STATUS AND ECOLOGY OF THE ANDAMAN CRAKE

Thesis submitted to the

Bharathiar University, Coimbatore

for the award of the Degree of

DOCTOR OF PHILOSOPHY

in

ZOOLOGY

by

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March 2009

CERTIFICATE

This is to certify that the thesis, entitled **"Status and Ecology of the Andaman Crake"** 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 research work done by **Miss. N. Ezhilarasi** during the period April 2004 to March 2009 of her research in the Department of Zoology at **Sàlim Ali Center for Ornithology and Natural History, Anaikatty, Coimbatore - 641 108** under my supervision and guidance, and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship /Fellowship or any other similar title of any candidate of any University.

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DECLARATION

I, **N. Ezhilarasi** hereby declare that the thesis, entitled **"Status and Ecology of the Andaman Crake"** 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 research work done by me during **April 2004 to March 2009** under the supervision and guidance of **Dr. Lalitha Vijayan** Senior Principal Scientist, Division of Conservation Ecology at **Sàlim Ali Center for Ornithology and Natural History, Anaikatty, Coimbatore - 641 108,** and it has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or any other similar title of any candidate of any University.

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Acknowledgements

I express my in-depth thanks to Dr. Lalitha Vijayan for supervising the project, and her constant support, guidance and invaluable suggestions. Her commitment and patience throughout this program made this thesis possible.

I am grateful to Dr. V.S. Vijayan, founder Director of SACON, for his support and encouragement. I am deeply indebted to Dr. R. Ravisankaran, Director, SACON for his constant support in the field and at the office. His exceptional guidance has been a tremendous academic influence. I would like to thank Dr. P.A. Azeez, Director in-charge and Drs. P. Pramod, S. Bhupathy, S.N. Prasad, P. Balasubramanian and S. Muralidharan at SACON for their help in various ways. All the above scientists helped me to substantially improve my thesis. I consider it my privilege to have them at hand for discussion and guidance on any topic irrespective of their field of interest.

Dr. K. Thiyagesan, Reader, Department of Zoology and Wildlife Biology, AVC College, Mayiladuthurai does require a special mention for his statistical advice. Dr. B. Sreekumar, scientist of BSI helped me in identifying the plants.

The unfailing support and co-operation of the Department of Forests and Wildlife of Andaman & Nicobar Islands was integral to this project and made this work possible. My special thanks go to Messrs. S.R. Mehta and S.S. Patnaik the Principal Chief Conservator of Forests; Messrs. Khazan Singh and S.S. Choudhary, PCCF & Chief Wildlife Wardens; Messrs. Pratap Singh. Kala and Alok Saxena, Conservators of Forests (Wildlife). Accommodation was provided by them and assistance offered by several forest officials is immeasurable. I thank the DCFs Messrs. R.C.S. Jayaraj, K. Ravichandran and Graham Durai; ACFs Parithosh Saha, Sabhu K. Thomas and P.N. Pal for their full support during the project period. Several field staff such as the Range Officers, Deputy Rangers, Camp Officers, Watchers of the Forest Department, Andaman District whose names are mentioned separately provided excellent cooperation in the field. I thank the staff of ANET Mrs. Aparna, Messrs. Andrews and John for their support in the field and for providing assistant.

I thank Mr. M. Manoharan and Ms. Santhi for their support at the SACON library. I would like to express my in-depth thanks to Mr. Vaithiyanathan, PA to the Director, for his assistance and, Mr. Srinivasan, computer assistant for helping me throughout the thesis writing period. I record my thanks to all the administrative and supporting staff including the security staff at SACON for their timely help.

I am grateful to my friends at SACON. Mr. Manchi Shirish helped me in field work and provided assistants. Messrs. V. Dhananjayan, K.S. Anoop Das, R. Eswaran, A. Sivakumar, E. Santhosh, L. Josheph Reginald, Nikhil Raj, Selvaraththinam, and Ms. N. Sheeba, J. Ranjini, Rachna Chanra, Aruna, Dhanya and Deivanayaki provided constant support throughout the project.

I am obliged to the Principal of Nirmala College for Women, Coimbatore, Rev. Sr. Paulin Mary for her constant support. I express my gratitude to my teachers: Mrs. Pawlin Vasanthi Joseph, Mrs. Anne Crysal, Rev. Sr. Sowriammal, Rev. Sr. Fabiola and Mrs. Roselin for their timely support and valuable suggestions. My thanks go to my colleagues Miss. Nithya Jeniffer and Miss. Dhanalakshmi for helping me by taking my classes and providing all other support.

My field assistant Tharsus and his family gave me accommodation and took special care at Pathilevel. I would like to express my heart felt thanks to them and to Xavier, Naveen, Tapuri and Alexander for their sincere support in the field.

I am very much grateful to my family members, mother, father, brother, sisters, brother-in-laws and small kutties Pavithra, Sowbernika and Sakthi who were the constant energy suppliers for my thesis work.

N. EZHILARASI

CONTENTS

Chapter 1

GENERAL INTRODUCTION

1.1. Introduction

Conservation of biodiversity has been given high priority in recent times with the understanding that species are being lost at a higher pace and more so in the Asian region (BirdLife International 2001). Species extinctions since 1600s have been largely attributed to anthropogenic causes such as hunting (23%), habitat loss (36%), competition with introduced species (39%) and others (2%) (World Conservation Monitoring Centre 1992). These effects are likely to increase with increased human population (Bridgman 2002). In the tropical Pacific, more than two thousand species of birds have been exterminated and many others have suffered local or regional extirpations (Dirrickson *et al.* 1998). Almost all the studies undertaken in several regions of the world show that flora and fauna have been greatly modified by human actions (Newton 1998). Assessing research findings from birds and other animals demand a note of caution, because studies in natural forests show how different are the species in compositions, densities, population dynamics, limiting factors, interaction and behaviour from what is seen in the same species in man-made landscape (Tomialojc and Wesolowski 1990).

The stresses limiting the survival of a species can vary from the outright over harvesting, habitat loss, and competition with exotic species to subtle changes in the quality of habitat. Habitat loss has been identified as one of the main factors for 1025 species of birds currently threatened in the world (Collar and Andrew 1988; Robinet *et al.* 2003). This alone affects a species in many ways from eliminating appropriate feeding or breeding sites to restricting range, which can affect dispersal patterns (Bridgman 2002). A form of habitat destruction, habitat fragmentation has been described as "the single greatest threat to biological diversity" (Stockwell *et al.* 2003; Reed 2004). Thus habitat loss and fragmentation have long-term effects causing extinction of population, generations after the destruction occurred and, even after deforestation practices were stopped, extinction continued for many of the species with small population sizes living in the forest (Kattan *et al.* 1994).

Endemic species need special attention as they are the worst affected by habitat destruction. Their restriction to one or more small discrete sites makes them inherently vulnerable to catastrophic and stochastic events that can eliminate population (Atkinson 1989; Whittaker 1998; Castellatta *et al.* 2000; Riley *et al.* 2002). "Any species with highly restricted range is at great risk of extinction from spatially localized forces" (Simberloff 1994). The small and limited population resulting from restrictions in habitat often exhibit low level of genetic diversity, further affecting the ability of a species to survive (Berger 1990; Roelke *et al.* 1993).

Status surveys for assessing the population form the top priority for all the species. Basic studies on the ecology are essential for their conservation and management. Detailed studies on the behaviour are also of importance to examine the habitat requirements during different activity *viz* breeding, feeding, resting, courtship etc. Conservation of birds requires sound understanding of the status, distribution, and ecology of the species (Vijayan *et al.* 1999) which needs avian research in extensive areas of natural habitat before such areas are gone forever (Newton 1998). Only then can we tell the full extent of human influence on population status. Successful conservation depends on disentangling and identifying the key environmental changes that have determined the distribution of each species. The distribution of birds on small islands has proved a source of information about biogeographical processes, such as the persistence of small population and rates of molecular evolution (Pimm *et al.* 1988).

1.1.1. Birds in Islands

Over 1750 species of birds (17%) of the world are confined to islands and among them 402 (23%) are listed as threatened (Whittaker 1998; BirdLife International 2001). About 12% of birds in Asia currently threatened with extinction, of which 39% are island endemics (Stattersfield *et al.* 1998; Vijayan *et al.* 2000; BirdLife International 2000, 2001).

The Island ecosystems are endowed with limited natural resources (Natrajan 1994). Island bird species are suffering from greatest rates of anthropogenic extinction in recent years, and contribute a disproportionately large number of currently threatened species (BirdLife International 2000). This island ecosystem with its highly limited resources is vulnerable to

any disturbance and species become threatened much faster than those in the mainland (Carew-Reid 1990). Human colonization of islands has led to several drastic environmental changes that have had massive impacts on the distribution and numbers of the insular fauna (Vijayan *et al.* 2000). Increasing demands on resources in the islands with the ever increasing human population and development activities have pressurized the fragile island ecosystems threatening their survival (Vijayan *et al.* 2000, 2005). Also, it is likely that species on smaller islands are extinction prone, due to natural processes (Davidar *et al.* 2001).

1.1.2. Indian context

India has two main groups of Islands, the Andaman and Nicobar Islands of the east coast and the Lakshadweep Islands of the west coast. Andaman and Nicobar Islands have been identified as a biodiversity hotspot for endemic species (BirdLife International 2000). These islands have varied and rich in flora and fauna (Rao 1989; Chandra 1999). The BirdLife International has reported the Andaman and Nicobar Islands as two of the 218 endemic bird areas of the world (Stattersfield *et al.* 1998). Nearly 270 species and subspecies of birds recorded from the island group include 106 (39%) endemics; this high proportion of endemism makes the Andaman and Nicobar Islands a priority area for avifauna conservation (Sankaran and Vijayan 1993; Vijayan *et al.* 2000). However, full species endemics are 18 according to Stattersfield *et al.* (1998) but 22 as per Rasmussen and Anderton (2005).

1.1.3. Ornithological research in Andaman and Nicobar islands

The earliest (eighteenth century) reports on the avifauna of Andaman and Nicobar Islands were given by Blyth (1845, 1846a, 1846b), Walden (1866, 1873) Tytler and Beavan (1867), Ball (1870, 1872), Hume (1874, 1875, 1876) and Butler (1899).

During nineteenth century, migratory and other birds of the Bay islands were reported by Butler (1900), Cory (1902), Richmond (1902) and Osmaston and Butler (1908), Wickham (1910), Whitehead (1912), Ferrar (1932), Stapylton (1933) and Vaurie (1959, 1965). After World War II the bird studies of Bay islands were resumed with reports by Abdulali (1965,

1967a, 1967b, 1971, 1976, 1981a, 1981b), Das (1971), Mukherjee and Dasgupta (1975), Dasgupta (1976), Mukherjee (1981) and Whitaker (1985). After a short-term survey Sankaran and Vijayan presented a review in 1993. The faunal exploration of Mount Harriet National Park was done by Chandra and Rajan (1996). Other research on birds were done by Sankaran (1998), Davidar *et al.* (1996). Sankaran and Sivakumar (1999) studied the ecology of the Nicobar Megapode *Megapodius nicobariensis.*

Bird studies in various aspects in Andaman Islands during twentieth century were reported by Vijayan *et al.* (2000), Dasgupta *et al.* (2002), Pande (2005, 2007) Pande *et al.* (2007). Bird community structure in different islands was studied by Vijayan *et al.* (2005). Birds of Chidiyatapu Biological Park were reported by Ezhilarasi and Vijayan (2006). The effect of introduced animals on biodiversity in the Andaman Islands was studied by Ali (2004). Status and impact of nest collection on the population of the Edible-nest Swiftlet was documented by Sankaran (1998) and ecological studies on this species and in-situ and ex-situ conservation programmes are continued. Population status of the Andaman Teal was documented by Vijayan (1999) and Vijayan *et al.* (2006) and site-specific recommendations for the Andaman Teal conservation were given. Although several research attempts have been made on the avifauna of the Andaman Islands, information on the biology and ecological requirements is available only for a few species (Davidar *et al.* 2007; Vijayan *et al.* 2006). Sivakumar (2000) studied the ecology of the Nicobar Megapode *Megapodius nicobariensis.*

1.2. Literature review

Watling (2001) reported that the Spotless Crake *Porzana tabuensis* population in Western Polynesia are declining precipitously as a result of introduced dogs, cats, mongooses and rats, whereas its population in the Pitcairn Island increased after eradication of rats (Rauzon and Fialua 2003) and after human occupation ceased (Taylor 1996). The tremendous increase in population of Woodford's Rail *Nesoclopeus woodfordi* was recorded by Hadden (2002) and he gave the reason for population increase as mainly isolation of Bougainville Island from the world because of war. Due to ban of coconut and cocoa, consequently ground cover of grasses, shrubs and other plants sprang up throughout the plantation which

provided ideal habitat for rails. The population fluctuation of the Black Rail *Laterallus jamaicensis* in relation to water flow in the dam was studied by Repking and Ohmart (1977). They reported increase in Black Rail population with increased water flow. Increasing trend in the population of Purple Swamphen *Porphyrio porphyrio* in the Iberian Peninsula was recorded by Sanchez-laruente *et al.* (1992). They found out the reason for increasing population as effective protection of the species and the areas used by it and also environmental changes such as the introduction of new farms and the creation of artificial wetlands.

Marchant and Higgins (1993) reported destruction of lowland rainforest habitat for agricultural and residential development as the major reason for the decline of the Red-necked Crake *Rallila Tricolor* in Australia. Eddleman *et al.* (1988) in their study on American Rallids found that Palustrine wetland loss resulted in rail population declines. Stinson *et al.* (1991) showed that the population of Common Moorhen *Gallinula chloropus* has been reduced nearly 36-52% in the 20th century. They found that the loss of wetlands, introduced competitors and predators posed the greatest threats to the Moorhen in the Marianas.

Red-legged Crake *Rallina fasciata* was reported as moderately common in Flores by Coates and Bishop (1997). Green (1995) and Jenkins and Ormerod (2002) followed the play-back method for surveying the breeding population of Corncrake *Crex crex,* and Water Rail *Rallus aquaticus* respectively. Coates (1985) in his study on birds of New Guinea reported the population status of Mayr's Forest-rail *R. mayri* and Red-necked Crake *R. tricolor* as common, whereas after ten years Gregory (1995) reported them as uncommon. Perennou *et al.* (1994) found that the Slaty-legged Crake *R. eurizonoides* was fairly common throughout south-east Asia. Population trends of Virginia Rail *Rallus limicola* and Sora *Porzana carolina* throughout North America from 1966-1991 were studied by Conway *et al.* (1994). They also estimated annual survival rate from radio-marked and banded birds in Arizona from 1985 to 1987 and nesting success using nest record cards throughout North America from 1920-1987. Frith and Frith (1990) studied the population of Chestnut Forest-rail *Rallina rubra* and they found the species as common in Australia.

Water Rail prefers the habitat with abundance of insects of the Orders Odanata, Plecoptera and Diptera (Jenkins and Ormerod 2002). The habitat of White-striped Forest-rail *Rallina leucospila* was interior montane forest, Forbes's Forest-rail *R. forbesi* was recorded in primary montane and mid montane forests while Mayr's Forest-rail was in mid-elevation montane forest between 1,100 and 2,200m (Taylor and Van Perlo 1998). Marchant and Higgins (1993) reported that Red-necked Crake preferred moist habitat. Coates (1985) in his study on birds of New Guinea, recorded the Red-necked Crake in rainforest, swamp forest and also in mangroves. Red-legged Crake was reported to occur in reedy swamps and marshes, rice and taro fields, rivers, streams, watercourses, riparian thickets and wet areas (Dickinson *et al.* 1991; Coates and Bishop 1997). Habitat choice, food, feeding and vocalization behaviour of the endemic Henderson Rail *Porzana atra* were studied by Jones *et al.* (1995). They compared the information with that of the Spotless Crake *P. tabuensis* the closest relative and probable ancestor. The comparison provides information on how these two taxa have differentiated since rails arrived on Henderson Island. Slaty-legged Crake occurred in the forest floor inside dense patches, and also reported to occur in well-wooded areas, dense scrub, and long grass with dense bushes (Lekagul and Round 1991). Habitat requirements of Auckland Island Rail *Rallus pectoralis* were studied by Elliot *et al.* (1991). Ruddy Crake *Laterallus ruber* preferred field edges (Slud 1964) fresh water habitat (Russell 1966), grassy areas (Monroe 1968) and abundant pastures (Saab and Petit 1992).

Habitat preference and distribution of the Gray-breasted Crake *Laterallus exilis* with respect to water level was studied by Stiles (1988). The Chestnut Forest-rail was recorded in the montane forest from 1500 to 3050 m and also in mossy mixed lower montane beech forest (Frith and Frith 1988). Gronow (1969) in his study on Rufous-sided Crake *Laterallus melanophaius* reported that it prefers ground, shallow water and floating vegetation for foraging.

Daily and seasonal activity of Common Moorhen was studied by Acuqarone *et al.* (2001). They found that the Moorhens do not increase the time spent feeding in the colder months nor do they increase their activity during days with lower temperatures. Schodde and Tideman (1990) reported Red-necked Crake as crepuscular and nocturnal, while Marchant and Higgins (1993) reported it being diurnal and most active at dusk and in the early

evening. They also described the species to feed on invertebrates and other small vertebrates. Slaty-legged Crake was observed to feed on earthworms, molluscs, insects and marsh plants (Taylor and Van Perlo 1998). Schmid (1993) reported that Forbes's Forest-rail ate insects and small vertebrates. Food and feeding habits of endangered Light-footed Clapper Rail *Rallus longirostris* were reported by Zembel and Fancher (1988) and they found that major food items of the species were crabs and snails.

Rail species mostly use the display behaviour and calls to establish and maintain territory (Taylor and Van Perlo 1998). Coates and Bishop (1997) reported the night time calling behaviour of Red-legged Crake. Activity budget of Purple Moorhen (Swamphen) and the daily activity pattern of Coot *Fulick atra* were studied by Bhupathy (1985) and Jayaraman (1985) respectively at Bharatpur, India. Unusual feeding technique by Bald Coots *Porphyrio melanotus* was observed by Rowley (1968). Gronow (1969) in his study on the breeding biology of Rufous-sided Crake reported that this Crake is an omnivore and feeds on the young of other small birds.

The influence of spatial patch structure and vegetation structure on nest-site selection and influence of weather, predation and anthropogenic activities on reproductive behaviour have been reported on Common Coot *Fulica atra* by Samraoui and Samraoui (2007). Jenkins and Ormerod (2002) in their study on Water Rail explained the significant relation between its breeding and presence of wet reed *Phragmites sp*. Rizi *et al.* (1999) stated that late egg-laying in the American Coots *Fulica americana* was due to the delay in rainfall. Nesting and courtship behaviour of the King Rail *Rallus elegans* were studied by Meanley (1992). Contreras (1988) reported the nesting season of Rufous-sided Crake as October to January; nest globular, made up of woven leaves and lined with *Cortadera* leaves; clutch size varied from 4 to 5, eggs white to cream; incubation period 20 days; chicks semi-precocial.

Little is known of the nidification of the *Rallina* species (Ripley 1977) and it is worth to review the existing knowledge in the context. Nesting biology of *Rallina* has been reviewed in Frith and Frith (1990). Breeding season and nesting details of Slaty-legged Crake *Rallina eurizonoides* was recorded by Stusak and Vo Quy (1986), which breeds

during south-west monsoon and makes platform shaped nest made up of leaves and grass. The egg and clutch of Slaty-legged Crake was reported by Schonwetter (1962), which lays 4-8 creamy white eggs. The clutch size of Red-legged Crake is 4-6, (Hoogerwerf 1949; Hellbrekers and Hoogerwerf 1967) and Slaty-legged Crake has an 'untidy pad of dead leaves and grasses and a few thin twigs with a slight central depression' on the ground or to a meter high for a nest in which 4-8 eggs are incubated by both sexes (Ali and Ripley 1969; Ripley 1977). Majnep and Bulmer (1977) imply that Forbes's Forest-rail builds a domed nest which may be located on the ground, raised up in *Microsorium* cane or in tree ferns or upon an epiphytic birds' nest fern; and suggested a clutch of 4-5 eggs. Ripley and Beehler (1985) reported Forbes's forest-rail nest at 5-6m on a horizontal fork of a small tree. This nest was 'a thick platform of dry' vegetative fiber and skeletonized leaves measuring 18 x 25 cm. The eggs were smooth glossy white, oval, pointed at one end. Mayr and Gillard (1954) described a roosting nest of this rail which was very similar to the Chestnut Forest-rail breeding nests described above. It was located 2.75 m above ground in the heart of a *Pandanus* tree.

Red-necked Crake nest was made up of a few leaves (Gill 1965) or a shallow circular cup of small dead twig pieces, vine tendrils and broad leaves, eggs number 2-7 (Coates 1985), both sexes incubate, with an incubation period of 18-22 days and chicks are pure black (Mason *et al.* 1981). These rails are reported to breed during wet season (Ripley and Bheehler 1985). Chestnut Forest-Rail nestlings were blackish grizzled with rusty or chestnut, unlike those of Red-necked Crake and Andaman Crake (Frith and Frith 1990). Domed nest for breeding and /or brooding are clearly common to Chestnut Forest-rail, White-striped Forest-rail and Forbes's Forest-rail not withstanding Mason's 'thick platform' nest of the latter species. The one egg clutch of Chestnut Forest-rail is, however, very much the exception within the Rallidae at present (Ripley 1977; Olsen 1978; Ripley and Beehler 1985), and if it is an adaptation to a cold wet highland environment might be found in other high altitude *Rallina* populations. Clearly, there are significant differences in nest structure, egg and clutch size, incubation periods and nestling down coloration among the *Rallina* species (Ripley 1977; Frith and Frith 1990).

1.3. Rationale for selecting Rail

Rails are remarkable because many species in the islands have evolved rapidly into flightless forms in the absence of predators, a fact which has led to the rapid extinction of numerous island taxa following the arrival of man and his commensals (Steadman 1995, 1997). Most rails are known for their shyness, and are only studied with great difficulty thus, making it difficult to know about the natural history of most species (Ripley 1977). Rails' habitats are disappearing rapidly and many rails are becoming endangered before investigating their habitat requirements so as to implement effective conservation measures (U.S. Fish and Wildlife Service 1988). Being little is known about many rails, their status and even their distribution cannot be established with any degree of confidence. In order to address this problem considerable amount of work needs to be done urgently on this poorly known group of species (Taylor and Van Perlo 1998).

The Andaman Crake *Rallina canningi* is a rare and endemic bird of the Andaman Islands (Stattersfield *et al.* 1998; Vijayan *et al.* 2000, 2005). There was not much information on the population, ecology, biology and behaviour of this species (Ali and Ripley 1987). This was kept under data deficient category (BirdLife International 2001). Listing of species in this category indicates that there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its range and or population status. More information was required on the status and ecology of this species (Islam and Rahmani 2002).

1.4. Thesis structure

This thesis comprises six chapters. In chapter I present the overview of available literature on rails and the rationale for this study. In Chapter 2, I describe the study area and study species. In Chapter 3, I examine the status of the Andaman Crake with respect to size classes of islands and different habitats. Chapter 4 deals with activities and food of the Andaman Crake. In Chapter 5, I discuss breeding biology of the Andaman Crake. In Chapter 6, I present the summary and conclusion. The literature cited and appendices are given in the last section.

Chapter 2

STUDY AREA AND STUDY SPECIES

2.1. Study Area

2.1.1. Andaman and Nicobar Islands

India has two main groups of Islands, the Andaman and Nicobar Islands on the east and the Lakshadweep Island on the west coast. Andaman and Nicobar Islands are the largest Archipelago system in the Bay of Bengal, consisting of 512 islands and rocks. This chain of islands is situated between 6° 45'N and 13° 41'N and 92° 12'E and 93° 57'E. The length between the extremities is about 355 km while the maximum width is only 60 km. The Andaman and Nicobar Islands have fringing reefs around many islands and a 320 km long barrier reef on the west coast. The geographical area is 8,249 km^2 with the coastline of 1,962 km (Singh 1981; Saldanha 1989) (Figure 2.1).

2.1.2. Andaman Islands

Andaman Islands have an area of about 6,408 km^2 with more than 325 islands of which 21 islands are inhabited (Singh 1981; Saldanha 1989). They are separated from the Nicobar by a 155 km channel known as the Ten Degree Channel (IIRS 2003). The Great Andaman group consists of North (1348 km^2), Middle (1070 km^2) and South (1731.6 km^2) Andaman Islands; with Baratang Island situated between Middle and South Andaman Islands. Rutland Island lies southeast of South Andaman and Little Andaman Island (731.6 km^2) across the Duncan Passage (Das 1999a; Das and Palden 2001) (Figure 2.2). The Andaman Islands have five national parks and 93 wildlife sanctuaries covering nearly 361.57 km^2 and 455.98 km^2 respectively (Andrews *et al.* 2006). The Bombay Natural History Society through the Indian Bird Conservation Network along with the BirdLife International has identified 16 Important Bird Areas in the Andaman Islands (Islam and Rahmani 2002). These islands are also endowed with vast stretches of reserve forest and protected areas as tribal reserves. Large areas of forest have been cleared by the settlers to practice agriculture (IIRS 2003).

Vijayan *et al.* (2005) classified the land cover of Andaman Islands into 16 types. Of the 16 types, the moist deciduous biome constitutes largest area (40%) followed by semi-evergreen (18%), mangrove (17%) and evergreen forest (16%). The tropical evergreen and semi-evergreen forest cover more than 56% of the total forest. The evergreen and semi-evergreen forests are dominated in South Andaman while mangroves are more in Middle Andaman. Forest Survey of India (FSI) report in 2003 showed 42% of the forest to be very dense and 34% moderately dense, making a total of 76% of dense forest and also showed 1.5% decrease during 1994-1998 (FSI 2003) and attributed it to encroachment in Diglipur, Havelock and Little Andaman. FSI reports of 1999 and 2003 showed a total decrease of 657 km^2 (8.6%) forest cover (from 7606 km^2 to 6949 km^2).

2.1.3. Geology and biogeography

Geologically these islands belong to a geosynclinal basin; the rocks are highly folded due to frequent tectonic movement in the past (Andrews *et al.* 2006). The Eustatic sea level rise following the Pleistocene in the Greater Sundas has led to the isolation of a continental land mass (Gascoyene *et al.* 1979). The Rakhine (Arakan) Yomas, which merges with the Himalayas, is considered to be the corridor along which continental Southeast Asia, including Great Andaman islands merge (Das 1999b; Das and Palden 2001).

Andaman Islands are highly volcanic islands, arising from a submerged mountain chain that follows southward extension of the continental shelf. Active volcanism with major eruptions was reported on Barren Island (IIRS 2003). The topography of large islands is hilly and undulating and small outlying islands are flat. Elevation is 0-732 m and Saddle peak in the north is the highest. The Andaman Islands are mostly interlaced with perennial and seasonal freshwater streams. There are no large rivers in the Andaman Island. Mangrove creeks lead out of the islands and mostly freshwater streams drain into these creeks (Andrews *et al.* 2006). The rocks of the island are primarily of marine origin, ranging from late Cretaceous to recent Serpentine, which comprise ultra basic, salty shale and basic rocks (Oldham 1885).

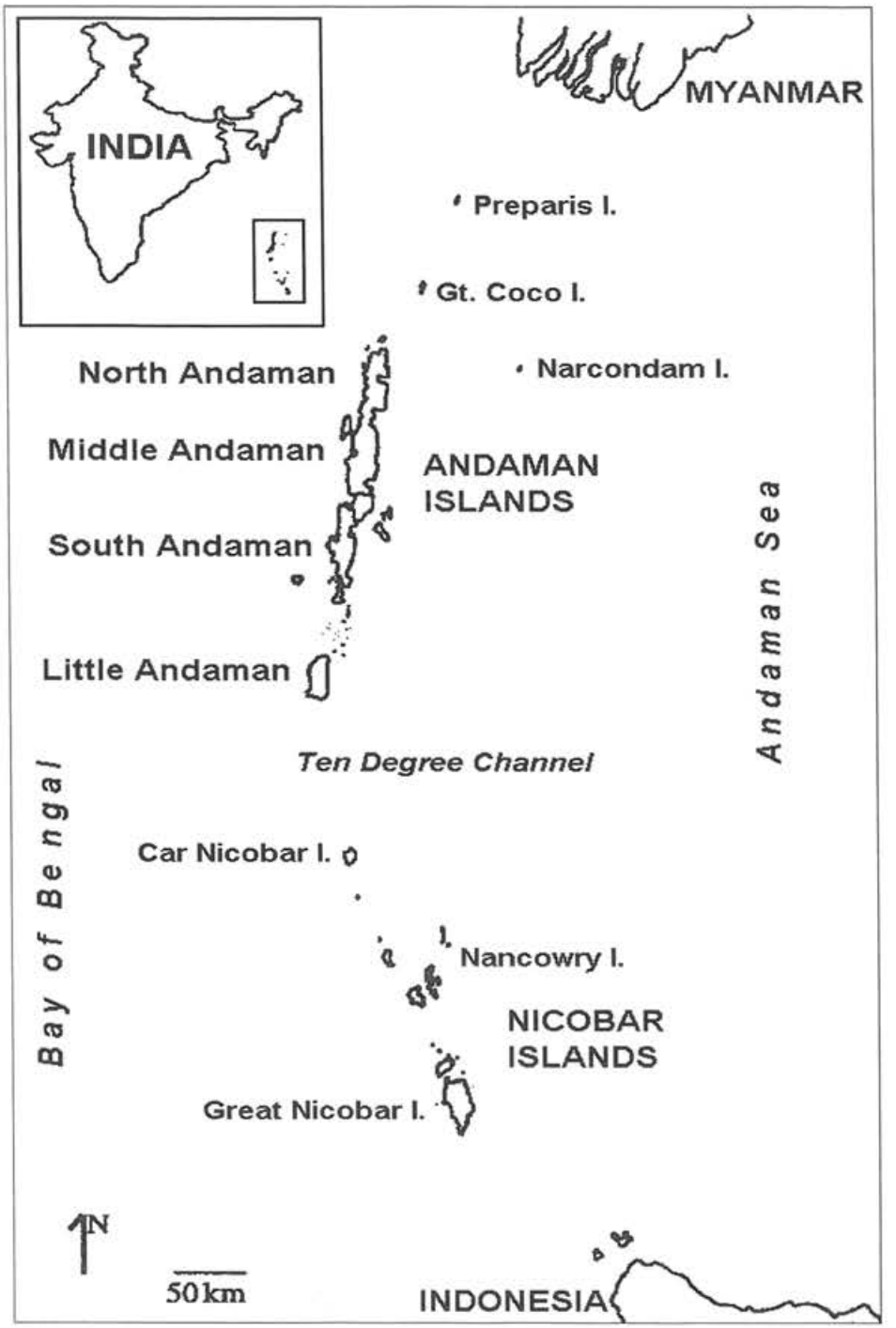


Figure 2.1. Location of Andaman and Nicobar Islands

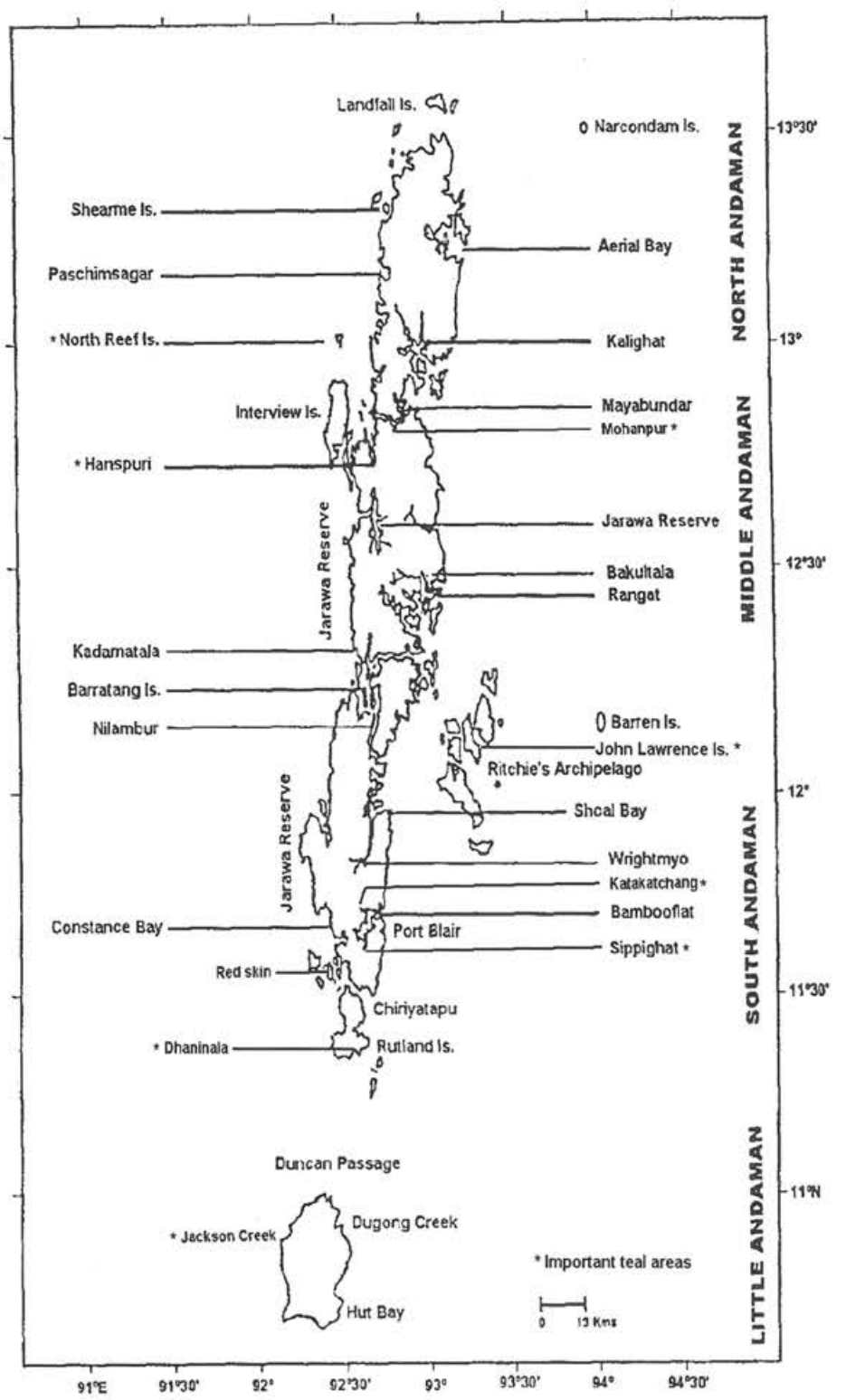


Figure 2.2. Map of the Andaman Islands.

Ganeshamurthy *et al.* (2000) have described the soil types and quality in the Andaman Islands. Soil types vary from heavy clay to clay loams, sandy loam and sand. There is considerable variation in soil from island to island in terms of composition, texture, depth, organic content, drainage, salinity and coloration. The soil of Andaman is grouped into three orders, Entisols, Inceptisols and Alfisols.

Soil is heavy clay with poor organic carbon and totally impeded drainage in some of the islands, whereas it is clay loam to sandy loam in other islands. The water holding capacity of soil also varies greatly (100-200 mm/m) with organic carbon content of more than 0.5%. The pH ranged from 4.5 to 8.5. Soil erosion activity of 8-20 tones per ha per year occur due to heavy rainfall and development activities. Andaman Island is susceptible to heavy soil erosion (IIRS 2003).

2.1.4. Climate

The Islands, due to their proximity to the equator, show weak seasonality. These islands have a tropical climate, the proximity of the sea and the abundant rainfall prevent extremes of heat. These islands experience both north-east and south-west monsoon with precipitation throughout the year, well marked between May and November.

2.1.4.1. Rainfall during the study period (2004-2006)

Andaman Islands receive less rainfall than the Nicobar Islands. Average annual rainfall of South Andaman Island is 3,200 mm and in the Nicobar it is 3,800 mm. The rainfall from January to December can range from 36 to 450 mm per month and rainy days for each month in a year can range from one to 21 days (Directorate of Economics and Statistics 2006). The south-west monsoon lasts from June to August and contributes much of the annual precipitation; north-east monsoon is experienced during September to November and some years into December as reported by Jayaraj and Andrews (2005). The pattern of rainfall showed slight variation with changes in the month of peak rainfall and number of rainy days in different years during 2004 to 2006 (Figure 2.3).

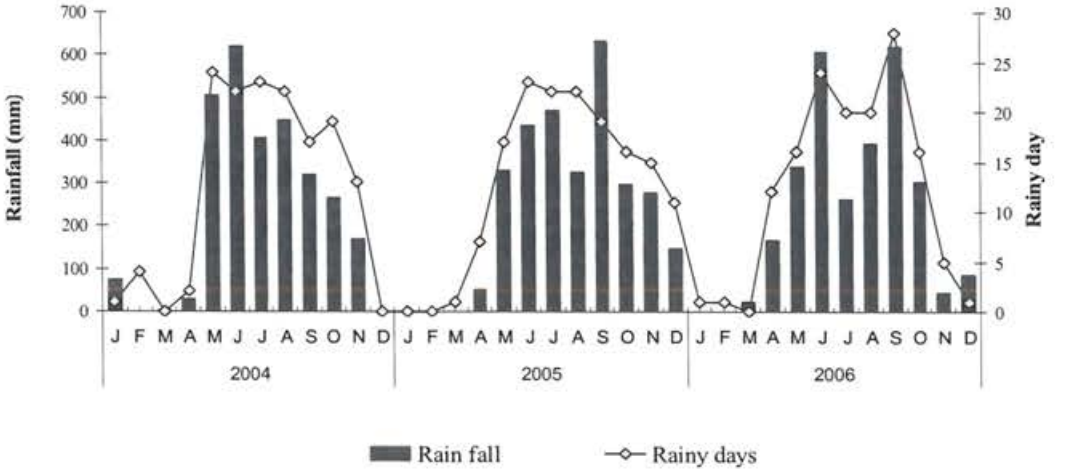


Figure 2.3. Monthly Rainfall and number of rainy days during the study period 2004- 2006.

2.1.4.2. Temperature, humidity and wind speed during the study period (2004-2006)

The maximum and minimum temperatures were 34°C and 22°C respectively. Monthly variation in temperature was not much; maximum temperature was recorded in April (Figure 2.4). The mean lowest minimum temperature was in January.

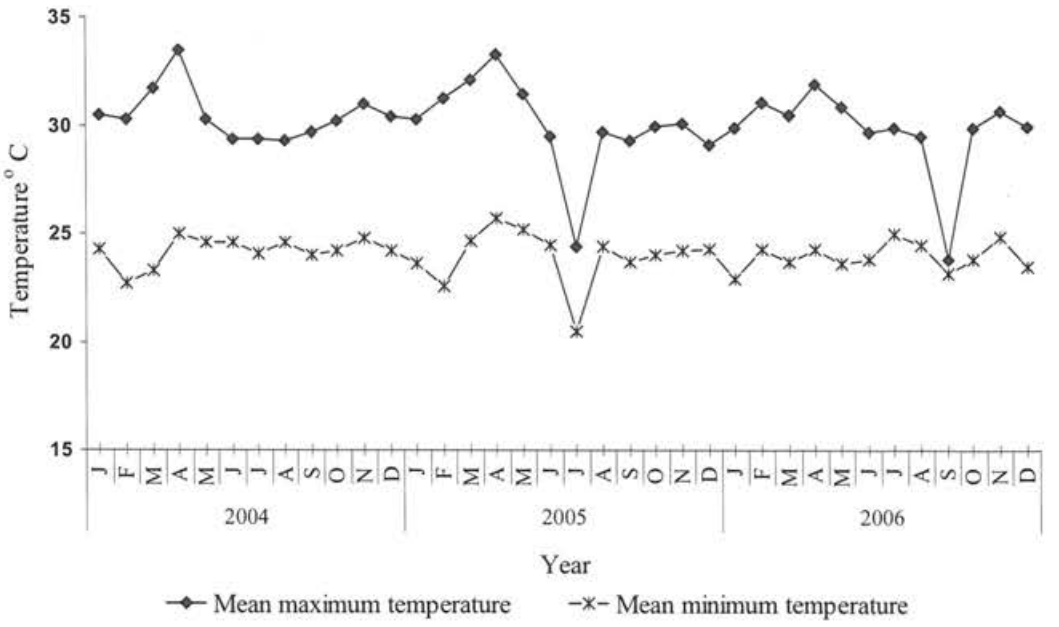


Figure 2.4. The average temperature during the study period 2004-2006

Relative Humidity (RH) ranged from 66 to 93 and the maximum in September (2006) (Table 2.1). Cyclones developed mainly during the change of the seasons, between May and June and during October - November. Wind speed averaged from 1.47 to 5.31 ms^{-1} and air density ranged from 1.15-1.19 kgm^{-3} (Khan 1987).

Table 2.1. Monthly mean percentage of relative humidity recorded during 2004-2006.

Month	08.30 h	Range (08.30 h)	17.30 h	Range (17.30 h)
January	70.23	72-76	74.37	70-71
February	69.67	70-71	70.63	68-72
March	68.83	71-72	70.87	67-70
April	67.23	70-75	72.70	66-68
May	79.27	82-86	83.73	77-83
June	85.73	86-91	88.43	83-89
July	83.93	84-87	85.47	83-85
August	83.73	85-86	85.80	82-85
September	85.97	85-93	87.97	83-90
October	81.80	84-87	85.50	80-83
November	76.30	79-82	80.37	75-79
December	71.67	69-81	75.43	65-80

2.1.5. Biodiversity

As per Biogeographic classification of India (Rodgers and Panwar 1988), Andaman and Nicobar Islands fall in biogeographic zone 10A/B. High temperature, high rainfall and high humidity results in rich biodiversity and endemism (IIRS 2003) in Andaman Islands. Isolation from the continental land mass (Andrews *et al.* 2006), and diversity in soils, climate, geology, and vegetation accounts for the exceptionally high endemism in this region (IIRS 2003).

2.1.5.1. Vegetation

The Andaman group of islands with the tropical climate supports the lush vegetation (Saldanha 1989). Most of the floral species are concentrated on the hills and hilly slopes. As per the State Forest Report 2003, forests occupied 6,964 km² (84%) of the total geographical area of 8,249 km². Of this, 5,387 km² is in the Andaman group and 1,577 km² in the Nicobar group. Mangroves cover an area of 644 km² in the Andaman Islands (FSI 2005).

IIRS (2003) has variously classified the land use in Andaman and Nicobar Islands into 14 types and they are : 1) evergreen forest, 2) littoral forest (beach forest), 3) wet bamboo forest 4) Andaman moist deciduous forest, 5) Andaman tropical evergreen forest, 6) Andaman semi-evergreen forest, 7) southern hill top tropical evergreen forest, 8) lowland swamp forest, 9) mangrove forest, 10) mangrove scrub, 11) *Syzygium* swamp (Millul swamp), 12) mixed evergreen forest, 13) Andaman secondary moist deciduous forest, and 14) brackish water.

Floristically, the Andaman and Nicobar Islands show Indo-Chinese and Indo-Malayan elements (Hajra *et al.* 1999). A total of 3552 plant species have been so far reported (Sreekumar 2002; Padalia *et al.* 2004) from these islands. A total of 14% of the angiosperms represented by 700 genera and 40 families is recorded from the Andaman Islands (Hajra *et al.* 1999). Of the 630 higher plants in the Red Data Book, 46 species occur in Andaman Islands (Sinha 1999). Dipterocarps are well represented in the Andaman Islands (Chaudhuri 1992). Aroids, ferns, mosses and climbers are mostly conspicuous in the semi-evergreen and deciduous forests. Six species of bamboo and 19 species of cane are found in the islands (Champion and Seth 1968).

An analysis of forest community of the Andaman by IIRS 2003 revealed that evergreen forest is the most diverse with maximum number of plant genera (349) followed by moist deciduous (294) and semi-evergreen forests (291). Dominant tree species include *Dipterocarpus griffithii, D. turbinatus, Sideroxylon longipetiolatum, Hopea odorata* and *Endospermum malaccense.* Moderate patches of deciduous forest were seen in North Andaman, Middle Andaman, South Andaman and Baratang Island (Balakrishnan 1989).

2.1.5.2. Fauna

Chandra (1999) has reported a total of 5988 insect species. Veenakumari *et al.* (1997) recorded 215 species of butterflies. Higher degree of endemism in butterflies (> 70%) at subspecies level was reported by Chandra (1999). Of 101 snails, 75 are endemic (Jayaraj and Andrews 2005). Reptiles and amphibians comprise over 125 species (Jayaraj and Andrews 2005), of which 16 reptile and seven amphibian species are endemic to Andaman Islands (Andrews and Sankaran 2002; Krishnan 2003).

The Birdlife International (2001) has reported the Andaman and Nicobar Islands as two of the 218 endemic bird areas of the world (Stattersfield *et al.* 1998). Out of 270 avian species and subspecies recorded from these islands 106 taxa (39%) are endemic indicating a high degree of endemism (Sankaran and Vijayan 1993; Vijayan *et al.* 2000). Review of the birds of South Asia (Rasmussen and Anderton 2005; Jathar and Rahmani 2007) has given a list of 20 endemic species in the Andaman Islands. The avifauna of Andaman and Nicobar islands closely resembled the avifauna of southwestern Burma (Ripley and Beehler 1989) and considered as Indochinese but not Indian (Wallace 1976; Udvardy 1969). In mammals 60% of the 58 species are endemic; these include several species of shrews, rats, palm civet (*Paguma larvata tytleri*) and 32 species of bats (Miller 1902). The Andaman and Nicobar Islands apart from being a storehouse of number of fascinating floral and faunal species are home to many tribes (Balakrishnan 1989; Rao 1989).

2.1.6. Intensive study area

Intensive study was carried out in two places Chidiyatapu Biological Park in South Andaman and Pathilevel in North Andaman.

2.1.6.1. Chidiyatapu Biological Park (South Andaman)

Chidiyatapu Biological Park (11° 30' 07.9 N & 92° 42' 14.6 E) is situated 25 km away from Port Blair and located in the southernmost tip of the South Andaman. Total area of the park is about 40 ha. This forest is notified as a reserve forest, which has already been extracted and regenerated subsequently. The park is composed of littoral, moist deciduous and semi-evergreen forest. The major tree species recorded in the study area *Syzygium*

cumini (Jamun), *Pometia pinnata* (Thitkandu), *Sageraea elliptica* (Chooi), *Bombax insigne* (Didu), *Dipterocarpus spp.* (Gurjan), *Terminalia bialata* (White Chugulam) and *Tetrameles nudiflora* (Thipok).

2.1.6.2. Pathilevel (North Andaman)

Pathilevel is a part of North Andaman (13° 02' 38.5 N & 92° 59' 51.9 E). The main forest type is Andaman moist deciduous forest with somewhat irregular top storey of predominantly deciduous trees about 40m or more in height with plenty of woody climbers. Beneath these trees is a definite second storey of numerous species including some evergreen species with a shrubby evergreen undergrowth of luxurious *Licuala peltata* (Silai pathi). The major tree species are *Pterocarpus dalbergioides, Terminalia bialata, Terminalia catappa, Bombax insigne* and *Tetrameles nudiflora.*

The list of plant species recorded in the intensive study areas is given in Appendix I. A total of 81 bird species belonging to 23 families were recorded that include 12 endemics and 10 near threatened species. Of the latter 9 are endamics. Checklist of birds in the intensive study area (Chidiyatapu and Pathilevel) is given in the appendix II.

2.2. Study species

2.2.1. Order Gruiformes

The Andaman Crake *Rallina canningi* belongs to the family Rallidae under the order Gruiformes. The order Gruiformes, for which even familial composition remains controversial, is perhaps the least understood avian order from a phylogenetic perspective (Livezey 1997, 1998, 2003; Fain *et al.* 2007). The Gruiformes comprises 10-12 modern families (Wetmore 1960) with only Pedionomidae and Turnicidae subject to alternative ordinal assignments in recent years (Sibley and Ahlquist 1990; Houde *et al.* 1997). The combination of widespread geographical distribution, extensive morphological and ecological divergence suggests an ancient origin of Gruiform families (Fain *et al.* 2007). All members of Gruiformes are monogamous (Taylor and Van Perlo 1998). The order Gruiformes consists essentially of ground-living birds and its only other widespread family is Gruidae (Cranes).

2.2.2. Family Rallidae

The Rails and Crakes fall under the family Rallidae which is the largest family in the Gruiformes, comprising 153 species, of which 16 are extinct (since c. 1600) (Taylor and Van Perlo 1998). The family Rallidae comprises a large but rather homogeneous group of small to large, terrestrial, marsh and aquatic non-passerine birds many of which live a secretive and skulking existence among dense ground vegetation (Sibley *et al.* 1993; Taylor and Van Perlo 1998). The natural history of many Rallidae species is not known even though the birds are widespread and locally common (Stiles 1988). The Rallidae exceeds all other Gruiform families in variation in body mass and most ecological parameters, including habitat, migratory habit, diet and reproduction.

2.2.2.1. Morphology

Rallids range in mean body mass from Finch-sized Crakes (*Porzana* and *Micropygia*; 25g) to Coots (*Fulica*; 500-2500g). In most of the species the sexes are similar in size, although male is slightly larger than female. The bodies of the rails are short, and often laterally compressed, wings are short, broad and rounded and normally have 10 primaries (Taylor and Van Perlo 1998). The bill is often brightly colored and has large depression in nostril (Ripley 1977). Rails have well-developed legs which are long and slender but are usually stronger. The plumage of rails is often cryptic and the downy plumage is typically black or dark brown. All Rallidae have powerful pelvic limbs and can swim, although members of the family exhibit a variety of specializations for life in dry uplands, wading in shallow water or aquatic locomotion (Livezey 1998).

2.2.2.2. Distribution

The Rallidae inhabit all major continental regions (exclusive of the Holarctic), as well as a multitude of oceanic islands from the equator to the sub-Antarctic (Ripley 1977; Taylor 1996). They are cosmopolitan and have one of the widest geographical distributions among families of terrestrial vertebrates (Olson 1973a). Endemic living rails (Aves: Rallidae) are currently known from a small number of islands in the world (*e.g.* Galapagos Island, Guam

Island, Okinawa Island, New Zealand and Henderson Island). They are mainly included in *Gallirallus*.

2.2.2.3. Habitat

Members of the Rallidae inhabit a range of ecological environments, the greatest variety of rails are found in wetlands, some found in the coastal wetlands, grassland and some others in warm forests from lowland to highland areas, including the interior and edge of primary and secondary growth, monsoon forest, swamp forest, dense riverine forest, forested ravines and dense evergreen and deciduous thickets (Olson 1973b; Livezey 1998; Taylor and Van Perlo 1998).

2.2.2.4. Food

Majority of the Rallidae is omnivorous, non-specific feeders and opportunistic (Taylor 1996). Forest-dwelling species are known to take very little plant material. Rails are known to prefer fresh waters; a few are known to survive on small oceanic islands with scarce or almost nil fresh water, such species drink salt water or obtain most of their water from their food (Olson 1973a, 1977). All rails swallow grit or small stones to help break up food in the gizzard. Very little information is available on the diet of the chicks of most rails, but it seems that the young, even of herbivorous species, are fed primarily on insects and other animal food (Taylor and Van Perlo 1998).

2.2.2.5. Breeding

Many of the forest rails are reported to breed between the start and end of wet periods. Little is known about the breeding of many other rails and the nest, egg and young of 23 species remain undescribed (Taylor and Van Perlo 1998). Most Rallidae are monogamous, construct terrestrial or slightly elevated, cup-shaped, variably concealed nests, have clutch size averaging 1-10 eggs and have precocious young characterized by brown to black natal plumages (Wintle and Taylor 1993; Taylor 1996).

2.2.3. Rails in India

Totally 23 species of Rails belonging to 10 genera (Appendix III) are recorded in India, which include 9 resident, four winter visitor, six species resident as well as migrant, and two species resident as well as winter visitor, one casual vagrant and status of *Gallinula chloropus orientalis is not* not known.

2.2.4. Genus Rallina

The genus *Rallina* comprises eight species of distinctively plumaged rails which inhabit forest or marshland in forest and are confined to Asia and Australasia (Taylor and Perlo 1998). The four species (Chestnut Forest Rail, White-striped Forest-rail (*R. leucospila*), Forbes's Forest-rail and Mayr's Forest-rail) endemic to New Guinea are sometimes separated into the genus *Rallicula*. Of the remaining four species Red-necked Crake was distributed in islands of New Guinea and NE Australia, Andaman Crake is endemic to Andaman Island, Red-legged Crake (*R. fasciata*) is reported from lowlands of south-east Asia and north-east India and Slaty-legged Crake (*R.eurizonoides*) occur in India, Nepal and Bhutan to China, Taiwan and Ryukyu (Roberts 1991). The two species (White-striped Forest-rail and Mayr's Forest-rail) which occur in mainland Asia are both resident and migratory within their normal ranges, while the Red-necked Crake is partially migratory in NE Australia. The species endemic to New Guinea are not globally threatened. White-striped Forest-rail Mayr's Forest-rail and Andaman Crake were data deficient (Collar *et al.* 1994; BirdLife International 2001) but when the status is revised only Mayr's forest rail is data deficient and other two are near threatened (BirdLife International 2008).

2.2.5. Conservation status

Many species of rails, mostly flightless, are distributed on oceanic islands throughout the world but are proved especially vulnerable to predators introduced by man; some 16 species of rails have become extinct since 1600 BC (Johnson and Stattersfield 1990). Based on the current IUCN criteria (SSC 1994), the current evidence indicates that 33 species, almost quarter of the 135 surviving rails species are globally threatened and the sub-species *tuerosi* of the Black Rail species is also endangered (Collar *et al.* 1994; BirdLife

International 2008). Further, seven species are categorized as near threatened, and five as data deficient. Thus, the survival of 45, nearly a third, of living rail species gives a cause for concern. Two of the 33 threatened species, namely Bar-winged Rail *Nesoclopeus poecilopterus* and Samoan Moorhen *Gallinula pacifica,* can be added to the list of extinct species (Collar *et al.* 1994). Taylor and Van Perlo (1998) recommended other two species Chestnut-headed Flufftail *Sarothrura lugens* and Striped Flufftail *S. affinis* to be considered as vulnerable. And also further five species, namely Little and Red-winged Wood-rails *Aramides mangle* and *A. calopterus* and Uniform Crake *Amaurolimnas concolor*, Isabelline Bush-hen *Amaurornis isabellinus* and Plain Bush-hen *A. olivaceus* have been recommended to be considered under Data Deficient. The inclusion of these seven species would increase the number to 52 (40%) species whose survival gives cause for concern (Taylor 1998).

2.2.6. Andaman Crake

The Andaman Crake (Plate 2.1) has 34 cm length and the largest *Rallina* species found in the Andaman Islands (Ali and Ripley 1987). Hume (1874) has described the species with measurements of the specimens from Andaman. Easily distinguished by deep maroon-chestnut head, neck, breast and entire upper-parts, bold black and white barring on under-parts, red iris, bright apple-green bill with narrow whitish tip, and olive-green legs and feet. Feathers always more or less ruffled up to produce a very round and ball-like outline (Butler 1900); tail long and fluffy; sexes alike.

a) Adult

b) Sub Adult

Plate 2.1. Andaman Crake

Chapter 3

STATUS, DISTRIBUTION AND HABITAT USE

3.1. Introduction

Birds are probably better researched and monitored than any other group of animals or plants. They are habitat specific and well placed to indicate the overall health of our environment (Bibby *et al.* 1998). Changes in the status of birds indicate the habitat loss, modification and also impact of these threats on other animals and plants (Greenwood *et al.* 1995). The international Union for Conservation of Nature and Natural Resources (IUCN 2001) has published Red list categories in which species are placed into certain threat categories based on the status of their population. Growing evidence from Breeding Bird Survey (BBS) data suggests decreasing population trends for many resident and migratory species (Peterjohn *et al.* 1995).

Still, geographical distributions of most species are poorly quantified or understood (Harrison 1989). The questions related to wildlife conservation, protection and management can only be answered by first answering the question about distribution of the species (IUCN 2001; Armsworth *et al.* 2006; Guisan *et al.* 2006). Species distribution is related to habitat association and this could help predict the likely effects of future environmental change and to assign objective conservation weightings (Prasad *et al.* 1998; Marzluff *et al.* 2000) for selection of protected areas (Thompson 2002; Jayson and Mathew 2003). Accurate estimates of distribution can only be achieved by reliably recording a species occurrence over large areas (Gibbons *et al.* 2007). Multiplicity of factors and scales that influence the key parameters of population dynamics are difficult to understand (Marzluff *et al.* 2000) which in turn hinder the effective and efficient conservation efforts.

The overall abundance of any bird species depends on the extent of its geographical range, the amount of suitable habitat within that range, food availability, inter and intra-specific competition (Newton 1998). Among these, food has an overwhelming influence on the major life history traits of individuals and population processes, and it controls directly or indirectly the effects of other factors (Martin 1987). As a general pattern, food is a fluctuating resource, changing in space and time in a predictable or unpredictable way

(Dempster and Pollard 1981), which might lead to evolution of bird migration over continents (Gauthreaux 1985). Thus, distribution of food among habitats affects the distribution of individuals in space (Hutto 1990). Landscape characteristics such as topography, soil, hydrology, climate and land use pattern determine the composition and the spatial arrangement of its inclusive habitat patches (Dunning *et al.* 1992).

The relationship between a species and its habitat is a close one. In order to conserve a species, one must be able to identify the habitat requirements of that species (Walsberg 1985). Habitat selection involves the choice of particular habitat among the available habitats and results in birds being non-randomly distributed in space. Habitat selection involves series of choices (Gochfeld 1977), namely general habitat selection, territory selection, and nest-site selection.

Forests offer a wide variety of habitats that differ in extent, physical structure, and availability to birds over both space and time (Mac Arthur 1959). Habitat loss and fragmentation have been identified as the main factors affecting the survival of the threatened birds (Robinsons and Wilcove 1994), especially forest and island birds (Collar *et al.* 1994; BirdLife International 2001). Concern for the future persistence for many avian species is justified because of the extensive threats to populations across their breeding, migratory, and wintering habitats such as habitat loss, nest predation, and brood parasitism (Asking 1993; 1995). Many threats to birds are related to changes in land use patterns; hence, biologists need to understand how habitat changes and loss affect avian communities (BirdLife International 2008).

The Rallidae are a diverse group in their habitat selection (Eddleman *et al.* 1988). Rails are cosmopolitan and occur almost everywhere except in Polar Regions, completely waterless deserts and mountainous regions above the permanent snow line (*del* Hoyo *et al.* 1996; Taylor and Van Perlo 1998). Members of the family Rallidae inhabit a range of ecological environments, the greatest variety of rails found in wetlands, some others in warm forests (Livezey 1998; Taylor and Van Perlo 1998).

Out of eight *Rallina* species Chestnut Forest Rail, White-striped Forest Rail, Forbes's Forest-rail, Red-necked Crake and Mayr's Forest-rail inhabit montane forest (Firth and

Firth 1988; Taylor and Van Perlo 1998). Red-legged Crake lives in reedy swamp; Slaty-legged Crake inhabits forest with a dense understory including forest edges, secondary growths, bamboo patches, and forest floor and also in the mangroves (Lekagul and Round 1991). However, detailed description of habitat requirements of these species is not known (*del* Hoyo *et al.* 1996).

Their generally secretive nature, the endangered status of several races and populations, and continued loss of habitat and threats to present habitat, warrant an examination of the conservation status (BirdLife International 2008). The overall effects of management programs relating to Rallid conservation have been assessed for a few species, and there is a need for a synthesis of such information for all species (Eddleman *et al.* 1988).

Since there was no definite information on the population status of the Andaman Crake, BirdLife International (2001, 2004) classified this under Data Deficient category. Recently this species has been classified under near threatened category (BirdLife International 2008). The information available before my study on the status of this species showed variation as common, rare or not sure of the status (Table 3.1). Hence it was necessary to take up the study on the Andaman Crake to understand its population status, distribution and habitat use.

Table 3.1. Existing record of the population status of the Andaman Crake.

Year	Place	Reference	Records	Remarks
2003-2004	Little, South, Middle, and North Andaman	Vijayan *et al.* 2005	Sightings	Rare
2000	Chidiyatapu	Falzon 2000*	Sighting	?
1998	South Andaman	Stattersfield *et al.* 1998	?	?
1993, 1997	Parnasala, Katakatchang	Vijayan 1993, 1997 & Vijayan *et al.* 2000	Sighting	Rare
1997	Mt. Harriet	Bawden & Kazmierczak 1999*	Sighting	?
1995	Mt. Harriet	Chandra & Rajan 1996*	Sighting	Common
1991	Port Blair & nearby places	Snetsinger *in litt.* 1999*	Sighting	?
1990	Port Blair &	Koeppel *in litt.* 1999*	Sighting	?

	nearby places			
1980	?	Ali and Ripley 1980	?	Common
1965	Wrightmyo	Abdulali 1965*	Sighting	?
1922, 1935	?	Baker 1926, 1929, 1935*	?	Common
1907	Rutland island	Eggs in BMNH, 1907*	Egg data	?
1907	Baratang island	Eggs in BMNH, 1907*	Egg data	?
1899, 1900	?	Butler 1900*	?	Very common
1889	?	Murray 1889*	?	Very common
1897	Port Blair & nearby places	AMNH, ANSP, BMNH, RMNH,FMNH, MCZ, SMF, MB*	Specimen	?
1874	Gopalkabung (Port Blair)	AMNH, ANSP, BMNH, RMNH,FMNH, MCZ, SMF, ZMB*	Specimen	?
1874	?	Hume 1874*	?	Exclusively rare
1873	?	Ball 1873*	?	Not commom

* Records from BirdLife International 2001,

? – No information

BMNH-British Museum of Natural History, London

AMNH-American Museum of Natural History;

ANSPA-Academy of Natural Science of Philadelphia

RMNH-Rijks Museum of Van Naturlijke Historie

FMNH-Field Museum of Natural History

MCZ-Museum of Comparative Zoology;

ZMB-Zoologisches Museum Berlin

3.2. Objectives

- Assess the population status and distribution of the Andaman Crake
- Understand the relationship between its distribution and habitat features, and
- Identify important areas for the conservation of this species.

3.3. Methods

Survey areas

Survey was carried out in outer (islands lying separated from main islands) and major islands of Andaman. The outer islands are classified into five categories depending on the size as very small (< 1 km^2), small (1-5 km^2), medium (6-10 km^2), large (11-50 km^2) and very large (51-100 km^2) (Table 3.3). The islands having the area above 100 km^2 are considered as major islands. During this study 38 islands were surveyed, which include 33 outer and five major islands. Outer islands include 15 very small, seven small, five medium, four large and two very large islands. Five major islands, namely South Andaman, Middle Andaman, North Andaman, Little Andaman and Rutland were surveyed. A total of 70 locations were covered.

3.3.1. Bird Survey (Playback method)

Surveys were conducted in various parts of the Andaman Islands. Prior to initiation of the systematic surveys, preliminary surveys were conducted; personal communication with field biologists, local people and particularly hunters, had given an idea of the occurrence of this species in various locations. Playback method was followed to survey the Andaman Crake as this method has been widely used to study the distribution of many rail species (Tomlinson and Todd 1973; Conway *et al.* 1993), and also from preliminary survey it was noted that Andaman Crake responded well to playback. A small portable tape recorder (Sony DV 7000) and speaker were used.

Andaman Crake were recorded while walking through transect and stopping at every 200m. If no Crake were heard or seen after two minutes, call was played from a tape. Playing lasted two minutes but was stopped if a bird responded. If the birds did not respond after five minutes, call was played again for two minutes (Bibby *et al.* 2000). These surveys were done during morning (before 09.00 h) and evening (after 15.00 h), as these periods were found to be the time of their call during the preliminary survey.

3.3.2. Habitat sampling

Nine major habitats types were surveyed; evergreen, semi-evergreen, moist deciduous, littoral, mangrove, dry deciduous, hill top, plantation and cultivation. GPS readings were taken in possible points. Other habitat variables including vegetation type, dominant plant species, canopy height (m), canopy cover (%), ground cover (%), distance to water (m) and distance to trek path (m) were recorded.

3.4. Data Analysis

- The encounter rate for different classes of islands and habitats was calculated as the number of birds per kilometer surveyed. Estimates of true abundance have not been possible because the proportion of Andaman Crake that respond when in range of call playback had not been studied until recently and also estimation of the distance of call was difficult.

- Basic statistical analyses such as mean and standard deviation were done.

- Spearmann's Rank Correlation was performed to know the relation between sightings of the Crake and habitat characteristics.

- Man-whitney *U* test was done to compare the abundance of the Crake between Island groups.

3.5. Results

3.5.1. Geographical distribution and abundance

Surveys were done in 33 outer islands and five major islands. Of the 38 islands surveyed, the Andaman Crakes were recorded in 12 islands. Out of 2001 points surveyed, 253 Crakes were recorded in 162 points with 73% (n = 118) of records by indirect method (call) and remaining 17% (n = 44) by direct observations (sighting). The total encounter rate was low, 0.63 birds per km, and the records being in only 8% of points surveyed. Most of the detections of the Crake were in pairs (53%), followed by single (46%) and a few sightings had three to four individuals.

3.5.2. Outer Islands

A total of 20 individuals were recorded from 114 km surveyed in the outer islands with the encounter rate of 0.18 bird/km (Table 3.2; 3.3).

Table 3.2. Abundance of the Andaman Crake in outer islands (< 100 km^2)

Islands	Area (km^2)	# of islands	# of points	# of Encounter	Encounter Rate/km
Very small	< 1	15	86	0	0.00
Small	1-5	7	127	5	0.20
Medium	6-10	5	116	0	0.00
Large	11-50	4	186	9	0.24
Very Large	51-100	2	54	6	0.56
Total		**33**	**569**	**20**	**0.18**

3.5.2.1. Very small islands

Islands having an area of < 1 km^2 are grouped as very small islands. Fifteen such islands were covered which are Aves, Bluff, Chester, Chota Neil, Dot, Grub, Kwangtung, Latouche, Malay, Oliver, Oyster, Sea Serpent, Snake, Spike and Surat. Depending on the size of the island, a minimum of two and a maximum of 10 points in 1 km were surveyed and the total was 86 points in 17.2 km (Table 3.2; 3.3). No Andaman Crake was recorded in very small islands during the surveys. The major forest types recorded in these islands were littoral and dry deciduous.

3.5.2.2. Small islands

Islands having area of 1-5 km^2 are classified as small islands. A total of seven such islands were covered, namely Alexandra, Boudeville, Hobday, Inglis, Neil, North Reef and Swamp. In 127 points in 25.4 km five Andaman Crake were recorded with the encounter rate of 0.20 bird/km.

Table 3.3. Locality-wise sightings and encounter rates of the Andaman Crake in the Outer islands.

Island category	Locality Surveyed	# of points	# of Crakes	Encounter Rate/km
Very Small	Chota Neil	9	-	-
Very Small	Latouche*	9	-	-
Very Small	Kwangtung*	6	-	-
Very Small	Sea Serpent*	8	-	-
Very Small	Snake*	2	-	-
Very Small	Surat*	3	-	-
Very Small	Aves	6	-	-
Very Small	Oyster*	10	-	-
Very Small	Oliver*	4	-	-
Very Small	Dot*	4	-	-
Very Small	Malay**	7	-	-
Very Small	Grub**	5	-	-
Very Small	Chester	5	-	-
Very Small	Bluff	4	-	-
Very Small	Spike*	4	-	-
Small	Neil	26	-	-
Small	North Reef*	14	-	-
Small	Boudaville*	15	2	0.65
Small	Alexandra**	18	2	0.55
Small	Hobday**	21	1	0.25
Small	Inglis	16	-	-
Small	Swamp*	17	-	-
Medium	Buchanan*	23	-	-
Medium	Stewart	26	-	-
Medium	Redskin**	16	-	-
Medium	Boat	22	-	-
Medium	Cinque**	29	-	-
Large	Anderson	42	5	0.6
Large	Sound	53	-	-
Large	Tarmugli**	55	4	0.35
Large	John Lawrence	36	-	-
Very Large	Havelock	24	3	0.65
Very Large	Hendry Lawrence	30	3	0.5

* - Sanctuary, ** - Part of Marine National Park

Of seven islands Crake was recorded from Alexandra, Boundeville and Hobday Island with the encounter rate of 0.55, 0.65 and 0.25 birds/km respectively (Table 3.2; 3.3). The major habitats recorded in these islands are deciduous forest, littoral and a few with wet forests. Andaman Crake was recorded from 7 of the 33 islands (21%); Out of these seven islands only one island is inhabited by people. Details of different islands and the number of Crake recorded are given below.

3.5.2.3. Medium islands

Islands of 6-10 km^2 are grouped as medium sized islands. Totally five such islands were covered, namely Boat, Buchanan, Cinque, Redskin and Stewart. A total of 116 points in 23.2 km were surveyed and no Andaman Crake was recorded during the survey (Table 3.2; 3.3). The major habitats recorded include deciduous, littoral, and semi-evergreen forests.

3.5.2.4. Large islands

Islands having area of 11-50 km^2 are termed as large islands. Totally four large islands were surveyed, namely Anderson, John Lawrence, Sound and Tarmugli. A total of nine Andaman Crake was recorded in 186 points in 37.2 km with the encounter rate of 0.24 bird/km (Table 3.2; 3.3). Of the four large islands Andaman Crake were recorded from Anderson and Tarmugli (0.6 and 0.35 bird/km) islands. The major forest types recorded were evergreen, semi-evergreen and deciduous forests.

3.5.2.5. Very large islands

Islands having area of 51-100 km^2 are classified as very large islands; two such islands Hendry Lawrence and Havelock were surveyed. A total of 54 points (10.8 km) was taken and six Crakes were recorded with the encounter rate of 0.56 bird/km (Table 3.2; 3.3). The major habitats surveyed in these islands were moist deciduous and semi-evergreen forests.

3.5.3. Major Islands

The islands having an area of more than 100 km^2 are grouped as major islands. Five major islands were covered, namely North Andaman, South Andaman, Middle Andaman, Little Andaman and Rutland. A total of 70 localities or sites were sampled and 233 Andaman

Crake was recorded in 1432 points in 286.4 km with the encounter rate of 0.81 bird/km (Table 3.4). The highest number of Crake was recorded in South Andaman (96) followed by Rutland (54), North Andaman (36), Middle Andaman (31) and Little Andaman (16). The highest encounter rate was in Rutland (1.31 bird/km) followed by South Andaman (0.92 bird/km), North Andaman (0.71 bird/km), Middle Andaman (0.66 bird/km) and Little Andaman (0.37 bird/km).

Table 3.4. Abundance of the Andaman Crake in Major Islands (>100 km^2).

Islands	# of Localities	# of points	# of Crake	Encounter Rate/km
North Andaman	13	254	36	0.71
Middle Andaman	13	236	31	0.66
South Andaman	25	522	96	0.92
Little Andaman	12	214	16	0.37
Rutland	7	206	54	1.31
Total	**70**	**1432**	**233**	**0.81**

3.5.3.1. North Andaman

In total, 254 points in 50.8 km were surveyed covering 13 localities, namely Aerial Bay, Durgapur, Jaganathdehra, Kallara, Kalpong, Kishori Nagar, Lamia Bay, Laxmipur, Milangram, Mohanpur, Radha Nagar, Saddle Peak, and Sita Nagar. A total of 36 birds were recorded with the encounter rate of 0.71 birds/km (Table 3.5 and Figure 3.1). Of the 13 locations, the Crake was recorded in 10 locations. The highest encounter rate was recorded from Jaganathdehra 1.36 bird/km followed by Sita Nagar (1.15 bird/km), Aerial Bay (1.00 bird/km) and Kishori Nagar (1.00 bird/km).

Table 3.5. Area-wise sightings and encounter rates of the Andaman Crake in North Andaman.

Area surveyed	# of points	# of individuals	Encounter Rate/km
Areial Bay	20	4	1.00
Durgapur	15	2	0.67
Jaganathdehra	22	6	1.36
Kallara	28	5	0.54
Kalpong	29	-	-
Kishori Nagar	30	6	1.00
Lamia Bay	14	1	0.36
Laxmipur	10	-	-
Milangram	13	2	0.77
Mohanpur	12	-	-
Radha Nagar	28	5	0.89
Saddle Peak	20	2	0.50
Sita Nagar	13	3	1.15
Total	**254**	**36**	**0.64**

3.5.3.2. Middle Andaman

A total of 236 points in 47.2 km was surveyed in 13 localities and 31 Crakes were recorded with the encounter rate of 0.66 bird/km (Table 3.6). The localities covered include Bakultala, Burmadehra, Dasaratpur, Kadamtala, Karmatang, Mithila, Nimbutala, Panchavati, Panighat Jetty (Austin Bridge), Parnasala, Rangat, Tugapur and Webi. Of the 13 locations, the Crake was recorded from nine locations. The maximum encounter rate was in Burma Dehra (2.50 bird/km) followed by Panighat Jetti (1.75 bird/km) and Rangat (1.30 bird/km) (Figure 3.2).

Table 3.6. Area-wise sightings and encounter rates of the Andaman Crake in Middle Andaman.

Area surveyed	# of points	# of individuals	Encounter Rate/km
Bakultala	26	2	0.38
Burma Dehra	6	2	2.50
Dasaratpur	5	-	-
Kadamtala	29	2	0.34
Karmatang	20	-	-
Mithila	21	2	0.48
Nimbutala	13	-	-
Panchavati	12	-	-
Panighat Jetty	20	7	1.75
Parnasala	19	2	0.53
Rangat	27	7	1.30
Tugapur	15	3	1.00
Webi	23	4	0.87
Total	**236**	**31**	**0.68**

3.5.3.3. South Andaman

A total of 522 points in 104.4 km was counted in 25 locations (Table 3.7) which include Bada Balu, Bambooflat, Burmanallah, Brichgunj, Chatham, Chidiyatapu, Corbinscove, Dhanikari, Garacharma, Jarawa Creek, Jirkatang, Kattakhari, Laltikri, Mangultan, Manjeri, Mini Bay, Mount Harriet, Mundapahad, Nayagarh, Northbay, North Wandoor, Shoal Bay, Tushnabad, Wimberleygunj and Wraffters Creek (Figure 3.3). A total of 96 birds were recorded and the encounter rate per km was 0.92.

Of the 25 locations surveyed, Crake was recorded in 20 locations. Highest encounter of Crake was observed in Wraffters Creek (2.13 bird/km), followed by Jarawa Creek (2.00 bird/km) and Brichgunj (1.83 bird/km) (Table 3.7).

Table 3.7. Area-wise sightings and encounter rates of the Andaman Crake in South Andaman.

Area surveyed	# of points	# of individuals	Encounter Rate/km
Bada Balu	30	1	0.17
Bambooflat	10	1	0.63
Burmanallah	19	2	0.53
Brichgunj	35	11	1.83
Chatham	10	-	-
Chidiyatapu	40	10	1.25
Corbinscove	10	-	-
Dhanikari	10	2	1.00
Garacharma	10	-	-
Jarwa Creek (Ratatgarh)	28	10	2.00
Jirkatang	35	3	0.50
Kattakhari	20	6	1.50
Laltikri	20	2	0.50
Mangultan	19	4	1.05
Manjeri	20	4	1.00
Mini Bay	15	1	0.33
Mount Harriet	30	4	0.67
Mundapahad	30	4	0.67
Nayagarh	15	4	1.33
North Bay	16	-	-
North Wandoor	13	4	1.54
Shoal Bay	15	4	1.33
Wimberleygunj	7	2	1.43
Tushnabad	20	-	-
Wraffters Creek	45	17	2.13
Total	**522**	**96**	**0.96**

3.5.3.4. Little Andaman

A total of 214 points in 42.8 km was covered in 12 localities (Figure 3.4) and 16 Crakes was recorded with the encounter rate of 0.37 bird/km. The locations surveyed were Beacon, Chetamale, Dugong Creek, Obeacha, John Richardson Bay, Ramakrishna Puram, Rokaralu, South Bay, Talande, Tandara, Totochilg and Waterfalls (Table 3.8). In these 12 locations, the Crake was recorded from six locations. Highest encounter rate was observed from Waterfall area and Totachilg (1.67 bird/km) followed by Obeacha (0.71 bird/km) and Ramakrishna Puram (0.59 bird/km).

Table 3.8. Area-wise, sightings and encounter rates of the Andaman Crake in Little Andaman.

Area surveyed	# of points	# of Individuals	EncounterRate/km
Beacon	8	-	-
Chetamale	14	-	-
Dugong Creek	26	2	0.38
John Richardson Bay	37	4	0.54
Obeacha	7	1	0.71
Ramakrishna Puram	17	2	0.59
Rokaralu	13	-	-
South Bay	35	-	-
Talande	8	-	-
Tandara	8	-	-
Totochilg	6	2	1.67
Waterfalls	35	5	0.71
Total	**214**	**16**	**0.37**

3.5.3.5. Rutland

Rutland Island is the largest outer island administratively part of South Andaman but having area of more than 100 km^2 and hence it is grouped under major islands. A total of 206 points (41.2 km) was taken from seven localities, namely Anarkali, Badakhadi, Bamboonallah, Forestdehra, Okildehra, Photonallah and Rola Deck. Totally 54 Andaman Crake were recorded with the encounter rate of 1.31 bird/km (Figure 3.5). Highest number of encounters were recorded in Forestdehra (1.95 bird/km) followed by Okildehra (1.65 bird/km) and Bamboonallah (1.55 bird/km) (Table 3.9).

Table 3.9. Area-wise, sightings and encounter rates of the Andaman Crake in Rutland Island.

Area surveyed	# of points	# of individuals	Encouner Rate/km
Anarkali	12	1	0.4
Badakhadi	51	10	1.00
Bamboonallah	49	15	1.55
Forestdehra	33	12	1.95
Okildehra	40	12	1.65
Photonallah	15	4	1.35
Rola Deck	6	-	-
Total	**206**	**54**	**1.35**

Figure 3.1. Map showing the survey locations in North Andaman.

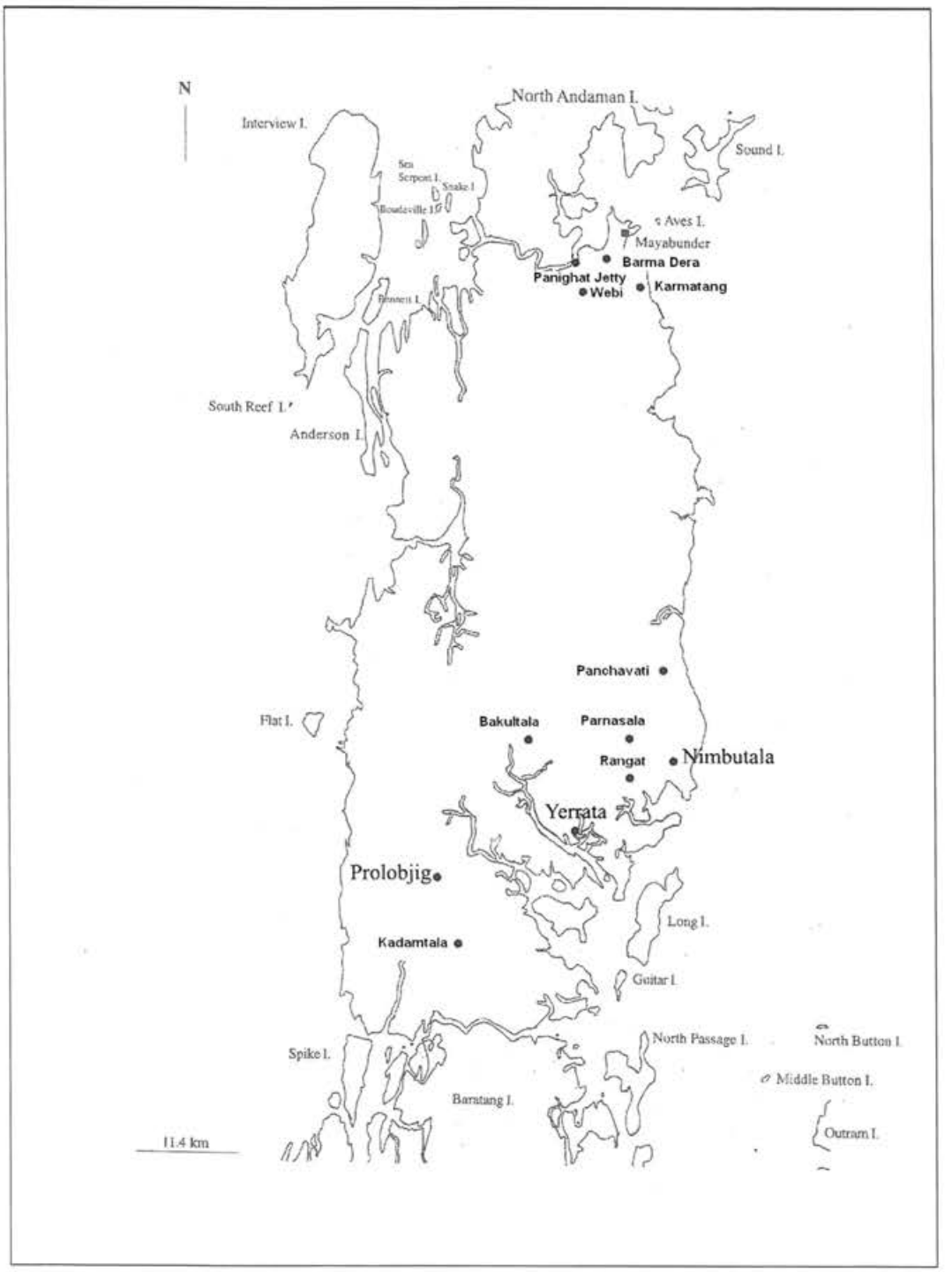


Figure 3.2. Map showing the survey locations in Middle Andaman.

Figure 3.3. Map showing the survey locations in South Andaman.

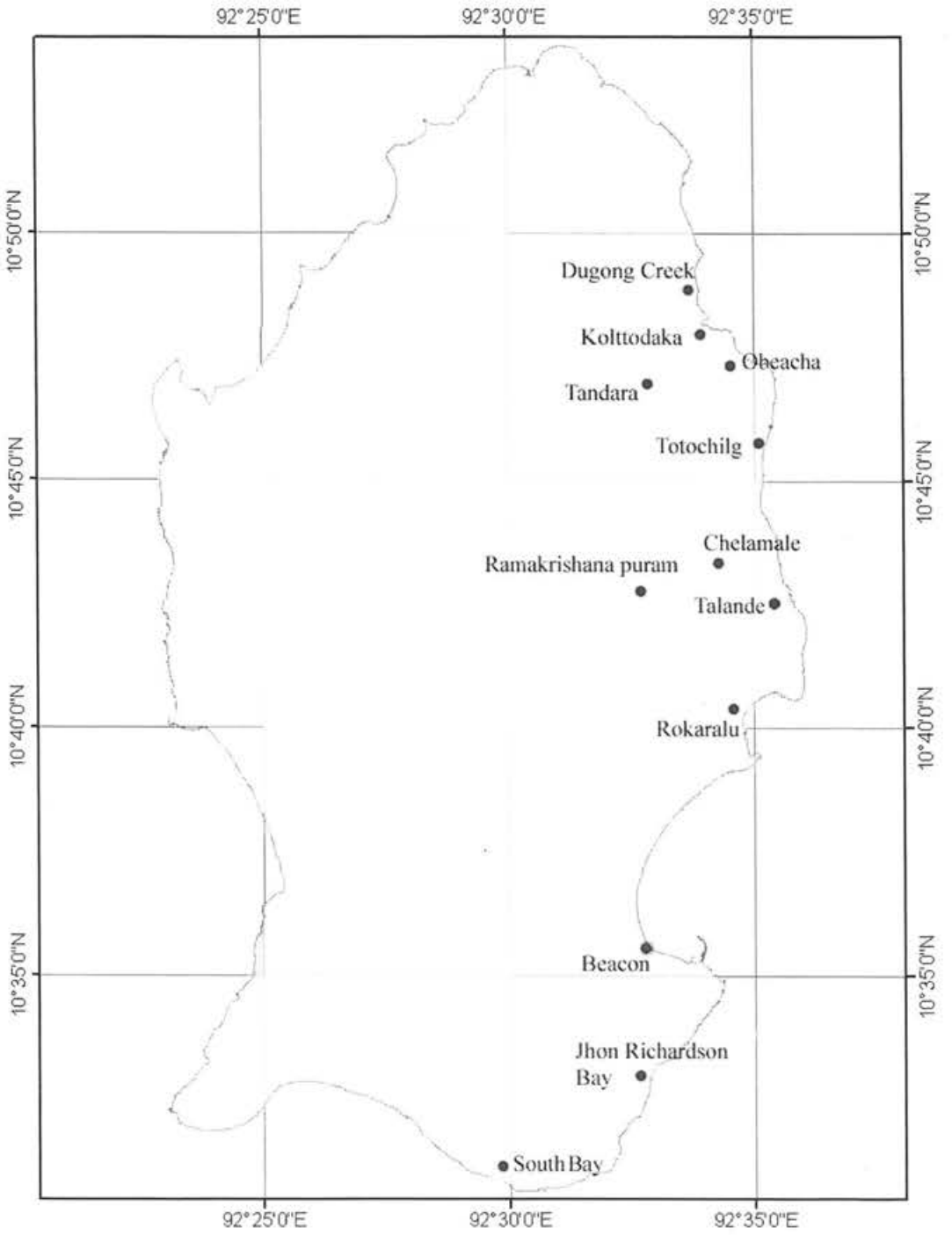


Figure 3.4. Map showing the survey locations in Little Andaman.

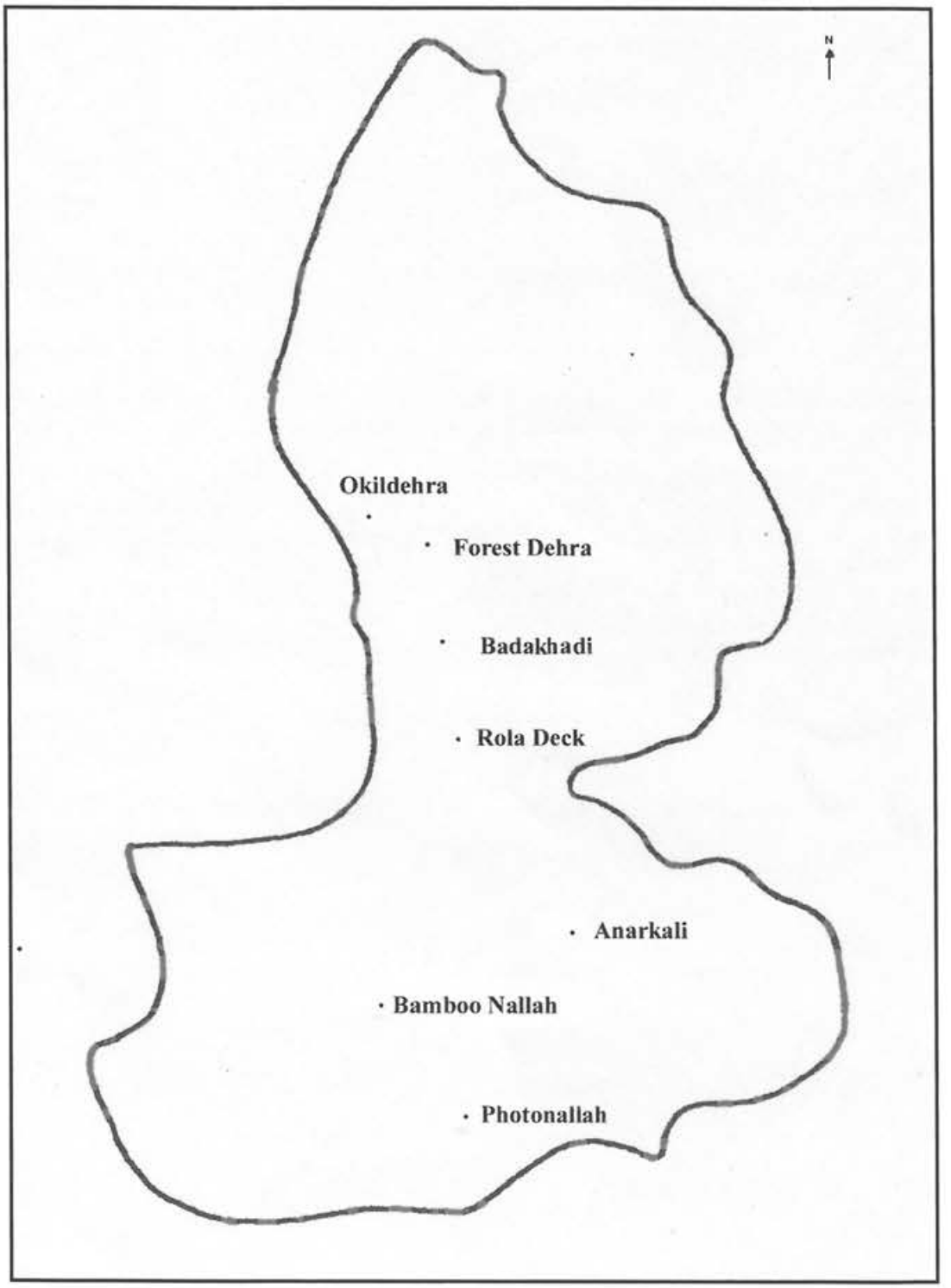
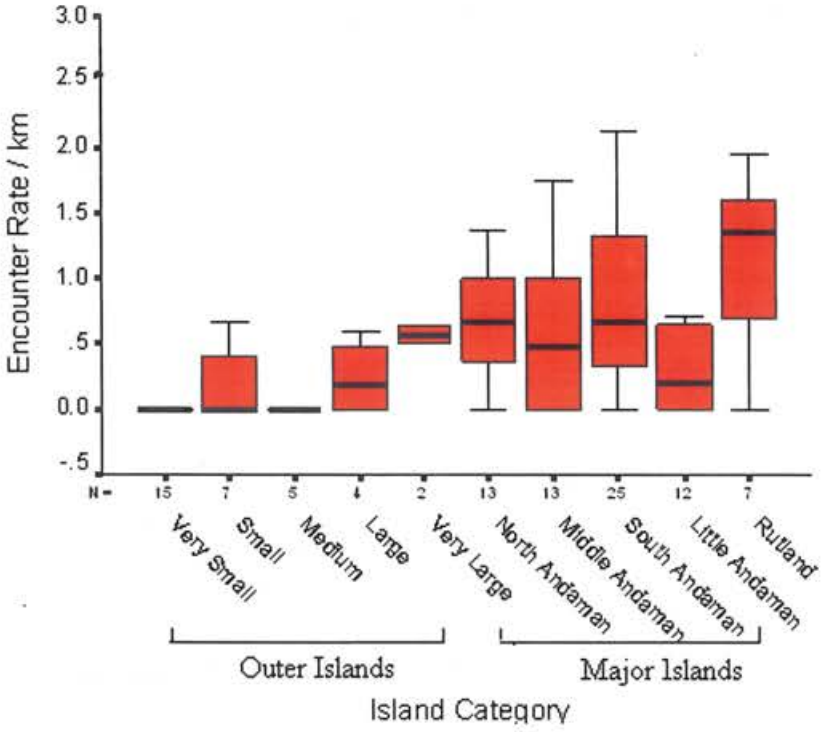


Figure 3.5. Map showing the survey locations in Rutland.

3.5.4. Comparison of abundance of the Andaman Crake in different islands.

The total mean encounter rate of the Andaman Crake was 0.63 bird/km. Compared to outer islands higher number of Crakes was recorded from major islands (0.16 and 0.81 bird/km respectively) (Figure 3.6). The variation among outer islands and major islands was significantly different (Mann-Whitney $U = 409$; $p < 0.01$).



Horizontal line - median, vertical line – minimum and maximum encounters.

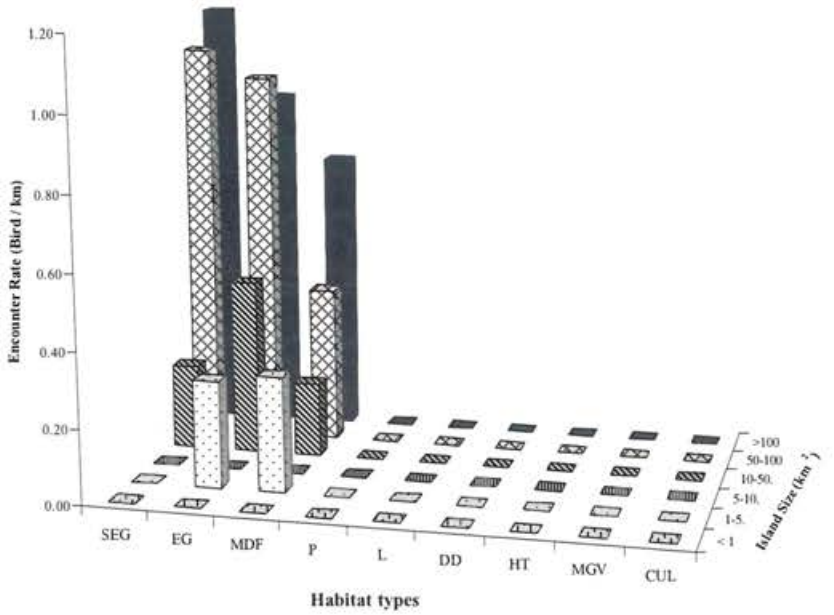
Figure 3.6. Encounter rate of the Andaman Crake in different islands of Andaman.

3.5.5. Habitat-wise distribution

Of nine different habitats surveyed Andaman Crake was recorded only from semi-evergreen (1.00 bird/km), evergreen (0.74 bird/km) and moist deciduous forest (0.61 bird/km). They were not found in the plantation, littoral, dry deciduous, hill top and mangrove forests and cultivated land (Table 3.10; Figure 3.7).

Table 3.10. Status of the Andaman Crake in different habitats

Habitat	# of points	# of Crake	Encounter Rate / km
Semi-evergreen	414	83	1.00
Evergreen	397	59	0.74
Moist deciduous	910	111	0.61
Plantation	37	-	-
Littoral	112	-	-
Dry deciduous	27	-	-
Hill top	19	-	-
Mangrove	38	-	-
Cultivation	47	-	-



SEG – Semi-evergreen forest
EG - Evergreen forest
MD - Moist deciduous forest
P - Plantation
L - Littoral forest
DD - Dry deciduous
HT - Hill top
MGV - Mangrove forest
Cul-Cultivation

Figure 3.7. Encounter rate of the Andaman Crake in various island size classes and different vegetation types.

The littoral forest was the most common (67%) in all islands surveyed. Deciduous forests were recorded on 45% of the islands and wet forests (evergreen and semi-evergreen) on 36% of the islands (Table 3.11). Wet forests were recorded in all the islands having area above 1 km^2 and it is more common in islands having area above 50 km^2. Out of 33 outer islands surveyed, 12 (36%) were recorded with wet forest (Table 3.12). The Andaman Crake was recored only in wet forests (semi-evergreen, evergreen and moist deciduous forests). Though the wet forests were recorded in all size classes of the islands, encounter rates increased with the increasing island size ($r = 0.835$; $p < 0.05$). Number of sightings of the Crake increased with the increasing survey effort in habitats such as evergreen, semi-evergreen and moist deciduous forests, but was not significant ($r = 0.990$; $p = 0.09$).

3.5.6. Distribution along elevational gradient

The lowest elevation of sighting of the Crake was 0 m and the highest 558 m. The number of Crakes observed decreased with increasing elevation but not statistically significant ($r = -0.991$; $p = 0.08$; Figure 3.8).

Table 3.11. Distribution of major forest types amongst the different island groups. (percentage in parenthesis)

Island category	# of Islands	Littoral	Deciduous	Wet
Very Small	15	15 (100)	-	-
Small	7	3 (43)	5 (71)	4 (57)
Medium	5	2 (40)	5 (100)	2 (40)
Large	4	1 (25)	4 (100)	4 (100)
Very Large	2	1 (50)	1 (50)	2 (100)
Total	**33**	**22 (67)**	**15 (45)**	**12 (36)**

Table 3.12. Distribution of wet forests with reference to island size (percentage in parenthesis)

Island category	# of Islands	Littoral	Deciduous	Wet
Very Small	15	15 (100)	0	0
Small	7	3 (43)	5 (71)	4 (57)
Medium	5	2 (40)	5 (100)	2 (40)
Large	4	1 (25)	4 (100)	4 (100)
Very Large	2	1 (50)	1 (50)	2 (100)
Total	**33**	**22 (67)**	**15 (45)**	**12 (36)**

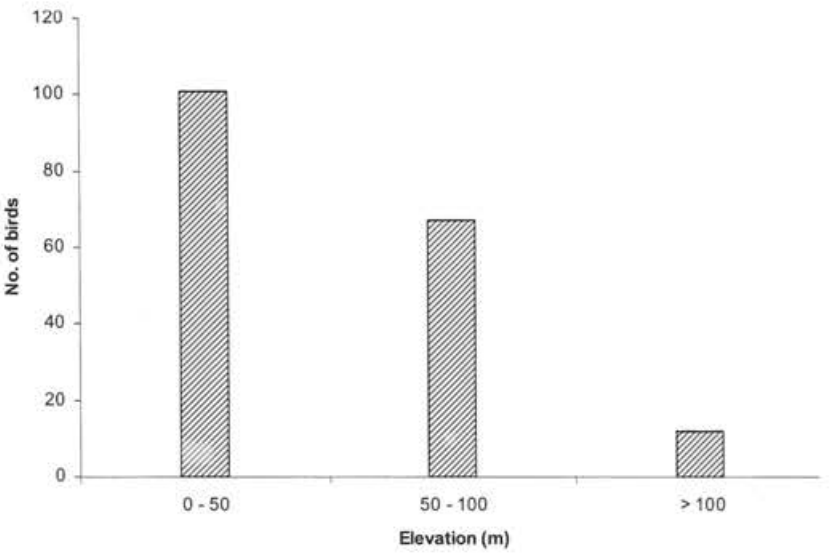


Figure 3.8. Distribution of the Andaman Crake in different altitudinal classes.

3.5.7. Habitat details of the Andaman Crake

Five pairs of the Crake were recorded within the intensive study area at Chidiyatapu. Crake has uneven distribution, clumped at certain locations. Territories of two colour-marked pairs were measured. Each pair was found to occupy a well defined area. The average size of the territory was 1.5 to 2 ha. The pair maintained its individual territory by retreat or attacking the intruder. However, some of the colour-marked individuals were not sighted in the area showing chance of their movement or loss. Encounter rate was negatively associated with the distance from stream ($r = -0.569$; $p < 0.01$). Besides this, the habitat was characterised with high canopy, moderate canopy cover (50.22±22.4), low ground cover (28.47±27.2), and high number of saplings (191.7±85.3). The feeding and breeding habitat details of the Andaman Crake are given in chapters 4 and 5 respectively.

3.6. Discussion

Andaman Crake lives singly, in pair or small family groups as other *Rallina* species such as, White-striped Forest-rail (Ripley 1977), Red-necked Crake (Mason *et al.* 1981) Red-legged Crake (Coates and Bishop 1997) and Slaty-legged Crake (Taylor and Van Perlo 1998).

3.6.1. Outer Island sruvey

The abundance and distribution of the Andaman Crake in different islands showed very low abundance in outer islands (ER 0.18 bird/km) while higher number of Crakes was recorded in the major islands (ER 0.81 bird/km) which was correlated with the size of the island. No Crake was recorded in the very small islands the reason may be these are hilly or rocky and without water source, and the major vegetation type recorded is littoral forest (Davidar *et al.* 1996). The restricted distribution of many species might be due to low dispersal ability or the inability of smaller islands to support viable populations of certain species (Davidar *et al.* 2007). Davidar *et al.* (1995, 2001) in their study on avifauna of Andaman Islands reported that the species on the small and very small islands tend to consist of vagrants which are widely distributed across all habitat types. Davidar *et al.* (2007) recorded Andaman Crake only from islands having area above 20 sq. km. But in

this study, out of seven small islands Andaman Crake was recorded in three islands which were characterized with wet forests. Neil Island did not have any record of this Crake because it was fully disturbed by human settlement; whole forest area in this island was converted for cultivation. In the medium sized islands no Crake was recorded, but according to hunters this species was sighted (hunted) in Butchannan Island which might be because of the time and duration of my survey. This species is difficult to be observed during short-term surveys, especially during the day when they are not active, even with playback of calls as in some other rails (Tailor and Van Perlo 1996).

3.6.2. Major Island Survey

Higher number of Crakes was recorded in the major islands with the encounter rate more or less similar in all the major islands except Little Andaman, which may be because of less area surveyed. The highest number of Andaman Crake was recorded from the Rutland Island. High population of Crake in Rutland could be due to the availability of regenerating forest, perennial river and streams and removal of people who engaged in logging. Similar observation was reported in Spotless Crake (Rauzon and Fialua 2003) in Pitcairn Island and Woodford's Rail (Hadden 2002) in Bougainville Islands, where the population increased after eradication of rat and elimination of human occupation. Presence of the Crake in secondary forest and edges shows that the Andaman Crake could use secondary growth forest along streams after forest clearance as reported in White-spotted Flufftail *Sarothrura pulchra* (Dowsett-Lemaire 1990). Edges are characterised by denser undergrowth vegetation compared to the forest interior which provides better cover from the predators (Ahmed 2005) and also local ecological factors play crucial role in determining avian diversity and abundance in a particular area Matlock and Edwards (2006).

3.6.3. *Habitat-wise distribution*

Andaman Crake was recorded only in wet forests such as semi-evergreen, evergreen and moist deciduous forests as reported in Red-necked Crake (Marchant and Higgins 1993). The distribution of consumers is an indication of the distribution of resources in general. Besides the nest site, the availability of food could also be a reason for utilizing wet forests by this Crake as in other birds (Ahmed 2005). These habitats provided food source with cooler substrates and ambient temperature as well as higher humidity; similar kind of

habitat requirements were recorded in Black Rail (Repking and Ohmart 1977) and Slaty-legged Crake (Lekagul and Round 1991). Proximity of water streams provided suitable conditions for the high abundance of invertebrates (Cousin 2004). Variation in the structure and abiotic conditions of forest landscapes, for their part, set the limits of microclimatic variability which in turn affect the distribution of species (Rykiel *et al.* 1988). Several works have suggested that higher bird abundance may be associated with greater arthropod abundance (Johnson and Sherry 2001). Food availability is the driving force behind habitat selection in birds (Johnson and Sherry 2001). Hence, densities are higher in where food is abundant than where it is scarce (Newton 1998).

The reason for absence of the Crake in the monoculture plantations might be that these habitats support minimal bird in the non-native area as observed in the case of many other endemics (Vijayan and Gokula 2006). One of the likely reasons perhaps may be the lack of their native insect fauna and thus having very little bird food resources (Cody 1985). In the littoral forests almost no ground vegetation layer was recorded; bare ground without much litter could not provide invertebrate food for this ground feeding bird. No Crake was recorded in the hill top vegetation; where the trees had stunted growth, not much buttresses and leaf litter. Absence of the species in the plantation, cultivation and other habitats except wet forests during this survey shows that the Andaman Crake is a strict habitat specialist and hence susceptible to habitat modification and destruction as found in most of the endemic birds (Brooks *et al.* 1997; Castelletta *et al.* 2000; BridLife International 2001).

Wet forest plays a major role in the distribution of the Andaman Crake and distribution of wet forest increased with the size of the islands. Wet forests in the small islands were the least frequent and their distribution was significantly related to island size (Davidar *et al.* 2001). Most of the small islands in Andaman group have dry forests (Davidar *et al.* 2001). The wet evergreen and semi-evergreen forests on larger islands are the reservoirs of biodiversity containing many rare and endemic species and habitat specialists (Hajra *et al.* 1999, Vijayan *et al.* 2005). They also found that when islands with similar levels of habitat diversity were compared, area was significantly related to species richness and when effect of area was controlled, habitat diversity significantly influenced species richness. Craig (2008) in his study on marsh bird reported that Virginia Rail, Marsh Wrens and Swamp Sparrows were absent from smallest sites even though suitable habitat was present. The

relationship between area and species occurrence and abundance is generally known in avian communities (Davies *et al.* 2000; Craig 2008). Brown and Dinsmore (1986) found that 68% of bird species either declined in abundance or were absent in similar habitat under 5 ha (*i.e.,* minimum threshold area was reached). Species-area relationship exists principally because of a positive habitat-area relationship (Rosenzweig's 1995). Although the present study species shows area is an important factor, regional factors, mainly habitat availability proximity to additional habitat, regional population phenomena and, density independent events also might influence species richness at the local scale.

Other *Rallina* species Chestnut Forest-rail (Frith and Frith 1988), Forbes's Forest-rail (Schmid 1993), White-striped Forest-rail and Mayr's Forest-rail (Taylor and Van Perlo 1998) were recorded in the montane forest ranging from 1000 to 2000 m altitude, whereas Andaman Crake was recorded in the low altitude forest (0 to 550m). Number of Crake was noted to decrease with increasing elevation mainly because of the nature of the hill top vegetation as explained earlier. Elevation range size varies among species and depends on various factors such as habitat availability, dispersal and establishment abilities, competition, predation, local abundance, and climate (Gaston 1996; McCain 2006).

Although Andaman Crake is weak in flight, many of the islands in this survey were in close proximity to each other making distance effects negligible. In a synthesis of 118 studies on birds found that area, and not isolation, had the greatest effect on distribution (Watling and Donnelly 2006). Davidar *et al.* (2001) in their study on the Andaman Island avifauna also reported that distance between islands did not have an effect on bird species distribution.

Andaman Crake is monogamous and territorial as many rail species (Taylor and Van Perlo 1998) and it was recorded throughout the year in the study area, even though the streams are dried during summer. Reduction in number occurred only at certain time of the year, at specific weather conditions which can be adjusted by the bird by adopting or changing their requirements (Newton 1998). The result shows habitat occupancy year round which suggests that the Andaman Crake is a resident species as the Black Rail (Repking and Ohmart 1977).

3.7. Conclusion

It was extremely difficult to estimate the population of the Andaman Crake because of low visibility and difficulty in estimating the distance of calls in the different types of forests. However, the encounter rates conformed that the Crake had higher abundance in larger islands and inhabit only wet forests as reported for many island birds by Devy *et al.* (1998), Yoganand and Davidar (2000) and Davidar *et al.* (2007). This study has shown that the Andaman Crake has distinct microhabitat preferences within evergreen, semi-evergreen and moist deciduous forests which in turn lead to the patchy distribution of the species. As distribution of these wet forest habitats is correlated with island size, conserving several small islands would not be as efficient as conserving large islands (MacArthur and MacArthur 1961; Davidar *et al.* 2007). As the bird has a weak flight capacity, it is very important to maintain the uninterrupted gene flow in order to avoid the inbreeding depletion. Considering all these factors, management regimes should ensure that adequate protection is given to places, namely Rutland Island, Jaganathdehra, Sitanagar, Aerial Bay, Kishori Nagar, Burmadehra, Panighat Jetti, Rangat, Wraffters Creek, Jarawa Creeke, Brichgunj, Totachilg and Ramakrishnapuram due to high species abundance.

3.8. Summary

- Status and distribution of the Andaman Crake were assessed in different size classes of islands and different habitats.
- Survey covered 33 outer islands and five major islands. Of the 38 islands surveyed Crakes were recorded mostly in larger islands.
- Totally 253 Andaman Crakes were recorded from 2001 points in 400 km surveyed with the encounter rate of 0.63 birds/km; only 8% of point counted had the Crake.
- Compared to outer islands (0.18 bird/km), higher number of Crakes was recorded from major islands (0.81 bird/km). The encounter rate varied significantly between the outer and major islands (Mann-Whitney U; $p < 0.01$).
- Habitat-wise survey showed presence of the Andaman Crake only in the wet forests, namely semi-evergreen (1.00 bird/km), evergreen (0.74 bird/km) and moist deciduous forest (0.61 bird/km).

- Though these wet forests were recorded in most of the islands, encounter rates increased with the increasing island size.

- Encounter rate is negatively associated with the distance from stream.

- The habitat was characterized with high canopy height, moderate canopy cover (50.22±22.4), low ground cover (28.47±27.2), and higher number of saplings (191.7±85.3).

- The places, namely Rutland, Jaganathdehra, Sitanagar, Aerial Bay, Kishori Nagar, Burmadehra, Panighat Jetti, Rangat, Wraffters Creek, Jarawa Creeke, Brichgunj, Totachilg and Ramakrishnapuram should be given priority for conservation.

- As the Andaman Crake inhabits only wet forests and the distribution of these habitats is correlated with island size, protecting several small islands would not be as efficient as protecting a large island for the conservation of this species as well as the biodiversity of the Andaman Islands.

Chapter 4

ACTIVITIES AND FOOD HABITS

4.1. Introduction

Self-maintenance and reproduction is a vital part of any animal's life (King 1974). Both these processes strongly reflect the wide variety of evolutionary solutions taken in exploiting resources of time and energy (Mugaas and King 1981, 1987). As time and energy are resources common to all organisms, a study on the resource utilization through the activities can serve both to quantify the diversity of interactions between an organism and its environment and to decipher evolutionary trends and their causes (Porter and Gates 1969; King 1974). This is the key to the vitality of the approach by which functional and evolutionary problems can be addressed simultaneously (Biedenweg 1983). Hence, such studies have been conducted on a diverse array of birds (Kushlan 1977; Wakeley 1978).

Each species has an optimal activity budget specifically adapted to the local environmental conditions, reproductive activities (Verner 1965), food availability (Boxall and Lein 1989), ambient temperature (Verbeek 1972), day length (Gibb 1956) and habitat (Eberharde *et al.* 1989) which can vary temporally, and are found to influence avian activity budgets. Examining the influence of temporal and environmental factors on a species time budget will enable us to understand the ecological significance of behavioural patterns (Boettcher *et al.* 1994). When evaluating habitat use, the time of day and the activity being performed by an animal need to be considered, because animals select particular habitats for specific types of activity (Palomares and Delibes 1992). A variable approach to ecological and evolutionary problem is available through the use of time and energy budget analysis (Biedenweg 1983). But budgets of wild animals are complex, involving multiple interacting elements that include endogenous reserves, food intake rates and behaviour (Bryant *et al.* 1985). The use of time-activity budgets to derive time-energy budgets has proven to be a convenient approach to assess a bird's use of time and energy expenditure (Bryant *et al.* 1985; Goldstein 1988). The degree to which activity budgets are influenced by daily and seasonal changes in the environment can provide important insight into the

mechanisms by which an animal adapts to its environment (Engel 1990; Engel and Young 1992).

Among the various activities, foraging is one of the most important activities of all living organisms (Ricklefs and Miller 1999). The spatial and temporal availability of the resources has the potential to influence all aspects of foraging behaviour (Homes and Schultz 1988) and foraging time. For example within habitats, species have been shown to partition vegetation spatially (MacArthur 1958) as differ in space (eg. habitat or foraging height) (Morse 1980), time (*i.e.* seasonally) (Hutto 1990; Heji and Verner 1990; Vila 1992), tree species use (Airola and Barrett 1985), foraging maneuvers (Robinson and Homes 1982), prey size and prey type (Cooper *et al.* 1990). Variation within species for any of these foraging variables can also be considered as an element of niche and in particular, the degree of specialization (Recher 1990).

Optimal foraging theory predicts foraging behaviour and food preferences using economic models of costs and benefits to individuals (Martin 1996). Resources are difficult to measure and the availability of resources to one species may be different from another species. The behavioural or morphological constraints of the birds and the escape behaviour, cryptic coloration, and size of prey can determine availability (Homes and Schultz 1988). Thus, availability cannot be measured just by determining relative or absolute abundance of food (Hutto 1990). Determining how birds perceive their environment is necessary to fully understand diet preferences. Diet based on faecal analysis is also difficult to quantify because digestibility is not the same for different prey items (Rosenberg and Cooper 1990). Arthropods are considered as a major food resource for most of the breeding birds (Pouline *et al.* 1992). The quantification of invertebrate prey availability is complicated; it is difficult to determine which preys are truly available to foragers (Hutto 1990; Poulin and Lefebvre 1997).

To understand the connection between activities and resource use, one needs to know the type of food, habitat that the birds use and the factors which influence their selection. Although information on the activities and foraging behaviour are available on many species of birds, it is very difficult to study the activity budget of rails especially those

inhabiting forests, due to their shy and secretive nature and dense habitat (Taylor and Van Perlo 1998). No such information was available for the Andaman Crake and hence this study was undertaken during 2004 to 2007.

4.2. Objectives

a) To study the daily and seasonal activity patterns and budgets of the Andaman Crake

b) To understand the habitat requirement for different activities

4.3. Methods

Activities of the Andaman Crake

Activities of the Andaman Crake were recorded and classified as foraging, calling, maintenance, agonistic, resting, breeding and others. (1) Foraging – pecking at substrate, walking and running in pursuit of prey, waiting or pausing while hunting prey, eating prey and food searching, (2) Calling - different types of vocal behaviour, (3) Maintenance - preening, bathing, shaking, fluttering, and head-scratching, (4) Resting - standing or sitting for some time without performing any activity, (5) Agonistic – activities such as threatening, fighting, and fleeing were categorized as agonistic behaviour, (6) Breeding - nest searching, nest building, pair formation, incubating and feeding chicks (7) Others – behaviour not included in the primary categories.

4.3.1. Activity and food (Direct method)

To study the activity budget and pattern of the Andaman Crake, focal animal sampling method (Altman 1974) was followed. Observation of bird activity started from 04.30 h to 18.30 h with slight variation depending on sunrise and sunset. The field work timing was divided into three periods of five hour duration to cover all the time periods of the day and, activity pattern was worked out for different seasons. The bird was observed as long as possible, whenever it was spotted. All occurrences of specific activities of individuals were recorded during each sampling period and the duration of each observation (in seconds) using an electronic stopwatch. For each activity, temperature at the time of each

observation using Thermometer, and elevation and atmospheric pressure noted with the help of Altimeter. Food items taken were noted whenever observed.

4.3.2. Diet composition (Indirect Method)

Faecal samples were collected and analyzed to determine the food items (Rosenberg and Cooper1990). Each sample was transferred to a Petri dish and then viewed under variable power dissecting microscope. Body fragments or hard exoskeleton, wings or wing fragments, body segments, head capsules, antennal segments, mouthparts and sometimes whole invertebrates were separated out of the faecal sample and identified up to the Order using literature such as Imms (1965) and Mani (1988).

4.3.3. Food abundance at the feeding sites

From the preliminary observations it was noted that the Andaman Crake feeds mainly on ground invertebrates. Availability of invertebrates was quantified using quadrate (Southwood 1978; Cooper and Whitmore 1990). Five quadrates of size 1 x 1 m were laid in a 10 x 10 m plot per month.

4.4. Data analysis

- Data were grouped into four seasons: winter (December -February), summer (March-May), south-west monsoon (June-August) and north-east monsoon (September - November).

- Mann-Whitney U test was performed to explain the variation in the activities and food items between breeding and non-breeding seasons.

- Kruskal-Wallis H test was performed to explain the variation in activities and food items among various seasons.

- Individual fecal samples were pooled to create a single sample for a particular season. Samples were sorted and identified the food items. Percentage occurrence of each prey items was calculated (Rosenberg and Cooper 1990).

- Species diversity: Shannon-Weaver and Equitability (Shannon-Weaver 1949) indices were used to estimate diversity of the invertebrates in the study area

  Shannon-Weaver Index (H') = $- \sum^{s} p_i \log_e p_i$

  $p_i = ni / N$

  S = Number of species

  Log e p_i = Natural log of Pi

  Equitability $E = \frac{H'}{2S}$

- Pearson correlation test was performed to know the relation between foraging activity and temperature.

All statistical tests were done using SPSS software version 10.0 and evaluated significance at $p < 0.05$ level.

4.5. Results

I spent about 5000 hours in the field during 2004 to 2007, but had only 382 contact hours with the Andaman Crake. As a result, a total of 2714 observations were made on the activities of the species.

4.5.1. Activity Pattern

4.5.1.1. Overall

The activity pattern of the Andaman Crake showed trimodal pattern of foraging with the peak in the morning hours 04.00 to 06.00 h, 09.00 to 10.00 h and evening 16.00 to 17.00 h. Foraging activity was noted less from 12.00 to 14.00 h (Figure 4.1).

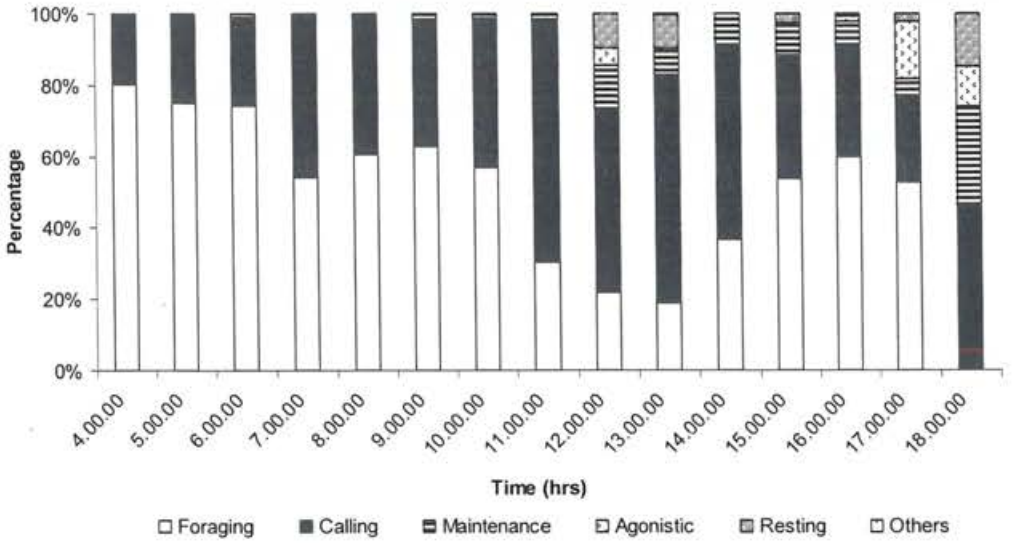


Figure 4.1. Activity pattern of the Andaman Crake (Overall)

The overall pattern showed most of the time the foraging and calling activities were inversely proportional to each other. Resting and maintenance activities, especially bathing were recorded mainly in the afternoon.

4.5.1.2. Activity pattern among seasons

Foraging activity in winter was high in the morning hours (04.00 - 09.00 h) and then started decreasing to reach the minimum at 13.00 h (Figure 4.2). Foraging activity showed increasing trend again from 14.00 to 16.00 h with the peak during 16.00 to 17.00 h. Maintenance activities were more in the afternoon hours. During summer, foraging activity showed peaks during 04.00 to to 08.00 h and 09.00 to 10.00 h and started decreasing towards noon time and recorded less during 12.00 to 14.00 h; it again increased with evening to reach peak during at 16 h to 17.00 h. Calling activities showed a similar trend as in winter (Figure 4.3), but was higher in the afternoon and late evening.

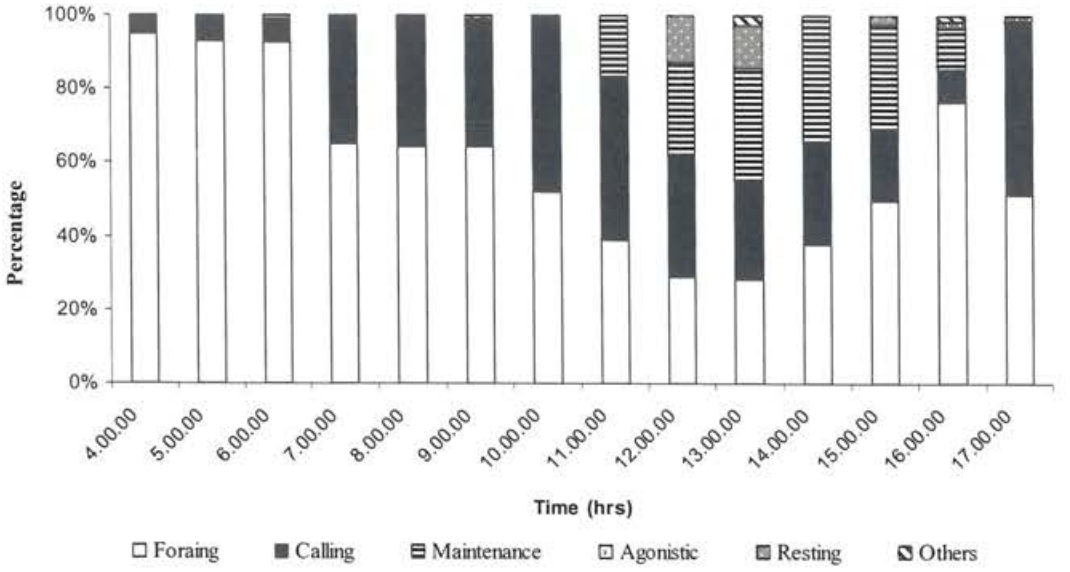


Figure 4.2. Activity pattern of the Andaman Crake during winter

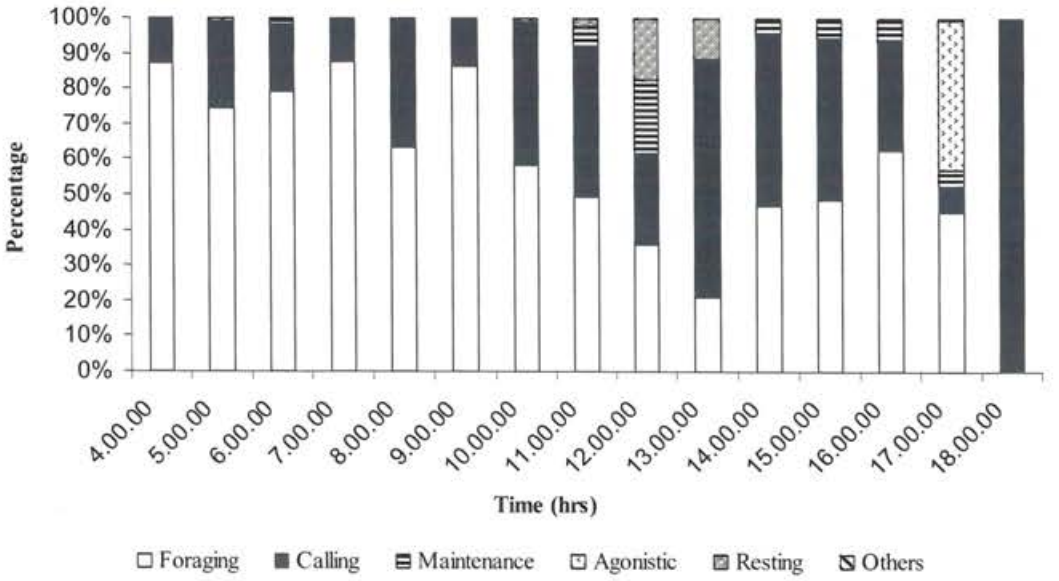


Figure 4.3. Activity pattern of the Andaman Crake during summer

The activity pattern during south-west monsoon (breeding season) showed less foraging with small alternative peaks but had more foraging activity in the morning and evening but

decreased during 12.00 to 14.00 h (Figure 4.4). Compared to other seasons time spent for foraging in each hour was less during breeding season and calling activities occupied more time, but no particular pattern in calling and breeding was recorded. Although it spent less time for maintenance than in other seasons, this activity was mainly during noon hours.

During north-east monsoon, foraging activity was recorded more in the morning and evening and less during noon hours, foraging peaked in the morning 04.00 to 05.00, 07.00 to 8.00, 10.00 to 11.00 h and afternoon 15.00 to 16.00 h. Though calling activity was recorded throughout the day, the time spent for calling in each hour was less than for other activities and in other seasons; No particular pattern was recorded in the calling activity. Unlike in other seasons the maintenance activity during this season occupied more time in most of the hours mainly from 11.00 to 15.00 h (Figure 4.5).

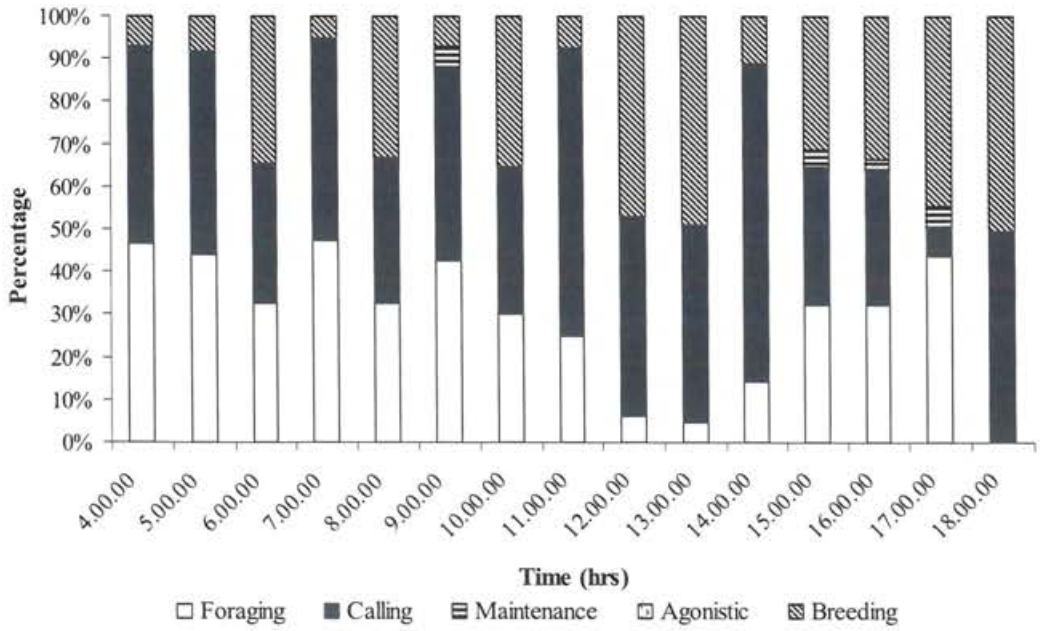


Figure 4.4. Activity pattern of the Andaman Crake during south-west monsoon

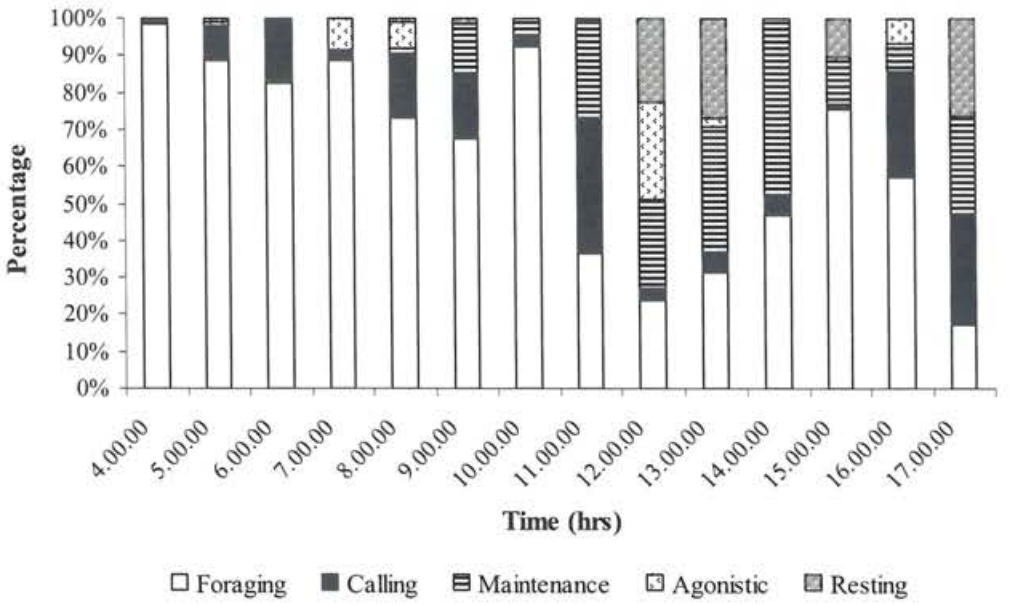


Figure 4.5. Activity pattern of the Andaman Crake during north-east monsoon

4.5.2. Activity budget

4.5.2.1. Overall

The total activity budget showed that the Andaman Crake spent the maximum time (49%) on foraging followed by calling (38%) and minimum time for breeding (9%), maintenance and resting (Figure 4.6).

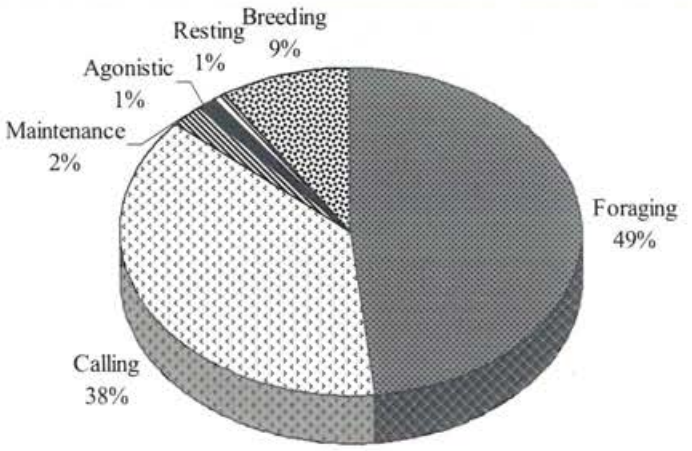


Figure 4.6. Overall activity budget of the Andaman Crake.

4.5.2.2. Activity budget during breeding and non-breeding seasons

During the non-breeding season the maximum time was spent for foraging (65%) followed by calling (27%). During breeding season the time spent for calling was more (47%) than foraging (35%) (Figure 4.7). Significant differences were recorded in activities such as foraging ($U = 758$; $p < 0.01$), maintenance ($U = 164$; $p < 0.01$) and agonistic ($U = 519$; $p < 0.05$) whereas no significant differences were recorded in calling and resting between breeding and non-breeding seasons. The day time activity budget of incubating bird showed 77% of the time for vigilance and the rest for rolling the egg, responding to its pair, nest maintenance, sleeping and others (Figure 4.8).

4.5.2.3. Seasonal variation in the activity budget

Time spent on various activities among seasons showed that more time was spent for foraging followed by calling in all the seasons except (Figure 4.9) during south-west monsoon (breeding season). The activities foraging (χ^2 39.7; df = 3; $p < 0.05$), Calling (χ^2 27.5; df = 3; $p < 0.05$), maintenance ($\chi^2 = 67.9$; df = 3; $p < 0.05$), agonistic ($\chi^2 = 23.7$; df = 3; $p < 0.05$) and resting ($\chi^2 = 77.4$; df = 3; $p < 0.05$) showed significant variation among seasons.

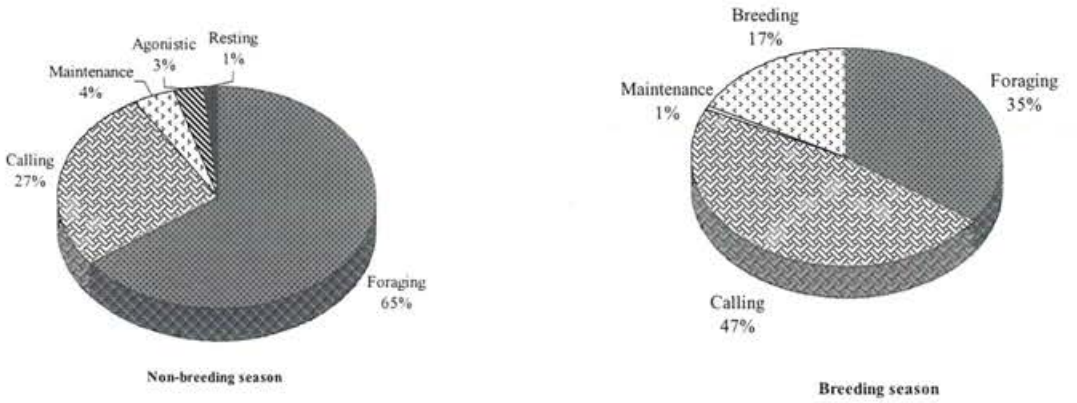


Figure 4.7. Activity budgets of the Andaman Crake during non-breeding and breeding seasons (2005-2006).

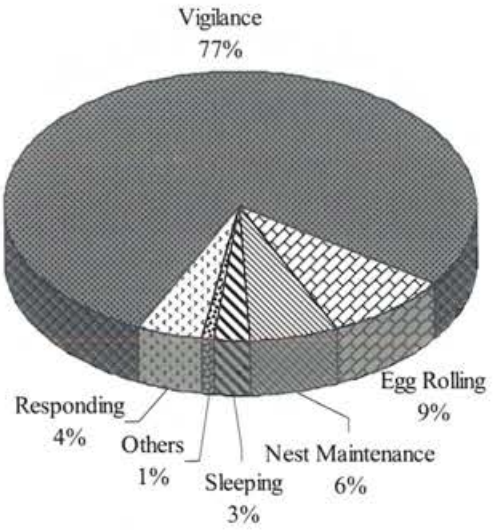


Figure 4.8. Activity budgets of the incubating bird

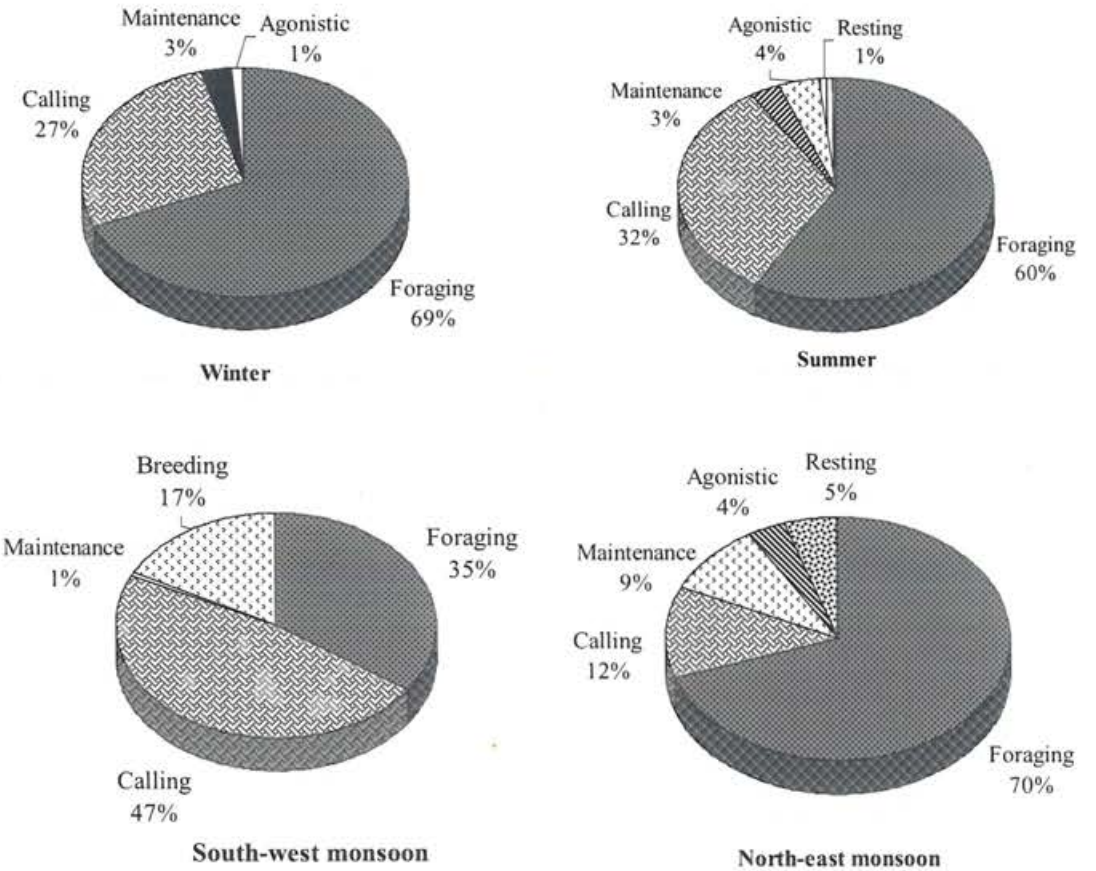


Figure 4.9. Activity budgets of the Andaman Crake during different seasons.

4.5.3. Foraging

4.5.3.1. Foraging habitat

Totally 1113 foraging observations were made. The Andaman Crake was noted to forage in the wet forest areas with tall trees, moderate canopy cover and low ground vegetation with dense leaf litter (Plate 4.1). Most of the sightings of the Crake were near streams and forest edge. The comparison between foraging and non-foraging areas showed significant difference in depth of the leaf litter, canopy cover, ground cover, distance to water source and forest edge (Table 4.1).

4.5.3.2. Invertebrate abundance in the foraging habitat

Total of 12 Orders of invertebrates were recorded from 160 quadrates. Invertebrate abundance and diversity were analysed seasonally. Although not much difference was recorded among seasons the invertebrate diversity of Orders was low in winter, but high during summer and south-west monsoon (Table 4.2). During winter (quadrat, N = 40) high abundance of Hymenoptera (48%) and Isoptera (39%) was observed. Other invertebrates belonging to the orders Araneae, Blattaria, Coleopteran, Gnathobdellida, Ixodida, Julliformia, Thysanura, Mantodea, Neooligochaeta, Orthoptera, Phasmida, Scolopendromorpha and Stylommatophora together forms 13% of the abundance. In summer Isoptera and Hymenoptera together formed 73% while other ten orders formed only 27% (Figure 4.10). During south-west monsoon neooligochaeta formed 45% while other nine orders together formed 55%. In north-east monsoon isopterans and thysanurans formed 59% and other 13 orders together formed 41%.

4.5.3.3. Food

Although 1113 foraging observations were made, exact feeding observations could not be recorded for all the observations because of the dense undergrowth, secretive nature of the bird and size of the prey. Andaman Crakes were noted to feed on invertebrates. The feeding observations indicated the intake of earthworms (Neooligochaeta), caterpillars (Lepidoptera), termites (Isoptera) and ants (Hymenoptera) (Table 4.3); very rarely (n = 2) noted to glean ecto-parasites from spotted deer.

Table 4.1. Habitat variables recorded in the foraging and non-foraging area of the Andaman Crake.

Variables	Foraging Area (N = 35)	Non-foraging Area (N = 35)	Z
Elevation (m)	48.3±36.7	58.0±72.8	1.797
Depth of leaf litter (cm)	4.85±4.36	3.95±1.80	-2.006*
Canopy cover (%)	51.6±25.4	47.9±24.7	3.111*
Ground cover (%)	20.2±25.4	28.9±24.9	-4.00**
Distance to road (m)	8.86±6.62	8.43±4.58	-2.12*
Distance to water (m)	20.2±20.2	39.7±45.9	-3.847**

* Significant at $p < 0.05$, ** $p < 0.01$

Six prey items were recorded as taken by fledglings, which included earthworms, caterpillars, ants, termites, beetles and grasshoppers. Of these, earthworms and caterpillars were mostly fed by parents.

4.5.3.4. Diet composition

In total, 60 faecal samples of the Andaman Crake were analyzed. Faecal materials showed prey items which mainly come under the orders, Isoptera, Hymenoptera, Stylommatophora and Coleoptera. Apart from the invertebrates soil also recorded. Ocurrence of Isoptera and Stylommatophora was more (22% and 20%) followed by Hymenoptera (15%) and Coleoptera (6%) (Figure 4.11). The major prey materials identified include mouthparts of ants and termites, cuticle of beetles and broken pieces of shells.

Table 4.2. Diversity of invertebrates in the feeding area.

Season	Diversity H'	Equitability	# of Order
Winter	0.53	0.19	9
Summer	1.42	0.50	9
South-west monsoon	1.36	0.48	9
North-east monsoon	1.18	0.42	13

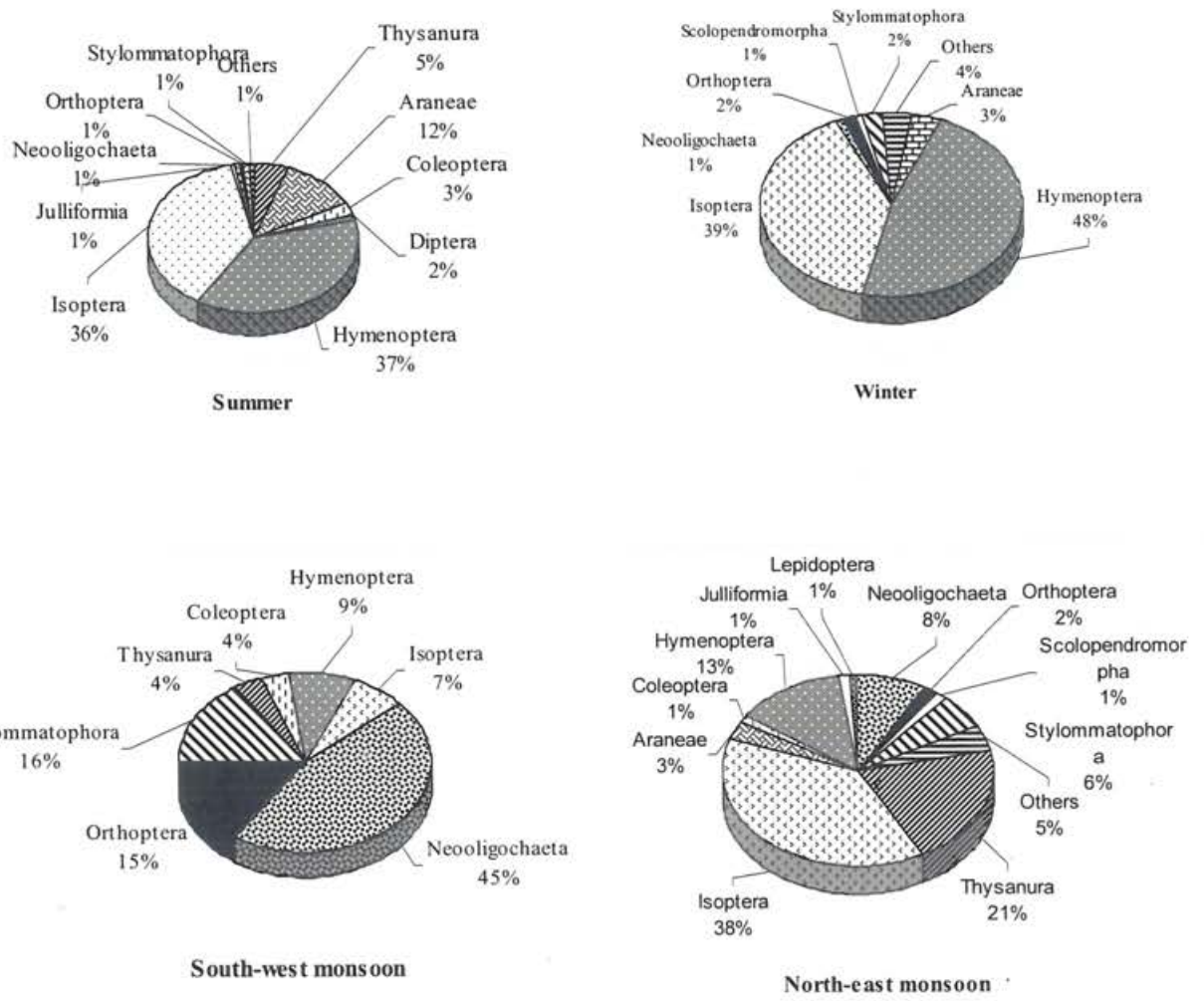


Figure 4.10. Abundance of invertebrates recorded in foraging areas of the Andaman Crake in different seasons.

Table 4.3. List of food items recorded from direct observation.

S.No.	Food Items	Order
1	Red ant	Hymenoptera
2	Black ant	Hymenoptera
3	Termite	Isoptera
4	Earthworm	Neooligochaeta
5	Leaf worm	Lepidoptera
6	Grasshopper	Orthoptera
7	Snail	Stylommatophora
8	Caterpillar	Lepidoptera
9	Beetle	Coleoptera

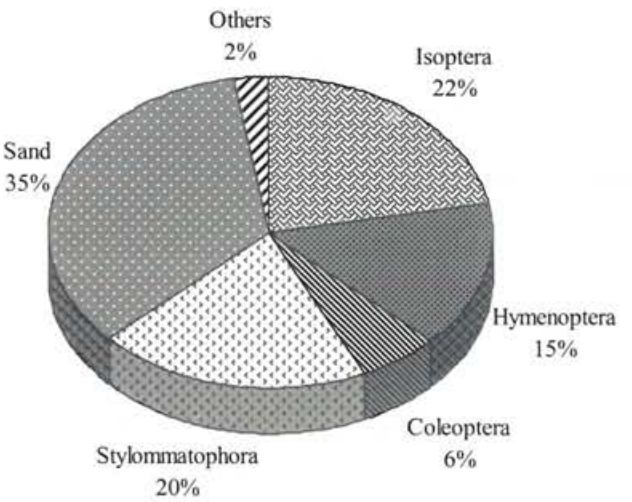


Figure 4.11. Food of the Andaman Crake based on faecal samples.

During winter and summer isopterans and hymenopterans were found more in the dropings, while Stylommatophora were high during monsoon (Figure 4.12). Coleopterans were more or less same throughout the year. When the food items were compared among seasons

significant difference was recorded in isopterans (χ^2 = 13.28; df=3; $p < 0.05$), hymenopterans (χ^2 = 22.08; df=3; $p < 0.05$), and stylommatophora (χ^2 = 35.44; df=3; $p < 0.05$), whereas no significant difference was recorded in coleopterans among different seasons. When the food items were compared between breeding and non-breeding seasons significant difference was recorded in Isoptera (U = 141; $p < 0.01$), Hymenoptera (U = 175; $p < 0.01$) and Stylommatophora (U = 119; $p < 0.01$).

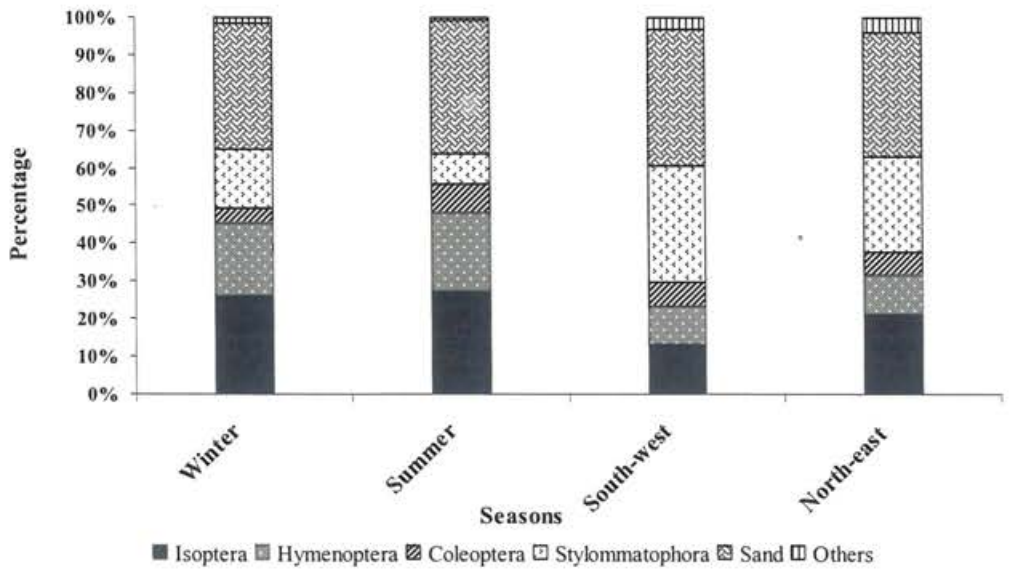


Figure 4.12. Food of the Andaman Crake in different seasons based on faecal samples

4.5.3.5. Feeding methods

Andaman Crake foraged throughout the day. When they were undisturbed they walked with tail down and darted their head to either side. They obtained food only with the bill; no crake was seen scratching the ground with its feet (Figure 4.13).

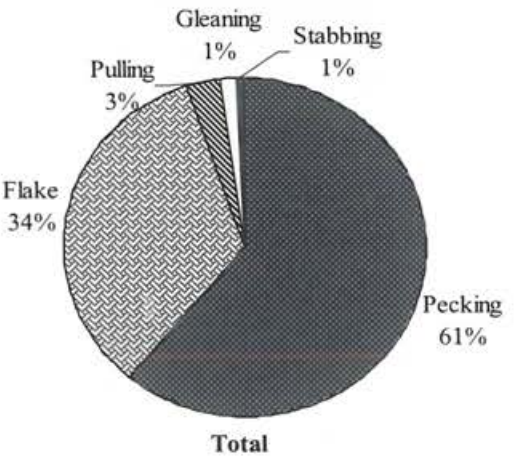


Figure 4.13. Feeding methods of the Andaman Crake (Overall)

Pecking was the major method used (61%) by the Crake to explore the food items. Apart from pecking, it used the flake method (35%) while other methods such as stabbing, pulling and gleaning (1%) were negligible.

Although there was difference in foraging method in different seasons it was not significant ($\chi^2 = 0.389$; df = 3; $p = 0.943$) (Figure 4.14). Whenever it took larger food items such as earthworm, caterpillar and big insects it was noted to kill the prey before swallowing. It used successive pecks (Hammer method), whenever it encountered ant and termite colonies.

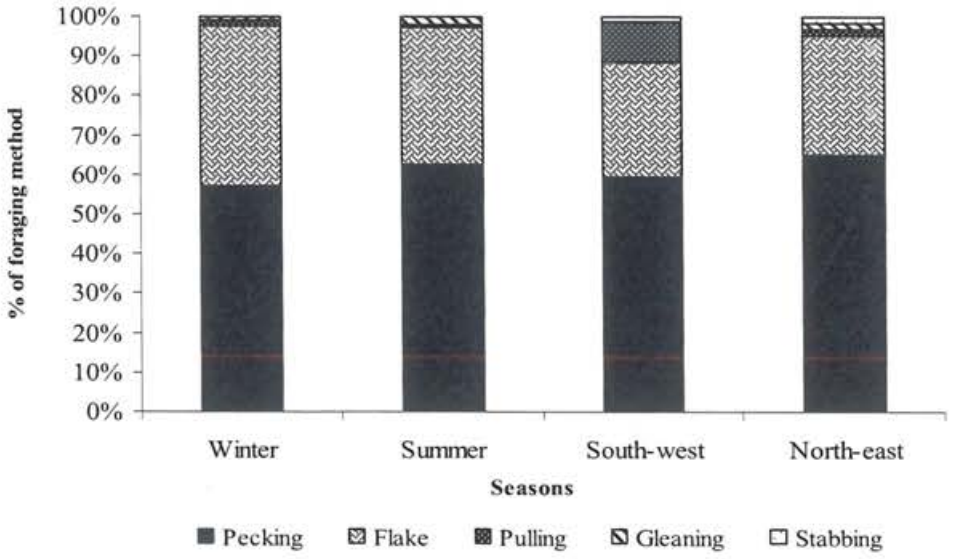


Figure 4.14. Foraging methods adopted by the Andaman Crake in different seasons.

4.5.3.6. Foraging Pattern

Overall budget of the Crake showed that the species spent 49% of the time in foraging. Foraging activity of the Crake among seasons varied and it was maximum in north-east monsoon (70%) followed by summer (69%) and winter (60%) while the minimum was in south-west monsoon (47%). Difference in the time spent for feeding in different seasons was significant (Kruskal Wallis; $\chi^2 = 39.7$; df = 3; $p < 0.05$). The average rate of foraging in each hour of the day was calculated to obtain the foraging pattern or feeding rhythm during the day. Foraging rhythm showed alternative ups and downs with the highest during 7.00 to 8.00 h followed by 9.00 to 11.00 h and then during 15.00 to 17.00 h (Figure 4.15). The season-wise foraging pattern is given in figure 4.16 and no significant difference was observed among seasons. The feeding rate had negative correlation with temperature ($r = -0.514$; $p = 0.06$).

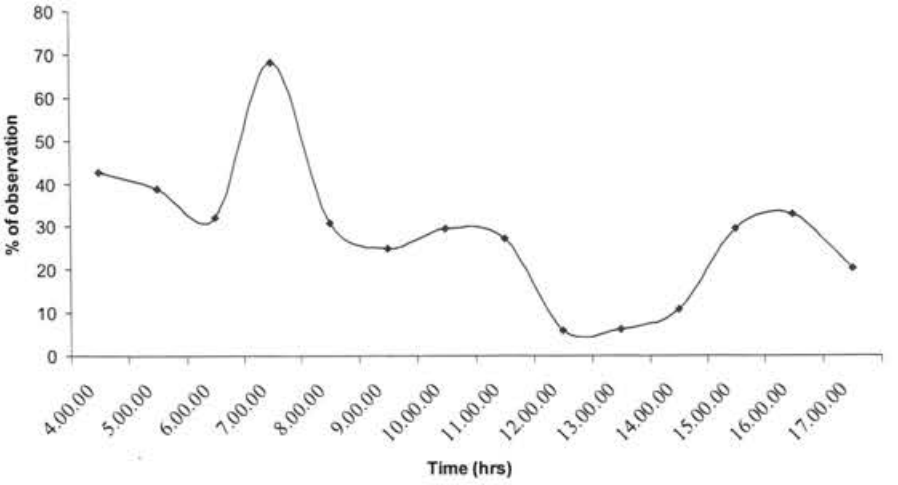


Figure 4.15. Feeding rhythm (pattern) of the Andaman Crake (Overall)

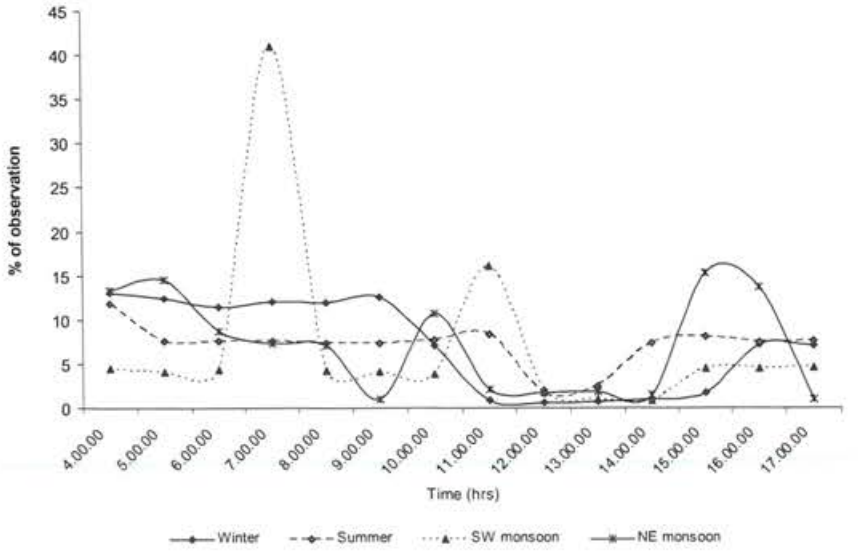


Figure 4.16. Feeding rhythm (pattern) of the Andaman Crake in different seasons.

4.5.3.7. Association of the Andaman Crake with other birds while foraging

Andaman Crake was noted to forage singly or in pairs and rarely in small groups. Of the 1113 foraging observations, 280 observations were made while the Andaman Crake was foraging along with other species. The association was more with the Emerald Dove followed by Ground Thrush, Oriental Magpie Robin, Red-whiskred Bulbul, White-rumped Shama and less with, White-headed Starling, White-breasted Water-hen and Common Myna (Table 4.4).

Table 4.4. Percentage frequency occurrence of the Andaman Crake with other birds (N = 280).

Common Name	Scientific Name	Frequency	Percentage
Emerald Dove	*Chalcophaps indica*	135	48
Ground Thrush	*Zoothera citrina*	61	22
Oriental Magpie Robin	*Copsychus saularis*	35	13
Red-whiskred Bulbul	*Pycnonotus jocosus*	21	8
White-rumped Shama	*Copsychus malabaricus*	18	6
Common Myna	*Acridotheres tristis*	6	2
White-breasted Water-hen	*Amaurornis phoenicurus*	2	1
White-headed Starling	*Sturnus erythropygius*	2	1

4.5.4. Calling

The calls varied from mild to harsh and included scream, trills, humming and frog-croaks. Calling occurred throughout the day but was more in the early morning and evening. The species was noted to respond well to playback of their recorded calls. It made three major kinds of calls.

Type 1: The call is loud *"kroop....kroop....kroop"*. While making this type of call, the bird was alone and the call lasted until its pair responded. This call of the Andaman Crake is audible up to 300m.

Type 2: It is very mild as "mm...mmm...mmm...mmmm", probably a contact call. This call was produced by the bird while foraging or walking.

Type 3: The call is of a single note "m...m...m" which lasts only one or two seconds mainly at the time of danger and, after this call the bird was noted to run.

4.5.5. Maintenance activities

A large number of movements relate to the care of the plumage and, to a less extent the skin and soft parts. Preening, bathing, shaking, fluttering, and head-scratching are the major activities of this Crake to maintain their body. Maintenance activities were recorded mainly in the noon hours.

4.5.5.1. Bathing

Andaman Crake bathed by standing in shallow water, alternately ducking the head in water and flipping water over the back and beating half-open wings in water. It also moved the body up and down in the water and dipped the tail. It preferred water depth within 10 cm. Though bathing was recorded throughout the day, it peaked in afternoon, anytime between 15.00 and 17.00 h.

Out of 106 bathing observations, in 66 occasions (63%) the Crake bathed alone. while at other times (n = 40) it was noted to share their bathing place with other birds, namely Andaman Red-whiskered Bulbul, White-headed Starling, Black-naped Monarch, Andaman Ground Thrush, Andaman Shama, Magpie Robin and Black-headed Bulbul (Table 4.5).

4.5.5.2. Preening, head-scratching and fluffing

Usually the Crake dealt with one feather at a time, seizing it at the base between the mandibles and working towards the tip by nibbling it continuously to clean the feathers. It preened frequently, especially after bathing. Head-scratching was performed by the foot, sometimes along with foraging and preening. Head-scratching was noted a few times, mainly for dislodging insects from the head and neck which were inaccessible to the bill.

Table 4.5. Percentage frequency of the Andaman Crake with other birds while bathing (N = 40).

Species	# of times	% of Frequency
Andaman Ground Thrush	8	16.33
Black-naped Monarch	8	16.33
Andaman Red-whiskred Bulbul	7	14.29
Magpie Robin	7	14.29
White-headed Starling	6	12.24
Andaman Shama	5	10.2
Black-headed Bulbul	4	8.16
Common Myna	4	8.16

4.5.6. Other activities

Standing or sitting without doing any activity was considered as resting, which was mainly recorded in the noon hours.

Andaman Crake was noted to chase the Andaman Crow-pheasant (N =7), Andaman Shama (N = 4) and rarely Ground Thrush (N = 3) and White-breasted Kingfisher (N =1). These activities are considered as agonistic activity.

The Crake usually roosted in the branches of the trees at a height of 5 to 10m from the ground. During breeding season it was observed to roost in the nest with chicks.

4.6. Discussion

4.6.1. Activity Pattern

Andaman Crake is diurnal, awake before sunrise and roost after sunset, as reported in other *Rallina* species such as Forbes's forest-rail (Ripley 1977). Foraging was recorded high early in the morning and evening as in other raillids *eg.* Purple Moorhen (Bhupathy 1985), White-spotted Flufftail (Taylor and Taylor 1986), Buff-spotted Flufftail, Red-chested

Flufftail (Taylor 1994) and Ruddy Crake *Laterallus rubber* (Russell 1964). Feeding patterns of the Andaman Crake were also influenced by relatively high ambient temperatures during mid-day. Birds avoid foraging during afternoon hours to avoid high-metabolic activities when the temperature was high (Robinet *et al.* 2003). The optimizing paradigm predicts that individuals perform activities at the most opportune time (Smith 1976). The ability to vary time and energy budgets is a "potent means of coping with a changing environment and retaining some degree of adaptation to it" (Pianka 1974).

Nutrient requirement and foraging efficiency also affect food choice (Krapu and Reinecke 1992). It was observed that considerable amount of time was spent for feeding followed by calling with the two activities being inversely related. It was reported that feeding and maintenance activities were inversely related in the Purple Moorhen *Porphyrio porphyrio* (Bhupathy 1985), Coot *Fulica atra* (Jayaraman 1985), Pheasant-tailed Jacana *Hydrophasianus chirurgus* and Bronze-winged Jacana *Metopidius indicus* (Ramachandran 1998). As reported in many rails species eg. Russet-crowned Crake *Anurolimnas viridis* (Lowen *et al.* 1997), Black-banded Crake *Anurolimnas fasciatus* (Hilty and Brown 1986), Rusty-flanked Crake *Laterallus levradi* and Ruddy Crake (Hardy *et al.* 1996) calling was observed throughout the day, but more in the early morning and evening. The calls of many species in forest tend to be masked by other sounds during the day and are normally given during the periods when background noise is minimal and signal attenuation from atmospheric disturbance is least (Wiley and Richards 1982). The male and female regularly took bath together in the middle of the day and in the late afternoon. Similar observations were reported in Captive Yellow Rail, White-spotted Flufftail (Yealland 1952) and Buff-spotted Flufftail (Taylor 1994).

4.6.2. Activity budget

In the Andaman Crake foraging and calling were the predominant daytime activities during all the seasons except during breeding as reported in many other birds (Ramachandran 1998; Bradter *et al.* 2007; Vinod 2007). Birds have extremely high weight-specific metabolic rates among vertebrates thus feeding is typically a dominant activity (Lasiewski and Dawson 1967). Crake spending more time for foraging might be due to its relatively

large body size and smaller size of the insect prey and higher searching time in the leaf litter. Food density has been known to influence negatively the amount of time spent feeding by an animal (Pianka 1974). The time spent for foraging is high prior to breeding season. The maximum feeding in summer might be because of the favorable condition with longer daylight and also the need for storing high energy for breeding in the forthcoming season (Tome 1991; Martin 1992a). To meet energy/nutrient demands of egg-laying and incubation, some species store lipid or protein prior to breeding season (Raveling 1979; Krapu 1981) and catabolise these resources during laying and incubation (Tome 1991).

4.6.3.Food and feeding

Feeding is the major activity of any animal for sustaining life and it varies according to the environmental and physiological conditions of the bird (Huntingford 1984; Rosenberg 1993). Selection of habitat with moderate to high canopy cover and density of trees is indicative of sites with potentially lower ground surface temperature, favoring a higher abundance of leaf litter invertebrates, compared to those areas with low canopy cover (Cousin 2004). Concurrently, these components also favor the production of a denser layer of leaf litter. The Andaman Crake was noted to forage in the leaf-litter of forest and thickets as Buff-spotted Flufftail (Taylor and Van Perlo 1998), Red-necked Crake (Marchant and Higgins (1993) and Forbes's forest-rail (Schmid 1993). Rails' major food is macro-invertebrates for which they forage in leaf litter (Taylor and Van Perlo 1998). Foraging habitat with high density of leaf litter and nearness to streams provided suitable conditions for high abundance of invertebrates as reported by Cousin (2004).

As observed in the Virginia Rail (Rundle and Fredrickson 1981), the Andaman Crake also avoided areas where the vegetation was very dense and moribund, such vegetation being difficult to penetrate and provide few good nest sites. The low ground cover of vegetation might have helped the bird in searching and finding food and escape from predator by running (Taylor 1996). The Andaman Crake is primarily an invertebrate feeder and opportunistic. Earthworm (Annelida), caterpillar (Insecta) and snail (Mollusca) were recorded more in the diet, which corresponded with the abundance of these invertebrates in the feeding area. Although only a few Oligochaeta were noticed in quadrat, direct

observation showed presence of more Oligochaeta in the food items of chicks. Seasonal variation in the proportion of food taken was reported for a number of species and it reflected the seasonal changes in availability of food (Blake and Loiselle 1991; Poulin *et al.* 1992; Van Schaik *et al.* 1993; Taylor and Van Perlo 1998). Since the Crake is territorial it might be adapting to the changes in the food abundance by being opportunistic. Bird's inherent flexibility allows them to adapt to changes by altering their foraging behaviour or primary food item (Rotenberry 1980; Hutto 1981) and thus might locate sufficient food without having to leave areas of low insect abundance (Sol *et al.* 2002).

On a few occasions, the Andaman Crake was noted to glean ectoparasites from the large mammals (Spotted Deer) as reported in Black Crake *Amaurornis flavirostris* (Taylor and Van Perlo 1998). The faecal analysis results showed soil or grit was almost at the same level in all the seasons as reported in many ground-dwelling birds which might have been taken along with the food items, used for grinding food, or providing calcium supplement (Griminger 1983).

Feeding method is a functional morphology of the species and its habitat (Rosenberg 1993). The Andaman Crake usually killed large live food items before swallowing as reported in Buff-spotted Flufftail (Taylor 1994). The feeding method adopted by the Crake in all the seasons was pecking, showing the specificity of the Crake which was probably most suitable for feeding on ground invertebrates. Crakes have relatively straight bills of moderate length and depth to take a wide variety of small to large food items, chiefly by probing, gleaning, digging, sifting litter, stabbing at large prey and raking in soft earth (*del* Hoyo *et al.* 1996). For searching, it turns over the dead leaves, digs and probes with the bill. The same kind of foraging method was recorded in most of the rails eg. Buff-spotted Flufftail (Taylor 1994), Red-chested Flufftail (Taylor 1994), Henderson Rail (Jones *et al.* 1995) and Chestnut-headed Crake (Parker and Remsen 1987). Terrestrial species which forage in leaf litter and soil use the bill to move or toss aside leaves and debris, and to turn over small stones, while searching for invertebrates (*del* Hoyo *et al.* 1996). Andaman Crake was not noted to scratch with its foot while searching food as in Henderson Rail (Jones *et al.* 1995). The rise in temperature influenced the feeding adversely (Bhupathy and Vijayan 1999; Tidemann 2004). Andaman Crake readily responded to the tape recordings of their

own calls, and they called, both spontaneously and in response to tapes, throughout the daylight hours as reported in Auckland Island Rail (Elliott *et al.* 1991), Henderson Rail (Jones *et al.* 1995), Russet-crowned Crake (Lowen *et al.* 1997), Rusty-flanked Crake *Laterallus levraudi* (Boesman 1997), Buff-spotted Flufftail and Red-chested Flufftail (Taylor 1994).

4.6.4. Other activities

Calling was another major activity in the Andaman Crake as in many other Rallids eg. White-spotted Flufftail (Taylor and Taylor 1986), Buff-spotted Flufftail (Taylor 1994) with extensive vocal repertoires, using calls to communicate in a wide variety of situations (Taylor and Van Perlo 1998). Most of the rails are vocal, as is to be expected in birds which inhabit areas with dense cover where visual contact is often very limited and communication by sound becomes very important (*del* Hoyo *et al.* 1996). Crake was noted to make different types of calls for different purposes as reported in many other rails (Taylor and Van Perlo 1998). Calling was recorded more throughout the year except north-east monsoon immediately after breeding season while maximum was during breeding season as it was meant for guarding territory as reported in many other birds (*See* Merila and Sorjonen 1994). Andaman Crake do not normally call at night as White-spotted Flufftail (Taylor and Taylor 1986). The calls are important in the life of rails in warning other birds of territorial rights or mutual dangers, in locating and recognizing mates and young ones, and in defending nests or brooding sites (*del* Hoyo *et al.* 1996). Calls are reported to be a behavioural response to the productive territory it occupied.

Maintenance activities were high during non-breeding season, while it was less during breeding season. Such variation was noticed in most of the birds (Ford *et al.* 1990; Hutto 1990). Resting was low, as the birds had to spend more time for feeding and other activities as observed in many insectivorous birds. Andaman Crake usually roosted off the ground, whereas during breeding season it used roosting nests as reported in Red-chested Flufftail (Pakenham 1943; Taylor 1994) and Red-necked Crake (Taylor and Van Perlo1998). It roosted in pairs as White-striped Forest-rail (Ripley 1977) and Forbes's Forest-rail (Rand and Gilliard 1967).

4.7. Summary

- About 5000 hours were spent in the field; as a result, a total of 2714 observations were made during 382 contact hours.
- The activity pattern of the Andaman Crake showed trimodal pattern of foraging with the peak in the morning hours 04.00 to 06.00 h, 09.00 to 10.00 h and evening 16.00 to 17.00 h. Foraging activity was noted less from 12.00 to 14.00 h.
- The overall pattern showed that most of the time foraging and calling were the major activities and were inversely proportional.
- Resting and maintenance activities, especially bathing were recorded mainly in the afternoon.
- The total activity budget showed that the Andaman Crake spent the maximum time (49%) on foraging followed by calling (38%) and breeding (9%) and minimum time was spent for maintenance and resting.
- During the non-breeding season maximum time was spent for foraging (65%) followed by calling (27%). During breeding season the time spent for calling (47%) was more than foraging.
- Significant difference in activities was observed between breeding and non-breeding seasons.
- Kruskal-wallis test was performed to explain the differences in activities among various seasons. All the activities showed significant variation among seasons.
- A total of 1113 foraging observations were made, Andaman Crakes were noted to feed on invertebrates. The feeding observations indicated the intake of earthworms (Neooligochaeta), caterpillars (Lepidoptera), termites (Isoptera) and ants (Hymenoptera).
- Faecal materials comprised five different prey items. The major prey materials identified included mouthparts of ants and termites, cuticle of beetles and broken pieces of shells.

- When the food items were compared among different seasons and between breeding and non-breeding seasons significant difference was recorded in isopterans, hymenopterans, and molluscs, whereas no significant difference was recorded in coleopterans among different seasons.
- Invertebrate diversity was high during summer and south-west monsoon.
- Pecking (61%) was the major method used by the Crake to explore the food items. Apart from pecking, it used the flake method (35%) while other methods such as stabbing, pulling and gleaning (1%) were negligible.
- Although there was slight difference in foraging method in different seasons, it was not significant ($\chi^2 = 0.389$; df = 3; $p = 0.943$).
- Foraging rhythm showed alternative ups and downs with peaks more in early morning and late evening.
- The feeding rate had negative correlation with temperature ($r = -0.514$; $p = 0.06$).

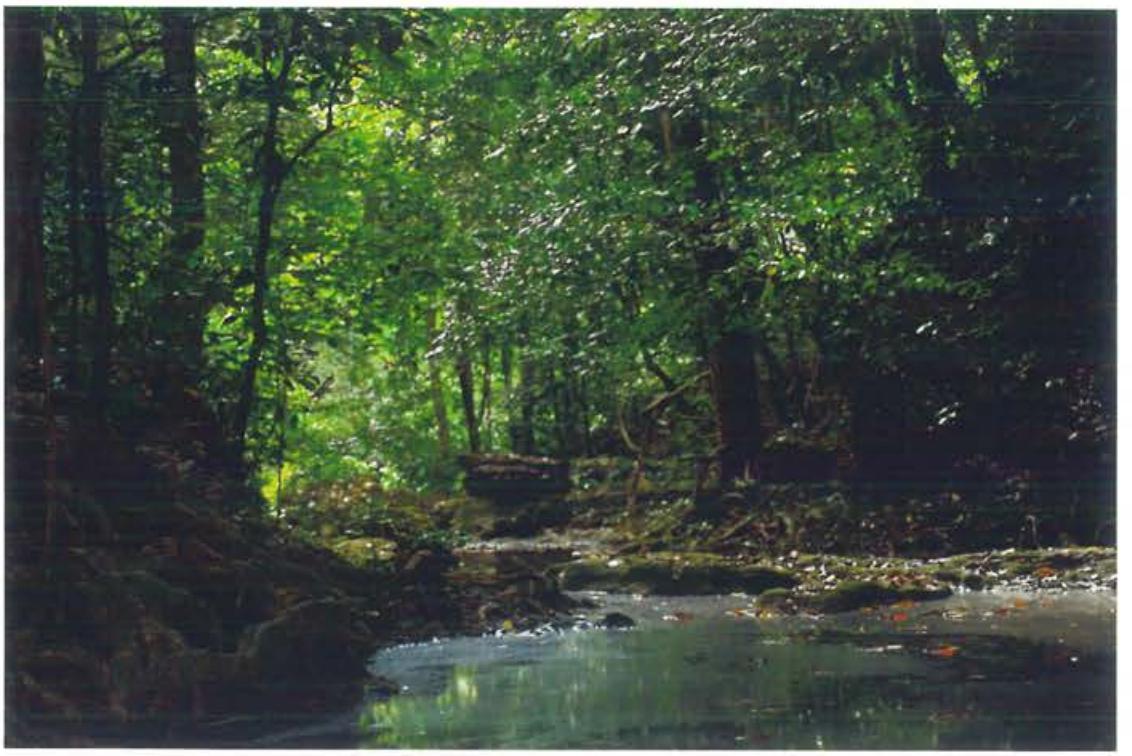


Plate 4.1. Habitat of Andaman Crake

Shirish

Chapter 5
BREEDING BIOLOGY

5.1. Introduction

The act of leaving offspring to the succeeding generation is the most important aspect of any animal's life (Perrins and Birkhead 1983). The reproductive success of birds depends largely on environmental factors, levels of predation and food availability (Martin 1992a, 1995). To reproduce successfully, birds should breed when the environmental conditions are most favorable (Earle 1981). Birds use environmental cues such as day length to time their breeding (Lack 1968). The time for breeding in birds has evolved through natural selection. Breeding season is however, fixed for most species and the degree of variability in factors determining favorable environmental conditions will play a major role in breeding success (Sankaran 1998). The overall period in which breeding occurs is controlled by 'proximate factors', which are the environmental cues used to predict the onset of suitable breeding conditions (Lack 1968; Immelmann 1971). The importance of timing in determining breeding success has been demonstrated in numerous species (Nilsson 2000). Fewer studies have examined the strength and direction of seasonal trends in breeding performance, and the advantage of early and late nesting in species (Mallord *et al.* 2008). Although seasonal reproduction occurs in many birds, it remains largely unclear how the seasonal timing is achieved (Wikelski *et al.* 2000).

A variety of factors determine nest success, of which nest-site selection is a major one. The factors potentially influencing nest-site selection include floristic composition, moisture regimes, amounts and kinds of feeding substrata, amounts of food, structure of the plant community and risks of nest predation (Steele 1993; Martin 1993a). Tropical birds have high nest predation, high adult survival and small clutch size (Lack 1968). Predation is the major cause of nest mortality in ground-nesting species (Mallord *et al.* 2007) and has been implicated in population decline of some species (Yanes and Suarez 1996). Nest-site selection is particularly important for birds constructing open nests, where predation is the basic cause of loss in progeny (Lauro and Nol 1995). Hence, avoidance of nest predators play a major role in specific choice of nest sites (Powell 2001). Nests must be placed in suitable locations to minimize predation of eggs and young (Holway 1991; Martin *et al.*

2000). Two main types of anti-predation strategies are favored. First, if prey cannot defend, avoid the predator by building or selecting nest sites that are sheltered and well hidden (Ehrlich *et al.* 1988). Second, prey can reduce the impact of predators through communal antipredator attacks or through dilution of predator effects (Picman 1988).

Food availability is another important factor for the prospects of successful breeding (Lauro and Nol 1995; Dias and Blondel 1996). Breeding success will not only be determined by the presence of adequate cover for nesting and hiding the young, but also by the availability of adequate food (Alagarrajan 1990). Birds are usually thought of as being limited by food during the breeding season (Lack 1954), under these conditions, evolution of the reproductive strategy should proceed towards the most efficient utilization of food and water. Accessible and seasonally stable resources must be available near the nest-site to meet the high energy demands of the young, because food is often important in determining reproductive success (Simons and Martin 1990). Breeding habitat has to be located close to abundant food resources, provide adequate nesting substrate, and offer protection against predators (Buckley and Buckley 1980).

Natural selection occurs when there are habitat differences between successful and unsuccessful sites, and this may modify habitat use for nesting over evolutionary time (Martin 1998a). The density and quality of vegetation at the time of nesting is important for the construction of a nest and the breeding success. Individuals may be using reproductive experience to assess habitat quality of the nest site (Switzer 1997).

Ground nest in forests are usually the most difficult to locate and ground-nesting species are poorly studied (Martin 1992a, 1993a). The ground-nesters are particularly area-sensitive and good indicators of habitat disturbance (Martin 1993a). Ground-nesting birds are often the first to disappear after the fragmentation of tropical forests (Pangau-Adam 2003). Hence, special efforts should be made to locate and monitor ground-nesting species (Martin 1993b). Understanding the population limitation, life-history traits and their evolution are crucial factors in developing conservation and management strategies for any avifauna (Newton 1998; BirdLife Interanational 2000). Nest-monitoring provides data on life-history traits of species, which allows identification of bottlenecks in the demography

of species and, also when taken together with nesting success may provide important insight into vulnerability of populations to disturbance (Martin 1993a). Understanding nest survival is critical for bird conservation since the low survival rates have been noted in many globally declining species (Moller 1991).

5.1.1. Scenario in Rails

Breeding biology studies are not many on Rails as their nests are well hidden and their chicks are precocial (*del* Hoyo *et al.* 1996). Rails are seasonally or permanently territorial, living either in pairs or small family groups and majority form monogamous pair-bond of at least seasonal duration. Little or no information is available on the breeding seasonality of many species (Taylor and Van Perlo 1998), because they are secretive and attract little interest from hunters (Conway *et al.* 1994), but most of the rails appear to breed seasonally, during the spring and summer in temperate regions and in or near the wet seasons in the tropics (Taylor and Van Perlo 1998). Little is known of the nidification of the *Rallina* species (Ripley 1977). The nests, eggs and chicks of 23 species remain undescribed (Taylor and Van Perlo 1998). Effective management and conservation of rails require identification of the environmental features affecting nesting success and survival (Conway *et al.* 1994).

There was no detailed information on the breeding biology of the Andaman Crake (Taylor and Van Perlo 1998; BirdLife International 2001) except for the records of nests and eggs (Baker 1934) and some other casual observations (Ali and Ripley 1987; BirdLife International 2001). Information on reproductive success and factors determining the same, such as habitat quality, food abundance, micro-climatically advantageous nesting site, predation pressure, parental care were not available for the Andaman Crake. Hence, this study was undertaken.

5.2. Objectives

a) Assess the factors affecting the breeding seasonality and success

b) Enumerate the nest and nest-site features and, examine nest-site selection

c) Study the breeding biology

5.3. Methods

Breeding biology of the Andaman Crake was studied at Pathilevel, North Andaman. Detailed description of the study site is given in Chapter 2.

5.3.1. Nest searching and monitoring

Most of the nests were searched by direct observation by intensive search in suitable habitat and by following the bird activity as described by Martin and Geupel (1993) and Martin *et al.* (1996). Each nest was numbered separately for 2005 and 2006. Located nests were monitored once in 3 – 5 days intervals to determine fate of the nest. Care was taken to avoid trampling or disturbance to the birds and vegetation at nest sites.

5.3.2. Seasonality

The breeding seasonality was determined from the nesting records in each month during the study period. Active nests with eggs were considered for recording breeding seasonality (Lack 1968). The relationships of nest abundance with rainfall, temperature and availability of food were observed.

5.3.3. Nest and Nest-site selection

After completion of nesting activity, nest-site variables were measured. A 10 ha plot was laid for the nest-site selection studies. Details of vegetation and nest-site characteristics were recorded for each nest. The method for determining nest-site selection was similar to that applied in a number of other studies (e.g. Bechard *et al.* 1990). Variables were taken at three levels, namely nests, nest site and nest patch.

Nest: Various aspects of nest morphometry were measured in the field, immediately after fledging of the young. The nest variables of 60 nests were measured (Table 5.4). Mean nest outer width, inner lining (twigs) width (cm) and nest depth (cm) were recorded.

Ten nests were collected from the field after the completion of breeding, examined and weighed the materials to get the composition (Hansell 2000).

Nest-site: After the completion of the nesting activity, nest-site variables were measured at two spatial scales; nest site (micro-habitat level) and nest-patch (meso-habitat level).

The nest-site was defined as that area within 1 m radius of the nest. The following nest site variables were recorded:

- Nest substrate – plant species, ground or termite mount
- Nest height above ground
- Height of the plant
- Concealment was estimated from 1, 3, 5 and 7 m from all four cardinal directions (Martin and Roper 1988). Based on the points from where the nest was seen, the concealment was calculated as low 13 - 16 points (0-25%), medium 9-12 points (25-50) high 5-8 points (50-75%), and very high 0-4 points (75-100%).
- Girth at breast height (GBH) of the trees (in cm) was recorded, size measured and categorized as small (< 15cm), medium (15-45cm) and large (> 45cm).

Nest Patch: The following variables were measured from within a circle of 15 m radius from the nest spot.

1) Canopy cover (%),

2) Ground cover (%),

4) Leaf litter depth (cm),

5) Number of trees, shrubs, dominant plant species,

6) Distance to the nearest tree (m) with more than 45 cm GBH,

7) Distance to water source (m),

8) Distance to forest edge (m),

Random site: The 10 ha plot established for nest searching was divided into 100 grids (20m x 50m). Grids were plotted on an enlarged topographic map of the study area and numbered and 20 grids were selected as random sites by lot system. To test nest-site selection, except for the nest measurements, all nest patch variables were recorded with one

tree at the centre of the 15m radius plot as done for the nest and, these were compared with similar measurements recorded at nest sites.

5.3.4. Details of breeding cycle

Direct observation at the nest was made to record nest building, laying, clutch, incubation, fledging, number of young, brooding the chicks and feeding the fledglings (Pettingill 1985). The chicks were followed as long as they could be observed. Once nest building commenced, nests were monitored daily to determine the date of egg-laying. Incubation period was determined by watching the nests periodically, once in every five days and on alternate days towards the later part of incubation. It was considered as the time difference between the laying and hatching of the last egg laid in each clutch, to the nearest whole day.

5.3.5. Reproductive success

Nesting success of the Andaman Crake was calculated from intensive monitoring of nests. Nest survival rates included a simple calculation of the number of successful nests divided by the total number of nests with eggs found (Jehle *et al.* 2004) and productivity as the number of young produced per pair. The nesting success was calculated as percentage of the number of fledglings from the total number of eggs laid (Murray 2000). The nest that fledged at least one young was considered successful and that which lost all eggs at one shot is considered as preyed upon. Observations of fledgling in or near the nest were taken as evidence of a successful nest. Depredation was assumed when eggs or nestlings disappeared. Nests failed because of predation, exposure or abandonment and damage were listed as unsuccessful (Bibby *et al.* 1998). Initiation dates, placement and concealment of the nest were quantified to examine the influence of these factors on nest success. Incubation period was divided into four stages 1-5 days (Stage I), 6-10 days (Stage II), 11-15 (Stage III), and 16-21 days (Stage IV). Success was calculated for the total period and also these different stages of the incubation.

5.4. Data Analysis

- Pearson Correlation was used to compare the number of nests in different months with environmental factors such as temperature, rainfall, humidity, wind speed and also invertebrate abundance.

- Species diversity: Shannon-Weaver and Equitability (Shannon-Weaver 1949) indices were used to estimate diversity of the invertebrates in the study area

  Shannon-Weaver Index (H') = $- \sum^{s} p_i \log_e p_i$

  $p_i = ni / N$

  S = Number of species

  Log e p_i = Natural log of Pi

  Equitability $E = \frac{H'}{2S}$

- Mean and standard deviation were taken for nest variables.

- Mann-Whitney U test was used to compare nest-site characters with random site and also for comparison between successful and unsuccessful nests.

- Principal Component Analysis was used to identify the patterns of covariation among the nest-site parameters.

- A smaller number of orthogonal components that accounted for the nest site data.

- Discriminate Function Analysis was done to find out the important factors which differentiate the successful nest from the unsuccessful nest.

- Ivlev's Index of selectivity (Ivlev 1961) test was carried out to understand the species-specific utilization (preference) of nesting trees.

Ivlev's Index of Selectivity = U-A/U+A where "U" denotes percent utilization of species and "A" denotes percent availability of the same species. Selectivity values of levels range between –1 and +1, where – indicates avoidance while + indicates preference.

- The nesting success was calculated as percentage of the chicks fledged from eggs laid.

$$\text{Hatching success} = \frac{\text{Number of eggs hatched}}{\text{Total number of eggs laid}} \times 100$$

Parametric tests were used wherever possible. Otherwise non-parametric tests were used (Zar 1999). The data presented are mean ± SE and values with $p < 0.05$ were considered significant.

5.5. Results

Breeding biology of the Andaman Crake was studied during June to September 2005 and June to September 2006 at Pathilevel in North Andaman. One fifty five nests were recorded; 35 and 120 nests during the years 2005 and 2006 respectively. Out of 155 nests, 22 were with eggs. In the present study, the nest of the Andaman Crake was first recorded on 24th June 2005. First description of the nest of the Crakes were made available to Science (Ezhilarasi and Vijayan – in press). Out of the 155 nests, the 120 nests recorded during 2006 were taken for analysis in detail.

5.5.1. Breeding season

The Andaman Crake breeds during South-west monsoon, June-August and at times extended up to September. Peak nesting was recorded during June (59 nests) followed by August (40) and July (16) (Figure 5.1 and Table 5.1). Most of the young were found in August, September and October. Only a few (five) nests were active during September. The number of nests had significant positive correlation with relative humidity ($r = 0.591$; $p < 0.05$) and number of rainy days ($r = 0.615$; $p < 0.05$) (Figure 5.2a). whereas no correlation was observed with wind speed ($r = 0.551$; $p > 0.05$), rainfall (Figure 5.2b) and temperature (Figure 5.2c). Invertebrate diversity did not show much variation in all seasons except winter (Table 5.2). The abundance of invertebrates showed no correlation with nesting season ($r = 0.363$; $p > 0.05$).

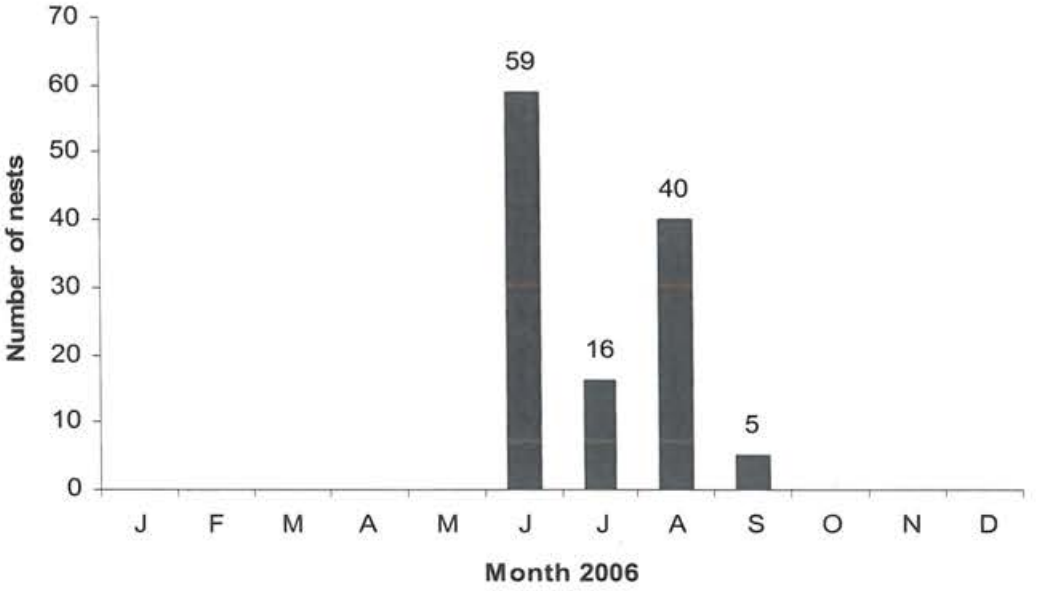


Figure 5.1. Breeding seasonality of the Andaman Crake during 2005 and 2006.

Table 5.1. Breeding chronology of the Andaman Crake during 2005 and 2006.

Months ▶ Activity▼	J	F	M	A	M	J	J	A	S	O	N	D
Copulation	-	-	-	-	-	♠	♠	♠	-	-	-	-
Nest building	-	-	-	-	-	♠	♠	♠	-	-	-	-
Incubation	-	-	-	-	-	-	♠	♠	♠	-	-	-
Chicks	-	-	-	-	-	-	-	♠	♠	♠	-	-

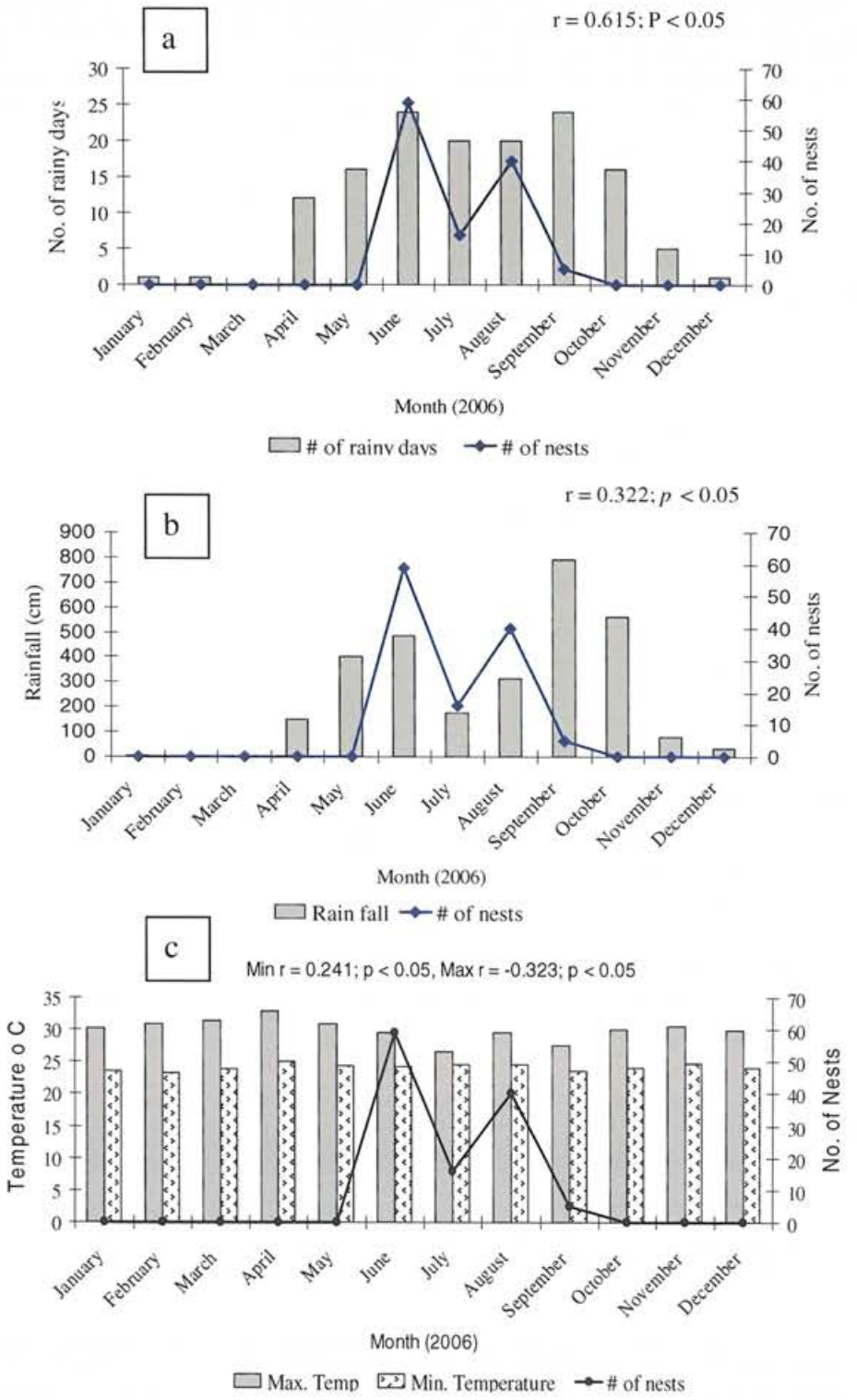


Figure 5.2. Correlation of breeding seasonality with number of rainy days, monthly rainfall and maximum and minimum temperature.

Table 5.2. Invertebrate diversity in the study area during different seasons

Season	Diversity H'	Equitability	# of Order
Winter	0.53	0.19	9
Summer	1.42	0.50	9
South-west monsoon	1.36	0.48	9
North-east monsoon	1.18	0.42	13

5.5.2. Nest and Nest-site selection

5.5.2.1. Distribution of nests

Out of 120 nests recorded during 2006, 39 were recorded inside intensive study area (10 ha) (Figure 5.3). Totally eight pairs of the Andaman Crake were recorded during the breeding season inside the 10 ha intensive study area with a density of 4.9 nests/pair. Among these nests, nine nests were with eggs, of which four nests were successful and five did not hatch. Those nests without eggs were used for roosting. More number of nests was recorded near the forest edge (within 50m) than the interior forest (Figure 5.4).

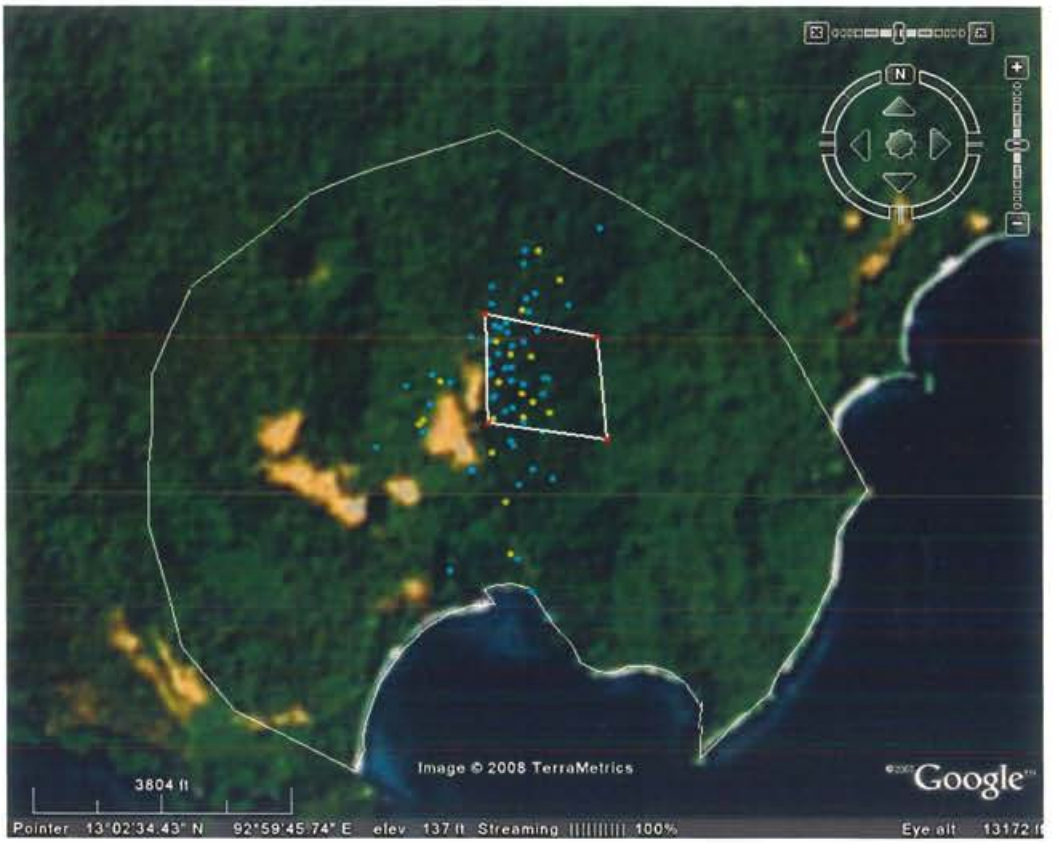


Figure 5.3. Distribution of nest in the study area, Pathilevel

*note – Square indicates 10 ha intensive study area
Yellow – nest with egg, Blue – nest without egg

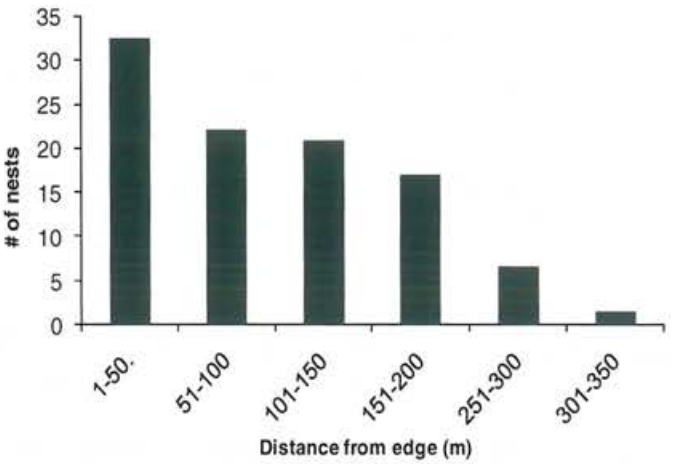


Figure 5.4. Distribution of nests with respect to the forest edge

5.5.2.2. Nest

The nest was typically a platform with a shallow cup, made up of dried leaves and twigs placed above the leaf litter. The nests have two distinct zones. First one is the loosely arranged leaves which form the outer zone and second tight shallow cup made up of twigs which is the inner zone. The twigs were flexible and soft, this layer was in direct contact with the eggs and chicks. Many of the nests (n = 89) were on the ground and a few (n= 16) above the ground up to 5m. The location of the shallow cup varied, in the corner for ground nest and in the center for others. The nests were highly concealed by surrounding vegetation. Sizes of 60 nests were measured and the measurement details are given in the Table 5.3. Nearly 96% of the nests were made with leaves and twigs and 4% with leaves, twigs and bark. Weight of the nests (n=10) showed twigs and leaves formed the bulk (Table 5.4).

Table 5.3. Nest variables of the Andaman Crake.

Nest variables	Mini	Max	Mean	SD
Outer diameter (cm)	18	36.2	26.47	7.34
Inner diameter (cm)	11.7	17.5	15.03	1.41
Depth (cm)	3.2	6.5	4.73	0.81
Concealment (points)	4	16	13.81	2.76

Table 5.4. Composition of nests of the Andaman Crake (N=10).

Nest Material	**Weight (g)**	**Percentage**
Leaf	24.96 ±3.98	27.8
Twigs	44.38±14.84	49.5
Others	20.3±19.08	22.6
Total	89.64±19.08	--

The nest materials composed leaves of 21 species of trees (17 identified, Table 5.5), twigs materials were flexible less than 4 mm in diameter.

Table 5.5. Leaves of the plants recorded in the nests of the Andaman Crake.

Local name	**Trees**	**Family**
Padauk	*Pterocarpus dalbergioides*	Fabaceae
Thejpathi	*Celtis timorensis*	Ulmaceae
Silka balli	*Sterculia villosa*	Sterculiaceae
Kalaballi	*Diospyros crumenata*	Ebenaceae
Kusum	*Schleichera oleosa*	Sapindaceae
Baranga	*Claoxylon indicum*	Euphorbiaceae
Lakko	*Pterygota alata*	Sterculiaceae
Dhoop	*Canarium euphyllum*	Burseraceae
Sagavan	*Miliusa tectona*	Annonaceae
Kadam	*Anthocephalus chinensis*	Rubiaceae
Machchune	*Pterospermum acerifolium*	Anacardiaceae
Jamun	*Syzygium samarangense*	Myrtaceae
Lohra balli	*Diospyros laurzii*	Ebenaceae
Chooi	*Sageraea elliptica*	Annonaceae
Marium	*Bouea oppositifolia*	Anacardiaceae
Garjan	*Dipterocarpus grandiflorus*	Dipterocarpaceae
Jaipal	*Knima andamanica*	Myristicaceae

After hatching, the family would move to either one or a series of 'roost nests', where the chicks roosted until they became independent. These nests were similar to incubation nests but were built before laying or after hatching and were usually more lightly constructed,

made up of only leaves. One pair of Crake was observed to build three or more roost nests and used on consecutive days following hatching.

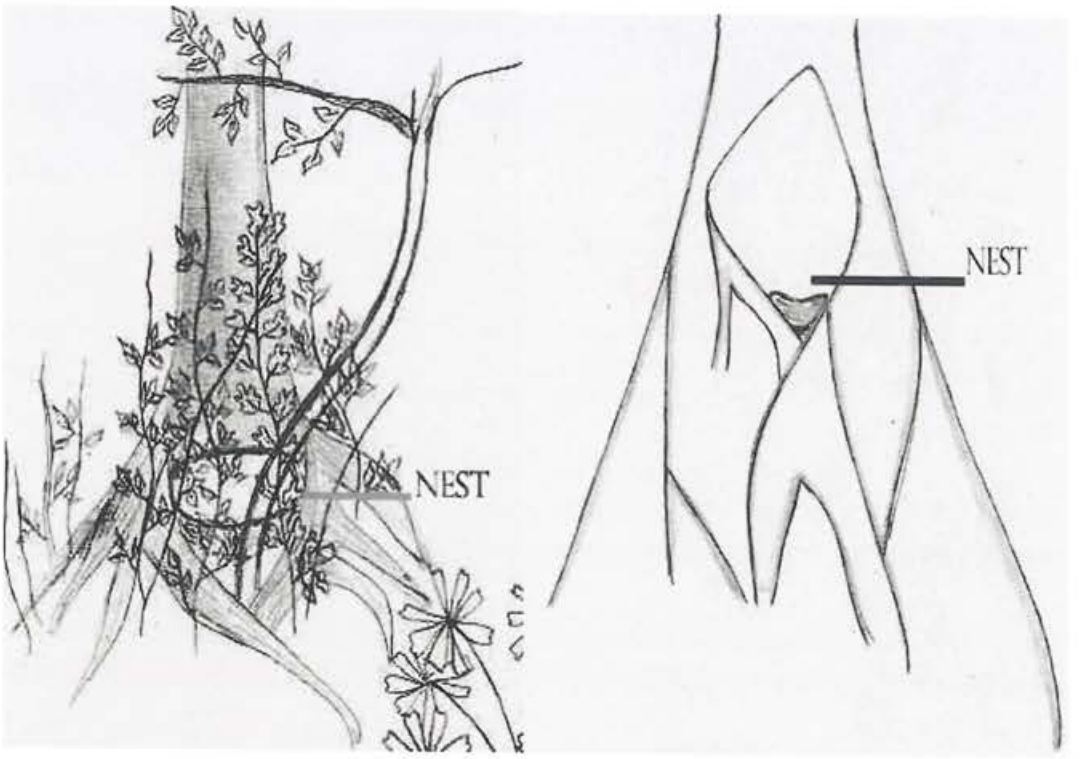
5.5.2.3. Nest placement

Of the 120 nests, 99 were (82%) recorded on ground and remaining 21(17%) nests were recorded above ground. Nests were recorded in four different places, which are given below (Table 5.6).

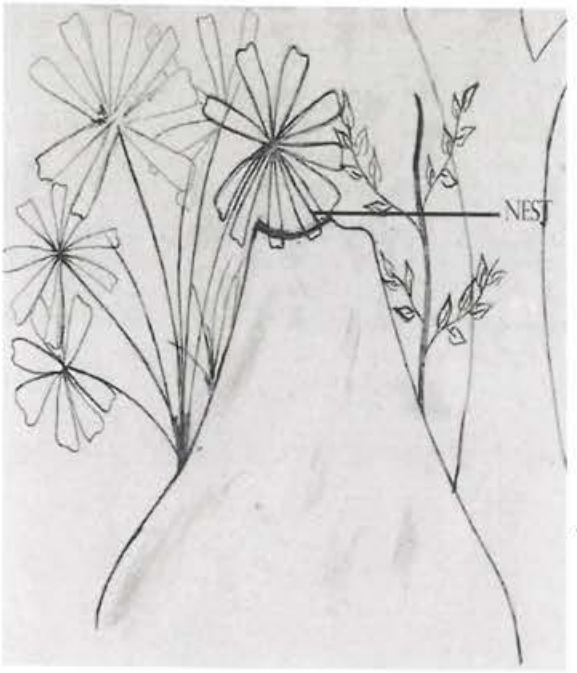
1) Between Buttresses of the tree: Out of 120 nests, 105 nests (87.50%) were located between the buttresses of trees. Among the 105 nests, 89 (84.76%) were recorded on ground (Figure 5.5a, b) and 16 (15.24%) above the ground. Both these types of nests were highly concealed by undergrowth (shrubs, climbers) and the folding of the buttresses. The minimum and maximum concealment recorded there was with 60% and 100% respectively. All nests placed on the ground were raised on a layer of decaying leaves. They were devoid of attachment materials. This type of nests was placed on the corner of the buttresses, where the backside of the nest was supported as well as concealed by main tree trunk. A few nests were with stones or shrubs between the buttresses which served as a support for the nest. The nests got protection from rain as they were concealed in the depression of the buttresses.

Table 5.6. Placement of nests of the Andaman Crake.

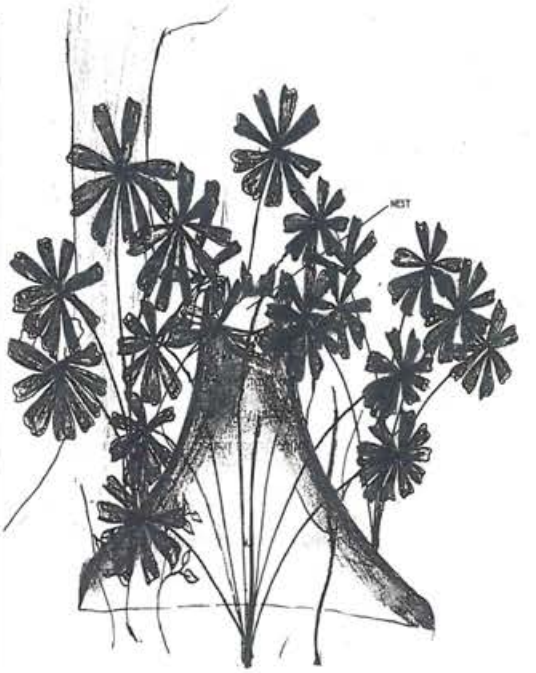
Nest Substrate	Number of nest	Percentage
Between buttresses	105	87.50
On the termite mount	7	5.83
On the top of dead tree	4	3.33
On branches	4	3.33



a. & b. Nest located between buttresses of the Tree



c. On termite mount



d. On top of dead tree stump

Figure 5.5. Different types of placement of nests of the Andaman Crake

e. On branches of trees

2) Top of termite mount: Out of 120 nests, 7 (5.83%) were recorded on the top of the termite mount (Figure 5.5c). Of these seven nests, four nests were over the termite mount located between the buttresses. The remaining three nests were on the mount standing alone in the forest. The height of the mount varied from 1-1.5m. Concealment recorded ranged from 25-100%.

3) Top of dead tree stump: Out of 120 nests, 4 (3.33%) nests were recorded on top of the dead tree stump (Figure 5.5d) which was cut by the villagers. Nest was placed on the center shallow region. The height of the trees varied from 1-1.5m. Mostly these trees were partly or fully concealed by undergrowth or nearby tree. The minimum and maximum concealment recorded was four to sixteen points (25-100%).

4) Branches of trees: Four out of 120 (3.33%) nests were recorded on the branches of trees with support from climbers (Figure 5.5e). The height of the nest ranged from 2-10m. These nests were supported from below by two or more branches. One nest was in the center of a huge leaf of *Licuala peltata* supported by branches of the nearby tree and nearby other *Licuala* shrubs and mostly well concealed ranging from 25-100%.

5.5.2.4. Nesting plants

During the study period, the Crake used 151 plants for nesting belonging to 21 species under 12 Families (Table 5.7).

Table 5.7. Nest tree species utilized by the Andaman Crake.

Tree Name	Family	Number	% of use	*E*
Spondias pinnata	Anacardiaceae	1	0.66	-0.27
Terminalia manii	Combretaceae	2	1.32	-0.47
Endospermum diatenum	Euphorbiaceae	1	0.66	-0.91
Bombax insigne	Bombacaceae	7	4.64	-0.35
Pongamia pinnata (D)	Fabaceae	2	1.32	-0.41
Syzygium samarangense	Myrtaceae	1	0.66	-0.76
Dillenia indica	Dilleniaceae	2	1.32	-0.90
Pterygota alata	Sterculiaceae	**18**	11.92	**0.86**
Parishia insigni	Anacardiaceae	1	0.66	-0.82
Pterospermum acerifolium	Sterculiaceae	1	0.66	-0.66
Bouea oppositifolia	Anacardiaceae	2	1.32	-0.84
Lannea coromandelica	Anacardiaceae	1	0.66	-0.80
Pterocarpus dalbergioides	Fabaceae	**34**	22.52	**0.63**
Ficus arnottiana	Moraceae	1	0.66	0.18
Miliusa tectona	Annonaceae	3	1.99	-0.12
Celtis timorensis	Ulmaceae	9	5.96	**0.68**
Tetrameles nudiflora	Tetrameliaceae	**37**	24.50	**0.84**
Terminalia bialata	Combretaceae	**20**	13.25	**0.53**
Diospyros crumenata	Ebenaceae	1	0.66	-0.16
Terminalia catappa	Combretaceae	5	3.31	0.41
Canarium euphyllum	Burseraceae	2	1.32	0.32

E – Ivlev's electivity index

While most of the nests were on live plants, three were on dead trees, two *Terminalia catappa* (Combretaceae) and one *Bouea oppositifolia* (Anacardiaceae) species. The four species *Terminalia nudiflora* (Thipok), *Pterocarpus dalbergioides* (Padauk), *Terminalia bialata* and *Pterygota alata* (*Tetramelaceae*, Fabaceae, *Combretaceae* and

Sterculiaceae respectively) together contributed 72.12% while 17 other species together contributed 27.81% of nest trees.

Preference index was calculated for 21 species. The preference test results showed that the Andaman Crake had a higher preference for five species, namely *Tetrameles nudiflora* (Thipok) (E = 0.84), *Pterocarpus dalbergioides* (Padauk) (E = 0.63), *Terminalia bialata* (White chugulam) (E = 0.53) *Pterygota alata* (Lakko) (E = 0.83) and *Celtis timorensis* (Thejpathi) (E = 0.68). It was also found that they avoided 13 species, namely *Spondias pinnata, Terminalia manii, Endospermum diadenum, Bombax insigne Pongamia pinnata, Syzygium samarangense, Dillenia indica, Parishia insigni, Pterospermum acerifolium, Bouea oppositifolia, Lannea coromandelica, Miliusa tectona, Diospyros curumenata*. Thirty five nests were recorded during 2005 and 120 nests during 2006. Three nests were placed at the same location as found during 2005.

5.5.2.5. Nest-site characters

The Principal Component Analysis of environmental parameters in nest-site showed that six components accounted for 80% of variance. The PC I had high positive loadings to the distance to nearby tree and number of cane. The second component was associated positively with number of buttresses. The PC III had high positive association with climber and ground cover around the nest. PC IV was associated with negatively with concealment points (less points more concealment) and number of trees, PC V with distance to water and PC VI with distance to edge, canopy cover and buttresses' height (Table 5.8).

5.5.2.6 Nest-site and non-nest site variables

The nest sites of the Andaman Crake were closer to water and had larger trees, more number of saplings in the area. Nest-site variables were compared with that of non-nesting site and significant differences were recorded in GBH of the nesting tree, number of saplings and the distance of the nest to water. The GBH of the nesting tree is greater than the non-nesting tree (Man-Whitney $U = 171.5$, $p < 0.05$), more number of saplings were recorded in the nesting place than the non-nesting area ($U = 34$, $p < 0.05$) and also number of nests were more near water/stream ($U = 65$, $p < 0.05$).

Table 5.8. Factor loadings the nest-site variables of the Andaman Crake with the principle components.

Component / Variables	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6
Tree height (m)	-.291	.118	-.076	-.033	.149	.067
Dist. to water (m)	-.023	.078	.049	-.049	.483*	-.022
Dist. to edge (m)	.030	.049	.127	-.184	.076	.334*
Climber	.007	.061	.330*	.134	.250	.179
Canopy cover (%)	.029	.008	-.177	.211	-.030	.324*
Ground cover (%)	-.086	-.040	.364*	.052	-.007	-.097
Concealment (points)	.071	.135	-.062	-.357*	.105	.009
GBH (cm)	.089	.183	-.242	.162	.205	.014
No. of Buttresses	.066	.346*	-.053	.023	.109	-.078
But. Height (cm)	.022	-.126	-.033	-.051	.009	.503*
But. Length (cm)	.013	-.246	.148	-.019	.290	.149
But. Width (cm)	.172	.363*	-.018	.164	-.057	.068
Saplings	.107	.043	.187	.075	-.108	.042
Cane	.310*	.107	-.088	.023	.215	.127
Distance to nearby tree (m)	.397*	-.116	-.110	-.035	-.039	-.056
Shrub	.139	-.120	-.076	-.176	.198	-.231
No. of tree	.038	.002	.104	.416*	-.049	-.003
Eigen value	4.304	2.332	2.233	1.843	1.461	1.433
% cumulative variance explained	25.316	39.034	52.168	63.011	71.603	80.034

No significant differences were observed in other parameters such as tree height, canopy cover, shrub cover, ground cover, distance to edge, number of cane, climber, big trees (GBH > 45cm) and medium trees (> 12 - 45) (Table 5.9).

Table 5.9. Nest-site and Non-nest site variables of the Andaman Crake.

Nest parameters	Nest site	Non-nest site	U
Tree height (m)	25.62 ± 5.74	22.41± 6.22	145.5
GBH of the nesting tree (m)	227.9 ± 159.7	151.3 ± 67.77	171.5*
Big tree (>45 cm)	9.744 ± 6.317	10.36 ± 11.45	102
Medium tree(>12-45 cm)	8.636 ± 9.219	8.8 ± 6.46	151
No. of Saplings	177.5 ± 90.1	96.36 ± 40.17	34*
Canopy cover (%)	30.93 ± 25.43	21.58 ± 16.28	132
Shrub cover (%)	14 ± 21.87	22.5 ±17.9	49
Ground cover (%)	24.91 ± 22.2	29.16 ± 24.07	123
Dist. to water (m)	17.56 ± 16.15	30.46 ± 24.24	65*
Dist. to edge (m)	99.61 ± 68.73	119.77± 82.77	6
Number of Cane	7.176 ± 7.133	8.2 ± 5.59	156
Number of Climbers	8 ± 8.39	7.5 ± 7.95	101

* Significant at $p < 0.05$

5.5.2.7. Nest-site characteristics and nesting success

Success was recorded in seven nests. Among them, two had 100% success while one had 80% and another 60%.; in three nests the percentage of hatching could not be recorded. Comparison of nest variables between successful and unsuccessful nests

showed concealment (U = 6.5, $p < 0.005$) and distance to the nearest tree (U = 10.5, $p < 0.002$) as the significant factors (Table 5.10). Discriminant functional analysis was also done with the nest-site characteristics of the successful and unsuccessful nests which showed the distance to the near by tree are the factor influence the success of the nest.

Table 5.10. Comparison of successful and unsuccessful nest sites variable of the Andaman Crake

Nest parameters	**Successful nest**	**Unsuccessful nest**	**U**
Tree height (m)	25 ± 4	22 ± 4	5
GBH (m)	194.23 ± 93	91 ± 17	0
Buttresses' ht. (cm)	105.21 ± 85	65.53 ± 26	8
Buttresses' width (cm)	63.45 ± 51	41 ± 32	4
Buttresses' length (cm)	136.27 ± 115	92 ± 31	8
Canopy cover (%)	41.25 ± 28	21.25 ± 26	18
Ground cover (%)	30 ± 17	24.16 ± 15	31.5
Concealment (%)	91.25 ± 9	66 ± 28	6.5*
Dist. to water (m)	26.66 ± 21	11.14 ± 5	5.5
Dist. to edge (m)	106.28 ± 59	78.93 ± 66	34
Dist. to near by tree (m)	1.697 ± 1	5.43 ± 3	10.5*
# of cane	7.67 ± 6	14.2 ± 14	11.5
# of climbers	11.5 ± 13	15.33 ± 4.23	12.5
# of buttresses	10.66 ± 5	8 ± 3	5.5
# of shrubs	7.33 ± 11	31.16 ± 39	5.5
# of trees	12 ± 10	7.22 ± 4	5
# of saplings	160.3 ± 77	161.3 ± 128	14

* Significant at $p < 0.05$

5.5.3. Breeding biology

5.5.3.1. Nest building

Nest building activity was recorded from only one nest. In the case of type one nest (between buttresses) the Crake was noted to clean the nesting place by removing old leaves and twigs before construction of nest. Nest was built by both members of the pair. The contribution of the male and female in the nest building activity was not known. Birds carried nest material in the bill and kept it on the nest. The Andaman Crake built the nest by piling up the materials simply on top of one another. The cup is shaped with movements of breast while sitting on the nest. The bird never approached the nest site directly with the material. The period required for construction was three days.

5.5.3.2. Copulation and display

The Andaman Crake is a monogamous species. Only five instances of copulation activity could be observed during this study. Generally copulation was recorded near the nest. Courtship occurred during foraging when the pair were close to one another, male chased its partner and mated. While mating, the male mounted on the back of the female and holding her crown or nape feathers made treading movements with his feet which were placed over the lower extremities of the female's scapulars and flapped wings to maintain balance. Then the male showed pushing movements, tail and rump moving side-to-side in an effort to establish cloacal contact.

5.5.3.3. Egg Laying

Observations showed that eggs were laid in the morning hours (06.00 and 8.00 h) on successive days. The laying interval was usually 24 hours (n = 6). But in one nest three eggs were laid on successive days and the fourth egg was laid after three days.

5.5.3.4. Eggs and clutch size

Egg of the Andaman Crake was glossy white, ovoid and without any spots much like that of domestic hen (Plates 5.1). The eggs of abandoned nests (n = 18) were weighed. The mean weight, length and width were 24g, 4.2 cm and 2.2 cm respectively. When

Plate 5.1. Nest -site of the Andaman Crake

incubation progressed, the eggs turned creamy yellow; hatching occurred almost synchronously within a couple of hours.

Clutch size varied from 4-8 and maximum nests had 5 eggs (n = 8; 53.33%), followed by 6 and 4 eggs (n = 3; 20%) and only in one nest (6%) 8 eggs were found. The mean clutch size was 5.75 ± 1.71 (n = 15). Nests with one egg and three eggs were recorded, but these nests were predated or abandoned and hence not considered as completed clutch. Unhatched eggs were removed from the nest by the parents. There was no marked difference in the clutch size between ground nest and other types of nests. The nests at the starting period of breeding season (June) had six eggs (n = 3), whereas those in July and August had four (n = 1) and five eggs (n = 1).

5.5.3.5. Incubation

Incubation was shared by both the sexes, but it was difficult to identify the sex of the incubating bird, as they are similar in appearance (Plate 5.2). Hence, nest attentiveness by each sex could not be calculated. However, the available data showed that one member of the pair dominated each day of incubation. When one bird of the pair relieved its mate from nest, it continued incubating and one uninterrupted attentive session was noted. Nest was occupied for more than 90% of the time. The incubating birds seldom flush. Incubation period was calculated from the completion of clutch to the commencement of hatching (Table 5.11). The incubation period was recorded from four nests; in all the four nests chicks hatched on the 21st day.

Table 5.11. Incubation period of the Andaman Crake

Nest ID	Clutch initia-tion	Clutch comple-tion	Clutch Size	Incubation initiation date	Hatching date	Incu-bation period
11	5/06/06	9/06/06	5	9/06/06	29/06/06	21
30	13/06/06	17/06/06	5	17/06/06	07/07/06	21
83	16/06/06	20/06/06	5	20/06/06	10/07/06	21
98	17/08/06	21/08/06	5	21/08/06	16/09/06	21

a) Incubation

b) Hatchlings

Plate 5.2. Nesting details of the Andaman Crake.

5.5.3.6 Chicks

Andaman Crake chicks are precocial and leave the nest immediately within a day of hatching. Chicks were covered with down feathers. Chicks made "*cheer... cheer*" calls when inside the nest and the calls were heard from 3m distance. Observing the chick in the forest was difficult because it camouflaged with the surroundings. Chicks were noted to roam with parents and returned to nursery nest with parents. They spent nearly 30-32 days with the parents. Female parent (colour-ringed) was noted to be with the chicks attending to them while the male brought food (mainly earthworm) often to the chicks. Chicks were fed bill-to-bill generally for a few days to weeks by both the parents. But while roosting female roosted with chicks in nest and the male roosted in a nearby tree. After a month, parents were noted to chase the juveniles. Success of the chicks could not be ascertained as they were very difficult to be observed inside the forest except for occasional sightings. Although a few individuals were marked, no information could be drawn on their dispersal.

Measurements of a few chicks, young and adults were taken (Table 5.12). Chicks of two nests were ringed, three chicks on the fifth day after hatching from one nest and three more from another nest on the eighth day and one of which was recaptured and measured after two days (10^{th} day).

Table 5.12. Mean measurements of the chicks of the Andaman Crake at different stages.

Parts	Chicks			Juvenile (n=3)	Adult (n=11)
	5th day (n=3)	8th day (n=3)	10th day (n=1)		
Wing (mm)	12.3	12.6	12.8	143±30	158±4
Tail (mm)	-	-	-	75±27	79±16
Culmen (mm)	17	17±1	20	30±6	33±3
Tarsus (mm)	31±4	32±2	39	59±5	76±2
Weight (g)	49±4	52±2	53	195±42	253±43

5.5.3.7. Brooding

Although both male and female incubated, brooding chicks was done only by female which was observed at night for nearly 30-31 days (n=2). Though nest was recorded in different places brooding was recorded only in the nursery nests on ground between the buttresses.

5.5.3.8. Nest success and failure

Of the 22 nests with eggs, seven nests (32%) were successful and fifteen failed because of multiple reasons. During 2005 all five nests failed and during 2006 ten failed. In the successful nests exact number of eggs and chicks were recorded only from four nests. Totally 77 eggs were recorded from 22 nests of which only 17 hatched (22%) (Table 5.13). Two nests had 100 % hatching, one 80% and another 60%. The success rate was high in the case of earlier nesting pairs (75%) than late breeders (25%).

Table 5.13. Hatching success during 2005 and 2006.

Year	# of nests	# of egg	# of eggs hatched	% of success
2005	35	23	0	0
2006	120	54	17	32
Total	155	77	17	22

Out of 155 nests, 133 were (86%) without eggs and 17 (14%) with eggs. In 2005 productivity was nil, while in 2006, out of the 17 nests, 41% was successful with a mean of one chick per pair, the fate of which was also not sure. The major causes of nest failure were predation, abandonment and damage (Table 5.13; 5.14; Figure 5.6).

Predators in the breeding ground

The predators of the Crake recorded during this study were monitor lizard, snakes and coucal. Predation was observed in three stages, eggs, chicks, and adults. Eggs were mainly preyed upon by the monitor lizards and snakes. Monitor lizard was sighted near the nest on three occasions and once it was noted to feed on the Andaman Crake eggs and on other two occasions on adult birds.

Table 5.14. Fate of the nests of the Andaman Crake during 2005 and 2006.

Nest Number	Clutch Size	Hatching Results	# of eggs hatched	Reasons for failure
1	6	Preyed on	-	Crow-pheasant
2	5	Abandoned	-	Human disturbance
3	6	Preyed on	-	Monitor Lizard
4	1	Abandoned	-	Unknown
5	5	Preyed on	-	Snake
6	5	Hatched	4	-
7	5	Damaged	-	Human disturbance
8	?	Hatched	?	-
9	5	Hatched	5	-
10	1	Abandoned	-	Unknown
11	3	Preyed on	-	Unknown
12	4	Preyed on	-	Snake
13	4	Damaged	-	Bad weather
14	?	Hatched	?	-
15	5	Hatched	5	-
16	1	Abandoned	-	Unknown
17	5	Hatched	3	-
18	4	Preyed on	-	Monitor Lizard
19	5	Abandoned	-	Human disturbance
20	1	Abandoned	-	Unknown
21	?	Hatched	?	-
22	6	Preyed on	-	Monitor lizard

? – No. of eggs and chicks were not sure

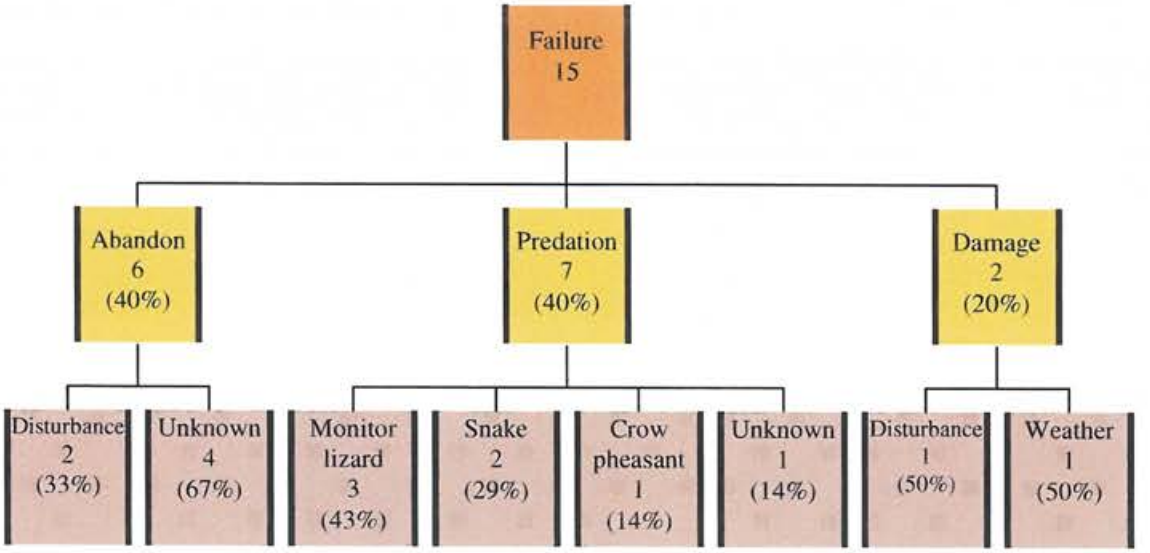


Figure 5.6. Causes of nest failure.

Among snakes, pit-viper and cat-snake were widely distributed in the breeding ground and in one nest cobra was found to feed on the eggs. One nest was preyed upon by the Brown Coucal (Andaman Crow-pheasant). Predators recorded from this study, and from interview with local people are given in the table 5.15. Dogs and cats are also reported to catch chicks and adults of the Andaman Crake.

Table 5.15. Predators of the Andaman Crake

Name of predator	**Information from local people**	**This study**	**Target**
Human	+	+	A
Dog	+	+	C & A
Cat	+		C
Monitor Lizard	+	+	E, A & C
Snake	+	+	E
Brown Coucal	+	+	E

A = Adult, C = Chicks & E = Egg

Nest abandonment

Abandonment of nests by the parents was another reason for nest failure; out of 22 nests, six nests (40%) failed due to abandonment. Two nests were abandoned because of human disturbance while for others the reasons could not be confirmed.

Damage

Breakage of the branch of the nesting plant was recorded in two nests, in one nest due to cutting of nesting tree and another due to harsh weather (heavy wind and rain). If the damage was only due to natural reasons the hatching success would have been 41%.

5.5.3.9. Failure of nest with respect to progress of incubation

Maximum losses were during the 1st and 3rd stages, abandoning was more in the former while predation was more in the later stages (Figure. 5.7). The rate of nest abandonment was high during the first week, then significantly decreased in the remaining weeks of incubation (Proportion test $\chi^2 = 24.40$; $p < 0.05$). Although abandonment was observed in the last period of incubation, it was due to human disturbance.

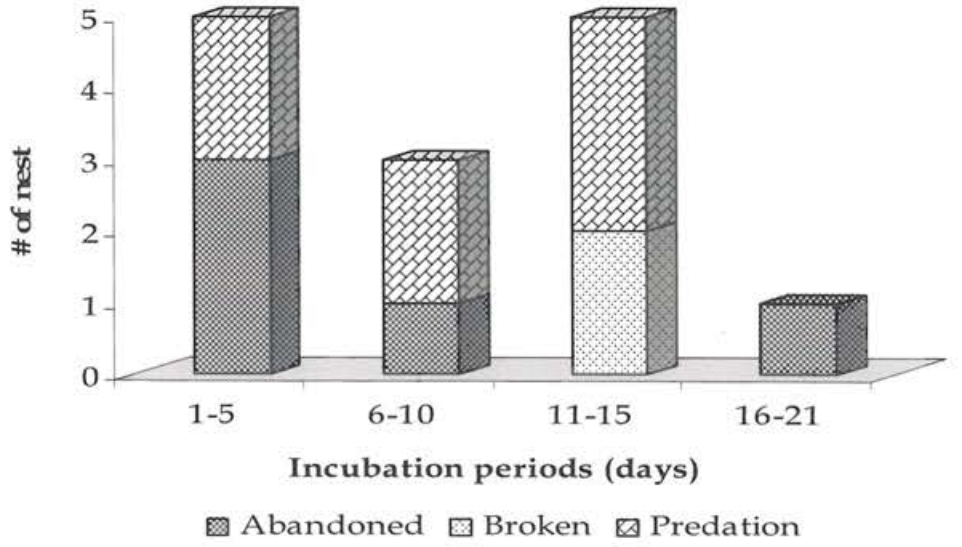


Figure 5.7. Nest failure recorded in different stages of incubation

5.5.3.10. Success of nest with respect to nest placement

Out of 22 nests with eggs, more number of successful nests was recorded on the ground between buttresses, followed by that on the termite mount; while others had no success. The result showed that hatching was recorded more in the nest of termite mount (50%), followed by ground between buttresses (35%) but no success was recorded in the nest located on multiple branches and on the top of dead tree stump.

5.5.3.11. Success of nest with respect to distance from the edge

Nesting success was high in those nests which were placed away from the forest edge ($r = 0.674$; $p < 0.05$) (Table 5.16). Out of seven successful nests, five were more than 100 m away from the forest edge and two below 100 m. Among the failed 15 nests 12 nests were below 100 m from the forest edge and the rest ($n = 3$) above 100 m.

Table 5.16. Success of nest with respect to distance from the edge

Dist. from the edge (m)	No. of nests	No. of successful nests	No. of failed nests	% of success
0-50	7	1	6	14
50-100	7	1	6	14
100-150	3	3	-	100
> 150	5	2	3	60

5.6. Discussion

5.6.1. Breeding Season

Andaman Crake is a seasonal breeder (June to September). Breeding of this species during June to August is reported by Ali and Ripley (1969) and Taylor and Van Perlo (1998). Extention of breeding to September as found in my study is similar to the records of other *Rallina* species such as Red-legged Crake (Hellbrekers and Hoogerwerf 1967) and Slaty-legged Crake (Stusak and Vo Quy 1986). The significant factors were relative humidity and number of rainy days, but not the amount of rainfall. With the initiation of rain in April, the ground invertebrates increase in the decaying leaf litter on the ground (Haskell 2000). Heavy rainfall in September will be

harmfull to nests as the ground nests could be destroyed or washed off. This phenomenon of termination of nesting with heavy rainfall has been recorded in many tropical birds (Immelmann 1971, Vijayan 1984). Waterbirds which nest in wetlands wait for full flooding for nesting so that the nests will not be damaged as found in Bharatpur (Vijayan 1994). Many rails make their nests during rainy season when forest floor is filled with water (Taylor 1994, 1996). Breeding in monsoon is reported from Chestnut-headed Flufftail (Taylor 1994), Red-chested Flufftail (Steyn and Myburgh 1986), Tasmanian Native-hen and Spotless Crake (Taylor and Van Perlo 1996). Rizi *et al.* (1999) argued that the start of late egg laying in the African Coots might be because of late rainfall. A study of the breeding seasons of waterbirds in south-western Australia showed that rails' laying period was best correlated with peak rainfall (*del* Hoyo *et al.* 1996). Temperature and rainfall are the major factors which regulate the breeding season of the forest birds in the Western Ghats (Vijayan *et al.* 1998; Das 2008). The factor that heralds a suitable breeding environment for several tropical species of birds is rain and it is more of the effect of rainfall (Earle 1981). Several studies have shown the link between rainfall and the breeding environment of birds, which can be as dramatic as that in rainfall-dependent wetland systems (Sankaran 1991, Vijayan 1991). Increased rainfall is correlated with increased food abundance and hence, monsoon is an apt season for insectivorous birds to breed (Das 2008). Abundance of insects increasing with onset of rain was observed in Anaikatty (Nirmala 2002) and in Mudumalai (Gokula 1998) in the Western Ghats. Sodhi (2002) found that rainfall has strong influence on the breeding of the birds.

The temporal organization of reproduction in a tropical bird is crucial because reproduction is very energy demanding, and therefore needs precise timing to coincide with good environmental conditions (Lack 1968; Perrins 1970; Van Noordwijk *et al.* 1995). Rainfall and clutch size might be linked via food availability (Goth and Vogel 1996). Lack (1968) suggested that the breeding season of birds coincides with the period of maximum food availability for rearing young. Moreover, females need a sufficiently abundant food supply to initiate egg laying, and the laying must be timed such that the young are hatched when food resources are abundant (Lack 1968; Perrins 1970). Here also the chicks are produced during and immediately after rain when food abundance was high. Some of the groups of invertebrates are high during summer when the birds prepare for breeding. This crake is an

opportunistic feeder making use of the situation which might be influencing the starting of breeding. Seasonal reproduction in many tropical organisms remains unclear (Gwinner and Dittami 1985). It was assumed that tropical organisms use mostly short-term cues like rainfall to learn about, and react to changes in environmental conditions (Immelmann 1971). Little is known about how predictable tropical rain forests are for their inhabitants. Many organisms reproduce seasonally even in tropical forests, which are supposedly among the more "constant" environments (Leigh *et al.* 1982). Because these breeding events occur at more or less regular times of the year, this implies that environmental conditions are to some degree predictable in rain forests (Colwell 1974; Poulin *et al.* 1992).

5.6.2. Nest

Nests of the Andaman Crake were made up of leaves, twigs and bark as in the Red-necked Crake (Coates 1985; Ripley and Beehler 1985) and Slaty-legged Crake (Delacour and Jabouille 1931). According to Ali and Ripley (1987) and Taylor and Van Perlo (1998) nest of the Andaman Crake was with collection of grass and old leaves, placed at foot of forest tree or under tangled forest undergrowth. But in this study no nest was with grass. The size (corner width) of the buttresses might have influenced the amount of nest material used as well as size of the nest. Although dead leaves of 21 species of plants were recorded in the nests, no species were recorded in the nests dominating or present in all nests which showed that these birds used the available leaf materials for nest. All the nests of this Crake are different from those of other forest rails, namely Chestnut Forest Rail *Rallina rubra* and White-striped Forest Rail *Rallina leucospila* which make dome-shaped nests (Taylor and Van Perlo 1998).

5.6.3. Nest Placement

The Andaman Crake nests were recorded on the ground between buttresses as in the Red-necked Crake (Coates 1985; Ripley and Beehler 1985). Building the nest on the corner of the buttresses appeared to be adaptive. Building nest between the buttresses might be beneficial because of the following reasons; 1) maximum concealment - immediately nest was covered on three sides by buttresses itself (minimum 60% to maximum 100% concealment), Nests that are easy to find and have access should be depredated more frequently, resulting in selection for more concealed nests

(concealment hypothesis; Cresswell 1997), 2) protection from rain, wind and direct sunlight, 3) least chance of getting trampled by cattle and 4) besides giving enough support for nest placement, the darkness of corner of the buttresses provides a camouflaging background which supports the 'background matching hypothesis' (Martin 1998a).

Nests on tree stump are similar to that of Slaty-legged Crake (Taylor and Van Perlo 1998). Nests placed on a multiple branch site, may be secured simply by its weight, and alternatively, attachment materials were to prevent it being dislodged (Hansell 2000). Large birds, particularly when building nests in trees, may be expected to build nests to bear greater stresses from parents, eggs and chicks than smaller species and probably have most of the nests on the ground (Hansell 2000).

5.6.4.Nesting plants

Nests were recorded in 21 species of trees. In this study *Tetrameles nudiflora* and *Pterocarpus dalbergioides* were the most preferred nesting trees. They are relatively huge and have more number of buttresses providing suitable nest sites which might be the reason for preferring these trees. Another factor which regulates the nesting plant preference may be the architectural suitability to place the nest (Das 2008).

5.6.5. Nest site

Andaman Crake was noted to nest in evergreen, semi-evergreen and moist deciduous forests. Nest was recorded on the forest edge as well as inside. Crake appear to be selective in its nest site, showing a preference for more protected locations and little regard for plant species composition. When comparing nest sites with non-nest sites GBH of the nesting trees, number of saplings around the nest and distance from water were the three important parameters which determined the selection of nesting site. The trees with higher GBH occupy larger area and because of their huge size most of them have more number of buttresses which in turn provide suitable nest site.

Nest sites were selected in areas within the forest where the density of small trees was greater than random sites and possibly in response to the amount of leaf litter created by larger number of trees. Taller trees provide increased amount of leaf litter as a substrate for foraging (Hoover and Brittingham 1998). Leaf-litter depth is correlated

positively with invertebrate biomass (Haskell 2000). In addition, areas within the forest with larger number of tree and shrub stems could be indicative of concealment and favorable moisture regime that might influence the use of an area by the Andaman Crake. Single most important variable correlated with nesting success was nest-concealment as in many other species (Martin 1995; Clark and Shutler 1999). The possible reason for their preference for nearness to water might be that the invertebrates concentrated at the bank of the stream (Vijayan 1984; Vinod 2007). Birds are usually thought of as being limited by food during the breeding season and under these conditions, evolution of the reproductive strategy should proceed towards the most efficient utilization of food and water (Lack 1968). Breeding habitat has to be located close to abundant food resources, provide adequate nesting substrate, and offer protection against predators (Buckley and Buckley 1980). A critical factor determining breeding success is the amount of food available; hence selected breeding environments should provide an abundant food supply (Lack 1968; Sinclair 1983).

The Principal Component Analysis of all parameters influencing nest-site selection showed six components accounting for 80%. The first factor had positive loadings to the distance to nearby tree and cane which might give protection against heavy wind, rain, sunlight and also give concealment. The PC II was associated positively with the number of buttresses and buttresses' width. Trees with more number of buttresses provide choice for the Crake to choose good nest site which was evidenced by the observation of maximum of three nests in one tree having more buttresses, i.e, roosting nests also in the same tree which might save the searching time of the bird for new nesting area. The PC III had positive association with climber, ground cover and number of saplings around the nest. More number of saplings, climbers and ground cover make the place inaccessible to the hunters and guard the nest from cattle trample. Angelstam (1986) found that concealing vegetation in the area surrounding the nest, not at the nest itself, was important in reducing depredation for ground nesting birds. PC IV associated with concealment and number of trees that high concealment will hide the nest from predator bird such as brown coucal and eagle and number of big trees (nesting trees) around the nest may increase the concealment and also use of abundant species at a location may reduce the nest predation, because the predator's search time would increase and foraging efficiency decrease (Martin 1992b, 1993b and Hernandez *et al.* 1999). PC V was associated with distance to

water; as discussed above, the possible reason for this preference for nearness to water might be food abundance. The PC VI was associated with tree height. The taller trees have more number of buttresses which in turn provide nest site for the crake and also increased amount of leaf litter as a substrate for foraging and nesting (Hoover and Brittingham 1998).

Nest-site characteristics were compared between successful and unsuccessful nests and the result showed concealment and distance to the nearest tree as the significant factors. Even though there are numerous studies demonstrating the positive effects of concealment on nest survival (Martin 1996; and Vinod 2007), other studies were unable to find such an effect (Willson and Gende 2000). The nests that are concealed regardless of the particular plant structure will be more successful than those that are not so concealed because of reduced auditory, olfactory and visual cues to potential predators (nest concealment hypothesis; Martin 1993a; Cresswell 1997).

5.6.6. Nest building

Nest building activity was rarely sighted because of the elusive nature of the bird and the thick undergrowth which made it extremely difficult to locate most of the nests during the early period of construction. Andaman Crake is a monogamous species (Taylor and Van Perlo 1998). Monogamy is to be expected as the predominant mating system in the group because, although rail chicks are precocial or semi-precocial, they need intensive parental care at an early age (*del* Hoyo *et al.* 1996). The period of nest construction was 2-3 days as reported in Buff-spotted Flufftail (Taylor 1994). Nest materials are often gleaned from surrounding vegetation as reported in many rail species (Taylor and Van Perlo 1998). The simple piling up technique was used by the Crake as reported in Virginia Rail, White-throated Crake and other ground nesting species (Hansell 2000).

5.6.7. Copulation, egg and clutch

Copulation usually takes place near the nest as recorded in King Rail (Meanley 1992). Egg was layed in the early morning with 24 hours interval as reported in many *Rallina* species (Taylor and Van Perlo 1998). Various explanations are given by various researchers for the adaptation of laying eggs at a particular time such as 1) Avoidance of egg breakage (Schifferti 1979), 2) Enhances foraging efficiency due to

reduction of body mass after laying (Cheng *et al.* 1983), 3) Reduction of risk of predation (Watson *et al.* 1993) and 4) variation among species because of phylogeny, but has no selective advantage (Oppenheimer *et al.* 1996).

The egg color of the Andaman Crake was white and the clutch size 4-6, more or less similar to other *Rallina* species, Forebes's Forest-rail which has glossy white eggs, with clutch size 4-5 (Manjep and Bulmer 1977), Red-necked Crake with 3-7 white eggs (Taylor and Van Perlo 1998), Red-legged Crake with 3-6 chalky white eggs and Slaty-legged Crake with 4-8 creamy white eggs (Schonwetter 1962). Andaman Crake egg and clutch size is different from another *Rallina* species Chestnut Forest-rail which has half white colour egg and clutch size is only one (Firth and Firth 1990). Eggs of rails are mostly blunt oval, smooth and usually fairly glossy (*del* Hoyo *et al.* 1996) as reported for several species. A smaller clutch size during the late breeding season was observed in the Andaman Crake. Larger clutch size towards earlier breeding has been found in different groups of birds (McCleery and Perrins 1998).

5.6.8. Incubation

Incubation was started after the completion of clutch; rails do not start incubating until they complete egg laying (Elliott *et al.* 1991). The participation of both sexes in incubation follows the general pattern of Rallids (Ripley 1977; 1985). Biparental care can improve 1) incubation efficiency, 2) nest and brood survival and 3) mate condition to the extent it is important for reproductive success (Oring 1982). Shared incubation enables the nest to be covered almost all the times. The incubation period of the Andaman crake is 21 days as recorded in King Rail (Meanley 1992), Spotless Crake (Marchant and Higgins 1993), Henderson Rail (Jones *et al.* 1995) and Red-necked Crake (Mason *et al.* 1981). Generally the incubation period of Rallina species is 18-22 days (Mason *et al.* 1981). The incubating birds seldom flush until the intruder is right at the nest as recorded in King Rail (Meanley 1957). As the hatching date approaches they exhibit an even more striking tenacity; same kind of behaviour is recorded by Meanley (1953) in King Rail.

5.6.9. Chicks

Chicks hatch covered in down and are precocial as reported in Red-necked Crake (Mason *et al.* 1981). The capture and recapture measurements of the chicks showed

that the Andaman Crake legs grow faster than other parts of the body, which is the general character of the rails (Taylor Van Perlo 1998). They roost in the nest with the young chicks and at other times apparently roost above the ground in bushes and trees as White-spotted Flufftail (Taylor and Taylor 1986). One pair of Crake, which built three roost nests used on consecutive days following hatching, after which they moved between nests apparently randomly as in the Spotless Crake (Marchant and Higgins 1993) and Henderson Rail (Jones *et al.* 1995). Andaman Crake was noted to build roost nests before laying as the Spotless Crake (Kaufmann 1987).The juvenile of 3-4 weeks was almost fully feathered. Parents were noted to chase the fledglings from the territory after 3-4 weeks (once the chicks become independent) as reported in Red-necked Crake (Mason *et al.* 1981). The general fledgling period of rails is 3-4 weeks (*del* Hoyo *et al.* 1996).

5.6.10. Failure of the nest

Nesting success of the Andaman Crake recorded during this study was only 22% with the maximum of 32% in the second year, far less than other open-nesters which is generally 45% (Lack 1954). Many factors affect the reproductive success of the Andaman Crake which include predation, abandonment and damage of the nesting branch. It was inferred that predation pressure could be a major factor determining nesting success and hence nest-site selection. The primary cause of nest failure among forest nesting birds is predation (Martin 1993a). The clumped distribution of nests with increasing nest density as in this Crake is expected to increase predation as a result of a successful find in the area with restricted searching (Hoi and Winkler 1994), increased patchy use or development of a search image (Ford 1999; Lariviere and Messier 2001). The high nest density has the disadvantage of increasing intra-specific competition for food and nest site which also influences breeding success (Wiens 1989).

The nest predator community consisted of a variety of birds, snakes and other reptiles especially monitor lizard. Diversity of predators was responsible for the relatively high rate of failure in the Andaman Crake. The techniques used by the nest predators when searching for prey are also diverse and, as a group they would not be expected to detect nests at any one height better than another (Filliater *et al.* 1994). The primary predator recorded was monitor lizard and snakes. Monitor Lizard was noted to return

to recently depredated nests. Watching the nests after they fail may be an effective and less intrusive technique for documenting nest predators (Farnsworth and Simons 2000).

Among snakes Pit-viper and Cat-snake are widely distributed in the breeding ground and in one nest Cobra was found to feed on Andaman Crake eggs. Edges provide snakes the thermal properties of both adjoining habitats, allowing greater flexibility for thermoregulation (Blouin-Demers and Weatherhead 2002). Snake predation on nest is wide spread and affects the nesting success of many species of birds (Weatherhead and Blouin-Demers 2004).

Birds such as Coucal (Crow-pheasant) and raptors are the possible predators of the eggs of the Andaman Crake. Andaman Serpent Eagle and Black Baza were often recorded near the nest which might be predators of the chicks of the Andaman Crake. Nest success was recorded more in interior forest than edge. Interior forest nests are scattered in space. By scattering nests in space or time could reduce potential density-dependent predation as a result of the development by predators of clearly-defined search images as explained above. High rates of nest predation along edges are common in forest landscapes (Das 2008). Arts and Messier (1996) found positive relationship between probabilities of hatching and distance to nearest field edge. So nests placed farther from edges are expected to face reduced predation; however, evidence for this remains equivocal (*see* Fisher and Wiebe 2006).

The prevailing fragmentation hypothesis suggests that predation rates are higher in fragmented landscapes than in contiguous forest (Robinson *et al.* 1995). Nesting success often declines with the decreasing fragment size (Moller 1988; Small and Hunter 1988; Hoover *et al.* 1995). Nesting success may be affected by area-dependent changes in predator assemblages, but other factors could also be important. For example, nesting birds may be attracted to edge-dominated environments, and higher nest densities may attract nest predators or improve their foraging efficiency (Hanski *et al.* 1996; Rodewald (2002). Therefore low nesting success in edges as in the case of fragmented habitat of the Andaman Crake could be due to density-dependent mortality from predation.

The loss due to abandonment was also a major cause of failure and the reason for which was partly human disturbance. It may also be because the eggs were not hatching, as the embryo died. In case of the birds which have successful breeding experience, nest abandonment before egg laying could be suggested by their ability to sense a new potential threat that did not exist until nest building such as arrival of a new potential predator in their territory. This could be considered as a 'Predictive ability' of the experienced bird to clearly predict a loss and does not invest further. Such behaviour would always be favored by natural selection.

The earlier nesting pair was successful in the case of the Andaman crake. Earlier nesting gives some advantages, for example obtaining a good territory (Mitrus 2004) and reduced search image of the predators. Many studies have shown a positive correlation between early breeding and reproductive success (Johnson 1997; Vinod 2007).

5.6.11. Success of nest with respect to nest placement

Although more number of nests was recorded in the type one placement (on ground) success rate was recorded higher in nests placed on termite mount. This may be because predators would be expected to direct their search efforts towards the substrate that represent potential sites for encountering prey ('rare site hypothesis' Martin 1998b, 1993b; Filliater *et al.* 1994). The experienced predators may use previous experience for nest searching (Martin 1998a); where they get more number of nests on the ground between buttresses their searching may concentrate in that area.

5.7 Summary

- One fifty five nests of the Andaman Crake were recorded; 35 and 120 nests during 2005 and 2006 respectively. Out of 155 nests, 22 were with eggs.

- Nests had a clumped distribution. Totally eight pairs of the Andaman Crake were recorded during the breeding season inside the 10 ha intensive study area. Thirty nine nests were recorded with a density of 4.11 nests/pair.

- The Andaman Crake nested during South-west monsoon, June-August as reported in other Forest Rails.

- The nest was typically platform-shaped with a shallow cup, made up of dried leaves and twigs above the leaf litter.

- Totally 151 trees belonging to 21 species in 12 Families were used for nesting. The five species *Tetrameles nudiflora, Pterocarpus dalbergioides, Terminalia bialata* and *Pterygota alata* and *Celtis timorensis* together contributed 72% while 17 other species together contributed for 28% of nest trees.

- The most important variable influencing nest-site selection and nesting success of the Andaman Crake was concealment.

- Nest was built by both the members of the pair. The period required for construction was three days

- Eggs were laid early in the morning between 06.00 and 8.00 hrs on successive days. Eggs of the Andaman Crake are glossy white in color, ovoid and without any spots. The mean weight, length and width were 24g, 4.2 cm and 2.2 cm respectively.

- Clutch size was 5.75 ± 1.71 ranging from 4-8,

- Incubation was shared by both the sexes of the pair and the incubation period was 21 days.

- Nest success of the Andaman Crake was 22%, with a maximum of 32% in the second year which is comparatively lower than that of several threatened species.

- Maximum losses were during the 1st and 3rd stages of incubation, abandoning was more in the former while predation was more in the later stages.

- Nesting success was high in those nests which were placed away from the forest edge ($r = 0.674$; $p < 0.05$)

- Nest losses were caused by predation and abandonment partly (25%) because of human disturbance. Major predators observed were monitor lizard, snakes and Coucal; dogs and cats are also reported to catch the young and adults.

Chapter 6

SUMMARY AND CONCLUSION

6.1. Summary

Andaman Crake is a rare and endemic bird of Andaman Islands. There was no detailed information available on this species and was listed as data deficient till recently. Hence a study was undertaken during 2004-2007 to collect baseline data on the population, ecology and biology of the Andaman Crake. A variety of factors is responsible for Andaman Crake's habitat degradation and loss. In this chapter I briefly highlight key findings of this study, major threats to this species and suggestions for conservation and future research. While these threats and recommendations are given for the conservation of the Andaman Crake, they pertain to several other species ecologically dependent on the wet forests.

Status and distribution of the Andaman Crake were assessed in different islands of different size classes and in different habitats. A total of 253 birds were recorded in 8% of points surveyed from 2001 points with the encounter rate of 0.18 birds/km. The encounter rate of this Crake was significantly higher in the five major islands of above 100 km^2 (0.81 bird/km) compared to outer islands (0.18 bird/km). Andaman Crake was recorded from about 255 sites majority of them were in unprotected areas. Habitat-wise survey showed presence of the Andaman Crake only in wet forests, namely semi-evergreen (1.00 bird/km), evergreen (0.74 bird/km) and moist deciduous forest (0.61 bird/km). Although these forests were recorded in most of the islands, encounter rates increased with the increasing island size. The lowest elevation of sighting of the Crake was 0 m and the highest 558 m. The number of Crakes observed decreased with increasing elevation. Andaman Crake had clumped distribution with the encounter rate being positively associated with the presence of stream. The habitat was characterized with high canopy height, moderate canopy cover, high number of saplings and low ground vegetation with dense leaf litter.

To study the activities of the Andaman Crake about 5000 hours were spent in the field; as a result, a total of 2714 observations were made in 382 contact hours. The activity pattern of the Andaman Crake showed trimodal pattern in foraging, peak recorded in the morning 04.00 to 05.00 h, 09.00 to 10.00 h and evening 16.00 to 17.00

h. The overall pattern showed that most of the time the foraging and calling activities were inversely proportional. Resting and maintenance activities, especially bathing were recorded mainly in the afternoon.

The total activity budget showed that the Andaman Crake spent the maximum time (49%) for foraging followed by calling (38%) and breeding (9%) and minimum time was spent for maintenance and resting. During the non-breeding season maximum time was spent for foraging (65%) followed by calling (27%) while during breeding calling was more (47%) than foraging (35%). Significant difference in activities was observed between breeding and non-breeding seasons and also among the seasons.

A total of 1113 foraging observations were made. Andaman Crakes were noted to feed on invertebrates. The feeding observations indicated the intake of earthworms (Neooligochaeta), caterpillars (Lepidoptera), termites (Isoptera) and ants (Hymenoptera). In total, 60 faecal samples of the Andaman Crake were collected and analyzed. Faecal materials comprised mainly five different prey items including mouthparts of ants and termites, cuticle of beetles and broken pieces of shells. When the food items were compared between breeding and non-breeding seasons and among different seasons significant difference was recorded in Isoptera, Hymenoptera, and Stylommatophora, whereas no significant difference was recorded in Coleoptera. Invertebrate diversity was high during summer and south-west monsoon. Pecking was the major method used by the Crake for feeding (61%). Apart from pecking, it used the flake method (35%) while other methods such as stabbing and gleaning were negligible (1% each). Although there was slight difference in foraging methods in different seasons it was not significant. Foraging rhythm showed alternative ups and downs but peaks were more in early morning and late evening. The feeding rate had negative correlation with temperature ($r = -0.514$; $p = 0.06$).

Breeding biology of the Andaman Crake was studied during June to September in 2005 and 2006 at Pathilevel in North Andaman. A total of 155 nests was recorded, 35 and 120 nests during 2005 and 2006 respectively. The Andaman Crake breeds during south-west monsoon, June-August as reported in other forest rails. Totally eight pairs of the Andaman Crake were recorded during the breeding season inside the 10 ha intensive study area which made 36 nests with a density of 4.9 nests/pair. The proximity of nests was confirmed by the observations, and those without eggs were

used for roosting which is reported as a common character of rails. The nest was typically platform-shaped with a shallow cup, made up of dryed leaves and twigs above the leaf litter, mostly placed on the ground between buttresses. Totally 151 trees belonging to 21 species in 12 families were used for nesting. The five species *Tetrameles nudiflora, Pterocarpus dalbergioides, Terminalia bialata*, *Pterygota alata* and *Celtis timorensis* together contributed 72% while 17 other species together contributed for 28% of nest trees. They showed preference for the above five speceies of trees. The most important variable influencing nest-site selection and nesting success of the Andaman Crake was concealment; other factors such as nearness to stream, density of saplings, climbers, large trees and buttresses were also important.

Nest was built by both the members of the pair. The period required for construction was three days. Eggs were laid early in the morning between 06.00 and 08.00 h on successive days. The laying interval was usually 24 hours. Eggs of the Andaman Crake were glossy white in color, ovoid and without any spots; the mean weight, length and width were 24g, 4.2 cm and 2.2 cm respectively. Clutch size varied from 4-8 and maximum nests were with 5 eggs. The mean clutch size was 5.75 ± 1.71. Incubation was shared by both the sexes of the pair and the incubation period was 21 days (N = 4). Andaman Crake chicks are precocial and leave the nest within 0-1 day of hatching; brooding was done only by female for 30-31 days (N = 2). Nesting success of the Andaman Crake for the two years was 22%, with no success in 2005 and 32% in 2006 which is comparatively lower than that of several threatened species. Out of 155 nests, 17 (14%) with eggs wheras 133 were (86%) without eggs. In 2005 productivity was nil, while in 2006, out of the 17 nests, 41% was successful with a mean of one chick per pair, the fate of which was also not sure. The major causes of nest failure were predation, abandonment and damage. The early season nests had better survival rates than the late season nests. Maximum losses were during the 1st and 3rd stages; abandoning was more in the former while predation was more in the later stages of incubation. Nesting success was high in those nests which were placed away from the forest edge ($r = 0.674$; $p > 0.05$).

6.2. Key threats to the Andaman Crake

There have been direct and indirect ecological consequences of human disturbances with both planned and unplanned development activities on the Crake and other birds in the Andaman Islands.

6.2.1. Habitat destruction / alteration

Although the Andaman Crakes were recorded near settlements inside the forest, no Crake was recorded in any cultivation and plantation during this survey. Absence of the species in these altered habitats and its presence only in moist forests shows that the Andaman Crake is a strict habitat specialist and hence susceptible to habitat loss and modification. In the major islands many areas were converted for agriculture and human inhabitation which caused the habitat patchiness. Such small habitat patches were less likely to be occupied than large ones. Development activity in Portblair has destroyed whole forest habitat in Abardeen Bazaar, where Butler (1900) once trapped 80 Andaman Crake per Sq. km. Large forest areas were converted for cultivation of coconut, paddy and teak. This shows that availability of suitable habitats could be one of the limiting factors influencing the population of the Andaman Crake. Neil and Havelock Islands are almost fully under cultivation and also most of the forest areas are occupied by settlers from mainland. Habitat alteration in the forest area creates edge effect which provides snakes the thermal properties of both adjoining habitats, allowing greater flexibility for thermoregulation (Blouin-Demers and Weatherhead 2002). Snake was noted to prey on the eggs and affect the nesting success of the Andaman Crake. The prevailing fragmentation hypothesis suggests that predation rates are higher in fragmented landscapes than in contiguous forest (Robinson *et al.* 1995). Slow encroachment of the forest habitat by the settlers through firewood collection and thinning the edges is a common practice near settlements. As the Andaman Crake prefers to nest near the forest edges biotic pressure would lead to the degradation of nesting habitat and increase in predation.

6.2.2. Introduced species

The introduced animals such as dogs and cats have become predators for adults and chicks of the Andaman Crake. The larger herbirovres introduced here include three species of deer and Asian Elephant. The number of saplings seen were also a few in

some areas, an effect that would be expected if seedlings were not allowed to grow, which obviously affect the habitat of the Andaman Crake. Ali (2004) in his study found the absence of saplings of *Terminalia manii* and very few *Dipterocarpus* saplings which are the nesting trees for the Andaman Crake. This indicates that browsing might be selectively removing some species. Missing of understory in most of the places reported by Ali (2004) is a major challenge for survival of the Andaman Crake, an understory species. Sivaganesan and Kumar (1993) reported heavy damage of vegetation by Elephants on Interview Island with bamboo and *Pandanus* having shown a major decline. They also found damage to a number of trees that were uprooted or debarked. Debarking also results in the death of trees; but Elephant was not an issue in the other areas. The sapling proportion test of trees of Interview Island by Ali (2004) showed a negative trend in about 80% of the commoner species; analysis of the vegetation indicated that as trees die, they are unlikely to regenerate due to browsing by another introduced species, the chital, wide spread in the Andaman Islands.

6.2.3. Hunting

Hunting by the settlers is another serious problem facing the Andaman Crake. The Crake is hunted for meat; they were trapped by nooses, especially during breeding season when calls were frequent. Illegal selling of the Andaman Crake was reported in Dugapur (North Andaman).

6.3. Recommendation

Andaman Crakes were not recorded in the island having area below 1 sq km. Population of the Andaman Crake increased with the increasing island size. However, 58 of the reserves in the protected area network are smaller than 1 km^2 and of these, 13 are less than 0.1 km^2 in area (Pande *et al.* 1991; Andrews *et al.* 2006). Only four of the reserves are larger than 30 km^2. As forests on large islands are not adequately represented in the current protected area network, it is important that remaining patches of primary forests on large islands are protected on a priority basis. These patches should be large enough to include habitat diversity which would support many rare species. Though Andaman Crake was recorded in the edges it preferred huge trees in the moist forest for nesting. The primary wet evergreen forests of the

Andaman Islands are being destroyed and degraded at an alarming rate by forestry operations and encroachments (Davidar 1996). Protecting large areas of forests on the large islands will be essential to conserve the vegetational mosaic and species diversity (Davidar 1996). This study shows that wet forests, especially evergreen and semi-evergreen forests on large islands are very important in the conservation of the Andaman Crake. This non-random distribution of the Andaman Crake suggests that small islands, however numerous, are not equivalent to large islands for the conservation. A protected area network has been established in the Andaman Islands with seven National Parks and 93 Sanctuaries encompassing a total area of about 818 km^2 (Andrews *et al.* 2006). This, however, constitutes a mere 14% of the total land area of the archipelago (Vijayan *et al.* 2005). Thus there is a need for developing programmes to protect/restore the forests which are in the major islands encompassing localities of greater abundance of this Crake. Conservation of an endemic species requires the maintenance of sufficient area of suitable habitat to harbor a viable population for long-term survival. Establishment of larger conservation complexes rather than smaller protected areas is crucial for the long-term survival of the Andaman Crake and many other endemic species. Apart from this, hunting of Andaman Crake should be stopped. Environmental education and public awareness programmes also should be taken up intensively and regularly. Removal of introduced animals has to be permitted in order to protect the ecosystem to which they cause damage.

6.4. Research implications

Although the habitat preservation approaches are of prime importance, the long-term conservation of the Andaman Crake requires further understanding of such life history and other parameters as age of first breeding, lifespan, adult survival rates, annual fecundity; nest survival in protected and unprotected / fragmented areas; movements and demographic trends. Therefore, some of the immediate research needs for the conservation of the Andaman Crake are: 1). breeding status of the species in selected islands and habitats that could not be surveyed during this study and 2). Monitoring the populations including marking of individuals to identify population changes in relation to environmental and anthropogenic factors.

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Appendix I. Checklist of plants recorded in the study area during 2004-2006.

S.No.	Species Name	Vernacular Name
	Major Trees	
1	*Aegiceras corniculatum*	Safed Khari
2	*Aglaia andamanica*	Letauk, Latao
3	*Aglaia ganggo*	Lal Neem
4	*Aglaia hiernii*	Lalchini
5	*Albizia lebbeck*	Koko
6	*Albizia odoratissima*	Kala siris
7	*Albizia procera*	Safed siris
8	*Alstonia kurzii*	Chattiyan
9	*Anacardium occidentale*	Kaju
10	*Anthocephalus chinensis*	Kadam
11	*Antiaris toxicaria*	Lakuch
12	*Artocarpus chama*	Jungli Kathal
13	*Artocarpus chaplasha*	Jungli Kathal
14	*Artocarpus gomezianus*	Lakuch
15	*Atalantia malabarica*	Jungli Nimbu
16	*Baccaurea ramiflora*	Pharsa Balli
17	*Barringtonia asiatica*	Dotta
18	*Bischofia javanica*	Pani Padauk
19	*Blumeodendron kurzii*	Kartoos
20	*Bombax insigne*	Didu
21	*Bouea oppositifolia*	Marium
22	*Calophyllum inophyllum*	Poon
23	*Calophyllum soulattri*	Lalchini
24	*Calopyllum wallichianum*	Chota poon
25	*Canarium euphyllum*	White Dhup
26	*Canarium srtictum*	Black Dhup
27	*Caryota mitis*	Mari patti
28	*Celtis timorensis*	Tejpatti
29	*Champereia manillana*	Meetha Bhaji
30	*Chukrasia tabularis*	Agil
31	*Chydenanthus excelsus*	Bhelwa
32	*Cinnamomum obtusifolium*	Jungli Dalchini
33	*Cinnamomum tamala*	Tejpatti
34	*Claoxylon indicum*	Bharanga
35	*Cocos nucifera*	Naryal
36	*Dillenia indica*	Korkot
37	*Diospyros crumenata*	Kala Balli
38	*Diospyros marmorata*	Kala Lakri
39	*Diospyros pilossiuscula*	Chotapatti Kendu
40	*Diospyros pyrrhocarpa*	Badapatti Kendu
41	*Diospyros undulata*	Agia Balli
42	*Diploknema butyracea*	Hill Mahuwa
43	*Dipterocarpus costatus*	Gurjan
44	*Dipterocarpus gracilis*	Chotapatti Gurjan
45	*Dipterocarpus grandiflorus*	Lambapatti Gurjan
46	*Dipterocarpus incanus*	Garjan
47	*Dolichandrone spathacea*	Pharsa
48	*Dracaena spicata*	Surmai
49	*Drimycarpus racemosus*	Char
50	*Dysioxylum arborescens*	Danda Balli
51	*Endospermum diadenum*	Bakota
52	*Ficus benjamina*	Gular
53	*Ficus racemosa*	Lal Gular
54	*Ganophyllum falcatum*	Jungli Neem
55	*Garcinia cowa*	Khatta Phal

56	*Garcinia speciosa*	Khaiya
57	*Goniothalamus macranthus*	Bhasa Balli
58	*Hibiscus tiliaeceus*	Safed Chilka
59	*Hopea odorata*	Thingam
60	*Horsfieldia glabra*	Banda Jaiphal
61	*Horsfieldia irya*	Chooglum
62	*Knema andamanica*	Bara Patti Jaiphal
63	*Lagerstroemia hypoleuca*	Pyinma
64	*Lannea coromandelica*	Nabbe
65	*Macaranga tanarius*	Golpatti
66	*Mangifera indica*	Aam
67	*Manilkara littoralis*	Khari Mahua
68	*Miliusa tectona*	Jungli Sagawan
69	*Mitragyna parvifolia*	Karmi
70	*Murraya paniculata*	Malai Lakri
71	*Myristica andamanica*	Jaiphal
72	*Myristica prainii*	Lal Jaiphal
73	*Orophaea hexandra*	Jungli Sarifa
74	*Pajanelia longifolia*	Jhingum
75	*Pandanus andamanensis*	Kasam
76	*Parishia insignis*	Lal Dhup
77	*Phoenix paludosa*	Khari Khajur
78	*Pisonia umberllifera*	Baniya
79	*Planchonella longipetiolatum*	Lamba Patti
80	*Planchonia valida*	Red Bombwe
81	*Podocarpus neriifolius*	Titmil
82	*Polyalthia jenkinsii*	Kari Patti
83	*Polyalthia simiarum*	Kari
84	*Pometia pinnata*	Chitkandu
85	*Pongamia pinnata*	Karanj
86	*Prunus javanica*	Thingam
87	*Psychotria adenophylla*	Safed Balli
88	*Pterocarpus indicus*	Malay Padauk
89	*Pterocymbium tinctorium*	Jungli Papita
90	*Pterocarpus dalbergioides*	Padauk
91	*Pterospermum acerifolium*	Makchun
92	*Pterygota alata*	Lakho
93	*Rinorea bengalensis*	Jungli chai
94	*Sageraea elliptica*	Chooi
95	*Sageraea listeri*	Chooi
96	*Samanea saman*	Jungli siris
97	*Schleichera oleosa*	Kusum
98	*Semecarpus kurzii*	Bhelwa
99	*Semecarpus prainii*	Jungli Kaju
100	*Spondias pinnata*	Ambara
101	*Sterculia villosa*	Chilka
102	*Streblus asper*	Khaksi
103	*Syzygium andamanicum*	Jungli Amrood
104	*Syzygium cumini*	Jamun
105	*Syzygium samarangense*	J.Jamun
106	*Tabernaemontana crispa*	Koraya
107	*Tectona grandis*	Teak
108	*Terminalia bialata*	White chuglam
109	*Terminalia catappa*	Badam
110	*Terminalia mannii*	Black Chuglam
111	*Terminalia procera*	White Bombay
112	*Tetrameles nudiflora*	Teepok
113	*Thespesia populnea*	khari kapas
114	*Xanthophyllum andamanicum*	Letphew
115	*Xylocarpus granatum*	Khari Sundri

	Herbs	
116	*Acrostichum aureum*	Khari Bhaji
117	*Amorphophallus longistylus*	Jungli-ol
118	*Blumea lacera*	Ka karanda
119	*Costus speciosus*	Bander Louri
120	*Musa acuminata*	Jungli Kela
121	*Phrynium paniculatum*	Jungli Haldi
122	*Striga lutea*	Agia Balli
123	*Strobilanthes glandulosus*	Charigarua
	Shrubs	
124	*Acronychia pedunculata*	Jungli Nimbu
125	*Allophylus cobbe*	Charai Garua
126	*Anaxagore luzonensis*	Jinda Balli
127	*Areca triandra*	Jungli Supari
128	*Calamus andamanicus*	Mota Bet
129	*Calamus longisetus*	Jungli Bet
130	*Calamus palustris*	Malai Bet
131	*Calamus viminalis*	Rassi Bet
132	*Daemonorops kurzianus*	Sanga Bet
133	*Dinochloa scandens*	Bel Bamboo
134	*Dracaena angustifolia*	Bakripatti
135	*Gelonium bifarium*	Jungli Kathal
136	*Leea aequata*	Bhagora Balli
137	*Licuala peltata*	Selaipatti
138	*Licuala spinosa*	Khari Selai Patti
139	*Maesa andamanica*	Lal Buti
	Climbers	
140	*Astragalus hamosus*	Jungli Newa
141	*Byttneria aspera*	Hathi bel
142	*Caesalpinia crista*	Billi Kanta
143	*Capparis sepiaria*	Kanthari
144	*Cissus hastata*	Khatta Bel
145	*Entada phaseoloides*	Madrasi Bel
146	*Ficus sagittata*	Pepal Bel
147	*Freycinetia insignis*	Surumai Bel
148	*Mikania cordata*	Kerala Bel
149	*Murraya koenigii*	Jungli Karipatti
150	*Piper betle*	Jungli Pan
151	*Piper nigrum*	Kali Mirch
152	*Scindapsus officinalis*	Hathi Bel
153	*Strychnos minor*	Kanta Bel
154	*Thunbergia laurifolia*	Chuti bel

Appendix II. Rails of India (Family Rallidae)

S.No.	Family	Common Name	Scientific Name	Status
1	Rallus	Water Rail	*Rallus aquaticus korejewi*	R
2		Water Rail	*Rallus aquaticus indicus*	WV
3	Gallirallus	Slaty-breasted Crake	*Gallirallus striatus albiventer*	R
4		Slaty-breasted Rail	*Gallirallus striatus obscurior*	R
5	Rallina	Red-legged Crake	*Rallina fasciata*	R/M
6		Slaty-legged Crake	*Rallina eurizonoides amauroptera*	R/LM
7		Andaman Crake	*Rallina canningi*	R
8	Crex	Corn Crake	*Crex crex*	CV
9	Porzana	Little Crake	*Porzana parva parva*	WV
10		Baillon's Crake	*Porzana pusilla pusilla*	WV
11		Spotted Crake	*Porzana porzana*	WV
12		Ruddy-breasted Crake	*Porzana fusca fusca*	R/M
13		Ruddy-breasted Crake	*Porzana fusca zeylonica*	R/M
14	Amaurornis	Black-tailed Crake	*Amaurornis bicolor*	R
15		Brown Crake	*Amaurornis akool akool*	R
16		White-breasted Waterhen	*Amauronis phoenicurus phoenicurus*	R
17		White-breasted Waterhen	*Amauronis phoenicurus insularis*	R
18	Gallicrex	Water Cock	*Gallicrex cinerea cinerea*	R
19	Gallinula	Common Moorhen	*Gallinula chloropus indica*	R/WV
20		Common Moorhen	*Gallinula chloropus orientalis*	UN
21	Porphyrio	Purple Swamphen	*Porphyrio porphyrio seistanicus*	R/M
22		Purple Moorhen	*Porphyrio porphyrio poliocephalus*	R/LM
23	Fulica	Common Coot	*Fulica atra atra*	R/WV

R = Resident, WV = Winter Visitor, M = Migrant, LM =Local Migrant, CV= Casual Vagrant, UN = Unknown.
Source : Ali and Repley 1980; Grimmet *et al.* 1999.

Appendix III. The Checklist of birds recorded in the study area during 2004-2006.

S.No.	FAMILY	COMMON NAME	SPECIES	CT	PL
1	ARDEIDAE	Pacific Reef Egret	*Egretta sacra*	+	+
2		Great Egret	*Casmerodius albus*	+	+
3		Cattle Egret	*Bubulcus ibis*	+	+
4		Indian Pond Heron	*Ardeola grayii*	+	+
5	PICIDAE	Andaman Woodpecker @#	*Dryocopus hodgei*	+	+
6		Fulvous-breasted Woodpecker	*Dendrocopos macei*	+	+
7	ALCEDINIDAE	Blue-eared Kingfisher	*Alcedo meninting*	+	+
8	HALCYONIDAE	Stork-billed Kingfisher	*Halcyon capensis*	+	+
9		Ruddy Kingfisher	*Halcyon coromanda*	+	+
10		White-throated Kingfisher	*Halcyon smyrnensis*	+	+
11		Black-capped Kingfisher	*Halcyon pileata*	+	+
12		Collared Kingfisher	*Todiramphus chloris*	+	+
13	MEROPIDAE	Chestnut-headed Bee-eater	*Merops leschenaulti*	+	+
14	CUCULIDAE	Indian Cuckoo	*Cuculus micropterus*	+	+
15		Oriental Cuckoo	*Cuculus saturatus*	+	+
16		Asian Emerald Cuckoo	*Chrysococcyx maculatus*	+	+
17		Violet Cuckoo	*Chrysococcyx xanthorhynchus*	+	+
18		Asian Koel	*Eudynamys scolopacea*	+	+

S.No.	FAMILY	COMMON NAME	SPECIES	CT	PL
19	CENTROPODIDAE	Brown Coucal@	*Centropus andamanensis*	+	+
20	PSITTACIDAE	Vernal Hanging Parrot	*Loriculus vernalis*	+	+
21		Alexandrine Parakeet	*Psittacula eupatria*	+	+
22		Red-breasted Parakeet	*Psittacula alexandri*	+	+
23		Long-tailed Parakeet	*Psittacula longicauda*	+	+
24	APODIDAE	Glossy Swiftlet	*Collocalia esculenta*	+	+
25		Edible-nest Swiftlet	*Collocalia fuciphaga*	-	+
26		Brown-backed Needletail	*Hirundapus giganteus*	+	+
27	STRIGIDAE	Andaman Scops-owl @#	*Otus balli*	+	+
28		Andaman Hawk-owl #	*Ninox affinis*	+	+
29	CAPRIMULGIDAE	Large-tailed Nightjar @	*Caprimulgus macrurus*	+	+
30	COLUMBIDAE	Rock Pigeon	*Columba livia*	+	+
31		Andaman Wood Pigeon @#	*Columba palumboides*	+	+
32		Red-collared Dove	*Streptopelia tranquebarica*	+	+
33		Andaman Cuckoo-dove @#	*Macropygia rufipennis*	+	+
34		Emerald Dove	*Chalcophaps indica*	+	+
35		Nicobar Pigeon @#	*Caloenas nicobarica*	+	+
36		Pompadour Green Pigeon	*Treron pompadora*	+	+
37		Green Imperial Pigeon	*Ducula aenea*	+	+

S.No.	FAMILY	COMMON NAME	SPECIES	CT	PL
38	RALLIDAE	Andaman Crake @#	*Rallina canningi*	+	+
39		White-breasted Waterhen	*Amaurornis phoenicurus*	+	+
40		Baillon's Crake	*Porzana pusilla pusilla*	+	+
41		Common Moorhen	*Gallinula chloropus*	+	+
42	SCOLOPACIDAE	Whimbrel	*Numenius phaeopus*	+	+
43		Eurasian Curlew	*Numenius arquata*	+	+
44		Common Redshank	*Tringa tetanus*	+	+
45		Common Greenshank	*Tringa nebularia*	+	+
46		Common Sandpiper	*Actitis hypoleucos*	+	+
47		Curlew-Sandpiper	*Calidris ferruginea*	+	+
48	LARIDAE	Gull-billed Tern	*Gelochelidon nilotica*	+	+
49		Lesser Crested Tern	*Sterna bengalensis*	+	+
50		Black-naped Tern	*Sterna sumatrana*	+	+
51		White-winged Tern	*Chlidonias leucopterus*	+	+
52	ACCIPITRIDAE	Black Baza	*Aviceda leuphotes*	+	+
53		White-bellied Sea Eagle	*Haliaeetus leucogaster*	+	+
54		Andaman Serpent Eagle @#	*Spilornis elgini*	+	+
55		Changeable Hawk-eagle	*Spizaetus cirrhatus*	+	+
56	IRENIDAE	Asian Fairy Bluebird	*Irena puella*	+	+

S.No.	FAMILY	COMMON NAME	SPECIES	CT	PL
57	LANIIDAE	Brown Shrike	*Lanius cristatus*	+	+
58	CORVIDAE	Mangrove Whistler	*Pachycephala grisola*	+	+
59		Andaman Treepie @#	*Dendrocitta bayleyi*	+	+
60		House Crow	*Corvus splendens*	+	+
61		Large-billed Crow	*Corvus macrorhynchos*	+	+
62		Eurasian Golden Oriole	*Oriolus oriolus*	+	+
63		Black-naped Oriole	*Oriolus chinensis*	+	+
64		Black-hooded Oriole	*Oriolus xanthornus*	+	+
65		Large Cuckoo-Shrike	*Coracina macei*	+	+
66		Bar-bellied Cuckoo-Shrike	*Coracina striata*	+	+
67		Small Minivet	*Pericrocotus cinnamomeus*	+	+
68		Scarlet Minivet	*Pericrocotus flammeus*	+	+
69		Crow-billed Drongo	*Dicrurus annectans*	+	+
70		Andaman Drongo @#	*Dicrurus andamanensis*	+	+
71		Greater Racket-tailed Drongo	*Dicrurus paradiseus*	+	+
72		Black-naped Monarch	*Hypothymis azurea*	+	+
73	MUSCICAPIDAE	Orange-headed Thrush	*Zoothera citrina*	+	+
74		Brown-chested Jungle Flycatcher	*Rhinomyias brunneata*	+	+
75		Asian Brown Flycatcher	*Muscicapa dauurica*	+	+
76		Red-throated Flycatcher	*Ficedula parva*	+	+
77		Tickell's Blue Flycatcher	*Cyornis tickelliae*	+	-
78		Oriental Magpie-Robin	*Copsychus saularis*	+	+
79		White –rumped Shama	*Copsychus malabaricus*	+	+

S.No.	FAMILY	COMMON NAME	SPECIES	CT	PL
80	STURNIDAE	Asian Glossy Starling	*Aplonis panayensis*	+	+
81		Common Myna	*Acridotheres tristis*	+	+
82		Hill Myna	*Gracula religiosa*	+	+
83		White-Headed Starling@	*Sturnus erythroygius*	+	+
84	PYCNONOTIDAE	Black-Headed Bulbul	*Pycnonotus atriceps*	+	+
85		Red-Whiskered Bulbul	*Pycnonotus jocosus*	+	+
86	ZOSTEROIDAE	Oriental White-Eye	*Zostrepos palpebrosus*	+	+
87	MUSCICAPIDAE	Large-Billed Leaf Warbler	*Phylloscopus magnirostris*	+	+
88	NECTARINIIDAE	Plain Flower-pecker	*Dicaeum concolor*	+	+
89		Olive-Backed Sunbird	*Nectarinia jugularis*	+	+
90	ESTRILDINAE	White-Rumped Munia	*Lonchura striata*	+	+

Note: CT - Chidiyatapu, PL – Pattilevel, @ - Endemic, # - Near threatened.