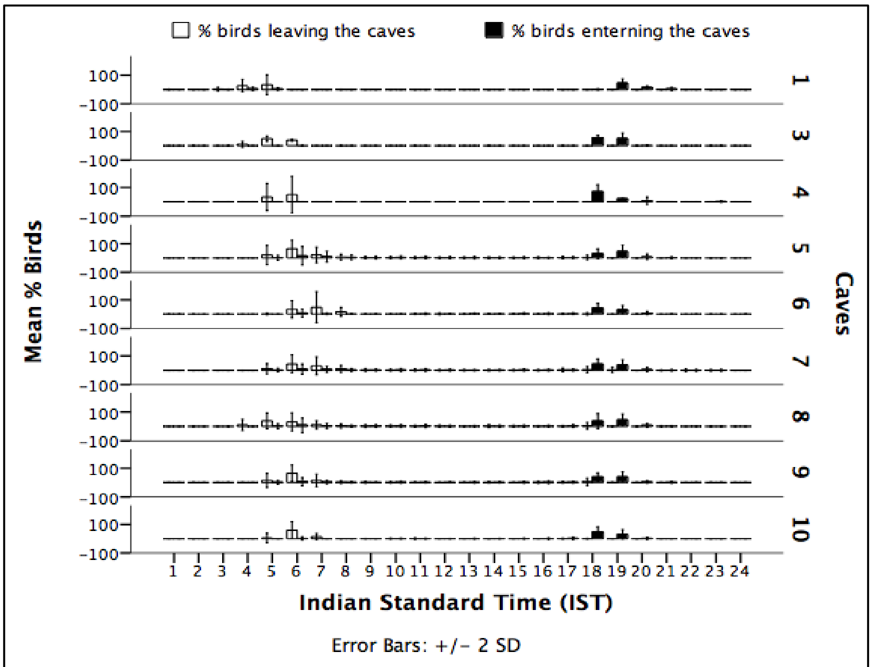

Figure 4.3: Mean (%) birds enter and exit within 24 h from caves with Non-breeding populations of AENS

4.5.2. Breeding biology

Chronology and seasonality: Akin to Manchi (2009) the AENS was found to be a synchronous seasonal breeder in the A & N Islands. AENS breeds from December to August in the Andaman Islands. Nest construction was seen beginning in December (around 15th Dec). Eggs were laid at the beginning of summer (3rd week 15-25th February). Hatching took place in the pre-monsoon season (second week 10-20th March). The fledging started during the pre-monsoon showers (April end) and continued to fledge till the end of June. The second brood eggs were laid with the onset of the monsoon (around 15th May). Egg-laying continued through the peak monsoon till the end of July when the chicks started hatching. For the present study, data were collected till nest harvesting followed by the fledging of the first brood.

Generally the breeding season for this species is seen ending with the fledging of the second brood during late August at Interview Island (Manchi 2009). The population of AENS at Interview Island (site 1) delayed its breeding by two weeks as compared to Chalis-ek (site 2) and Baratang (site 3) populations of AENS.

Nest building: The nest construction was seen starting only in Interview Islands in February and by March the nests construction reached to >50% whereas, at Chalis-ek and Baratang birds were seen constructing the nests comparatively early (Table 4.2). In the absence of human/nest harvesting pressure, the nest construction duration was observed to be as high as 61.10±10.96 days (n=207 nests). At Baratang Islands nests were dull coloured compared with Chalis-ek and Interview Islands. The proportion of nests constructed at different sites in different months varied significantly $F(5, 3317)=97.61$, $p<0.0001$; Table 4.2). Further, Tukey's test revealed that the January, February and March were distinct months in all the sites and all sites differed from each other w.r.t. nest construction by AENS.

Table 4.2 Proportion of (Mean, SD) nest constructed/empty nests of AENS in months and sites

	Months						
Sites	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
Interview	--	6.6±3.44	57.4±2.43	11.5±2.43	4.3±2.43	3.3±2.43	0.0±3.44
Chalis-ek	90.9±2.43	96.1±1.30	27.1±3.44	--	--	--	--
Baratang	52.8±0.65	55.3±0.63	23.7±0.59	2.8±0.70	3.4±2.29	--	--

Incubation: The average clutch size of the AENS in Andaman Islands was observed to be 2 eggs (observations=185), with some exceptions (rarely 3 eggs, based on 5 observations). The AENS was seen laying eggs usually during the night hours (Manchi 2009) with an interval of 2.07±0.71 days (n=1147). The Interview Island (site 1: 17.6±24.14 days) and Chalis-ek (site 2: 17.2±23.55 days) revealed similarity in egg laying and incubation stage ($t(65)=0.107$, $p>0.05$) whereas, Chalis-ek (site 2: 17.2±23.55 days) & Baratang (site 3: 13.5±21.90 days) and Baratang (site 3: 12.4± 21.28 days) and Interview (site 1: 18.6±23.65 days) shows dissimilarity ($t(65)=2.074$, $p<0.05$ and $t(71)=-2.230$, $p<0.05$ respectively ; Figure 4.4) in egg laying and incubation. The variation in the hatching success among different colonies was highly significant $F(5, 3311)=185.26$, $p<0.0001$) (Figure 4.5). Further, Tukey's multiple comparison tests suggested that the population class 6, 1, 2 and 4 were distinct with high breeding success whereas class 3 & 5 were in one group with the highest hatching success (refer Table 4.1 for cave numbers and population class).

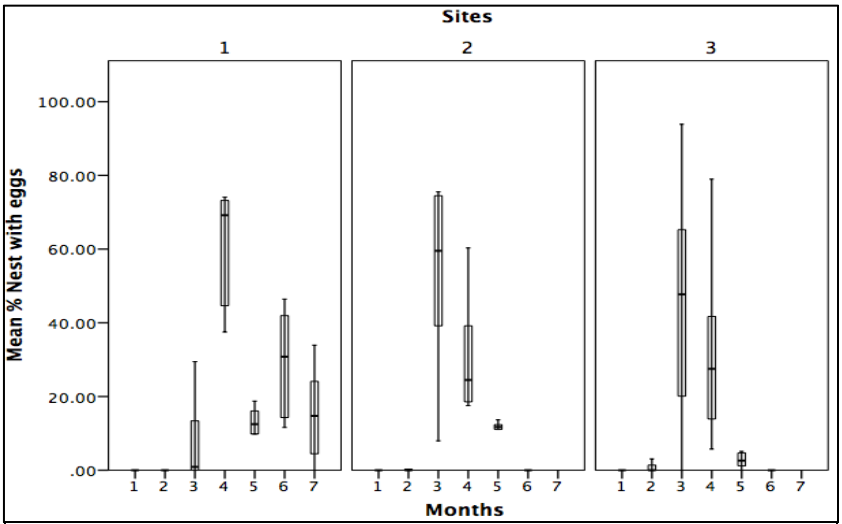

Figure 4.4: Variation in incubation time of AENS in different sites
Note: Site1: Interview Is., Site 2: Chalis-ek and Site 3: Baratang Island

Nestling & fledging: The fledgeling period was longer in the AENS (Range=32-50 days). Chick fledging observed in Baratang were of 36.31±4.15 days (n=85) where as at Chalis-ek and Interview they were

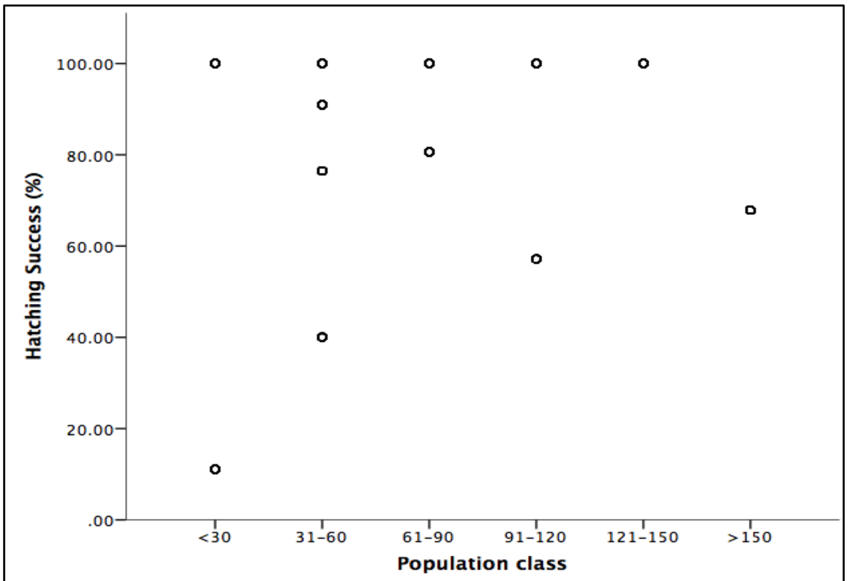

Figure 4.5: Hatching success (%) of the AENS at different population class

(43.03±6.44 days; n=1147). The paired sample t-test revealed that all sites are similar in the proportion of nests with nestling & fledgeling [site 1 Interview: (17.6±26.04), site 2 Chalis-ek: (13.0±19.98) and site 3 Baratang: (11.9±22.27). For site 1 & 2: (t(65)=1.227, p>0.05); for site 2 & 3: t(65)=0.243, p>0.05; and for site 3 & 1: t(71)=-1.838, p>0.05 (Figure 4.6). However, there was a significant difference in the proportion of nestling & fledgeling's presence in different months [F(10, 282)= 13.91, p<0.0001)]. In the Interview Island, hatching started in April (14.4±20.61% chicks in nests), and the peak was in May (64.7±1.99% chicks in nests). In July, the last batch of chicks from first brood fledged (7.4±4.12% chicks in the nest). Whereas, Chalis-ek and Baratang Is., hatching started in March and peak was in April (Chalis-ek: 43.8±16.04% and Baratang: 50.6±23.91% chicks in nests). This stage lasts from June till the nest harvesting followed by fledging of chicks. Significant variation was seen in the fledging success among different

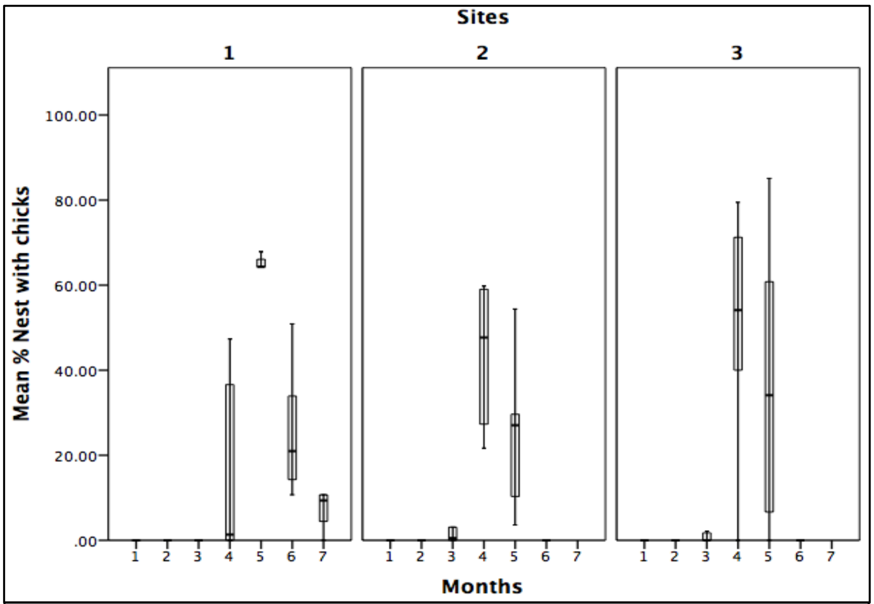

Figure 4.6: Variation in Nestling & fledgling time of AENS in different sites. Note: Site1: Interview Island, Site 2: Chalis-ek & Site 3: Baratang Island

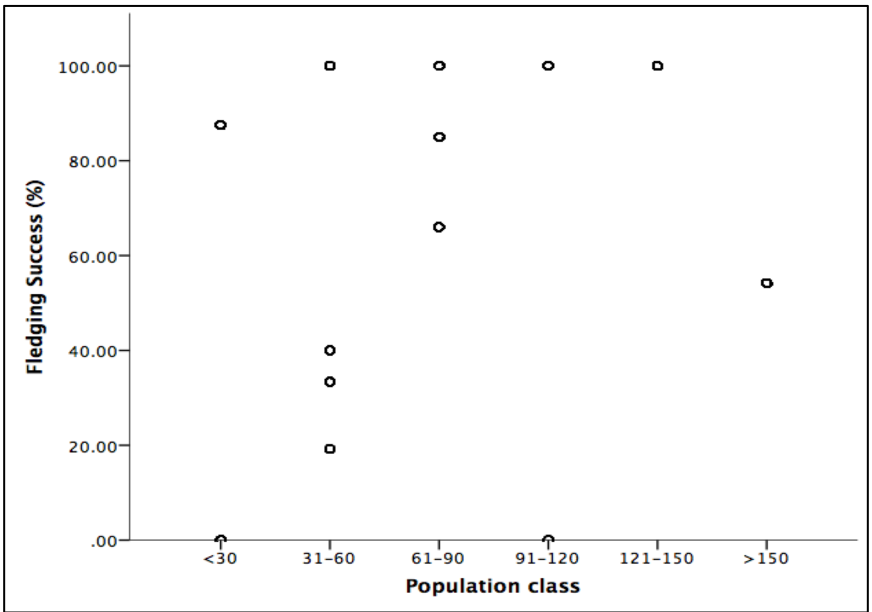

Figure 4.7: Fledging success (%) of the AENS at different population class

colonies $F(5, 3311)=362.32$, $p<0.0001$; Figure 4.7). Further, Tukey's multiple comparisons suggested that the population class 2, 6, 1, 4, 3 and 5 have increasing breeding success from class 2 to 5 (see table 4.1 for cave numbers and population class). The variation in the breeding success among the various colonies was highly significant $F(5, 3311)=648.48$, $p<0.0001$) (Figure 4.8). Further, Tukey's multiple comparisons suggested that the population class 1, 4, 3 and 5 were distinct and has increasing breeding success from classes 1 to 5 where as classes 6 and 2 were in one group with lowest breeding success (see table 4.1 for cave numbers and population class).

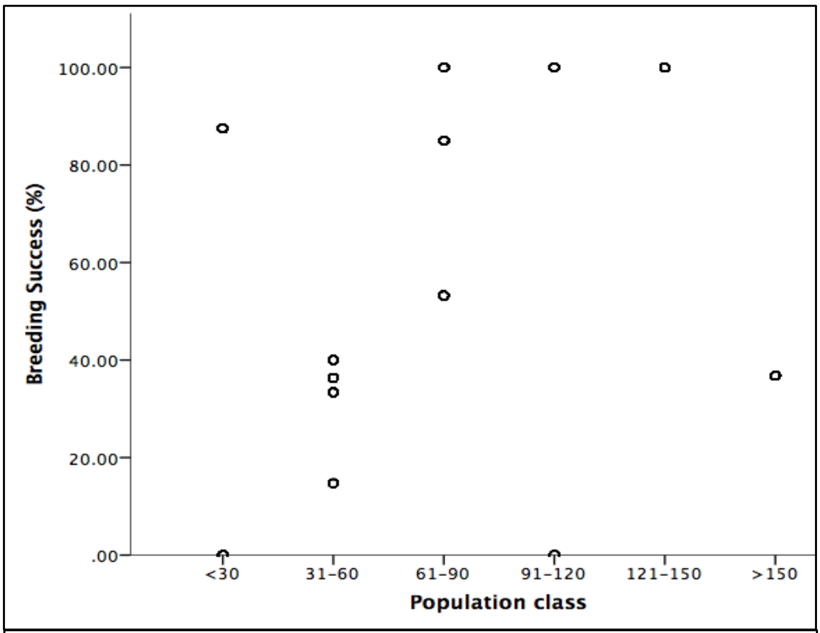

Figure 4.8: Breeding success (%) of the AENS at different population class

Breeding seasonality and roosting pattern: Among the breeding stages, the proportion of birds returned within peak roosting hours (PRH:1700 to 2000) differed significantly ($\chi^2=9.162$, df=3, $P<0.05$). A higher proportion of birds returned within PRH during nest-building and fledgeling stages (94.06±07.05% SD, n=28 and 95.80±07.91% SD, n=4 respectively), as compared to the incubation (Mean=71.13±12.55% SD, n=25) and nestling stages (Mean=71.07± 24.77%SD,

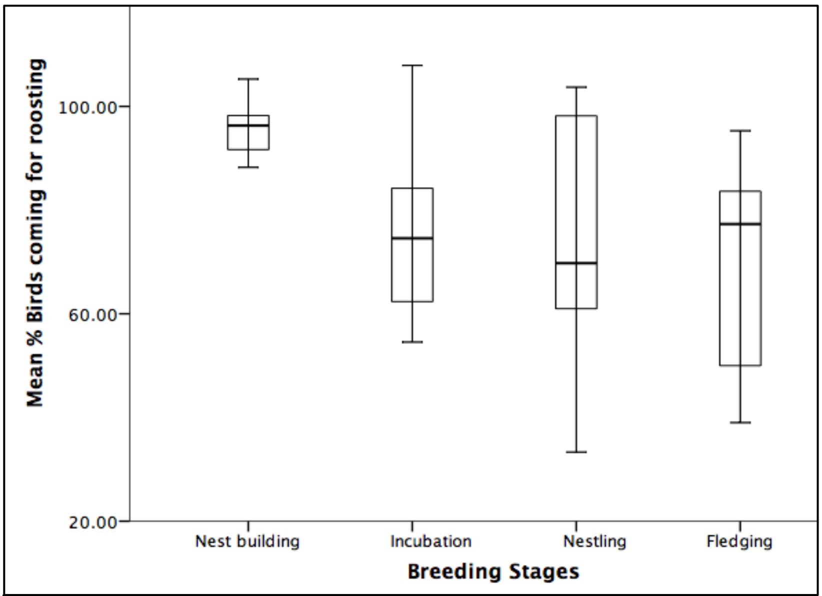

Figure 4.9: Mean % birds coming for roosting in different breeding stages at Andaman Islands

n=24). Kruskal-Wallis Test showed that the entry and exit proportion of birds varied significantly in different breeding stages (Entry: χ^2=253.53, df=3, p<0.05 and for Exit: χ^2=386.35, df=3, p<0.05; Figure 4.9). The Wilcoxon Test showed the difference in the proportion of birds during nesting & incubation (W=33, P<0.05). Further, a significant variation was found in the time of the first arrival among different breeding stages (χ^2=15.276, df=3, *P*<0.005). In addition, the first bird arrived significantly later during the nest-building stage (nest-building =1724±0.01h SD; Incubation =1714±0.00h SD; Nestling =1718 ± 0.01h SD; Fledging =1715±0.00h SD).

4.5.3. Co-existing species inside the caves

Several instances of predation of nests, eggs, nestlings and adult swiftlets were observed in the A & N Islands since 1999 onwards (Manchi & Sankaran 2009). Along with the known predators of swiftlets from present and past studies, some potential predators were also observed coexisting inside caves (Annexure 4.1). During the 422 observations to identify the potential predators of the AENS and its nest, various fauna co-existing in 16 caves at Baratang Island cave complex were encountered. In total, 2340 Crabs (Arachinid), 1905 Whip spiders (Amblypygi), 1663 crickets (Rhaphidophoridae), 1682 Cockroaches (Nocticolidae), 1352 bats (Chiroptera), 276 Andaman bent-toed gecko *Cyrtodactylus rubidus*, 120 spiders (Hymenoptera), 37 Centipedes (Thereuopoda), 03 Frogs (Asian common toad & Indian burrowing frog) and 02 Red-tailed Trinket Snake *Gonyosoma oxycephalum* were counted (Annexure 4.2). Crabs (31.8±26.67), Whip spiders (23.6±18.91), crickets (16.8±16.40), cockroach (14.2±20.05) were more abundant followed by Geckos (5.8±8.94), Spiders (3.5±9.58) and Bats (3.4±15.05). Centipedes (0.5±2.80), Frogs (0.1±0.83) and Snakes (0.03±0.41) were less abundant inside the caves. Potential predators encountered in different

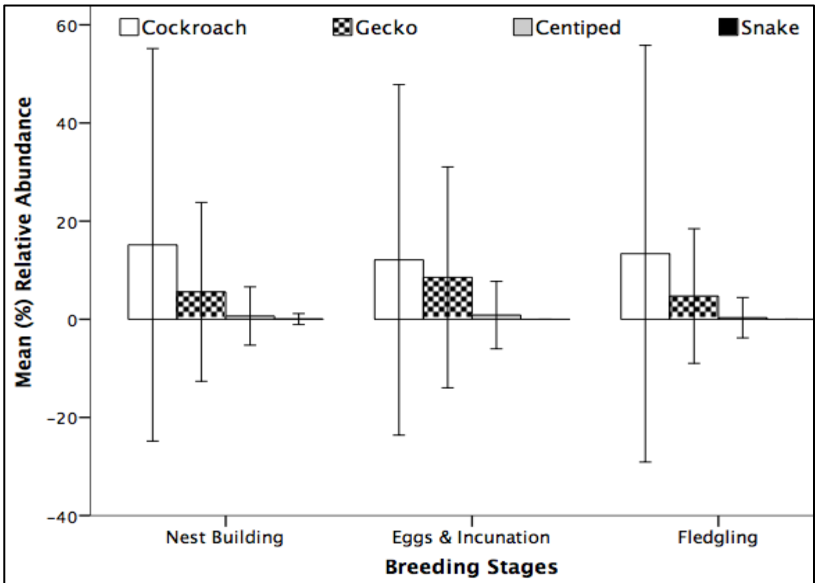

Figure 4.10: Mean (%) Relative Abundance of potential predator species in different breeding stages of AENS

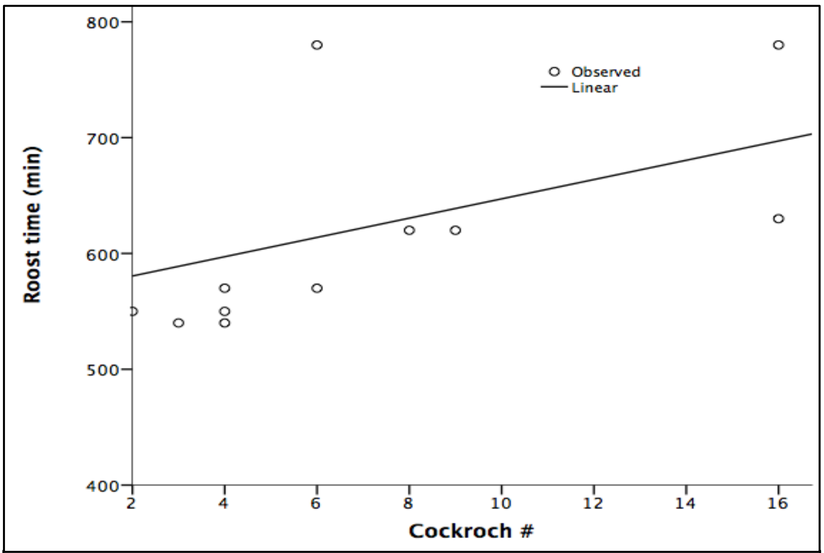

Figure 4.11: Roost Period (min) of AENS and Cockroach numbers inside the caves at Andaman Is. Y (Roosting period) =563.86 (8.33 (Cockroach#)); F=1.146; p=0.045 (p<0.050); Adj. R^2=0.044

breeding stages were mainly Cockroaches, Geckos, Centipede and Snakes (Figure 4.10). The presence of some species in the caves showed their effect on roosting behaviours of AENS. With the positive correlation, a daily roosting period of AENS varied significantly [F(3,87)=4.471, P<0.01] according to the abundance of the cockroaches inside the cave (Figure 4.11). Further, Tukey's Post Hoc test revealed that roosting Period class 01 (400-500 minutes), 02 (501-600 minutes) and 03 (601-700 minutes) are different from class 04 (>700 minutes) when cockroaches were relatively more abundant inside the cave (Table 4.3). Further, Crickets, Bats, Gecko and Whip spider abundance also differed significantly with breeding stages (Table 4.4). As per Tukey's Post Hoc test, Crickets were more abundant during fledgeling time whereas bats were seen more in nest building time. In birds eating bats (e.g. *Megadarma* sp.) were encountered in any of the surveyed caves. The Geckos are known for predation on eggs, they found were abundant when eggs were present inside the nests. On the contrary, Crickets were found abundant except during incubation stage. Rest of the species did not show any relation with the breeding stages or roosting period. The abundance of all co-existing species varied in different caves (Annexure 4.2).

Table 4.3 Pearson's correlation matrix to show the relationship between minimum roosting Period (min) of AENS and abundance of the Co-existing species inside the caves at Baratang

	cockroach	**spider**	**cricket**	**bat**	**gecko**	**whip spider**	**Pill bug**	**crab**
Roosting Period	.210*	-0.032	-0.062	-0.004	-0.01	0.068	0.039	-0.012
cockroch	---	0.106	-.217*	-0.04	0.359**	-0.097	-0.064	-0.152
spider	---	---	-.341**	-0.063	0.159	-.306**	-0.104	-.359**
cricket	---	---	---	-0.095	-.205*	.711**	-0.089	.722**
bat	---	---	---	---	-0.065	-0.027	.699**	-0.05
gecko	---	---	---	---	---	-.315**	-0.108	-.300**
webspider	---	---	---	---	---	---	-0.029	.683**
blackinsect	---	---	---	---	---	---	---	-0.03

*. significance at the 0.05 level (2-tailed). **. significance at the 0.01 level (2-tailed).

Table 4.4 Analysis of Variance for Co-existing species abundance in breeding stages of AENS

Species		**Nest building**	**Eggs & Incubation**	**Fledgling**	**F**	**P**
Cricket	Mean	13.3	16.4	23.18	15.974	0.0001
	SD	15.782	15.228	16.27		
	N	229	65	128		
Bat	Mean	6.25	0	0	9.397	0.0001
	SD	20.011	0	0		
	N	229	65	128		
Gecko	Mean	5.58	8.54	4.74	4.081	0.05
	SD	9.112	11.253	6.859		
	N	229	65	128		
Whip spider	Mean	13.3	16.4	23.18	3.656	0.05
	SD	15.782	15.228	16.27		
	N	229	65	128		

Note: other than mentioned species, P>0.05

4.5.4. Potential predators outside the caves

Owl abundance and activity: Total 1584 observations of 05 Owl species at 17-point stations were recorded at Baratang. The most common Owl species was Andaman Scops Owl *Otus balli* (ASCO) (57.01%, n=903) followed by Hume's Hawk Owl *Ninox scutulata obscura* (HHO) (20.58%, n=326), Andaman Hawk Owl *Ninox affinis* (AHO) (16.29 %, n = 258), Oriental Scops Owl *Otus sunia* (OSCO) (05.62%, n=89) and Andaman Barn Owl *Tyto deroepstorffi* (ABO) (0.51%, n=8) (Figure 4.12). These owls were seen distributed in all the forest types available in the study area (Figure 4.13, Plate: Owls at study site). However, their relative abundance varied significantly between the forest types (F=15.931, df=3, P=0.000).

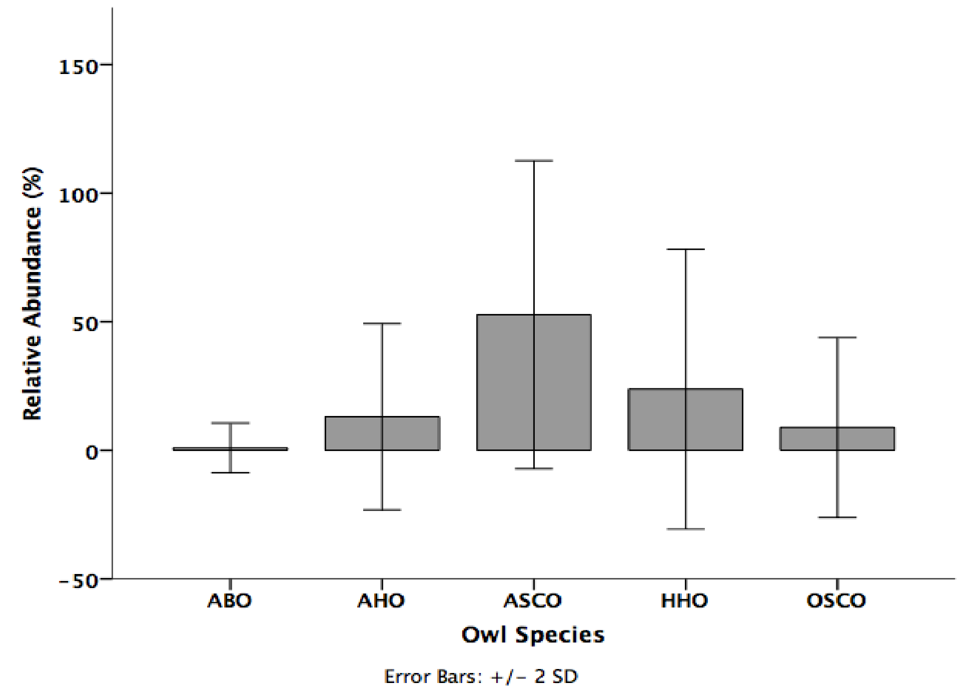

Figure 4.12: Owl Abundance at Baratang Islands Note: Andaman Barn Owl *Tyto deroepstorffi* (ABO), Andaman Hawk Owl *Ninox affinis* (AHO), Andaman Scops Owl *Otus balli* (ASCO), Hume's Hawk Owl *Ninox scutulate obscura* (HHO) and Oriental Scops Owl *Otus sunia* (OSCO)

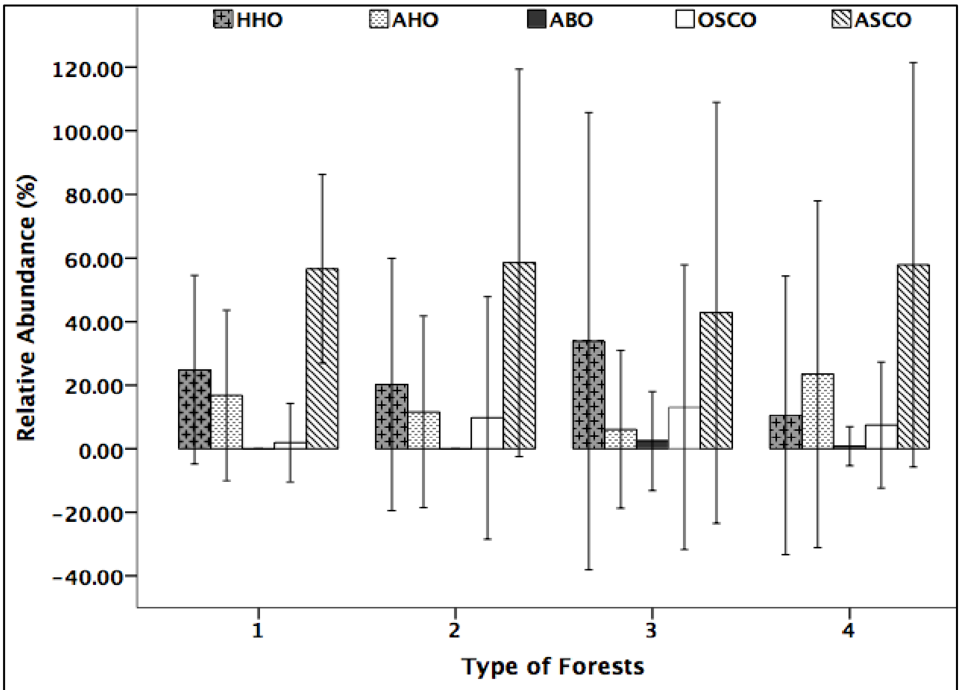

Figure 4.13: Abundance of Owls in Different forest areas Note: Forest Types: 1) Mangroves adjoining Agricultural area 2) bamboo brakes, 3) Evergreen forest and 4) Plantation.

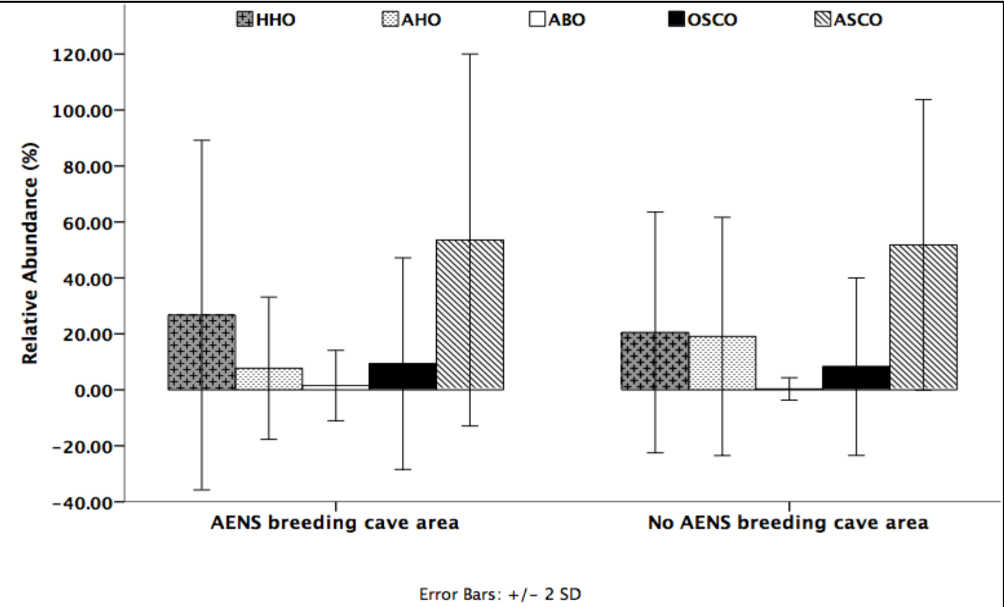

Figure 4.14: Abundance of Owls in AENS breeding cave area and No AENS breeding area

The owls were most abundant (42.57%) in bamboo brakes followed by Teak plantation (26.87%), Mangroves adjoining Agricultural area (20.45%) and Evergreen forest (10.11%). Among all the species AHO (F=7.590, df=3, p=0.000) and HHO (F=5.797, df=3, p=0.001) showed highly significant variation with high abundances in the Teak plantation and Evergreen forest respectively (Figure 4.13). Whereas, the abundance of remaining species also varied among habitats (for ASCO: F=3.171, df=3, P=0.026; for OSCO: F=2.954, df= 3, p=0.034 and for ABO: F=2.833, df=3, p=0.040). Though the overall owl abundance does not vary much in the AENS breeding cave area and No AENS breeding area (Figure 4.14), AHO had a significant variation in high abundance in the AENS breeding cave area compared to the No AENS breeding area (F=17.675, df=1, p=0.000).

Different species of owls were observed calling or began calling in various light conditions. The Owls usually started calling during dusk in the presence of 40.8±32.41 Lux of natural light. The HHO was first to call, in the presence of 48.90±32.46 Lux of natural light, followed by AHO (44.72±32.38 Lux of natural light) and ASCO (42.55±32.41 Lux of natural light). The OSCO was the late riser, always started calling in almost dark conditions (13.41±32.47 Lux of natural light, Figure 4.15). The ABO was heard less and only in the dark.

The regression models were suggestive of the role played by different environmental factors in the presence of owls in various habitats. Overall, the relative abundance of owls was influenced significantly by the macro habitat, i.e. forest type (Table 4.5), wherein the owls were found more abundant in the moist bamboo forest and least abundant in the evergreen forest. The identified potential predator, HHO and AHO abundance was then checked with different environmental conditions with a regression model. The forest plantation and highest tree branch height (standardised β=0.0034 and -1.739, respectively) showed an adverse effect on the relative abundance of the HHO (Table 4.6). Similarly, in the case of the AHO standardised β was close to zero for the highest branch height and canopy cover, and was negative for tree GBH and the Evergreen forest. This indicates that the AHO avoided the dense evergreen forest at the Baratang Islands (standardised β=-1.379; Table 4.7).

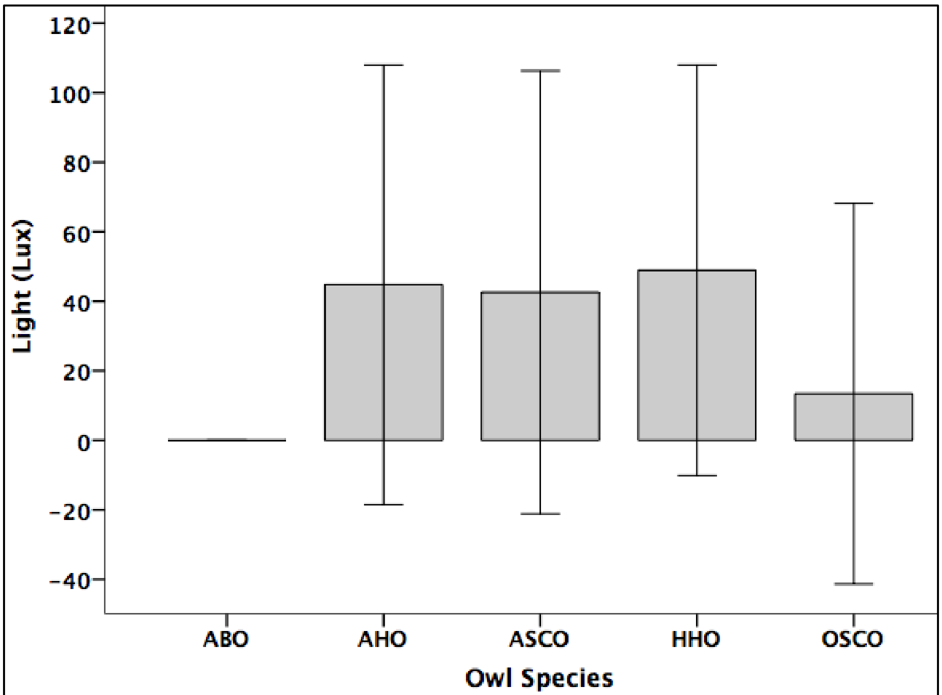

Figure 4.15: Owl activity during dusk light

Table 4.5 Multiple regression (Forward type) to show the Owl abundance in different environmental conditions at Baratang Island, Andaman.

Multiple regression equation for predicting Owl numbers /movement in the Baratang Is.: Owl number =11.867 + 0.001 [Environmental Light (during first call)] - 2.911 (Evergreen Forest) + 6.215 (Moist Bamboo Forest); Adj R^2= 0.334; F=12.395.

Model	Unstandardized Coefficients		Stand. Coeff.	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	11.867	0.761		15.596	0.001	10.357	13.377					
Environmental Light	0.001	0.016	0.005	0.054	0.957	-0.03	0.032	0.275	0.005	0.004	0.727	1.376
Evergreen Forest	-2.911	1.309	-0.197	-2.223	0.028	-5.508	-0.313	-0.376	-0.218	-0.182	0.854	1.171
Moist Bamboo Forest	6.215	1.349	0.539	4.609	0.001	3.54	8.891	0.399	0.42	0.378	0.492	2.033

Plate: Owls at study site; A = Hume's Hawk Owl *Ninox scutulata obscura*, B = Andaman Scops Owl *Otus balli*, C = Oriental Scops Owl *Otus sunia* and D = Andaman Barn Owl *Tyto deroepstorffi*

Table 4.6 Multiple regression (Forward type) to show the abundance of Hume's Hawk Owl (HHO) in the Baratang Island, Andaman.

Multiple regression equation for predicting Hume's Hawk Owl numbers /movement in the Baratang Is.: Owl number =1.774 + 0.034 [Highest Branch Height (ft)]- 1.739 (Teak Forest); Adj R^2= 0.162; F=9.757.

Model	Unstandardized Coefficients		Stand. Coeff. Beta	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error				Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	1.774	0.464		3.824	0.001	0.854	2.694					
Highest Branch Height (ft)	0.034	0.012	0.259	2.848	0.005	0.01	0.057	0.257	0.273	0.259	1	1
Teak Plantation	-1.739	0.511	-0.31	-3.402	0.001	-2.753	-0.725	-0.308	-0.321	-0.31	1	1

Table 4.7 Multiple regression (Forward type) to show the abundance of Andaman Hawk Owl (AHO) in the Baratang Island, Andaman.

Multiple regression equation for predicting Andaman Hawk Owl numbers /movement in the Baratang Is.: Owl number = -0.573 + 0.065 [Highest Branch Height (ft)] + 0.058 [Canapy (%)] - 0.016 [Tree GBH (cm)] - 1.379 (Evergreen Forest); Adj R^2= 0.223; F=7.100.

Model	Unstandardized Coefficients		Stand. Coeff. Beta	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error				Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	-0.573	1.051		-0.545	0.587	-2.659	1.513					
Highest Branch Height (ft)	0.065	0.013	0.531	4.908	0.001	0.039	0.091	0.32	0.442	0.435	0.67	1.492
Canopy cover (%)	0.058	0.019	0.322	3.065	0.003	0.02	0.095	0.055	0.294	0.272	0.711	1.406
Tree GBH (cm)	-0.016	0.006	-0.258	-2.524	0.013	-0.029	-0.003	-0.001	-0.246	-0.224	0.753	1.328
Evergreen Forest	-1.379	0.605	-0.204	-2.28	0.025	-2.578	-0.179	-0.173	-0.223	-0.202	0.985	1.015

4.6. DISCUSSION

Variations in roosting movement and roosting period were seen to be a function of the colony size. Therefore, it can now be documented that the AENS partially follows the hypothesis that birds in big colonies forage possibly far and for a long time to get the maximum bouts of the day for a successful breeding. This needs further confirmation, as the distance covered by the individuals away from cave could not be measured in the present study. Earlier documents, (Manchi 2009, Manchi & Sankaran 2010, Manchi & Mane 2012, Mane & Manchi 2017) have linked arrival timing of AENS with distance travelled for foraging, which suggests that the longer the distance travelled by the bird for foraging away from the breeding or roosting cave and the intense is its foraging attempt till last light, the more is the arrival timing of the bird to its cave. From the findings of the present study and the available literature, it can be inferred that the species supports the hypothesis mentioned above.

Some of the AENS colonies were without non-breeding population. These populations were seen returning to their roosting sites earlier than the colonies with the non-breeding populations. As observed by Manchi and Sankaran (2010) during breeding the AENS do not go far from the breeding colonies for want of their presence to perform parental duties (like incubation and chick rearing). Since the non-breeders have no such responsibility, they may go far to avoid the competition for food with the breeders foraging near the breeding sites. Further, they may be returning late to their roosting sites.

As the timing of breeding of most species in tropics is the reflection of their ecological niche, the insectivores breed close to the arrival of the rains when insects thrived (Immelmann, 1971). Similarly, the breeding seasonality of swiftlets depends on food availability and weather conditions at foraging grounds (Medway 1962a, Francis 1987, Nguyen *et al.* 2002, Lim & Cranbrook 2002, Manchi 2009, Tarburton & Tarburton 2013). The AENS in India has a well-marked breeding season (Sankaran 1998, Manchi 2009), unlike Borneo and some other South East Asian countries where *A. fuciphagus* is known to breed round the year (Lim & Cranbrook 2002). The AENS breeds from December to August with two peaks in egg laying like *A. germani* (Nguyen et al. 2002). Most of the species have been evolved to stay in synchrony with the seasonal variability to enhance their fitness for survival (Hau 2001, Helm *et al.* 2009) but the population at West coast, Interview

Island found delaying it is breeding by two weeks than East coast population at Baratang Island and Chalis-ek. This is possibly due to the variations in the local precipitations, which can affect local food availability for the species (Johnson 1969, Schowalter 2016). Though table 4.2 depicts no nest construction during January in Interview Island, few pairs (2% population of the colony) out of our sampling were observed building their nest foundations. This might have resulted in a change in breeding time, as the AENS are known to forage close to their breeding caves during the breeding season (Manchi & Sankaran 2010).

The nest construction period is extended (61.10±10.96 SD days) in the study area, during which individuals returned after dusk for longer roosting bouts. The birds were also seen leaving the roost site before dawn, for foraging, maybe to accomplish the relatively high protein/energy requirement, during the nest-building season, to produce enough saliva in the seasonally enlarged salivary glands (Marshall & Folley 1956, Medway 1962b, Lim & Cranbrook 2002, Manchi 2009). Like other swiftlets, AENS also has one parent obliged to be at the nest during the incubation period (Medway 1962b Lim & Cranbrook 2002, Nguyen *et al.* 2002, Manchi 2009). Both parents try to forage maximum, just before roosting and try returning to attend the nest and eggs as quickly as possible. However, during the nestling and fledging period, throughout the day, parents make multiple visits to the nests and chicks for feeding the chicks (Manchi 2009). This also allows them to forage longer before roosting, resulting in comparatively less proportion of birds returning for roosting within the PRH. As food/energy requirements in different breeding stages influence the roosting patterns of the species, fluctuations were seen in the proportion of birds roosting in caves (Manchi 2009, Manchi & Sankaran 2014).

Though AENS were understood to get adapted to caves for security, they still have threats from predators. Predators of swiftlets include both vertebrates (e.g., cats, rats, bats, owls, raptors, snakes and geckoes) and invertebrates (e.g., centipedes, cockroaches, crickets lice and flies) (Sankaran 1998, Lim & Cranbrook 2002, Naguyen *et al.* 2002, Manchi & Sankaran 2009). Predation can affect the population of colonial breeders (Manchi 2009). The cockroach is a known nest predator, and its abundance seemed to have influenced the roosting period of AENS, which gets longer with more abundance of the Cockroach. As the Cockroaches destroy the nests, the birds may have to spend a long time inside the cave to repair the nests. The Crickets, Bats, Geckos and Whip spider abundance differs with breeding stages. Geckos abundance while egg laying and incubation time of AENS was high, as they are known to predate on eggs. The Giant Crickets in South-East Asia are known as predators of the swiftlets, and they were found abundant except during the incubation stage, but no such records of predation /damage were recorded from the study area. As documented from the Dandak cave of Kanger Valley National Park in India, Cricket *sp.* in the study caves was more abundant (Biswas & shrotriya 2011), particularly during the fledging time of AENS. Bats were found more common during the nest building. The detailed study of these co-existing species will throw light on the competition among these co-existing cave dwellers. The survey month was the major factor determining the presence of species in cave sectors, indicating that cave-dwelling taxa show strong seasonality in activity and distribution. The interactions between sampling period and microclimatic features for multiple species suggested the microhabitat association by species throughout the year.

The AENS do not have predators only inside the cave but even outside the caves. The well-known predators of swiftlets in the A & N Islands are Owls. At Baratang Island owls are more active during the dawn and dusk (Mane & Manchi 2013) particularly at the cave openings. The presence of these predators does affect the roosting behaviour of the species, which compels for adaptation as an anti-predatory strategy. As described by Tarburton (2009), swiftlets have developed the anti-predatory strategies either by changing their arrival time for roosting or by entering the roosting caves in a group. Since the AENS in the islands were never seen entering the caves in-group for roosting, the variations in the roosting the movements of the AENS were confirmed as an anti-predatory Strategy (Mane & Manchi 2017).

Hunting behaviour of the Owl is based on the diurnal or nocturnal nature of its prey. However, they mostly hunt after sunset (Taylor *et al.* 1988, Petty 1989, Green *et al.* 1993, Yosef & Deyrup 1994, Rubolini *et al.* 2003). Additionally, the proportion of the canopy cover for camouflaging and height of the first branch suitable for perching are the key factors while hunting. The results depict that the habitat and environmental factors were influencing the presence of owls in the study area (Ulmschneider 1990, Rubolini *et al.* 2003). Apart from a variety of fauna, the HHO is the known to predate on the AENS in the islands (Manchi & Sankaran 2009). The study showed that the species is more abundant in the Evergreen and AENS breeding area where the swiftlet caves are available. Possibly the HHO has more influence on the population of bats and swiftlets as compared to other owls due to crepuscular nature and strategies to hunt the swiftlets and bats in the area. HHOs' were observed hunting of swiftlets in the cave openings of Interview, Chalis-ek and Baratang Islands while the birds entered or exited from the caves at dusk and dawn. As well as, the HHO was seen roosting just below the AENS colony on the manmade scaffolding inside the cave at Interview Island (Manchi 2009). The high abundance of owls in the deciduous and open forest of bamboo brakes and teak plantation was possibly the result of better visibility of the prey compare to the other habitats. The fluctuation in activity and abundance of all owl species AENS breeding area in evergreen forest and non-swiftlet area was seen possibly due to change in prey abundance and co-existing species niche separation. The detailed study of the owl's territory and diet analysis following radio tagging techniques can help in understanding the amount of the hunting pressure by the owls on the AENS population.

By now, now it is known that the biotic factors affect the AENS in several ways concerning their roosting patterns and behaviour. This suggests exploring further more regarding other related factors that influence the species.

Chapter 5: Abiotic factors and roosting patterns of the Andaman Edible-nest Swiftlet

5.1. INTRODUCTION

Akin to biotic, abiotic factors also are known to influence the roosting and foraging habits / patterns of animals (Anthony *et al.* 1981, Bakken & Lee 1992, Klomp & Furness 1992, Rahman *et al.* 2004, Lang *et al.* 2006, Lillywhite & Brischoux 2012, Cozzi *et al.* 2012). It is difficult in most of the cases to understand how significantly particular environmental factors may influence a particular behaviour of an animal. Many studies focused on understanding the changes in roosting or foraging habits and predator-prey interactions of different taxa resulted by various abiotic factors like light, temperature, wind, and rainfall (Nelson 1989, Mougeoto & Bretagnolle 2000, Powell *et al.* 2008). Roosting sites represent secure resources for breeding, which also provides shelter from harsh weather and concealment from the potential predators and thermal stability (Nilson 1984, Cody 1985, Kortner & Geiser 2000, Woltmann 2004,). Roosting behaviour and roost site selection are known to have impacts on individual fitness and deciding a precise cost for energy budgets (Vonhof & Barclay 1996). The social attraction to breed near successful conspecific to benefit the same favourable local environmental conditions is observed in many bird species which possibly played a role in the evolution of the coloniality (Cody 1985, Danchin *et al.* 1998, Jones 2001). It is also understood that most of the species select roosting sites by the availability of foraging grounds (Cody 1985).

Swiftlets, the trogloxenes, roost inside caves or in cavern-like spaces, where they cling to the surface of walls or ceilings or their self-supporting bracket-shaped nests while roosting (Ford & Cullingford 1976, Lim & Cranbrook 2002). As swiftlets have a strong instinct towards nest site fidelity, they use particular roosting /nesting places throughout the years. They build the nest in inaccessible places inside the caves where the microclimate is stable, and predators are few (Tarburton 1987, Manchi 2009) and which strongly affect the breeding success and the population dynamics within the population (Viruhpintu *et al.* 2002, Manchi 2009, Suwanrat 2014). The ability to echolocate enables Edible-nest Swiftlet to navigate in the dark zones of caves to roost and nest (Medway 1959). Studies related to the habitat of swiftlets discuss the occurrence of the species in different habitats and weather conditions (Medway 1962b, Langham 1980, Hails & Amirrudin 1981, Waugh & Hails 1983, Lim & Cranbrook 2002, Nguyen *et al.* 2002). Swiftlets have a known foraging range of about 250-300 km from the breeding site (Phach *et al.* 2002), therefore above said possibility might not be considered by the species for the roost site selection. Moreover, availability of the cave or cave like structure may be a limitation for the swiftlets while selecting a place for roosting or breeding.

Moonlight controls the plasma melatonin levels (Tarlow *et al.* 2003) and also affects sexual signalling and territorial displays (York *et al.* 2014) in some birds. Overall, these studies have highlighted the effects of moonlight on the physiology and activity pattern of birds. The study on breeding biology and influence of cave structure, microclimate and nest harvesting was done on the White-nest Swiftlet *Collocalia fuciphaga germani* in Vietnam (Phach & Voisin 1998) and Andaman Edible-nest Swiftlet *A. f. inexpectatus* (Manchi 2009). Environmental variables like day length, sunrise, sunset times, temperature, humidity, cloud covers, environmental wind, environmental light, moon phase, cave structures, cave openings, length, the shape of the cave mouth, type of caves are never considered in details to study the roosting pattern of *Aerodramus* swiftlet. The present study is the first to document the temporal roosting patterns of any Edible-nest Swiftlet *Aerodramus fuciphagus*, after the natural history observations by Medway (1962b) in Sarawak. The external environment and its effect on roosting of *Collocalia maxima* and *Collocalia salangana* were briefly addressed by Medway (in 1962 a & b). To bridge gaps in knowledge and methods, present study endeavoured to find the relation between roosting behaviour and most determinant environmental factor affecting the roosting site selection and behaviour of the AENS.

5.2. OBJECTIVES

This section of the study was initiated with an objective to identify the environmental factors and understand their role in roosting decisions of the AENS

5.3. FIELD METHODS AND DATA ANALYSIS

The cave location information was collected for 314 caves in the Andaman Islands. The microhabitat characters of the roost-sites of the AENS were studied in 39 caves on Baratang Island in the North and Middle Andaman Islands. Details of the study area and caves are mentioned in chapter 2.

5.3.1. Roosting habitat

To study the roosting site characters, data was collected from the active and inactive roost locations of AENS (table 5.1). Inactive roosting sites (used earlier by the birds) were identified by the marks left behind by roost/nest on the rock surface and also verified by the nest collectors. The random point were laid along the strait line transects on the cave walls at different heights (60 cm vertical distance from each other) and transverse distance (100 cm from each other).

Table 5.1: sampling efforts to study physical characters of Cave (Micro-level)

Sampling methods	# Samples	# Caves sampled
Random points	1199	30
Active roost	173	33
Inactive roost	200	15

The methods for the macrolevel physical characters (Cave Type, Cave Size, Light Zones, Vegetation Type & Rock Type of Area and Direction of Cave Length) of the caves (n=204) are discussed in chapter 2.

Data regarding roost-site characters were collected using following methods:

1) Surface Texture: Several methods are available to measure the surface texture (R) of cave/even wall or rock surfaces (De Freitas & Schmekal 2003 & 2006, Rasouli & Harrison 2004, Thornbush & Viles 2004, Cunat *et al.* 2005, Walker *et al.* 2005, Lemy *et al.* 2006, Fischer & Lüttge 2007, Baker *et al.* 2008, Tatone & Grasselli 2012, Medapati *et al.* 2013). Since most of the available methods were not cost-effective or suitable inside inaccessible caves with small openings, we tried to develop an innovative and cost-effective imprint ridge count (IRC) method. A graph paper was placed over the rock surface/roost site. The wax pencil was rubbed over the paper with uniform pressure in a vertical direction to get an imprint of the rock surface at the point of interest, covering 3 cm radius circle (Figure 5). Once the imprint is taken on the graph sheet, the impression of the ridges per cm^2 was counted. For each roost site, $8cm^2$ area was sampled. The ridges were counted in each square centimetre area. The average numbers of ridges were used to represent the various scales of the surface texture. Higher the number of ridges smoother the surface texture, similarly, a low number of ridges represent high roughness of the rock surface. Accordingly, the classes of the surface texture were categorized as Rough (<20 average ridges/cm^2), Slightly rough (21-40 average ridges/cm^2) and smooth (41-60 average ridges/cm^2).

2) Support: Support is usually an accumulation of calcium carbonate developed at the base of the nest because of the repetitive nesting at the same place, or an outgrowth of the rock can be used for holding while roosting. The presence of any such support at the sample point was observed visually and noted (Viruhpintu *et al.* 2002, Manchi 2009).

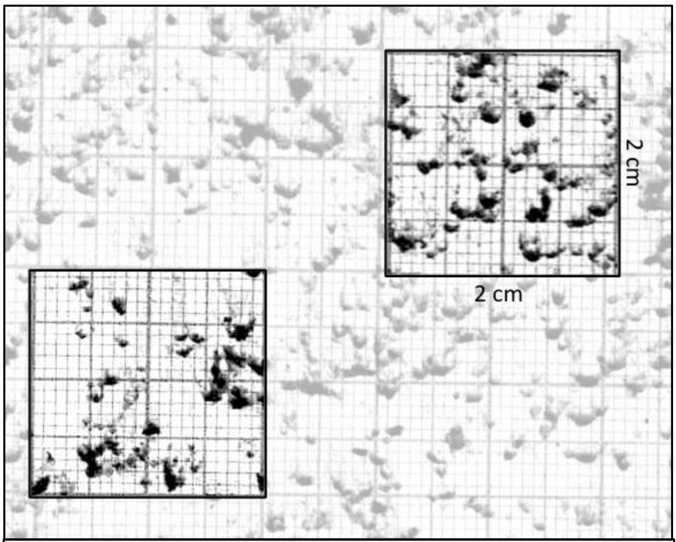

Figure 5: Imprint of the rock surface at point of interest

3) Wall inclination: Unevenly structured limestone caves of the Andaman Islands have the inside cave walls standing randomly in various angles concerning the ground. Following Manchi (2009) the inclination of the cave wall was qualitatively classified on visual basis into three categories:

a) *flat* (St): wall approximate at 90° to the ground,
b) *inwardly inclined* (I): wall making an acute angle with the ground and
c) *outwardly inclined* (O): wall making an obtuse angle with the ground.

4) Roost site to cave mouth (RCM): Minimum distance (cm) from the roost site to the cave opening was measured using the Freemans' measuring tape.
5) Slope (Slp): Slope at the sample point was estimated in degrees using the SUNTO MC-1 clinometer mirror compass to measure the length of one side (b) of a triangle. The formula to calculate angle: sin B/b=sin A/a. Where 'A' is known the angle, and 'a' is known side of a triangle. The side 'b' of the triangle was measured with a scale clinometer compass, and angle 'B' was calculated. Then, the formula: C=180 - A- B was used to calculate the slope at the sample point.
6) The roost height (NH): The minimum distance between the sample point and the approachable ground was considered to be the point where droppings of the bird fall from the roost. The distance was measured in cm using the Freemans' measuring tape.
7) The total height (TH): The distance between the sample point and the cave floor was considered as the height of the roosting/nesting place and measured in cm using Freemans'

measuring tape.

8) Nest density (Den): Nest density also gives us the number of birds roosting in a group or isolation. It was estimated by counting the number of nests or nesting sites per square meter (Nests/m^2). The nests at a distance of more than 1 meter from the group or any other nest were not considered as part of the group and were mentioned as a single nest (Sng)/ pair roosting site.
9) Neighboring pair roosting distance (NPR) was measured in cm with measuring tape.
10) Distance from nearest light source (NL) was measured in cm from the place of light penetration inside the cave to the roost site.
11) Since bats (*Chiroptera*) & glossy swiftlet do compete roosting sites in caves with AENS, the distance (in cm) from co-existing species (DCS) was recorded wherever available.
12) The presence of mud at sampling site was recorded as Little Mud (LMd): if 5-25% surface area covered with mud, Medium Mud (MMd): if 26-45% surface area covered with mud and High level of Mud (HMd): if >45% surface area covered with mud. The surface area=3cm radius circle at sampling point and considered as not suitable for roosting if at >5% of the area is covered by mud.
13) Presence and absence of water (Wtr) at roosting/sampling site was recorded with visual observations and placing a piece of paper over the surface.

5.3.2. Environmental factors

1) Wind velocity (WV) from cave mouth to each 5 meters distance inside the cave and at the roosting site was recorded using handheld Digital Anemometer AM4201 (meter/sec).
2) Light intensity (Lt) at cave opening and every 5 meters distance inside the cave till the zero light zone and sampling site were recorded using Digital Traceable® Dual-Range Light Meter (illuminance/square meter).
3) Micrometeorological parameters such as temperature (^oC) and relative humidity (RH%) were recorded near the roosting colony (n=six caves) and outside the caves twice a day at 06:00 hours and 18:00 hours. The observations were repeated twice in a week throughout the breeding season of AENS using Digital (288ATH) thermo-hygrometers.
4) Day length (hours) data for the geographical locations of three islands on the particular observation days, was accessed from an online source (http://www.timeanddate.com).
5) Sunset and sunrise timings for the geographical locations of three islands on the particular observation days were accessed from an online source (http://www.timeanddate.com) and cross-checked with data recorded during roost counts in the field.

6) During roosting time and time of first bird arrival and departure was also recorded (detail method for roost count is discussed in chapter 3).
7) Moon Phase: New moon (NM) and Full moon (FM) illumination data on roost count days were accessed from an online source (http://www.timeanddate.com) for the study site.

5.3.3. Statistical analyses

Binary logistic regression (Forward Step (LR)) was employed to predict the probability of the presence of the AENS in a cave concerning its habitat characters. The predictor variables were cave location type, cave type, forest type, cave size, cave opening shape, cave length direction, cave opening width & length, the number of cave openings, Multiple Regression (Forward type) was performed to determine the preference by the roosting population of AENS in caves at Baratang. (Detailed habitat characters were mentioned in chapter 2 results). Cave sizes and the difference in population was checked using Analysis of Variance followed by Tukey's multiple comparisons. Cave type location and AENS population were compared by performing independent sampled t-test. The Pearson's correlation was checked among the width, length and area of cave opening and AENS population. Statistical analyses were performed using IBM SPSS Version 22. The values are expressed as mean±SD, and in all the statistical analyses $p<0.05$ were considered significant.

Habitat preference of the AENS was assessed using both pooled and unpooled data of sampled roost-site characteristics after estimating the proportionate difference between roost sites (used) and random points (availability) using contingency tables (Moore & Cobby, 1998). The data was sorted into multiple combinations of 16 characters and probable combination preferred at study site was reckoned. The. Ivlev's Electivity Index (E)$Ei=(ui-ri) / (ui+ri)$ was followed to estimate the preference of the characters at the roost site. Where ui is the proportion of rock character or the combination i at roost sites (used), and ri is the percentage of the rock character or combination at random sites (available) in the caves. E values range from -1 to +1, with values above zero indicating a preference, values below zero indicating avoidance, and values equal to 0 indicating no selection (Alwany 2003). A character or combination with less than five observations was merged with most closely associated neighbouring character and combination for the analysis. To study the microhabitat and roosting patterns, Binary logistic regression (Forward Step (LR)) employed to predict the probability that birds roosting site selection with population change.

Further, the significant variables indicated by the model were described in detail.

Linear regression was performed to understand the environmental variables and change in the proportion of birds roosting and time spent in the roost. Univariate Analysis of Variance was performed followed by Tukey's Test for multiple comparisons, to check a variation in movement during different day length, sunset-sunrise timings at various hours of a day, months, at caves and sites. Further, performing Wilcoxon signed rank test, with continuity correction, tested the significance of the influence of lunar phase on time and proportion of roosting birds. The 43 observations were analysed using Kruskal-Wallis test with continuity correlation, to examine the variations in AENS' roosting behaviour after sunset time, with the breeding stage. Statistical analyses were performed (Zar 2008) using Excel: Mac 2011, Ver. 14.6.2. IBM SPSS Version 22 and the statistical programming language R 3. 2. 3 with R-Studio as an interface (R Studio Team 2015).

5.4. RESULTS

5.4.1. Roosting habitat (Micro level):

The proportion of different microlevel characters available in the caves and used by AENS in caves varied significantly. The result of logistic regression showed coefficient and odds ratio for each of the predictors (Table 5.2). The Binary Logistic Analysis indicated that Total Height of the roost-site (THT), Surface Texture, Wall Angle (Inward) and Roosting Support (Yes) had a significant effect ($p<0.05$) on the selection of roosting sites by birds in Baratang Islands.

Table 5.2: Binary Logistic regression analysis Forward Step (LR) to predict the probability that AENS roosting site selection with population change.

The dependent variable which measures the usage of roosting with population increase is YES. YES is equal to 1 if the growth in bird number and birds would still use the site for roosting and 0 otherwise. The predictor variables were Slope, Roost Height (RH), Total Height from the ground (TH), Surface Texture (R), Wall Angle, Roost/Nest Support, Rock surface covered, dry and wet of the wall surface and three dummy variables coding the scenario.

Variables in equation	**B (S.E.)**	**Exp(B)**	**95%C.I. of Odds Ratio**	
			Lower	**Upper**
Constant	-28.179 (7567.159)	—	—	—
TH	0.024 (.002)**	1.02	1.02	1.03
R	0.055 (.010)**	1.06	1.04	1.08
Wall Angle	—	—	—	—
Wall Angle(Inward)	1.654 (.267)**	5.23	3.10	8.83
Wall Angle(Stright)	0.338 (.365)	1.40	0.69	2.87
Roost/Nest Support (Yes)	1.814 (.196)**	6.14	4.18	9.00
Wall surface	—	—	—	—
Wall surface (Pit)	0.935 (9586.129)	2.55	0.00	0.00
Wall surface (Mud)	-5.192 (9775.377)	0.01	0.00	0.00
Wall surface (Rock+Mud)	19.456 (7567.159)	281736300.50	0.00	0.00

'**'=P<0.005

Table 5.3: The proportionate (%) distribution of roost site combinations of AENS preferred, used and available inside the caves.

Combinations	**% usage (U)**	**% Available (A)**	**E=U-A/U+A**	**Rank**
Sf-Hm-Y-In-Rs	17.33	0.29	0.97	1
Sf-Hm-N-In-R	8	0.29	0.93	1
Sf-Hh-Y-In-Rs	8	0.29	0.93	1
Sf-Ha-Y-In-Rs	8	0.29	0.93	1
Sf-Hm-N-St-R	2.67	0.29	0.8	2
Sh-Hh-Y-Ot-Rs	2.67	0.29	0.8	2
Sf-Hm-Y-Ot-Rs	1.33	0.29	0.64	3
Sf-Hm-N-In-Rs	4	0.87	0.64	3
Sf-Hs-Y-Ot-R	16	4.91	0.53	5
Sf-Hs-Y-Ot-Rs	5.33	2.31	0.4	4
Sn-Hs-Y-In	1.33	0.87	0.21	4
Sn-Hs-Y-Ot	1.33	0.87	0.21	4
Sn-Hs-Y-Ot-Rs	1.33	1.45	-0.04	5
Sf-Hs-Y-In-Rs	2.67	4.34	-0.24	6
Sf-Hs-Y-St-R	1.33	2.6	-0.32	7
Sf-Hs-N-Ot-R	6.67	18.5	-0.47	7
Sf-Hs-N-In-Rs	5.33	21.1	-0.6	8
Sf-Hs-N-Ot-Rs	1.33	6.07	-0.64	8
Sf-Hs-N-In	1.33	7.8	-0.71	9
Sf-Hs-N-In-R	4	26.3	-0.74	9

Note: Sf=Slope <45 ^{o}, Sn=slope 45-90^{o}, Sh=>90-135^{o}, Hs= dropping height <200cm, Hm= dropping height 200-400 cm, Hh= dropping height 400-600 cm, Ha= dropping height >600cm, Y= presence of Roost/Nest support, N= absence of roost support, In= inwardly inclined wall, Ot= outwardly inclined wall, St= Stright wall, R= Rough surface texture, Rs= slightly rough surface texture. Rank= small value (1) indicates high preference and large value (9) indicates high avoidance.

Pooling the data showed that Roost-sites of the AENS with a combination of slope <45° at the height of 200-400cm, with or without support on the inwardly inclined wall and rough /slightly rough surface texture were preferred (E=0.97 & 0.93) (Table 5.3). Out of the 20, six combinations were most preferred by AENS for roosting, and eight combinations were avoided.

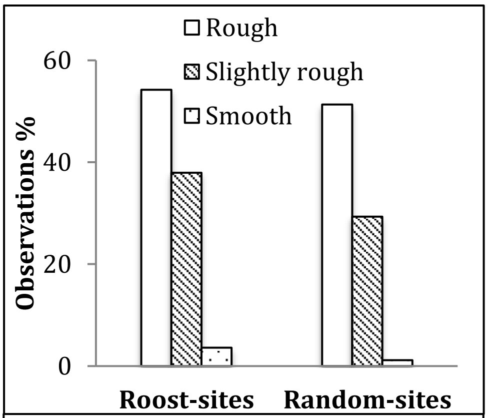

Figure 5.2: Proportion of roost/ random site observations of different surfaces

Roosting height: The total height of roost from the ground (THT) and the roost height (NH), was analysed for the roost and random sites showed, >80% birds roost above 200cm height (Figure 5.1 & 5.2). Around 88.33% birds preferred to roost at and above 400 cm to 600 cm (E=0.98). The roost height >600 cm (77%) was preferred for roosting (E=0.90). The height less than 200 cm was avoided for roosting (10.84%, E=-0.80).

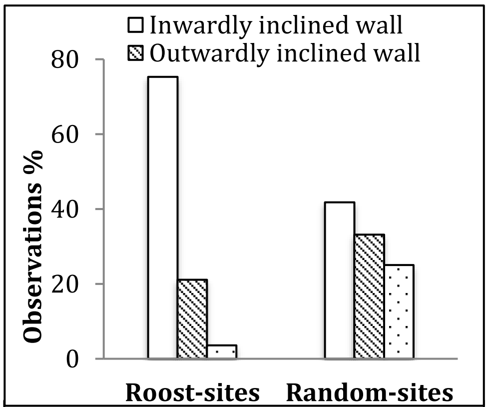

Figure 5.3: Proportion of roost/ random site observations of AENS at various wall inclinations

Surface texture (R): The AENS mostly roost on the rough or slightly rough surface than the smooth surface (Figure 5.2). However, there is no apparent preference or avoidance was depicted towards any surface texture type by the species [Rough (E=0.02), Slightly rough (E=0.08) and smooth (E=0.45)]. AENS avoided roosting at uneven surfaces (E=-1) with mud (E=-1) and wet walls (E=-1). The wall surface with more

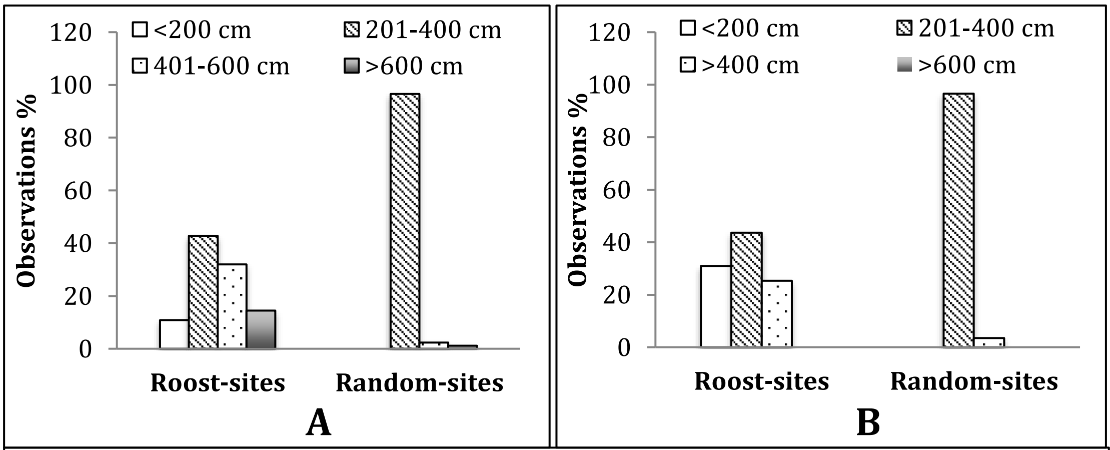

Figure 5.1: Proportion of roost/random site observations at A: total heights from ground and, B: at roost heights

than 60 ridge counts at point location (i.e. very smooth surface) was also avoided (E=-0.56). **Cave wall inclination:** Though not very strong, AENS showed preference towards inwardly inclined walls (E=0.29) for roosting over outward inclined and straight wall (Figure 5.3). The walls with the outward inclination (E=-0.22) or straight angle (E=-0.75) were avoided.

Roost/Nest support (NS): For roosting, AENS preferred the sites with support (E=0.63) over without support (E=-0.53; Figure 5.4).

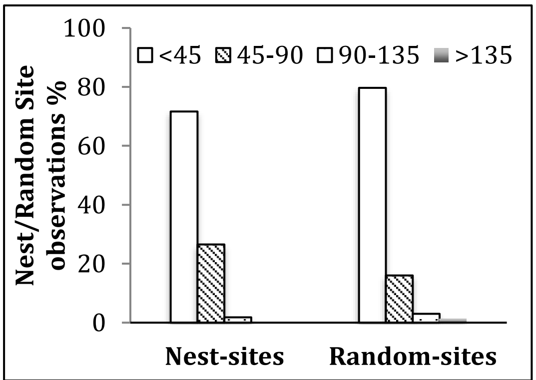

Figure 5.5: Proportion of roost/random site observations of different slope categories

Slope: The roosting sites with the slope less than 45° were used in highest proportion (E=-0.06), however, the preference of AENS was more towards 45-90° slope (E=0.24). The slope >90° (E=-0.29) used less (Figure 5.5).

5.4.2. Roosting habitat (Macro level)

All the macrolevel physical characters (Cave Type, Cave Size, Light Zones, Vegetation Type & Rock Type of Area and Direction of Cave Length) of the study caves are discussed in the 'study caves' section of chapter 2 (page no.10-14). Further, the binary logistic regression predicted that the cave size (Big and Very Big) and the cave opening shape (Arch and Rectangular shapes) influence the presence of the AENS in the caves at Baratang Island (Table 5.4).

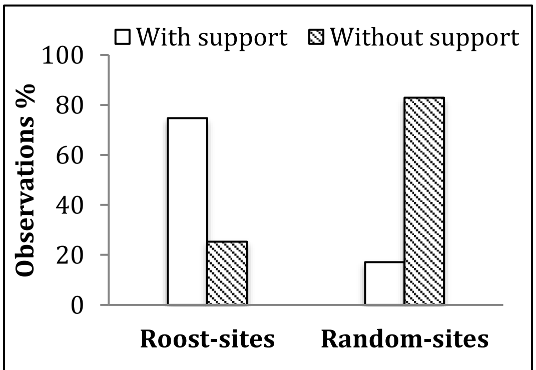

Figure 5.4: Proportion of roost/ random site observations of AENS with/ without support

Considering the population of AENS inside the caves, multiple regressions revealed that cave size, type of cave location, cave mouth shape and cave openings are the most influencing factors in determining the roosting population of AENS in the caves of Andaman Is. As standardize co. Beta values are higher for following parameters: Cave type location (Inland above ground), cave mouth shape (Oval) and caves with multiple openings (cave mouth number 3) are the most important deciding parameters for AENS population in the caves of Andaman Islands (Table 5.5).

Table 5.4: Binary Logistic regression (Forward step LR) showing Influence of different variables on the presence of AENS in the caves of the Andaman Islands.

Dependent Variables: presence of AENS; Variables: cave location, cave type, forest type, cave size, cave opening shape, cave length direction, cave opening width & length and cave opening number

Variables in the equation	**B (SE)**	**Exp(B)**	**95% CI of Odds Ratio**	
			Lower	**Upper**
Constant	-0.514 (.367)	---	---	---
Cave size - Very Small	---	---	---	---
Cave size - Very Big	1.884 (.689)*	6.579	1.705	25.387
Cave size - Big	2.346(.791)**	10.444	2.217	49.188
Cave size - Medium	0.864(.442)*	2.373	0.997	5.649
Cave size - Small	1.110(.449)*	3.034	1.259	7.313
Cave mouth - Triangular	---	---	---	---
Cave mouth - Arch	1.299(.473)*	3.666	1.45	9.271
Cave mouth - Circular	-0.582(1.131)	0.559	0.061	5.127
Cave mouth - half circle	0.416(.729)	1.516	0.363	6.332
Cave mouth - irregular	20.854(17464.859)	1139107104	0	0
Cave mouth - Oval	0.279(.538)	1.321	0.46	3.796
Cave mouth - Rectangular	0.948(.456)*	2.58	1.055	6.312

‘**’=P<0.005, ‘*’=P<0.05, B= Betas, SE=Standard Error, Exp(B)=Odds Ratio, CI=Confidence Interval

Table 5.5: Multiple regression (Forward type) determining size the roosting population of AENS in different caves

Dependent: the Roosting population of AENS; Variables: cave opening width/ height, area, cave size, cave location, cave opening shape, cave type, cave length direction, # of cave openings, forest type. Multiple regression equation for predicting AENS population size in the caves of Andaman Is.**: A**ENS population=5.141-0.027+15.673(cave size: very big)+12.165(cave size: Big)+29.898 (cave location: Inland above ground)+57.143(cave opening shape: Oval)+ 28.674(cave openings: 3)

Coefficients[a]

Model	**Unstandardized Coefficients**		**Stand. Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**		**Correlations**			**Collinearity Statistics**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**	**Zero-order**	**Partial**	**Part**	**Tolerance**	**VIF**
(Constant)	5.14	2.67	--	1.92	0.06	-0.13	10.41	--	--	--	--	--
cave opening width (cm)	-0.03	0.01	-0.12	-2.23	0.03	-0.05	0	-0.16	-0.15	-0.11	0.81	1.23
cave size: Very big	15.67	4.19	0.2	3.74	0	7.41	23.94	0.23	0.25	0.18	0.85	1.17
cave size:Big	12.17	4.2	0.15	2.9	0	3.88	20.45	0.1	0.2	0.14	0.94	1.07
cave location :Inlad above ground	29.9	4.33	0.38	6.9	0	21.35	38.44	0.55	0.44	0.34	0.8	1.26
cave mouth shape:Oval	57.14	9.01	0.33	6.34	0	39.38	74.9	0.48	0.41	0.31	0.89	1.12
cave mouths: 3	28.67	7.28	0.21	3.94	0	14.32	43.03	0.35	0.27	0.19	0.86	1.16

Adj R^2= 0.503; F=36.358; p<0.001

Analysis of variance showed the significant difference in the population of AENS among the different sizes of caves (F=5.066,p<0.001). Very Big (25.8±56.75), Big (17.2±24.34) and Medium (10.4±25.15) caves had maximum roosting population followed by Small (8.7±15.32) and Very Small size (1.3±1.88) caves. Moreover, the AENS population varied (t=3.767,p<0.001) between inland underground caves (4.2±6.22) and inland above ground (48.2±60.73) caves. The Pearson's correlation showed, there is no correlations between cave opening height (R=-0.72,p=0.297) and area (R=-0.115,p=0.097) with AENS population but the negative relationship was seen among cave opening width and population of AENS inside the cave (-0.160,p<001).

5.4.3. Roosting pattern and environmental factors

Temperature and humidity: Slight correlation (R^2=0.049) was observed between the average outside environmental humidity and total roost time spent by AENS inside caves (Figure 5.7 D). The cave temperature, humidity and environmental temperature did not show any relation with the proportion of birds roosting or with the roost time spent inside the cave (Figure 5.6 A, B & Figure 5.7 C).

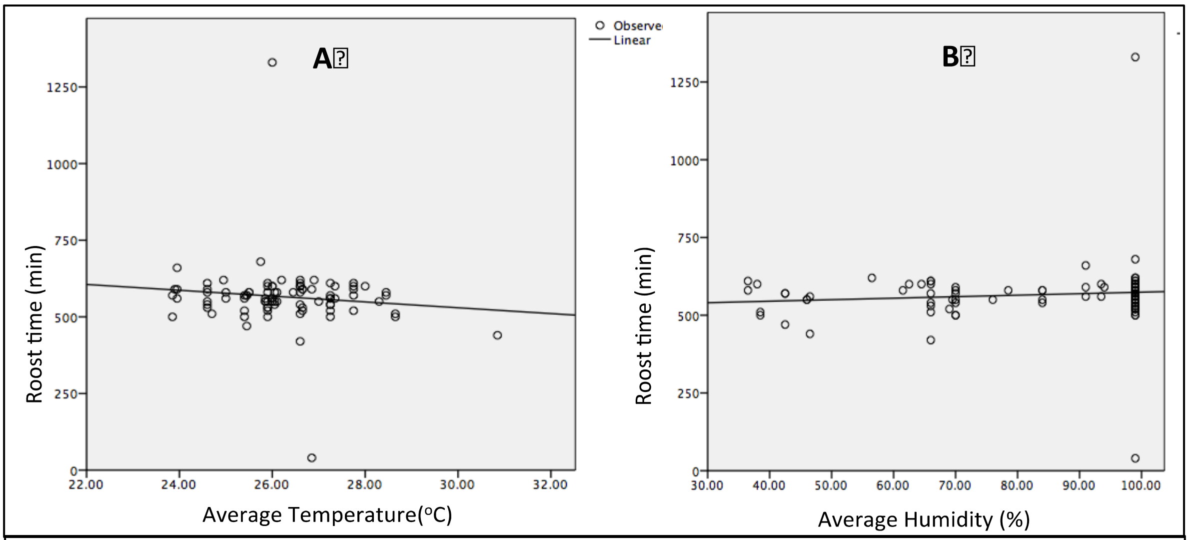

Figure 5.6: Total Roost time & Cave climatic factor (A) Temperature & (B) Humidity
Average Temperature: y(roost time)=814.90–(9.51 Average cave Temperature), F=1.089, P>0.05, Adj.R^2 =0.001; Average Humidity: y(roost time)=525.71+(0.48 Average cave Humidity), F=0.77, p>0.05, Adj.R^2 = -0.003

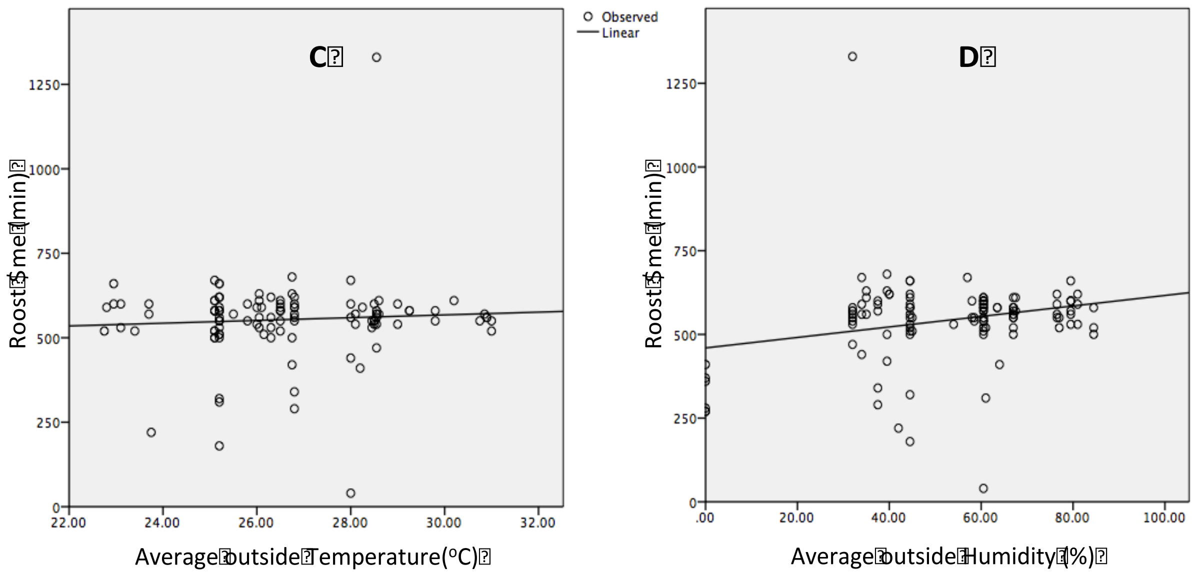

Figure 5.7: Total Roost time & outside climatic factor (C) Temperature & (D) Humidity. y(roost time)=444.89+(4.09 Average outside Temperature), F=0.491, p>0.05, Adj.R^2 =-0.005; y(roost time)=459.59+(1.57 Average outside Humidity), F=7.086, p<0.05, Adj.R^2=0.049

Environmental light and wind: wind velocity and light present at cave opening did not show any correlating with the roost time spent by AENS inside the caves (Figure 5.7 A&B)

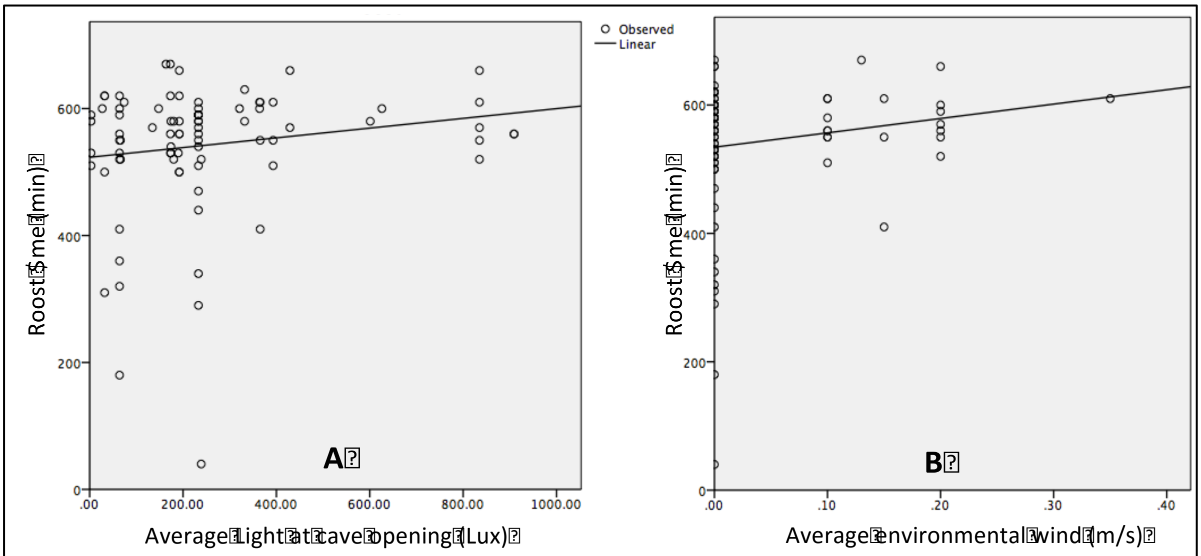

Figure 5.7: Total Roost time & outside climatic factor (A) Light at cave opening & (B) Wind y (roost time) = 523.19+(0.08 Average outside Light), F=2.35, p>0.05, Adj.R^2 =-0.016; y (roost time)=534.22+(223.99 Average outside Wind), F=2.19, p>0.05, Adj.R^2 =0.014

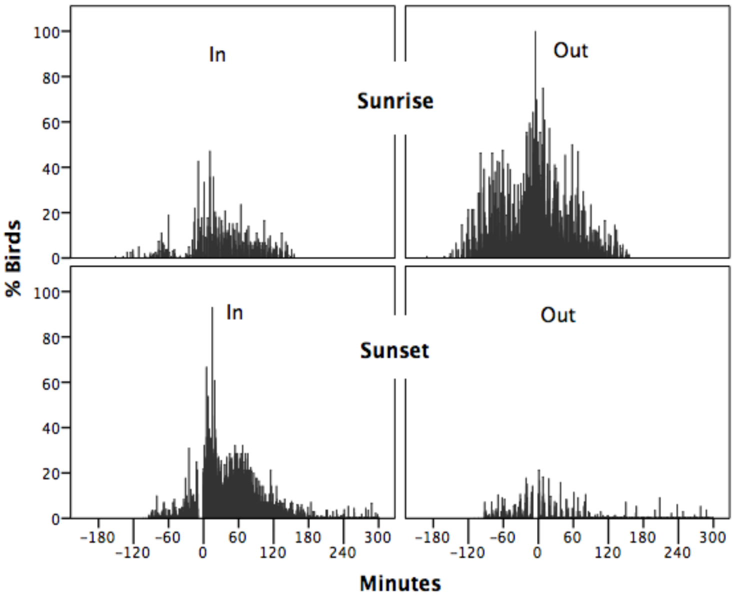

Figure 5.8: Birds (%) showing in and out movement during sunrise and sunset at caves.
Note: A negative value at X-axis indicates activity before sunset/sunrise and '0'minutes on the X axis indicates sunset/sunrise time.

Roosting activities during dusk and dawn: Although some, AENS individuals returned to their roosting caves before sunset, most (Mean=92.68± 9.03 %SD) of the individuals returned to their roosting caves only after sunset (Z=2.160, p<0.05). However, the variation in sunset timing did not significantly affect the proportion of birds arriving for roosting within PRH (χ^2= 4.876, df=3, p=0.181) or the timing of the first bird arriving for roosting (χ^2 = 4.645, df = 3, *p* = 0.2) (Figure 5.8). Nevertheless, the frequency of first bird returning before sunset was higher (64.03 %) than after sunset (35.07 %). Among the breeding stages, the proportion of birds returning after sunset time differed significantly (χ^2=8.742, df=3, *P*<0.05): a higher proportion of birds returning after sunset during the stage of nest-building and fledging (94.43±07.03%SD, n=22 and 92.58±10.47% SD, n=2 respectively), as compared with incubation (Mean=85.94±05.87 %SD, n=8) and nestling stages (Mean=88.72±12.54%SD, n=11). Most birds leave the roosting caves before sunrise (Mean=39.28±29.55%SD) than after sunrise (Mean=37.65±34.00%SD).

Roosting activities & day length: Length of day did not affect movement of the birds leaving caves before sunrise (F(59,55)=1.336, p>0.05) but it affected the movement after sunrise (F(59,55)=1.573, p<0.05), before sunset (F(81, 126)=4.743, p<0.001) and after sunset (F(81, 126)=3.699,p<0.001; Figure 5.9). Proportion of the birds (Mean=15.599 ±11.030%SD) left the caves after sunrise on long days were comparatively less than on short days (Mean=42.228±29.860%SD). Whereas, more birds (Mean=53.931±38.135%SD) left the caves before sunrise on long days than the short days (Mean=42.653±30.160%SD). Most AENS were found coming for roosting after sunset in short (Mean=93.95±6.590%SD) and long (Mean=76.88±22.95%SD) days. With monthly increasing length of the day, between January and March more birds (N=87 observations, Mean=53.39±35.31%SD) did leave caves after sunrise. Whereas, from April onwards, high population left the roost before sunrise (N=28 observations, Mean=53.39±35.31%SD). Most of the birds returned to cave after sunset (Mean=78.79±18.21%SD). The bird movement after sunset was maximum in January (Mean=92.80±4.53%SD) and February (Mean=87.68±11.50%SD and minimum in March (Mean=59.47±15.66%SD). During April and May, it did not vary significantly (April: Mean=76.56±16.09%SD, May: Mean=82.37±15.39%SD). Total time spent to leave the caves was less (Mean=57.70±37.57minSD) in month of January compare to the other months (February: 64.15±39.53minSD; March: 64.48±26.56minSD; April: 62.18±39.44 min SD; May: 86.50±28.72minSD; June and July 99.00±00.00minSD). However, no such difference found at the time taken to enter caves for roosting ($F(6, 201)=1.229$, $p>0.05$).

Spatial variation in roosting during dusk and dawn: Movement of the birds in Caves 3 and 1 was found distinct than rest of survey cave, with comparatively early departure before sunrise (Cave 3: Mean=83.34±0.60%SD; Cave 1: Mean=64.44±14.22%SD). Bird movement after sunrise was seen higher in Cave 4 (Mean=62.50±41.98%SD) and Cave 6 (Mean=69.30±28.75%SD). AENS had similar roosting activity before sunset ($F(9, 198)0.742$, $p>0.05$) and after sunset ($F(9, 198)1.450$, $p>0.05$) in all the caves (refer result section of chapter 3 for details of the AENS movements in different caves at different sites). At Interview Island, birds left the cave before sunrise (Mean =64.44±14.22%SD) whereas, at other two sites, they left even after sunrise. In Interview Island, birds took a long time (Mean=90.11±35.51minSD) to leave the cave than Chalis-ek (Mean=35.25±13.02minSD) and Baratang Island (Mean=63.90±35.00minSD). At all the three sites, few birds (Mean=4.27±7.04%SD) came for roosting before sunset than after

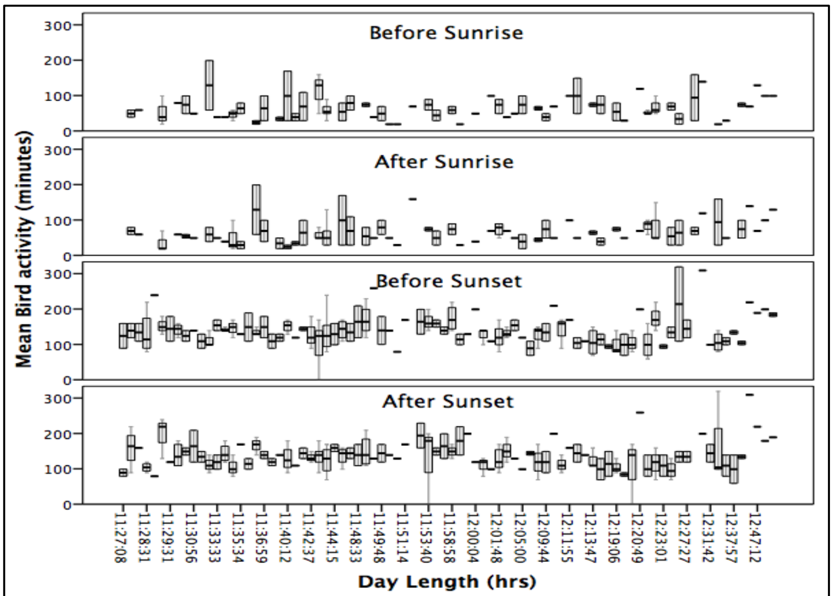

Figure 5.9: Mean birds activity (in minutes) at sunset and sunrise in different day lengths (hours) at Andaman Islands.

(Mean=78.79±18.21%SD). Unlike after sunset, roosting activities of AENS varied before sunset (F(2, 205) 5.974, $p<0.01$) at all the sites (Chalies-ek: Mean=11.26±21.63%SD, Interview Island: Mean=0.10±0.31%SD, Baratang Island: Mean=04.20±05.83%SD).

Roosting activities & lunar phase. The fewer birds returned to roost during PRH on full moon nights than new moon nights (Z=10.063, n=81, p< 0.0001) (Figure 5.10). Furthermore, the first bird returned earlier to roost during new moon nights (Mean=1720±0.01 hSD), compared to full moon nights (Mean=1717±0.01hSD), (Z=-7.851, *P*<0.0001). The last bird returned to roost significantly later during a full moon night (Mean=1935±0.04hSD) (Z=-7.428, p<0.0001) than on a new moon night (Mean=1925±0.03hSD), after excluding the single event of six late arriving birds at 2350h on a same full moon night. Moreover, there was a significant difference (W=127.5, p<0.02) in the proportion of birds returning during PRH to roost on new moon nights (Mean=87.91±12.14%SD) compared to full moon (Mean=70.10±17.14%SD) nights.

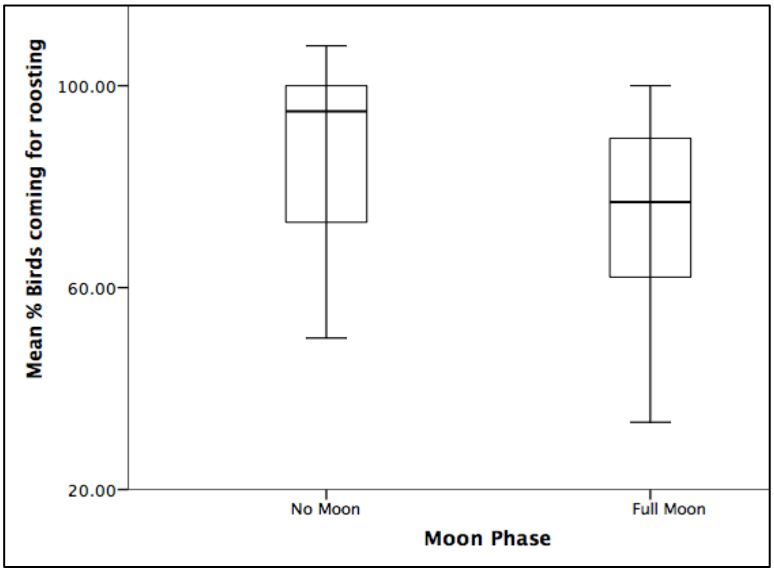

Figure 5.10: Mean (%) birds' arrival during Full moon and No moon nights during (1700-2000hrs) peak roosting hours (PRH).

5.4. DISCUSSION

Roost-site selection is the crucial process towards fitness and survival in most life stages of animals and possibly reflects the capacity of an individual to naturally select the appropriate micro habitat (Cody 1985, Danchin *et al.* 1998, Jones 2001). Unlike most avian species, the ability to navigate in the dark by echolocation enables most of the AENS individuals (Mean=92.68±9.03%SD) to return to their roosting sites after sunset. This study was an attempt to understand the abiotic factors, which affects the decisions and behaviour of AENS spaciotemporally in the Andaman Islands.

Roosting habitat (Macro characters): Macro Level Roosting Habiat are nothing but the ganaral physical characters of the caves explained above are first time connected to the presence of the *Aerodramus sp*. The only related information found documented was the mention by Nguyen (1998). In Vietnam, he found that 80% colonies at Da Nang and 58% colonies Khanh Hoa province of the *Collocalia fuciphaga germani* were found using the caves with wide openings. The present study depicted that presence of the AENS is dependent on the Rectangular and Arch shaped cave openings. At present, it is very difficult to understand the significance of these shapes for the presence of the species inside the cave. May be the shapes are much visible to the individuals, in search of new roosting or nesting places; this may be the reason for them to occupy most of the caves with wide openings in Vietnam (Phach & Voisin 1998). Alternatively, the shape of the cave opening may provide information regarding their safety inside the cave. This primary finding opens a new scientific opportunity to explore the sense of image birds can have and the information that different shapes can provide to the echolocating birds regarding features inside the caves. Another possibility may be that the shape of the cave opening alone may not be playing a role in the presence of the AENS. The other features around the cave mouth like angle/slope of the cave mouth concerning the ground level, the canopy cover at the cave mouth, the perching spots available for different predators, the visibility of the cave opening from above the canopy, and many others. Since the present study did not have these characters included, it should be considered as a preliminary finding to initiate further related research. The dependency of the population size on the cave size can be easily connected to availability of the nesting/roosting space inside the big and very big caves. Another reason can be the basic character of the colonial Aves to be part of the bigger colonies for the safety and survival (Rolland *et al.* 1998).

Roosting habitat (Micro characters): The Total height of roost (THT), Surface Texture, Wall Angle (Inward) and presence of Support (E=0.63) were found significant characters ($p<0.05$) affecting the selection of roosting sites. Whereas, roost site combination of slope $<45^0$ at height of 200-400 cm, with or without support on inwardly inclined wall (E=0.29, 75.30%)and rough & slightly rough surface texture were preferred (E=0.97 & 0.93) by birds suggesting important role in successful nesting and breeding success (Danchin *et al.* 1998, Viruhpintu *et al.* 2002, Manchi 2009, Suwanrat 2014). In Andaman Islands, AENS preferred 45-90^o slope at roost site, whereas, *A. maxima* at Borneo prefer >20^o (median 55^o) slope at roost/nest site (Manchi 2009, McFarlan *et al* 2015) which is dependent on the cave structure. Swiftlets are known to utilize the roofs of caves (Medway 1962a, 1962b, Sankaran

1998, Lim & Cranbrook 2002, Manchi 2009). In Andaman, the birds (88.33%) prefer (E = 0.98) to roost above 400 cm, possiblly, to avoid easy access to predators like snakes, owls and others. As per Viruhpintu *et al.* (2002) most nesting sites of *A. fuciphagus* at Si-Ha Islands found on the smooth surface of inwardly inclined walls, whereas, Manchi (2009) found AENS prefers rough and slightly rough rock surfaces. Similarly, AENS at Baratang mostly roosts on the rough or slightly rough surface than the smooth surface (IRC=40-60, E=0.45), may be for a better grip to nest/roost (Manchi 2009).

Environmental factors: As inside temperature and humidity always found almost constant throughout the season inside the dark zones of the caves (Medway 1962b), they were not found to be affecting the roosting activity of the AENS. However, the humidity outside cave showed a slight difference in the average roost time spent by AENS. It may be because they prefer roosting inside the caves more during the rainy season when the environmental moisture is more than the dry seasons. The study at Niah cave on the *Collocalia maxima and Collocalia salangana* showed rain conscious behaviour followed by the arrival of heavy rain. The tropical Islands of Andaman frequently receive the heavy rainfall and storm conditions (Saldanha 1989). The wind velocity and light present at cave opening do not show any correlating with the roost time, but for long distance foragers like swiftlets, the climate at foraging ground possibly act as an important deciding factor for movements. The foraging studies of the species, using the satellite tracking method, can help understanding the mysteries behind.

The variation was seen in different day length and after sunrise and before sunset movements possibly due to different parental duties during the breeding season. Similar to observations at Niah Cave (Medway 1962b) most of the birds leave the caves before sunrise (observation: Niah: 56 min; Andaman: 60-120 min) this variation possibly depends on the availability of the foraging ground at a different distances from the caves and the structures of the caves. In Andaman, Day length increases with +1:27 hr from January to June and decreases with -28 minutes from July to August where as Niah cave, Sarawak, day length varies with +7 minutes during January to June and -3 minutes from June to August, which is comparatively very less than Andaman Is. As day length is important in regulating the breeding (Medway 1962b), the high proportion of birds leave the caves before sunrise on long days and change in the movement before and after sunset and sunrise in different day lengths are directly related to the breeding stage and duties of AENS. Therefore, from

January till March most birds leave caves after sunrise where as, from April onwards, high population leave the roost before sunrise. The high proportion of birds comes late after sunset during nest construction period, i.e., January and February, so that they can forage more to meet the high energy demands of the nest building and before egg laying and also may be to explore new foraging grounds (Manchi 2009, Manchi & Sankaran 2010).

Unlike most diurnal foraging birds including many non-echolocating swifts and swiftlets, more than 92.68±9.03%SD individuals of the Edible-nest Swiftlet returned to their roosting caves after sunset. However, besides the capability of echolocation, Medway (1962a, 1962b) and Harrisson (1976) have recorded that the black-nest swiftlets (*Aerodramus maximus*) and mossy-nest swiftlets (*Aerodramus salanganus*) forage by night in the bright moonlight. Also, Tarburton (1987) observed the white-rumped swiftlet *Aerodramus spodiopygius* returning comparatively later to its roost sites on bright moonlit nights. Similarly, in the Andaman Islands, late return of birds during full moon nights than new moon nights was seen presumably the foraging and anti-predators strategy (Manchi & Sankaran 2010, Mane & Manchi 2017).

It is known that the average roosting time of birds gets affected by the roosting environment, habitat and reproductive biology (Jaberg & Blant 2003, Manchi 2009, Mane & Manchi 2017). The study pronounces the type and location of the cave, and other ecological and environmental factors as well affect largely to the daily activity of the species. The caves in the Andaman Islands are dynamic, and their physical and environmental characters vary at different sites (Mane & Manchi 2017). Further, it has been proved that habitat and environment are important deciding factors for AENS' movement in the Andaman Islands. Since the study conducted has many components studied for the first time, most of the findings can be used as the base for the further understanding of the function of the hypogene and epigene environmental parameters in a deciding the life strategies by the cave dwelling animals. Also, the detailed understanding of foraging range, habits and dispersal of this swiftlet, may be through satellite tracking studies, will help explain the delayed individuals at roost sites.

Chapter 6: Synthesis

Studying roosting Ecology of the Andaman Edible-nest Swiftlet has its direct application in the *in-situ* and *ex-situ* conservation of the species in the A & N Islands. The findings from the study have contributed to our understanding of the AENS and its habitat management in the *in-situ* and *ex-situ* conditions.

Communal roosts, particularly of predatory birds and scavengers, are most readily explained as a means of improving foraging efficiency (Newton 1979). Many communal roosts, adaptation strategies not understood in detail (Beauchamp 1999). The information centre hypothesis is most popular among insectivorous colonial roosters but the apparent paradox about information sharing (Ward & Zahavi 1973, Rabenold 1986) about successful, foraging grounds to familial associations in roosts. In this, the behaviour is more likely to benefit family members or roosting companions. Similarly, the roost site habitat and foraging ground selection by individual and group of individuals because of similar interest and limited available resources make these birds share roosting and foraging grounds.

One of the major findings of this study is that the presence and population of the AENS is affected by the size of the cave and shape of the cave opening. Most big populations of the ANES are in the big cave with multiple openings. Also, the presence of AENS has no effect of the size of the cave opening. This is an important and required contribution to modification of the ex-situ swiftlet houses built to farm the AENS for livelihood and economic development in the islands.

The innovative method to measure surface texture of the uneven cave walls is another major contribution of the study to the speleological research in the world. This can help us understand the microhabitat of many small invertibrates using the cave walls and spending their life on a single wall, may be with specific texture.

The additional information about the presence of nest support, rough surface texture, and inwardly inclined walls with maximum height are being the selective factors for AENS to roost/breed inside the caves at the Andaman Islands, adds to the knowledge of the miccrohhabitat the species required for better productivity in the ex-stitu houses.

The present study suggests that the roosting movements (entry and exit time) of breeding colonies of AENS vary place to place. This may be contributed by the resource availability in the region, which is known to result in a change in the breeding seasonality, breeding success, foraging strategy and others. This information gives an idea about different management strategies for the wild populations of AENS at different places, according to variations in the resource availability. Also, helps us consider the same while planning for the ex-situ habitat development. The local environmental conditions and dependent insect population are possible reasons for AENS population, to alter the breeding chronology. Which indirectly tells us that the nest harvesting time may differ place to place in the different region. Additionally, the energy requirements in different breeding stages influence the roosting patterns of the species. Further the management of local pristine forest condition can produce healthy insect population, which can directly contribute the conservation of the AENS.

The peak timings of the behaviours such as nest construction, preening, allopreening, feeding chicks by the AENS, while roosting inside the caves have spatial-temporal variations (hourly, monthly and site wise). This information can be used to chose the best timings to entre the caves for any management related work or survey at the respective sites.

Counts of absolute numbers will be most useful if combined with other estimates of population health. The non-invasive roost counts can help to understand the routine roosting behaviour of the AENS. The roosting timings can be used as the indicator of the breeding stage of the colony without entering the caves. The information can also be used to estimate the approximate breeding population inside the accessible and non-accessible caves of AENS and formulate further conservation strategies.

The study resulted in developing a hypothesis that bigger colonies forage for a longer time. The larger colonies were found to roost for a lesser time also the individuals in the larger colonies were observed returning later to the roosting caves. This might have resulted by the several reasons. One of the reasons could be the presence of the more non-breeding individuals in, the larger breeding colonies. As these non-breeding individuals are not bound with any parental duties, they may spend more time out of the roosting caves to forage more, find a partner or a new colony for roosting or breeding. Further, studies related to the dispersal patterns of the species using sattelite tags may reveal the secrets about the foraging and dispersal ranges of the AENS.

The study of the co-existing species is the first document to estimate the abundance of the cave fauna distributed in the Andaman Islands. It is a foundation stone to understand the most ignored hypogene habitat in these islands. The well-designed long-term study on subterranean fauna in the area can resolve the questions raised by this study. The co-existing species and potential predators population inside and around the subterranean habitat in relation to the AENS roosting period provided an exciting output. The abundance of Cockroach was found to affecting the roosting period of the AENS, since they feed on the edible nest of a swiftlet. The finder is an important input for the management of the *ex-situ* swiftlet houses. Though, it need further exploration for conformation.

Study of the predators confirmed that the Hume's Hawk Owl (HHO) *Ninox scutulata obscura*, the known predator of the AENS, is more abundant in the cave area than non-cave area. Since the species is later described as *Ninox obscura* and mentioned as endemic to the Andaman Islands (Rasmussen and Anderton 2005), it is an important finding that the species is more dependent on the caves with bats and birds in the region. It will be interesting now to understand the effect of the presence of HHO on the population of the AENS and also different bat (Chiroptera) species. This study will help the managers to evolve the habitat conservation and management strategies in the area to conserve the HHO and the related epigene & hypogene fauna as prey of the species in the Andaman Islands.

The first of its kind study related to the cave dwelling birds, discovered that the environmental conditions like sunrise, sunset time, day length, moon phase, environmental humidity are important factors for the AENS to decide its roosting and may be also the foraging strategies. This study is the first to report the lunarphilic nature of the cave dwelling Apodiformes.

The study of the biotic and abiotic factors have revealed their effect on the roosting habits and movements of the AENS, spatial-temporally. When these abiotic and biotic factors were treated wholistically by performing generalised linear models (GLM) with a Poisson error distribution and log link function (Gregory & Strien 2010, Mane & Manchi 2017) to test the effects of biotic and abiotic factors, it provided the best-fit models depicting the timing of the return to roost by these AENS' influenced by several variables (Table 6.1).

Table 6.1 Selection table for fits of the 15 competing Generalised Linear Models.

Model	**K**	**AICc**	**Delta_AICc**	***wi***	**Cum. *wi***	**LL**
MP*BS*Temp	**10**	**565.93**	**0**	**0.64**	**0.64**	**-271.4**
MP*BS	**7**	**568.35**	**2.42**	**0.19**	**0.84**	**-276.41**
MP*BS*Hum	12	571.09	5.15	0.05	0.88	-271.25
MP*BS* Temp *Hum	14	571.25	5.32	0.05	0.93	-268.44
MP*BS*FBT	11	572.11	6.18	0.03	0.96	-273.14
MP*BS* Temp *FBT	15	572.79	6.86	0.02	0.98	-267.71
MP*BS*Temp*SST	13	573.13	7.2	0.02	1	-270.85
MP*BS*Hum*FBT	18	577.57	11.64	0	1	-265.27
MP*BS*DL	15	578.28	12.35	0	1	270.45
MP* Temp	25	599.84	33.91	0	1	-263.1
MP+BS	4	610.72	44.79	0	1	-301.1
BS* Temp	5	637.9	71.96	0	1	-313.55
MP	7	643.67	77.73	0	1	-314.07
birds ~ 1	2	684.63	118.7	0	1	-340.24

MP = Lunar/Moon phase, BS = Breeding stage, FBT = First bird arrival with respect to sunset time, Temp = Day Temperature, Hum = Humidity, SST = Sunset Time, DL = Day Length. The number of parameters (K), Akaike Information Criteria (AICc), Delta information criteria (Delta AICc), model probabilities: Akaike weights (w_i), cumulative weight (Cum. w_i) and the log-likelihood (*LL*) for different models fitted to count observations (N = 43) of the AENS from caves .The largest w_i is shown in bold. Evidence ratio between models 'M1' and 'M6': 3.35

Table 6.2 Model-averaged parameter estimates from best-fit models from table 6.1

Birds encountered	**Estimate**	**SE**	**Adjusted SE**	**z value**	**Pr(>|z|)**
(Intercept)	-0.75	0.053	0.054	-14.143	< 2e-16 *
NM	0.665	0.065	0.066	10.175	< 2e-16 *
Incb	0.45	0.068	0.069	6.633	3.30e-11 *
Nest	0.617	0.071	0.074	8.593	< 2e-16 *
NM:Incb	-0.719	0.088	0.09	-8.162	3.30e-16 *
NM:Nest	-0.565	0.086	0.087	-6.588	4.45e-11 *

'*'depicts Significance *P* <0.001, NM = New Moon, Incb = Incubation, Nest = Nest-building, SE = Standard Error

The moon phase and breeding stage were estimated to be the most significant predictors in the first best-fit model (Table 6.2, Figure 6.1). Further, the model with day temperature showed the lowest AICc and one of the significant variables, affecting the roosting decisions of the individuals (Table 6.1). According to the models, humidity, sunset time, first bird arrival for roosting, day length and weather do not affect the timing of roosting behaviour of the AENS.

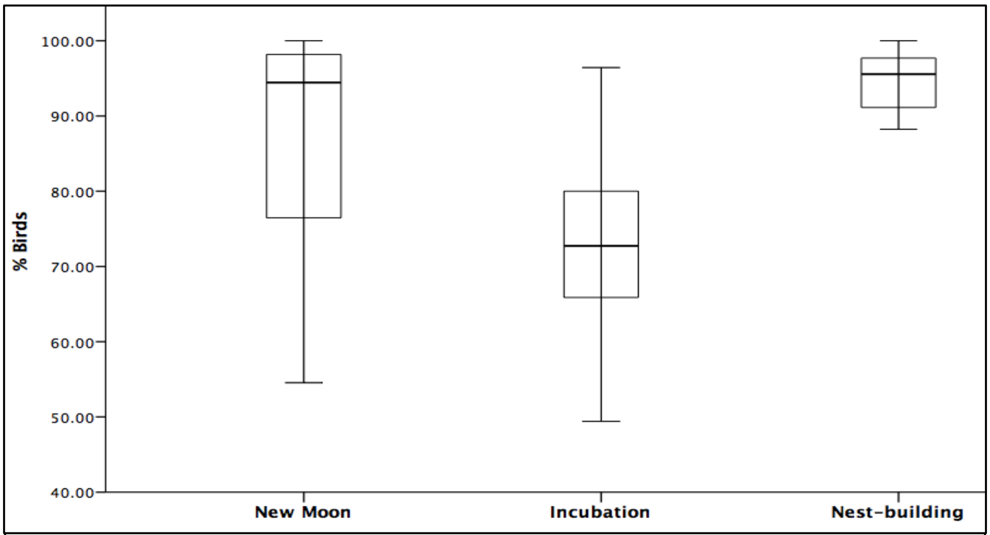

Figure 6.1: Mean % birds returning to roosting and breeding caves between Peak Roosting Hours (1700–2000h) on New moon night, Incubation time and Nest-building time.

Note: Boxes indicate interquartile ranges and the line inside the box shows the median. Limits of the whiskers represent minimum & maximum values of the data.

The anti-predator strategies (Tarburton 2009) of the AENS for survival and successful reproduction (Riou & Hamer 2008, Woods & Brigham 2008) must have resulted in the lunarphilic behaviour of the species. Because Owl in the region are most active during the dusk (Mane & Manchi 2013).

These ecological & oecological information about the species allows considering different environmental factors to improve the existing *in-situ* and *ex-situ* conservation management actions towards betterment of this economically important bird species.

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Annexure 2.1: Classification of the caves in the Andaman Islands

Island Name	Total caves	Caves surveyed	Cave Size					Cave Type						Rocks Layer Type
			VB	B	M	S	VS	A	AB	B	BD	Cii	D	
Chalis-ek (7)	35	35	4	5	6	20	0	1	0	0	0	4	30	Mk
Chidiya Tapu	1	1	0	0	0	1	0	0	0	1	0	0	0	Opl
Cuthbert Bay	3	3	0	0	0	3	0	0	0	3	0	0	0	Mk
East Is.	1	1	0	1	0	0	0	0	0	1	0	0	0	Arh
Henry Lawrence	20	20	0	0	5	15	0	0	0	20	0	0	0	Arh
Inglis	2	2	0	0	0	2	0	0	0	2	0	0	0	Arh
Interview Is.	35	35	1	2	4	28	0	0	13	0	0	22	0	Arh
Jarawa Main	2	0	NS	NS	NS	NS	NS	0	0	2	0	0	0	Flh
Jarawa Is. 1	1	0	NS	NS	NS	NS	NS	0	0	1	0	0	0	Flh
Jarawa Is. 2	2	0	NS	NS	NS	NS	NS	0	0	2	0	0	0	Flh
Jarawa Is. 3	1	0	NS	NS	NS	NS	NS	0	0	1	0	0	0	Flh
Little Andaman	4	0	NS	NS	NS	NS	NS	0	0	4	0	0	0	Opl
Middle Button	1	1	0	0	0	1	0	0	0	1	0	0	0	Arh
Neil	9	9	0	1	8	0	0	0	0	9	0	0	0	Arh
North Cinque	1	0	NS	NS	NS	NS	NS	0	0	1	0	0	0	Opl
Opposite Strait	1	1	0	0	0	1	0	0	0	1	0	0	0	Flh
Outram (3)	3	3	0	0	0	3	0	0	0	3	0	0	0	Arh
Passage	2	0	NS	NS	NS	NS	NS	0	0	2	0	0	0	Flh
Point	2	2	0	0	2	0	0	2	0	0	0	0	0	Mk
Ramnagar (3)	3	3	0	0	0	3	0	0	0	3	0	0	0	Opl
Redskin	1	0	NS	NS	NS	NS	NS	0	0	1	0	0	0	Flh
Reef	5	5	0	0	2	3	0	0	0	0	0	5	0	Arh
Rutland	5	0	NS	NS	NS	NS	NS	0	0	5	0	0	0	Opl
South Button	14	14	0	0	0	14	0	0	0	14	0	0	0	Arh
Strait	2	0	NS	NS	NS	NS	NS	0	0	2	0	0	0	Flh
White Cliff	4	0	0	0	4	0	0	0	1	0	3	0	0	Mk
Wraffter's Creek	175	175	15	20	35	34	71	0	0	0	0	175	0	Flh
Total Islands 27	335	310	20	29	66	128	71	3	14	79	3	206	30	

[A = on coast approachable on foot; B = on coast, entrance partially submerged and access by swimming into cave; AB = on coast, Approachable on foot after swimming ashore; BD = Cave above sea level on cliff face ending in the sea; Cii = in the forest, cavern bellow the ground; D = Midway on inland cliff. VB = Very big, BG = Big, M = Medium, S = Small, VS = Very small, NS = not surveyed cave, Mk = Mithakhari group of rock layers, Opl = Ophiolite group, Arh = Archipelago group, Flh = Flysch group]

Annexure 2.2: Details of woody plants recorded from the Baratang Karstland.

S. no	Species name	Family	R_abu	R_fre	R_dom	IVI
1	*Aglaia andamanica* Hiern*	Meliaceae	0.3	2	0.3	2.6
2	*Aglaia oligophylla* Miq..	Meliaceae	4.4	21.8	4.4	30.5
3	*Aglaia spectabilis* (Miq.) S.S.Jain & S.Bennet	Meliaceae	0.6	2	0.6	3.2
4	*Anaxagorea luzonensis* A.Gray*	Annonaceae	8.1	25.7	8.1	42
5	*Artocarpus gomezianus* Wall. ex Trécul	Moraceae	0.5	3	0.5	3.9
6	*Artocarpus incisus* (Thunb.) L.f.	Moraceae	0.2	1	0.2	1.3
7	*Atalantia monophylla* DC.	Rutaceae	0.6	4	0.6	5.2
8	*Barringtonia asiatica* (L.) Kurz	Lecythidaceae	0.2	1	0.2	1.3
9	*Bischofia javanica* Blume	Phyllanthaceae	0.3	2	0.3	2.6
10	*Blumeodendron kurzii* (Hook.f.) J.J.Sm. ex Koord. & Valeton*	Euphorbiaceae	1.9	9.9	1.9	13.6
11	*Bombax insigne* Wall.	Malvaceae	0.9	3	0.9	4.8
12	*Bouea oppositifolia* (Roxb.) Adelb.	Anacardiaceae	0.6	4	0.6	5.2
13	*Calamus pseudorivalis* Becc.*	Arecaceae	0.2	1	0.2	1.3
14	*Calamus andamanicus* Kurz*	Arecaceae	0.5	2	0.5	2.9
15	*Calophyllum soualattri* Burm.f.*	Clusiaceae	1.7	7.9	1.7	11.4
16	*Canarium euphyllum* Kurz	Burseraceae	0.6	4	0.6	5.2
17	*Canthium glabrum* Blume	Rubiaceae	0.9	5	0.9	6.8
18	*Caryota mitis* Lour.	Arecaceae	4.4	13.9	4.4	22.6
19	*Celtis timorensis* Span.	Cannabaceae	3.1	7.9	3.1	14.2
20	*Celtis philippensis* Blanco	Cannabaceae	16.1	51.5	16.1	83.6
21	*Champereia manillana* (Blume) Merr.	Opiliaceae	0.2	1	0.2	1.3
22	*Chydenanthus excelsus* (Blume) Miers	Lecythidaceae	2.8	13.9	2.8	19.5
23	*Dillenia andamanica* Parkinson*	Dilleniaceae	0.2	1	0.2	1.3
24	*Diospyros kurzii* Hiern*	Ebenaceae	0.2	1	0.2	1.3
25	*Diospyros marmorata* R.Parker	Ebenaceae	1.6	7.9	1.6	11
26	*Diospyros pyrrhocarpa* Miq.	Ebenaceae	1.6	9.9	1.6	13
27	*Dipterocarpus alatus* Roxb. ex G.Don.	Dipterocarpaceae	0.8	4	0.8	5.5
28	*Dracaena angustifolia* (Medik.) Roxb.	Asparagaceae	2.7	10.9	2.7	16.2
29	*Evodia glabra* (Blume) Blume	Rutaceae	0.2	1	0.2	1.3

S. no	Species name	Family	R_abu	R_fre	R_dom	IVI
30	*Ficus callosa* Willd.	Moraceae	0.6	4	0.6	5.2
31	*Ficus sagittata* Vahl	Moraceae	1.1	5	1.1	7.1
32	*Garcinia andamanica* King*	Clusiaceae	0.3	2	0.3	2.6
33	*Garcinia speciosa* Wall.	Clusiaceae	0.2	1	0.2	1.3
34	*Gnetum scandens* Roxb.	Gnetaceae	0.8	5	0.8	6.5
35	*Gyrocarpus americanus* Jacq.	Hernandiaceae	0.3	1	0.3	1.6
36	*Hibiscus tiliaceus* L.	Malvaceae	0.2	1	0.2	1.3
37	*Hopea odorata* Roxb.	Dipterocarpaceae	0.2	1	0.2	1.3
38	*Horsfieldia glabra* (Reinw. ex Blume) Warb.	Myristicaceae	0.2	1	0.2	1.3
39	*Intsia bijuga* (Colebr.) Kuntze	Fabaceae	0.2	1	0.2	1.3
40	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	1.1	5.9	1.1	8.1
41	*Leea indica* (Burm. f.) Merr.	Vitaceae	0.2	1	0.2	1.3
42	*Licuala spinosa* Wurmb	Arecaceae	1.2	2	1.2	4.5
43	*Litsea glutinosa* Lour. C.B. Rob	Lauraceae	0.8	4	0.8	5.5
44	*Mallotus philippensis* (Lam.) Müll.Arg..	Euphorbiaceae	0.2	1	0.2	1.3
45	*Mangifera sp.*	Anacardiaceae	0.2	1	0.2	1.3
46	*Mangifera sylvatica* Roxb.*	Anacardiaceae	0.3	2	0.3	2.6
47	*Manilkara littoralis* (Kurz.) Dubard*	Sapotaceae	0.2	1	0.2	1.3
48	*Miliusa tectona* Hutch. ex C.E.Parkinson	Annonaceae	2.3	13.9	2.3	18.5
49	*Murraya paniculata* (L.) Jack*	Rutaceae	1.1	5.9	1.1	8.1
50	*Myristica andamanica* Hook.f.*	Myristicaceae	3	15.8	3	21.8
51	*Myristica elliptica* Wall.	Myristicaceae	0.5	3	0.5	3.9
52	*Neonauclea excelsa* (Blume) Merr.	Rubiaceae	0.2	1	0.2	1.3
53	*Parishia insignis* Hook.f.	Anacardiaceae	0.8	5	0.8	6.5
54	*Pisonia umbellifera* (J.R. Forst. & G. Forst.) Seem.	Nyctaginaceae	1.1	6.9	1.1	9.1
55	*Planchonella longipetiolata (King & Prain) H.J.Lam*	Sapotaceae	3.1	14.9	3.1	21.1
56	*Polyalthia parkinsonii* Hutch.*	Annonaceae	0.6	3	0.6	4.2
57	*Pometia pinnata* J.R. Forst. & G. Forst.	Sapindaceae	1.7	9.9	1.7	13.3
58	*Pongamia pinnata* (L.) Pierre	Fabaceae	0.3	2	0.3	2.6
59	*Pterocarpus dalbergioides* DC.	Fabaceae	0.3	2	0.3	2.6
60	*Pterocymbium tinctorium* Merr.	Malvaceae	1.4	7.9	1.4	10.7

S. no	Species name	Family	R_abu	R_fre	R_dom	IVI
61	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	2	10.9	2	14.9
62	*Pterygota alata* (Roxb.) R.Br.	Malvaceae	2.7	14.9	2.7	20.2
63	*Randia andamanica* (Kurz) N.P. Balakr.*	Rubiaceae	0.2	1	0.2	1.3
64	*Sandoricum koetjape* (Burm.f.) Merr.	Meliaceae	0.2	1	0.2	1.3
65	*Semecarpus kurzii* Engl.*	Anacardiaceae	0.2	1	0.2	1.3
66	*Semecarpus prainii* King*	Anacardiaceae	0.2	1	0.2	1.3
67	*Sloetia sideroxylon* Teijsm. & Binn. ex Kurz	Moraceae	1.1	5.9	1.1	8.1
68	*Spondias pinnata* (L.S.) Kurz	Anacardiaceae	0.2	1	0.2	1.3
69	*Sterculia sp.*	Malvaceae	0.3	1	0.3	1.6
70	*Sterculia kayae* P.E.Berry	Malvaceae	0.3	2	0.3	2.6
71	*Sterculia villosa* Roxb.	Malvaceae	0.2	1	0.2	1.3
72	*Streblus asper* Lour.	Moracaea	0.9	4	0.9	5.8
73	*Streblus taxoides* (Roth) Kurz	Moracaea	0.2	1	0.2	1.3
74	*Strychnos acuminata* Wall.	Loganiaceae	0.2	1	0.2	1.3
75	*Syzygium andamanicum* (King) N.P.Balakr.*	Myrtaceae	0.3	2	0.3	2.6
76	*Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan	Myrtaceae	3.6	16.8	3.6	24
77	*Syzygium manii* (King) N.P.Balakr.*	Myrtaceae	0.9	5.9	0.9	7.8
78	*Syzygium samarangense* (Blume) Merr. & L.M.Perry	Myrtaceae	1.9	9.9	1.9	13.6
79	*Tabernaemontana alternifolia* L.*	Apocynaceae	0.6	4	0.6	5.2
80	*Terminalia procera* Roxb.	Combretaceae	0.2	1	0.2	1.3
81	*Terminalia bialata* (Roxb.) Steud.	Combretaceae	0.5	3	0.5	3.9
82	*Terminalia manii* King*	Combretaceae	0.6	3	0.6	4.2
83	*Tetrameles nudiflora* R. Br.	Tetramelaceae	1.2	7.9	1.2	10.4
84	*Trigonostemon viridissimus* (Kurz) Airy Shaw	Euphorbiaceae	0.3	2	0.3	2.6
85	unidentified1		0.3	1	0.3	1.6
86	unidentified2		0.2	1	0.2	1.3
		Grand total	100	100	100	300

Note: **R_abu**= Relative abundance; **R_fre** = Relative frequency; R_**dom** = Relative dominance; **IVI** =Importance value index; ***** = Endemic species

Annexure 4.1: Co-existing Cave Fauna and its relation to the AENS in the Andaman and Nicobar Islands

Sr No	common English name	scientific name	conservation status	Light zone	Dim Light Zone	Dark Zone	Threat observed to AENS	Species Category
1	Large Indian Civet	*Viverra* zibetha	LC	Y	Y	Y	Feeds on the fallen chicks	Trogloxenes
2	Masked or Himalayan Palm Civet	*Paguma larvata tytleri*	LC	Y	Y	Y	Feeds on the fallen chicks	Trogloxenes
3	Domestic cat	*Felis catus*	LC	Y	Y	N	Predates on the adults and fledglings	NA
4	Andaman horseshoe bat	*Rhinolophus cognatus*	EN B2 ab (iv)	N	N	Y	Competitor for the nesting and roosting site	Troglobites
5	Mason's Diadem Leaf-nosed Bat	*Hipposideros diadema masoni*	NE	N	N	Y	Competitor for the nesting and roosting site	Troglobites
6	Dawn Bat	*Eonycteris* spelaea	LC	N	N	Y	Competitor for the nesting and roosting site	Troglobites
7	Andersen's Leaf-nosed Bat	*Hipposideros pomona*	LC	N	N	Y	Competitor for the nesting and roosting site	Troglobites
8	Horsfield's bat	*Myotis horsfieldii*	LC	N	N	Y	Competitor for the nesting and roosting site	Troglobites
9	Black-bearded Tomb Bat	*Taphozous melanopogon*	LC	N	N	Y	Competitor for the nesting and roosting site	Troglobites
10	Andaman Intermediate Horseshoe Bat	*Rhinolophus affinis andamanensis*	NE	N	N	Y	Competitor for the nesting and roosting site	Troglobites
11	Lesser false vampire bat	*Megaderma spasma*	LC	N	Y	Y	Competitor for the nesting and roosting site	Troglobites
12	Andaman rat	*Rattus stoicus*	VU D2	Y	Y	Y	Feeds on the fallen chicks and nests	Troglobites
13	Andaman masked owl	*Tyto deroepstorffi*	NE	Y	Y	Y	Predates on the adults and fledglings	NA
14	Brown-Hawk Owl	*Ninox scutulata obscura*	LC	Y	Y	N	Predates on the adults and fledglings	NA
15	Besra	*Accipiter virgatus abdulalii*	NE	Y	N	N	Predates on the adults and fledglings	NA
16	Asian common toad	*Duttaphrynus melanostictus*	LC	Y	Y	Y	Not seems to be related	Troglobites
17	Indian burrowing frog	*Sphaerotheca breviceps*	LC	Y	Y	Y	Not seems to be related	Troglobites
18	Glossy swiftlet	*Collocalia esculenta*	LC	Y	Y	N	Competitor for the nesting and roosting site	Trogloxenes
19	Nicobar Reticulated Python	*Broghammerus reticulatus*	NE	Y	Y	Y	Feeds on the Adults, Chicks and Eggs	Troglophiles
20	Andaman Cobra	*Naja sagittifera*	VU, NE	Y	Y	Y	May be feeding on the Adults, Chicks and possibly Eggs	NA
21	Red-tailed Trinket Snake	*Gonyosoma oxycephalum*	LC	Y	Y	Y	Feeds on the Adults, Chicks and Eggs	NA
22	Andaman Pit Viper	*Trimeresurus andersoni*	NE	Y	Y	Y	May be feeding on the Adults and fledglings	NA
23	Yellow-lipped Sea Krait	*Laticauda colubrina*	NE	Y	Y	N	May be feeding on the fallen chicks	NA
24	Indian Rat Snake	Ptyas mucosa	NE	Y	Y	N	May be feeding on Adults and Chicks	NA
25	Andaman Green Bronzeback Tree Snake	*Dendrelaphis andamanensis*	NE	Y	N	N	NA	NA

Sr No	common English name	scientific name	conservation status	Light zone	Dim Light Zone	Dark Zone	Threat observed to AENS	Species Category
26	Andaman Keelback	*Xenocrophis tytleri*	NE	Y	N	N	NA	NA
27	Andaman Wolf Snake	*Lycodon hypsirhinoides*	NE	Y	N	N	NA	NA
28	Common Water Monitor Lizard	*Varanus salvator andamanensis*	LC	Y	Y	Y	Feeds on the fallen chicks may be also the nest	NA
29	Andaman bent-toed gecko	Cyrtodactylus rubidus	NE	Y	Y	Y	Predates on the Eggs	Trogloxenes
30	Crabs	Order: *Arachinid*, unidentified spp	NE	Y	Y	Y	Feed on the fallen chicks	Troglobites
31	Longleg spider	class *Arachnids* , Order *Opiliones*	NE	Y	Y	Y	NA	Troglobites
32	Spiders	Order: *Hymenoptera*	NE	Y	Y	Y	NA	Troglobites
33	Huntsman spider	*Heteropoda*	NE	Y	Y	Y	NA	Troglobites
34	Whip spider	Order: *Amblypygi*,unidentified spp	NE	Y	Y	Y	NA	Troglobites
35	Cockroach	Family: *Nocticolidae*, unidentified spp	NE	Y	Y	Y	Feeds on the Nest	Troglobites
36	Crickets	Rhaphidophoridae, unidentified spp	NE	Y	Y	Y	May be feeding on the chicks	Troglobites
37	Indian tiger centipede	*Otostigmus rugulosus*	NE	Y	Y	N	Feeds on the Chicks and Eggs	Troglobites
38	Cave centipede	*Thereuopoda* Order: *Scutigeromorpha*, unidentified spp	NE	Y	Y	Y	NA	Troglobites
39	Termites	Order: *Blattodea*, unidentified spp	NE	Y	Y	Y	NA	Troglophiles
40	Pill bug	*Armadillidiidae*, unidentified	NE	Y	Y	Y	Feeds on Nest	Troglobites
41	Ants	family: Formicidae	NE	Y	Y	Y	Predates on Chicks and Eggs	Troglobites

Note: LC=Least concern; NE=Not Evaluated; VU=Vulnerable; EN=Endangered; D2=restricted area of occupancy; B2ab(iv)=Severely fragmented, decline at number of locations; NA=Not Applicable; Trogloxenes = cave guests, spend only part of their life cycles in caves; Troglobites = animal that lives entirely in the dark parts of caves, land dwelling species; Troglophiles = able to live its entire life in a cave.

Annexure 4.2: Co-existing species observed in different caves

Caves		Cockroaches	Snakes	Spiders	Crickets	Bats	Gecko	Whip spider	Crabs	Frogs	Centipedes
A11	Mean	2.5	0	0	1	3.4	1.5	2.1	0	0	0
	SD	1.41	0	0	1.3	3.45	1.02	1.42	0	0	0
	N	24	24	24	24	24	24	24	24	24	24
A2	Mean	7.3	0	0	2.9	9.1	1.6	5.5	0.1	0	0
	SD	3.41	0	0	1.46	29.42	1.01	9.03	0.43	0	0
	N	22	22	22	22	22	22	22	22	22	22
A21	Mean	13.4	0	0.1	9	0	0.1	9.4	16.3	0	0
	SD	5.01	0	0.42	3.44	0	0.42	2.82	5.5	0	0
	N	23	23	23	23	23	23	23	23	23	23
A51	Mean	1.49	0	1.06	3.69	0	1	3.2	4.17	0	0
	SD	2.54	0	0.97	2.23	0	1.06	1.84	1.72	0	0
	N	35	35	35	35	35	35	35	35	35	35
A53	Mean	0.27	0	0.03	12.27	0	0	10.85	14	0	0
	SD	1.57	0	0.17	3.27	0	0	3.06	5.32	0	0
	N	33	33	33	33	33	33	33	33	33	33
A67	Mean	11.1	0	0	7.38	0	0	10.14	11.14	0	0
	SD	4.62	0	0	3.49	0	0	2.88	4.15	0	0
	N	29	29	29	29	29	29	29	29	29	29
A71	Mean	0.41	0	0.87	5.25	0	1.87	3.97	4.12	0	0
	SD	1.04	0	0.91	3.77	0	1.24	2.07	2.56	0	0
	N	32	32	32	32	32	32	32	32	32	32
A73	Mean	21.07	0	0	10.07	0	0	10.57	12.43	0	0
	SD	3.58	0	0	2.7	0	0	2.07	5.21	0	0
	N	14	14	14	14	14	14	14	14	14	14
B3	Mean	14.75	0.1	0.1	2.05	25	0.2	4.35	1.05	0	0.1
	SD	9.04	0.31	0.45	3.05	111.8	0.52	2.98	1.67	0	0.31
	N	20	20	20	20	20	20	20	20	20	20
B30	Mean	0.15	0	0.58	0.23	0	0.5	1.44	3.56	0	0
	SD	0.71	0	0.65	0.69	0	0.74	1.96	2.52	0	0
	N	48	48	48	48	48	48	48	48	48	48
B41a	Mean	0.17	0	0.25	1.75	0	0.08	1.5	2.83	0	0
	SD	0.58	0	0.45	1.06	0	0.29	1.38	1.53	0	0
	N	12	12	12	12	12	12	12	12	12	12
B42	Mean	0	0	0	2.63	0	0.88	2.5	1.75	0.06	0
	SD	0	0	0	1.75	0	0.72	1.51	1.65	0.25	0

	N	16	16	16	16	16	16	16	16	16	16
B45	Mean	0.31	0	0.35	0.82	0	0.63	1.43	2.69	0	0
	SD	1.16	0	0.52	3.74	0	0.8	1.72	1.88	0	0
	N	51	51	51	51	51	51	51	51	51	51
B5	Mean	3.28	0	0.04	2.16	12.64	1.32	2.56	3.2	0.04	1.4
	SD	2.32	0	0.2	1.18	33.19	0.8	1.19	2.4	0.2	0.82
	N	25	25	25	25	25	25	25	25	25	25
B59	Mean	0	0	0	2.17	0.22	0	3.11	7.17	0	0
	SD	0	0	0	1.34	0.73	0	0.96	3.15	0	0
	N	18	18	18	18	18	18	18	18	18	18
B8	Mean	3.05	0	0	3.15	12.5	0.05	3.6	6.35	0.05	0
	SD	5.42	0	0	4.79	55.9	0.22	3.19	5.19	0.22	0
	N	20	20	20	20	20	20	20	20	20	20