BEFORE THE NATIONAL GREEN TRIBUNAL (EZ), KOLKATA

(Under Section 18(1) read with Sections 14 & 15 of National Green Tribunal Act 2010)

Application No. 93 of 2024 (EZ)

Ashish Kothari ....Applicant

v.

MoEFCC and Anr. ...Respondents

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Certified to be true copies of the respective originals.
Dated on this the 11th day of November, 2024
Through

(MS 1421/2011)

A Yogeshwaran
Counsel for the Applicant
Ph: 9566254546
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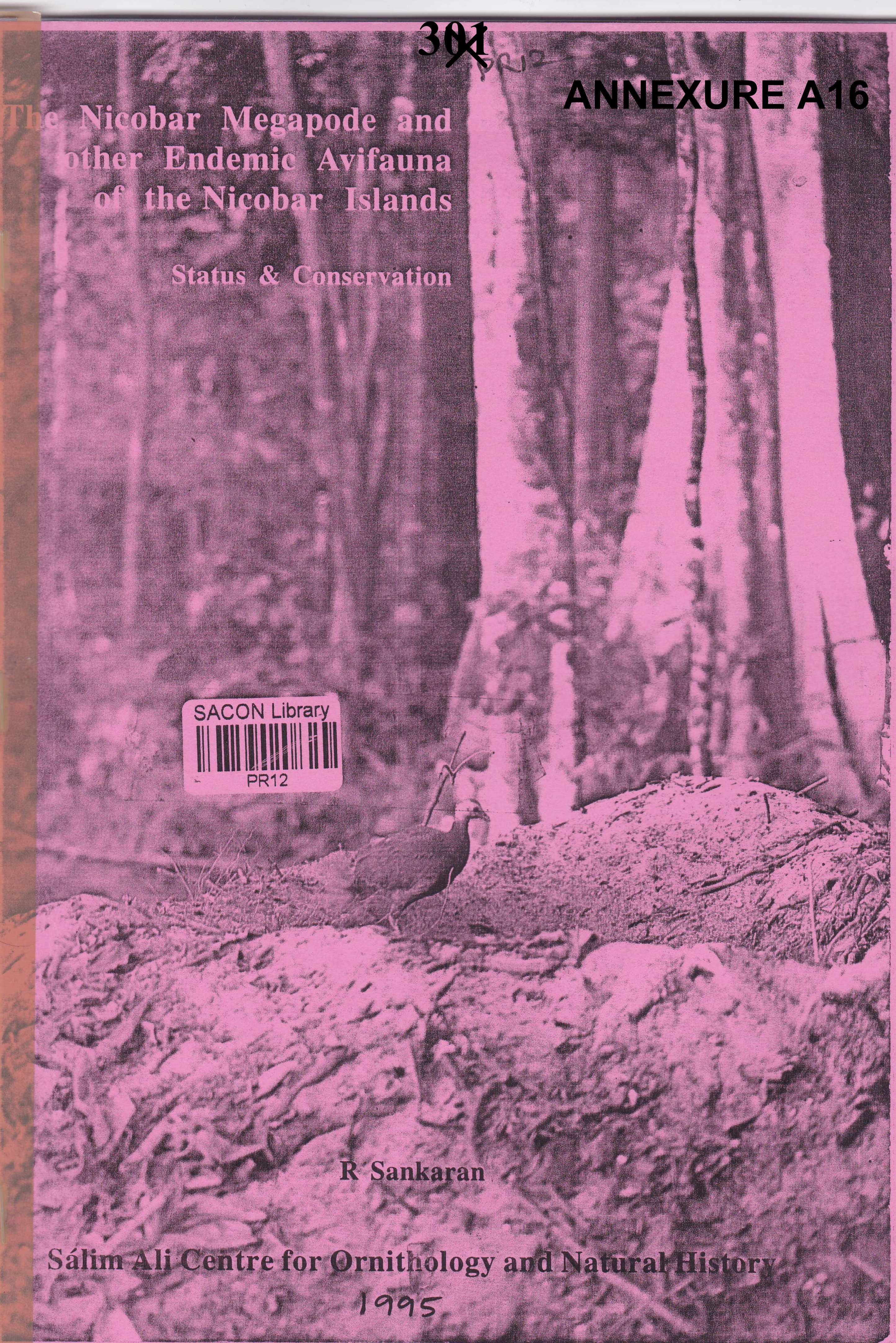
ANNEXURE A16

The Nicobar Megapode and other Endemic Avifauna of the Nicobar Islands

Status & Conservation



R Sankaran

Sálim Ali Centre for Ornithology and Natural History

1995

The Nicobar Megapode and other endemic Avifauna of the Nicobar Islands

Status and Conservation

A study funded by the Ministry of Environment and Forests, Government of India

R Sankaran

SACON - Technical Report 2

Sálim Ali Centre for Ornithology and Natural History
Coimbatore, India.

1995

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3003

R Sankaran is a Scientist in the Division of Avian Ecology. He was awarded a Doctorate from the Bombay University for his studies on the breeding behaviour of the Lesser Florican *Sypheotides indica* and Bengal Florican *Houbaropsis bengalensis*. He has worked in diverse habitats that include the *terai* of Uttar Pradesh, the subhumid grasslands of western India, the Thar desert, and the Himalayas. He is currently working on a project on the endemic avifauna of the Andaman & Nicobar islands and is involved in the conservation of the Lesser Florican.

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Back cover : Rain forest, Great Nicobar.

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Above all, I wish to thank my local assistants without whom this extensive survey would not have been possible. Jugulu Maheto and Prem worked with me in the Great Nicobar group. N. Illangoan was my field assistant in the Nancowry group. I could not have asked for better.

About the study

SACON has submitted a project proposal titled 'A study on the ecology, status and conservatio perspective of certain rare endemic avifauna of the Andaman & Nicobar Islands' to the Ministry c Environment and Forests, Government of India, for funding. The principal investigator of the project i Dr. (Mrs) Lalitha Vijayan and the co-investigator is Dr. R. Sankaran. The objectives of the proposed stud are:

1. To assess the status of endemic avifauna in the Andaman & Nicobar Islands and to identify taxa whic are rare, threatened or endangered.

2. To study the ecology of the Nicobar Megapode (*Megapodius nicobariensis nicobariensis* & *M. r abbotti*), Narcondam Hornbill (*Aceros narcondami*) and the Andaman (or Grey) Teal (*Anas gibberifron albogularis*).

3. To prepare a conservation management plan for rare endemic avifauna of the Andaman & Nicoba Islands.

However, realizing the urgent need for a detailed survey of the Andaman & Nicobar Islands, funds were granted from SACON to launch the first phase of the study, namely assessment of the Nicobar Megapode the endemic avifauna and the conservation issues currently threatening the Nicobar group of islands. The survey, between December 1992 and April 1993, covered eight islands. Further funds were made available by the Ministry of Environment and Forest, Government of India, to complete the first phase of the study and, between December 1993 and April 1994, 10 islands were surveyed. This report is based on data collected during those surveys, and covers all but three uninhabited islands of the Nicobar group of islands.

A version of the chapter on the Nicobar Megapode is in press in Biological Conservation.

Foreword

Geographical isolation of islands has resulted in the evolution of numerous endemic species of flora and fauna, many of which are restricted to one or a few islands and these ecosystems are so fragile and finely tuned that they are easily vulnerable to perturbations. The Andaman & Nicobar islands in the Bay of Bengal are no exception. Of the 270 species and subspecies of birds recorded, nearly 39% are endemic, many of which are highly restricted in range. Concerned about this and the rapid colonisation by the mainlanders and the subsequent development activities in the recent decades, SACON initiated a long-term study on the status, ecology and conservation perspectives of certain rare and endemic species of avifauna of the Andaman & Nicobar Islands.

Nicobar group of islands were selected, as a prelude to the major project, to assess the status of the Nicobar Megapode in particular, and the other endemic avifauna in general. This report documents the status of the Nicobar Megapode and conservation perspectives of other endemic avifauna of the Nicobar islands. It also highlights the threats that the habitat and avifauna of the Nicobar islands are subject to.

The findings of this study evoke mixed reactions. Although there is evidence of a decline in populations in some species, the status of most species of avifauna is not disturbing. What is alarming, however, is the proposed development plans for the Nicobar islands, particularly the building of a dry dock and refuelling base for international shipping in the Galathea bay and making Great Nicobar a free port. If implemented, the island ecosystem will be irrevocably damaged and the biodiversity lost, as the islands are much too small to sustain any significant impact on them. Further alteration of the ecosystem can only adversely affect all endemic species, and accelerate the extinction of endemic avifauna, including the Nicobar Megapode.

We feel that the Nicobar islands are biologically much too rich to be jeopardised by commercially attractive but ecologically hazardous projects. We thus recommend that no unsustainable development projects be undertaken in the Nicobar islands.

I record my appreciation on the hard work by Dr R. Sankaran of our Avian Ecology Division. Inspite of the inclement weather and tough field conditions he completed the survey as scheduled. We rejoice, moreover, his recovery from the *Falsiparum* malaria that he contracted while in the islands. It could neither hamper his survey seriously nor make him `extinct'.

Dr V.S. Vijayan
Director

Abstract

The Nicobar Megapode, a mound nesting megapode, occurs as two subspecies, *Megapodius nicobariensis nicobariensis* and *M. n. abbotti*, endemic to the Nicobar Islands. Thought to be endangered, this survey found it on almost all Nicobar islands where it historically occurred and concluded that, as a species, it is currently not endangered. It has probably become extinct only on inhabited Pilo Milo island. While *M. n. abbotti* is secure other than on small outlying islets, *M. n nicobariensis* is threatened on all but 3 islands of its range. Loss of population of *M. n. nicobariensis* was indicated both by significantly lower mound densities and by a higher proportion of abandoned mounds to active mounds when compared with *M. n. abbotti*. Data were collected for 127 active mounds of *M. n. abbotti* and 85 active mounds of *M. n. nicobariensis*, and it was estimated that 848 and 312 active mounds respectively are present, and the population of the species is between 4500 and 8000 adult birds. Although hunting and collection of eggs existed, the main threat is the loss of habitat, particularly coastal forest which is the megapode's primary nesting habitat, to coconut plantations.

Of the 176 species of birds that are endemic to the zoogeographic subregion of the Indian peninsula and its environs, 14 are endemic to the Andaman and Nicobar islands. Thus while the Andaman & Nicobar islands account for only 0.2% of the land mass of South Asia, it has approximately 8% of the endemic avifauna of the region, thus making the islands a high priority area in the conservation of India's avifauna. The new IUCN criteria for assigning threat status, have been applied to each species and subspecies endemic to the Nicobar islands. The application of the criteria on 45 species and subspecies indicates that 18 species or subspecies endemic to the Nicobar islands are endangered (1), vulnerable (6) or near threatened (11). Six species and subspecies are data deficient and 21 are of less concern or abundant. Six bird species have been introduced in the Nicobar islands. Of these, four are from the mainland and two from the Andaman islands. The introduced Andaman Redwhiskered Bulbul may result in the extinction of the endemic Nicobar Bulbul.

Although as much as 80 % of the Nicobar islands are still covered by primary forest, and that at least 60 % are relatively undisturbed, the trend over the last decade gives rise to grave concern. Based on the number of endemics present, the Nancowry group of islands was identified to be of primary importance to endemic avifauna followed by the Great Nicobar and Car Nicobar groups. The priority islands for avian conservation are Great Nicobar, Camorta, Katchall, Nancowry and Car Nicobar. A protected area network whereby the Nicobars will receive the necessary legislature to ensure their long-term survival is proposed. Two issues, population growth and development were identified as of primary concern of the Nicobar group of islands. Specific issues of concern that have grave implications to the Nicobar islands are given. The single largest threat is a proposal to make Great Nicobar a free trade port and to build a dry dock and refuelling facility in the Galathea bay which, if implemented, will destroy the Nicobar islands.

Keywords: Megapodes, Nicobar megapode, endemics, avifauna, Andaman & Nicobar Islands

The Andaman & Nicobar Islands

Introduction

Over 10 % of all bird species are threatened with extinction, the majority of which are found in tropical forests and islands (Mountford 1988). About 93 % of all avian extinction since AD 1600 have been island species, and most endangered avian taxa are island endemics (King 1981). Island ecosystems, in their natural state, tend to be finely tuned as the limits on the resource base are acute (Carew-Reid 1990). This ecological refinement makes them particularly vulnerable to changes resulting from human activities. Increased human populations, and increasing demands on resources have resulted in fragile island ecosystems being severely threatened.

India has two main groups of islands, the Andaman & Nicobar Islands off the east coast and Lakshadweep Islands off the west coast. The increase over recent decades in human activity through the expansion of agriculture by settlers, exploitation of natural resources, forestry operations, introduced flora and fauna, and increased tourism has resulted in concern over the fate of several of the endemic taxa in these Islands.

Geography

The Andaman & Nicobar islands in the Bay of Bengal are peaks of a submerged mountain range, arching from Arakan Yoma in Burma in the north to Sumatra in Indonesia in the south, between latitudes 6° 45′ and 13° 41′ and longitudes 92° 12′ and 93° 57′ (Saldanha 1989, Dagar *et al.* 1991), and are a southern extension of the Arakan Yoma mountain range. The island group comprises over 300 named and unnamed islands and over 260 named and unnamed rocks (Singh 1981), with a total coastline of about 1962 km. The entire island group covers 8,249 sq km; the Andaman group with over 325 islands (21 inhabited) covering 6,408 sq km, and the Nicobar group with more than 24 islands (12 inhabited) with an area of 1,841 sq km.

The climate of the islands can be defined as humid, tropical coastal climate. Proximity to the equator and the sea ensures a hot, humid, and uniform climate (Saldanha 1989). The islands receive rainfall from both the south-west and north-east monsoons. Maximum precipitation is between May and December, the driest period being between January and April. The mean annual rainfall is about 3800 mm (Saldanha 1989). Despite abundant rainfall, the only perennial river is on Great Nicobar. Temperature variations are low from a minimum of 20° C to a maximum of about 32° C (Dagar *et al.* 1991).

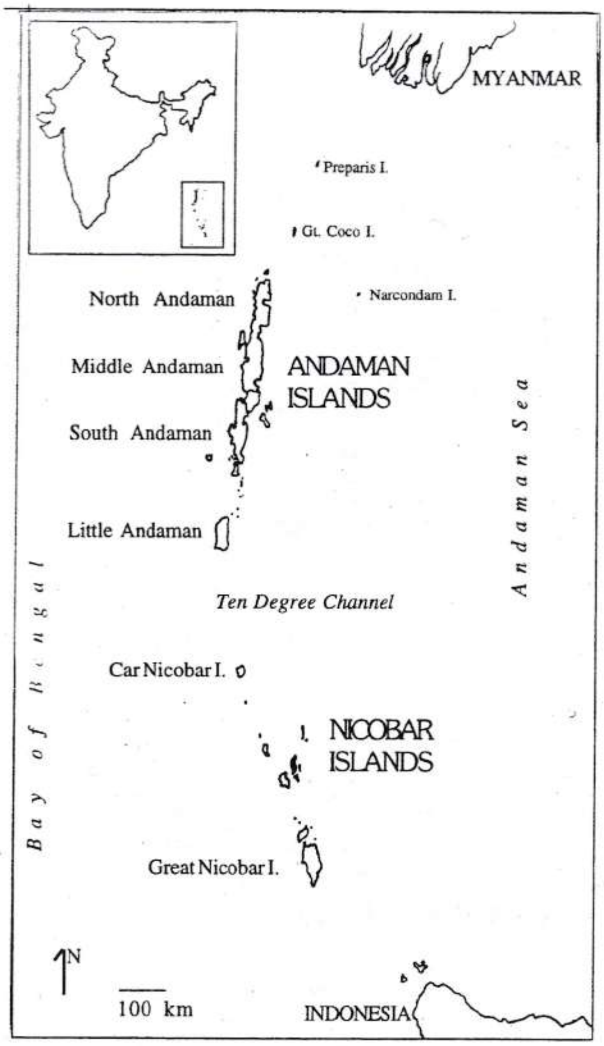

Figure 1. The Andaman & Nicobar Islands

People

The original inhabitants of the Andaman group of islands were tribes of negrito origin. Three broad groups were recognised. The Great Andamanese occupying the main Andaman islands were segregated into the Cheriar, Kora, Toba, Yere, Kede, Juwai, Kol, Bojigyab, Bea, Balawa and Jarawa; the Onge occupied Little Andaman, and the Sentinelese inhabited North Sentinel (Mathur 1968). The Nicobar group was colonised by people of mongoloid origin `sometime before the Christian era' (Singh 1978). Two distinct groups of people are present. The Nicobarese, who are essentially horticulturists inhabit the coast of 12 islands in the Nicobars with dialectic and cultural variations between different islands and island groups. The Shompen are essentially an interior forest dwelling tribe and only inhabit Great Nicobar.

In the late 18th century, the East India Company made concerted efforts to establish a permanent settlement in the Andaman Islands, to control piracy and to prevent the killing of shipwrecked mariners. An attempt in 1788 to establish a base at Port Cornwallis was aborted. After the First War of Independence in 1857 a penal settlement was established at Port Blair. Between the 1600s and the mid 1800s, the Danes made several attempts at colonising the Nicobar islands, unsuccessfully, and in 1848 formally renounced all claims of sovereignty. In 1869, the British announced the occupation of the Nicobar islands and briefly established a penal settlement on Camorta. During World War II, the Japanese occupied the Andaman and Nicobar islands between 1942 and 1945. With Independence, the Andaman & Nicobar islands became a part of the Republic of India.

Though there has been a tenfold increase in the human population of the islands, most indigenous tribes have drastically reduced in numbers. From about 3500 in 1857, only 32 Great Andamanese survive today; the cause - syphilis, pneumonia, measles and manslaughter, and only six of the original 11 tribes now survive (Mathur 1968). From 672 in 1901, the Onge now number only 98 (Verma 1989), and are confined to a tribal reserve at Dugong creek, while their former territories are now occupied by both mainland and Nicobari settlers (Saldanha 1989). Both the Jarawas and Sentinelese continue to be hostile to outsiders, though friendly contact has been made (Awaradi 1990, Pande *et al.* 1991). The Shompens were believed to number 348 in 1901, but declined to 212 in 1981 and 149 in 1989 (Verma 1989). Only the Nicobarese have been able to adjust to mainland civilizations and their numbers have increased over the years.

The increase in human population of the islands has mainly been due to immigrant mainlanders. Until 1941 the annual population growth rate was 0.5%. The post 1950 period saw an enormous population increase from 30,971 in 1951 to 1,88,741 in 1981 (Singh 1981). 88% of this increase has been in the Andaman group and has largely been due to immigrants from mainland India, refugees from Bangladesh and repatriates from Sri Lanka (Saldanha 1989).

Vegetation

The forest type of the Andaman & Nicobar Islands can be broadly classified as tropical evergreen, with minor variations from north to south depending on rainfall, type of soil and degree of salinity (Balakrishnan 1989).

About 15% of the total area of the islands is mangroves, dominated by *Rhizophora mucronata, R. conjugata, Bruguiera gymnorhiza, B. parviflora* and *Ceriops tagal*. Based on the proximity to the sea and salinity of the soil, Balakrishnan (1989) classified the vegetation into littoral and inland. Strand vegetation occupies the sandy coastal belt and includes herbaceous dune formations and wooded beach forests. *Ipomoea pes-caprae* normally dominates the outermost belt of herbaceous plants which grows just beyond the reach of the waves. Adjacent to or behind this, the vegetation is dominated by the dense shrubby growth of *Scaevola sericea* and its associate species. Where *I. pes-caprae* formations are absent, as in retreating coast lines, *Barringtonia* formations are seen. The beach forest which occurs behind the sand-dune zone and the *Barringtonia* formations is dominated by trees such as *Hernandia peltata, Thespesia populnea, Manilkara littoralis, Intsia bijuga, Syzigium samaragense, Sophora tomentosa* and *Glochidion calocarpum*.

Tidal or swamp forests occur in lowland coastal areas where the soil is wet or marshy but not flooded by the sea except during very high tides, and is characterised by small erect aerial roots emerging from the mud. The dominant trees in this forest type are *Cerbera odollam, Heritiera littoralis, Barringtonia racemosa,* and their associates like *Ficus retusa.*

Inland forests are comprised of two types. Evergreen forests are dominated by species like *Dipterocarpus griffithii, D. turbinatus, Hopea odorata, Sideroxylon longepetiolatum, Endospermum malaccense,* and *Planchonia andamanica,* with an understorey of smaller trees such as *Baccaurea sapida, Myristica glaucescens, M. andamanica* and *Buchanania platyneura.* Deciduous forests occupy hilly region and are dominated by *Pterocarpus dalbergiodes* or the Padauk. *Terminalia* spp., *Canarium euphyllum, Ailanthus kurzii, Parishia insignis* and *Albizzia lebbek* are also common.

The vegetation of the Nicobars shows striking dissimilarities with that of the Andamans. The genera *Dipterocarpus* and *Pterocarpus,* wide spread in the Andamans, are not present in the Nicobars. Genera such as *Cyathea, Otanthera, Astronia, Cyrtandra, Stemonurus, Bentinckia,* and *Rhopaloblate* present in the Nicobars are absent in the Andamans (Balakrishnan 1989).

Endemism

Of the 5357 species of fauna covering all major groups recorded by Rao (1989), 487 (9%) are endemic. If marine species are excluded (none of which are endemic), 13% (487 of 3704) are endemic. Endemism is very high in some faunal groups such as birds where 39% of the 270 species and subspecies recorded from the islands are endemic (Abdulali 1964a, 1964b, 1966, 1967, 1971, 1974, 1978, Das 1971, Dasgupta 1976, Ripley 1982). Other vertebrates also show high degrees of endemism; 60% of 58 species of mammals, 31.94% of 83 species of reptiles and 20% of 10 species of amphibians recorded are endemic (Rao 1989). High endemism is also seen in the flora; of the 1454 taxa of angiosperms 221 are endemic, 60 of which are only known from type specimens and 22 only from type localities (Rao 1986, Balakrishnan 1989).

The Nicobar group of Islands

The Nicobar islands can be divided into three distinct subgroups. To the south is the Great Nicobar group consisting of two islands larger than 100 sq km, nine islets smaller than five sq km, and a few rocks. Four islands are inhabited. The human population on Great Nicobar (6831 people) has both tribal (8%) and mainland Indians. The tribals are thinly distributed along the southern, western, and northern coasts. 55% of the mainlanders are in the township Campbell Bay midway up the east coast, and the remainder pursue agrarian livelihoods along the south-eastern coast. Little Nicobar has no mainland settlers and the tribals are distributed all around the island. Kondul and Pilo Milo are inhabited islets. Meroe, Treis, Trax, Menchal, Megapode, Cabra and Pigeon are uninhabited islets.

About 58 km north of the Great Nicobar group is the Nancowry group which consists of three islands larger than 100 sq km, two of 36 and 67 sq km, three less than 17 sq km, two islets and a few rocks. Seven islands in this group are inhabited with a population of 12,464 people comprised of both tribals (64%) and mainlanders. The tribals are distributed all around the islands. Mainlanders do not own land in the Nancowry group, and about 80% are either employed by Government Agencies, Tribal Cooperative Societies or trade sectors. 20% of mainlanders in the Nancowry group are Sri Lankan repatriates who have been settled on Katchall and who work on the 600 hectare rubber plantation there. Tillanchong and the Isle of Man are the only uninhabited islands of the group.

The northern most subgroup comprising of Batti Malv and Car Nicobar is 88 km north of the Nancowry group. Batti Malv is uninhabited and Car Nicobar has a population of over 19,000 people, 80% of whom are tribals. The mainlanders are mainly employed in Government and trade sectors.

While most Nicobar islands have been designated as tribal areas under the Protection of Aboriginal Tribals Act (1957), there has been colonisation and a continuing inflow of mainlanders. The settlement of ex-service men in Great Nicobar began in 1969 and 337 families were settled on Great Nicobar for which 1499.65 ha. of forest was cleared on the southeastern coast of Great Nicobar, each family receiving 4.45 ha (Saldanha 1989). However, the actual loss of forest was far more because of the construction of roads (the North South road is 51 km long, with settlements up to km 35, and the East West road is 41 km long with settlements up to km 8). 268 families of Sri Lankan repatriates were settled in Katchall in the early 1970s, and necessary infrastructure was built. With the opening up of these islands, there has been a rapid growth in the labour, fishing and trading sector. Thus, there is no inhabited island in the Nicobar islands which is free of mainland influences. Every Island, and most tribal villages, have some form of mainland activity and include powerhouses to generate electricity, schools, primary health centres, mainland fishermen or other floating mainlanders who stop by, use resources of, trade with or work for the Nicobaris.

The habitat characteristics of the islands vary. In the Great Nicobar group, all islands are completely forested. A small proportion of the coast of the larger islands is mangrove. In the Nancowry group of islands, the central portion of all islands, excepting Katchall and Tillanchong, are grasslands (over 60% of Trinkat and Teressa, 30-50% of Camorta and at least 20% of Nancowry and Bompoka), often extending to the coast itself. Various explanations exist for the occurrence of these grasslands, primarily that they are man made. However, there is no historic evidence that colonisers cleared forests for animal husbandry. Indeed, the existence of the endemic Nicobar Blue Breasted Quail *Coturnix chinensis trinkutensis* in these grasslands is an indication that these grasslands are so old that not only did colonisation take place, but speciation occurred as well. Within the grasslands there are patches of forest. A substantial area of the coast of Camorta, Trinkat and Nancowry is mangrove.

There are significant differences in the faunal profiles of these two groups, although they remain largely similar. For instance, the Blyth's Nicobar Parakeet *Psitacula caniceps* occurs on Great Nicobar, Little Nicobar, Kondul and Menchal but is absent in the Nancowry group. The Nicobar Bulbul *Hypsipetes nicobariensis* is present in the Nancowry group but is absent in the Great Nicobar Group. The Nicobar Megapode occurs as two distinct subspecies; *Megapodius nicobariensis nicobariensis* in the Nancowry group and *M. n. abbotti* in the Great Nicobar group. The Nicobar Racket-tailed Drongo occurs on Great and Little Nicobar, Katchall, and Car Nicobar, but is absent on other islands of the Nancowry group. The differences are also evident in the herpetofauna; Pit vipers are common on the Nancowry group but are either absent or very rare in the Great Nicobar group. The endemic Nicobar Crab Eating Macaque is present only on Great Nicobar, Little Nicobar, and Katchall.

Three islands in the Nicobar group, namely, Tillanchong, Batti Malv and Megapode Island, all uninhabited are wildlife sanctuaries. Great Nicobar is a Biosphere Reserve (885 sq km) whose core area consists of two National Parks (536 sq km).

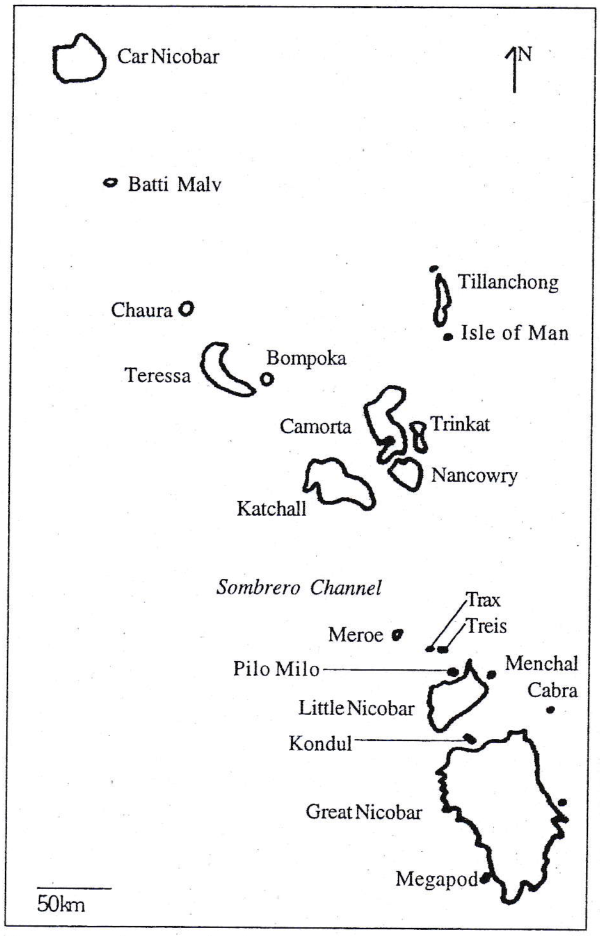

Figure 2. The Nicobar group of islands

The Status and Conservation of the Nicobar Megapode

Introduction

The family Megapodiidae consists of 19 species in six genera, most of which are island forms occurring in Australia, New Guinea and surrounding islands, eastern Indonesia, the Philippines, Niuafo'ou island, the Palau and Mariana islands and the Nicobar islands (Dekker 1990). Nine of these 19 species are currently threatened by habitat destruction, introduction of predators and over exploitation of eggs (Jones 1989).

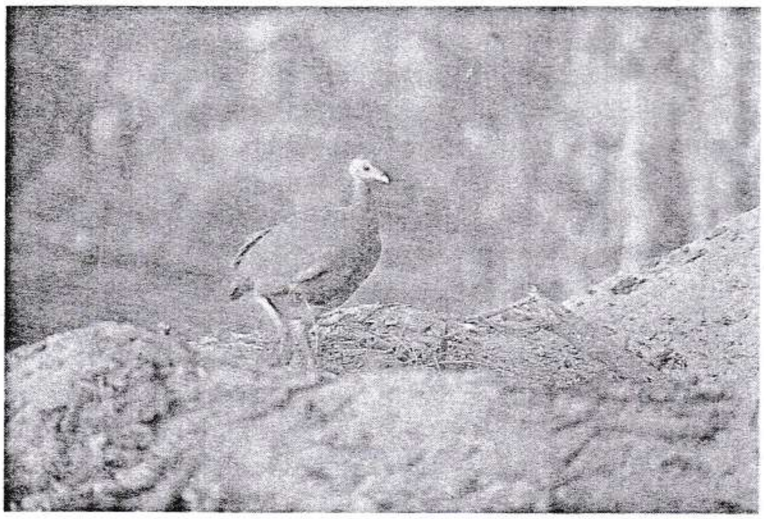

Figure 3. The Nicobar Megapode

Megapodes incubate their eggs in mounds of rotting leaves or in burrows at sun or geothermally heated grounds (Dekker & Wattel 1987). The chicks, on hatching, are fully feathered and are able to fly immediately and post-hatching parental care is absent. Within the group itself there are variations in the incubation and breeding strategies. *Macrocephalon* and *Eulipoa* lay eggs at communal nesting grounds where sun or volcanic activity provides heat for incubation. *Talegalla, Aephypodius, Alectura* and *Leipoa* build mounds of forest litter where organic decomposition provides necessary heat (Dekker 1990). *Megapodius* nest both communally in geothermally heated grounds as well as in mounds built by them (Dekker 1990).

The average weight of eggs varies between 75 gm (*Megapodius pritchardii*; Todd 1983) and 232 gm (*Macrocephalon maleo*; Dekker 1990); between 10-17% of the female's body weight (Vleck *et al.* 1984). The yolk content is as high as 50-67%, with burrow nesters having higher yolk content than mound builders (Clark 1964). This high yolk content in megapode eggs is probably due to the selection for extreme precocity (the chicks are independent of parents on hatching) during the evolutionary history of megapodes (Clark 1964, Seymour 1985). In contrast, chicken eggs weigh about 50-60 g and have a yolk content of only 30 %. Thus, megapode eggs are a sought after food, and may play a significant role in local economies (Dekker & Wattel 1987).

Though habitat loss is a major threat, the primary cause for the drastic reduction in megapode populations has been over exploitation of their eggs. The problem is particularly severe for species that have communal nesting grounds. In *Macrocephalon maleo*, 9705 eggs were harvested from a single communal nesting ground in a season in North Sulawesi, but 30 years later only 2 to 3 eggs were laid there per day (MacKinnon 1981). The number of eggs harvested by the inhabitants of a single village from a nesting ground of *Megapodius eremita* in New Guinea was estimated at 18,000 eggs per month (Dekker 1990), and 30,000 eggs were collected at another location per season (MacKinnon 1981). While egg collection had been regulated in the past, changing demographic, cultural, and social patterns have resulted in uncontrolled exploitation of eggs (Dekker & Wattel 1987). Mound building megapodes suffer heavy egg losses as well but the problem is not as acute because mounds are scattered through primary, and often inaccessible, forest and not all mounds are discovered (Dekker 1990).

Conservation of megapodes is relatively easy because restoration of populations can be achieved by the artificial or protected incubation of eggs collected from the wild, and the immediate release of the precocial young (Dekker & Wattel 1987). For instance, in Sulawesi, in two communal nesting grounds of *Macrocephalon maleo,* an estimated 3,500 eggs were laid by a population of 150-200 pairs, during the 1985/1986 breeding season, but the hatching success was close to zero under natural conditions. With the construction of protected hatcheries, and sustained patrolling at nesting grounds, the hatching success rose to 55 and 75% respectively and over 700 Maleos were hatched.

Historical distribution

The Nicobar Megapode, *Megapodius nicobariensis*, endemic to the Nicobar islands is geographically isolated, with its nearest congeneric about 1,600 km away (Olson 1980). Two subspecies are recognized; *M. n. nicobariensis* which is present on the Nancowry group of islands north of the Sombrero Channel, and *M. n. abbotti* on the Great Nicobar group of islands south of it (Ali & Ripley 1983; Fig. 2).

The Nicobar Megapode occurred on most Nicobar islands (Hume 1874, St John 1899, Kloss 1903) but not on Car Nicobar (Butler 1899) and Chaura (Abdulali 1967). It is said to have occurred on Batti Malv (Butler 1899). There were a few records from the Andaman group of islands (Hume 1874, Butler 1899, Sewell 1922) and from the Coco islands further north (Kloss 1903, Abdulali 1964). None of the records from the Andaman group are of recent origin and the species is believed to be absent there.

Three hypothesis can explain the absence of megapodes from the Andaman islands. Kloss (1903) believed that megapodes were introduced to the Nicobars by the Malays and explained their absence from the Andamans because voyagers were deterred from those islands by hostile natives, thus preventing their introduction. Olson (1980) suggests that megapode distribution is a result of competitive exclusion by other galliformes, but as wild galliformes are absent in the Andamans, this does not explain the absence of megapodes there. Dekker (1989) argued that because mound nesting megapodes are unable to survive in the presence of large carnivores, their absence in the Andamans might be explained by the introduction of the Palm Civet *Paradoxurus hermaphroditus* and Masked Palm Civet *Paguma larvata* (Dekker 1992, also by Kloss 1903), and considers the Nicobar Megapode as a relict population. Of the two civets in the Andamans only *P. hermaphroditus* is introduced, while *P. larvata tytleri* is a subspecific endemic, and it is therefore possible that megapodes could not colonise the Andamans at all.

Whether the megapode existed in the Andaman group needs confirmation as there are no specimens from those islands and shooting records appear to be hearsay. The mound reported from the Andamans (Hume 1874) could have been a nest of the King Cobra *Ophiophagus hannah*, a likely error if one has not seen a megapode mound before. Spot sampling during this survey in South Andamans failed to reveal old mounds, traces of which can be present for over 1000 years (Stone 1991). Many species are exclusive either to the Nicobars or the Andamans and it is probably true for the Nicobar Megapode as well. Tangible evidence, in the form of abandoned mounds, is needed before we can conclude that this species indeed existed in the Andaman group of islands.

The mound of the Nicobar Megapode

The Nicobar Megapode builds mounds of sand, loam, coral bits and rotting vegetation within which eggs are laid. Mounds vary in height from 10 cm to 2.1 m and in basal circumference from 7 m to 45 m. Basically three types of mounds are built by the Nicobar Megapode and have been described by Dekker (1992) as: type 'A' mounds or true mounds, regular in shape and built on an open spot away from trees; type 'B' mounds, irregular in shape, built against the buttress or stem of a large living tree; type 'C' mounds, also irregular in shape but built against, around, under or over a dead rotting tree stump or log (Fig. 4). Mounds are usually

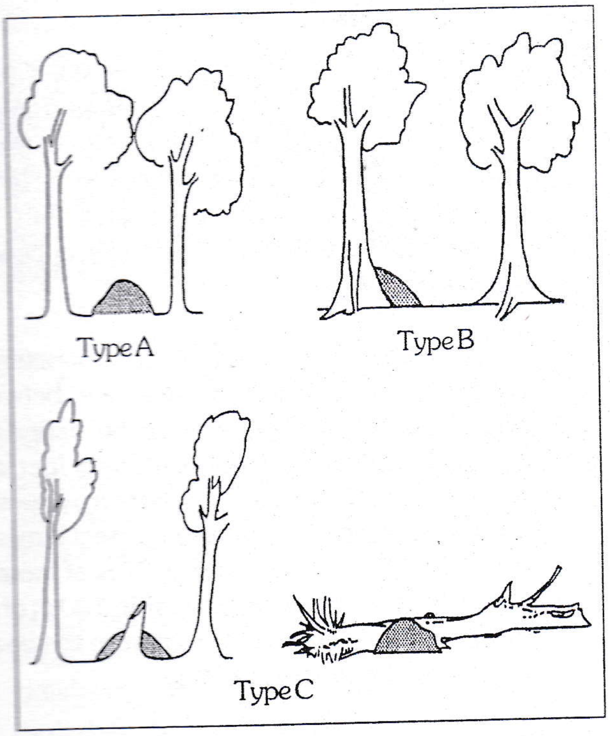

Figure 4. Mound types in the Nicobar Megapode

made close to the shore but are also present some distance inland (Hume & Marshall 1878, Baker 1930). This preference for nesting near the beach is common to at least one other species, *M. freycinet* (Stuebing & Zazuli 1986). Of the 188 active mounds for which measurements were taken during this study, 97% were found within 100 m (80% within 60 m) of the beach (Fig. 5). A few mounds were further inland (as far as 15 km inland on Great Nicobar), but these were difficult to find because of the hilly terrain and much lower densities.

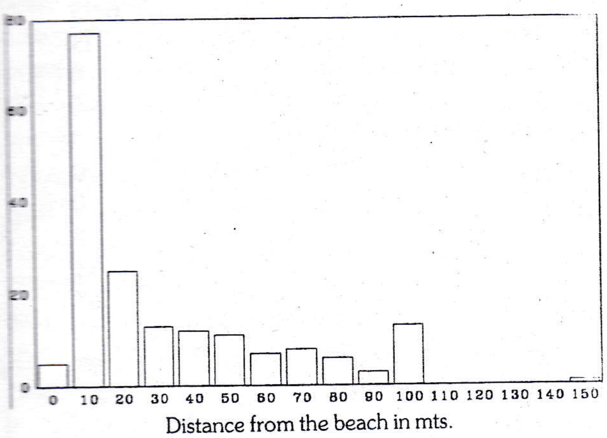

Figure 5. Frequency distribution of Nicobar Megapode mounds with respect to distance from the beach.

Status and Conservation

Throughout their distribution megapodes are threatened by habitat destruction, introduction of predator species, and over exploitation of their eggs (Dekker in press). The Nicobar Megapode is no exception. It is listed under Schedule I of the Indian Wildlife Protection Act (1972), and has featured in several lists of endangered species (Collar & Andrews 1988, Collar *et al.* 1994). In 1988, the Andaman and Nicobar chapter of INTACH (The Indian National Trust for Art and Culture) reported the extinction of the Nicobar Megapode from Kondul, estimated a population of fewer than 400 birds from Great Nicobar and predicted the extinction of the species in the next 5-10 years (Anon. 1988). Dekker (1992), however, estimated a population of about 780 breeding pairs in the coastal area of Great Nicobar and concluded that the megapode population on Great Nicobar is not threatened. However, the status of *M. n. abbotti* on Little Nicobar and the other islands was still unknown. Of greater concern was the absolute lack of information on *M. n. nicobariensis*.

Objectives

1. To assess the present distribution and population status of the Nicobar Megapode (*Megapodius nicobariensis nicobariensis* & *M. n. abbotti*).
2. To examine habitats presently holding these birds, estimate the area of available habitat and to identify threats to these habitats.

Methods

The Nicobar islands were surveyed between 10 December 1992 and 5 April 1993, and 20 December 1993 and 31 March 1994. 17 Islands were sampled by walking around each island and this survey covered the entire range of this species. Distances between sampling sites varied between 5 and 8 km on large islands and the entire coast of small islands was surveyed. A summary of the survey is given in Table 1.

As mounds are stationary, inanimate and represent breeding, the best way to estimate and monitor populations of megapodes is by assessing the number of active mounds (those in use). Active mounds were identified by signs of recent digging by megapodes. When digging signs were not obvious as when rains obliterated marks, the state of a mound was identified by checking whether the soil was compact and hard (abandoned mounds) or loose and easily penetrable with a stick (active mounds). A mound that was not active was considered abandoned. I prefer this classification over Dekker (1992) who called such mounds inactive, because inactive implies that a mound is periodically inactive and active, while in reality most abandoned mounds had not been used for considerable periods, were in stages of obliteration, and often had vegetation growing on them. This indicated that in the Nicobar Megapode, few mounds are brought back into use after being abandoned.

As mounds are predominantly placed in a narrow strip of forest along the seashore (Dekker 1992, this study), the survey concentrated on forests abutting the beach. The census consisted of two observers walking between 30 and 50 m abreast parallel to the seashore, with the observer closest to the sea about 20 to 30 m from the beach. As mounds within 20 or 30 m of the observer are easily located, most mounds within a belt of forest about 100 m wide starting from the beach were counted. The length of this modified belt transect was about 1.5 to 2 km (avg. 1.7 km, SD=1.3 km, range 0.2 - 8 km, n=64). Only three transects were shorter than 0.5 km, these were in terrain where available habitat was limited to the length of the transect, e.g. small bays amidst cliffs. The data from such transects have not been appended to other transects.

The census data consisted of three parameters: a) length of the transect, b) distance between mounds, and c) distance between the mound and the beach. I calculated mound density (per km^2) by the equation, $D = m/l.w$, where m = number of active mounds, l =length of transect (km) and w = width (100 m or 0.1 km) as 97% of mounds in coastal forests were found within 100 m of the beach. Mounds beyond 100 m from the beach were excluded from estimates.

To estimate the total number of active mounds, the coastline of each island was divided into segments based on similarity of habitats. This was necessary because the distribution of mounds was not uniform and were absent or very rare where cliffs or mangrove swamps abutted the shore or the forest was low-lying and periodically inundated (dominated by *Areca* or *Pandanus* palms), or the forest had been replaced by coconut. Thus, a

Table 1. Summary of details of the survey

Island	Area (sq km)	Coastline (km)	Transect No.	Transect km	% Coast surveyed	Survey days	Population Tribal	Population Mainlander
Great Nicobar	1045.1	213	19	30.4	14	56	536	6295
Little Nicobar	159.1	78	12	12.7	16	18	295	13
Megapode Island	0.13	2.4	1	1.0	42	1	0	0
Meroe	<3	5.25	1	5.25	100	3	0	0
Treis	<1	2.7	1	2.7	100	0.5	0	0
Trax	<0.2	1.2	1	1.2	100	0.25	0	0
Menchal	<2	3.3	1	1.5	46	2	0	0
Kondul	4.6	7.5	1	2	27	2	139	8
Pilo Milo	1.3	3.0	1	2.5	83	2	109	13
Camorta	188.2	112.5	8	12.2	11	17	1406	1567
Trinkat	36.3	30	2	4.0	23	5	350	0
Nancowry	66.9	44.3	4	10.25	7	4	907	107
Katchall	174.4	78.0	3	8	10	8	2491	2581
Teressa	101.4	53.25	5	11.95	22.4	12	1617	162
Bompoka	13.3	12.75	1	2.2	17.3	2	51	0
Tillanchong	16.82	42	4	6.2	14.8	7	0	0
Car Nicobar	126.9	–	–	–	–	4	15781	3555

segment was based on judging overall similarities in habitat and its suitability for megapodes. The total number of mounds for the forest abutting the coast (probably comprising 75% of mounds in Great and Little Nicobar, Katchall, Bompoka, and Tillanchong, and over 90% of Camorta, Trinkat, Nancowry, and Teressa) was then calculated by the equation:

$$\sum_{i=1}^{n} \frac{M_i}{L_i} \times S_i$$

where n = number of segments, i denotes a particular segment, Si = length of segment, Li = total length of transects within a segment, and Mi = total number of active mounds within Li.

Megapodes occur in the forests to the interior of the islands and in larger patches of forests within grasslands in the Nancowry group. These populations have not been considered in my estimates.

Measurements of distances have been approximate. Distances in the field were measured using a pedometer set at 45 cm, a setting arrived at by comparing strides taken to survey 1.5 km of megapode habitat abutting a metal road, and while walking on the road. Distances between the mound and the beach were measured either by pacing, or visually. Coastlines were measured from 1:150,000 scale hydrographic charts. Signs of predation, both natural and human, were recorded for every active mound seen.

Results and Discussion

Distribution

I found the Nicobar Megapode on all but one island (Pilo Milo, where it is probably extinct) in the Nicobars from where it had been reported. *M. n. nicobariensis* occurred on Camorta, Nancowry, Trinkat, Katchall, Teressa, Bompoka and Tillanchong. *M. n. abbotti* was present on Great and Little Nicobar, Megapod Island, Meroe, Treis, Trax, Menchal and Kondul. As the two subspecies have significant dialectic differences in their vocalizations, subspecific identification is possible in the field. It may have existed on Car Nicobar (78 km north of Teressa, the nearest megapode population) a century ago but I found no traces of mounds. Chaura is only 11.5 km from Teressa and, considering its occurrence on more remote Tillanchong, there is no reason why the megapode should not have existed there. Even if it did occur in the past, both Car Nicobar and Chaura are much too densely populated for the species to exist there now.

Status

Crucial to the population estimate is the information on number of pairs that use a mound in a year, whether larger mounds attract more pairs, differences in types of mounds and in the number of pairs using them, presence of mound tenacity, egg-laying frequency, number of eggs laid, and duration of reproductive period. This information is as yet unavailable and any population estimate will be tenuous. Thus, the best indicator of the status of megapodes is an estimate of the number of active mounds in an island.

However, Dekker (1992) estimated an average of two pairs per mound (for all three types) and emphasized that this was an absolute minimum, indicative of the breeding population for the month of March only. As the breeding is said to be through the year (Ali & Ripley 1983), the actual number of pairs that use a mound in a year would be more (cf. Dekker 1992). That more than two pairs use the same mound was also evident from trappers who had snared several birds from the same mound. In two other mound building megapodes, a maximum of four and five pairs have been estimated as using the same mound (Rand & Gilliard 1967, Stuebing & Zazuli 1986). Thus, for the population estimate I used two pairs per mound for the lower limit and 3.5 pairs per mound for a conservative upper limit (the mean of minimum number of pairs per mound for *M. nicobariensis* and the maximum recorded for megapodes in literature).

Megapodius nicobariensis abbotti

On Great Nicobar, *M. n. abbotti* was believed to have disappeared from all areas colonised by mainlanders (Dekker 1992). However, megapodes still survive there and four active mounds were located over a distance of 11 km. In areas not colonised by mainlanders, active mounds were present in all forests abutting the shore as was the case with all of Little Nicobar which has no mainland settlers. I estimated that there are over

Table 2. Population estimate of the Nicobar Megapode

Islands	Estimated no. of active mounds	Estimated no. of Breeding pairs (range)#
Great Nicobar[1]	515	1030-1802
Little Nicobar[1]	311	622-1088
Megapode Island[1]	2	4-7
Pilo Milo[1]	0	0
Meroe[1]	1	2-4
Treis[1]	4	8-12
Trak[1]	3	6-11
Menchal[1]	2	4-7
Kondul[1]	11	22-39
Camorta[2]	20	40-70
Trinkat[2]	8	16-28
Nancowry[2]	60	120-210
Katchall[2]	69	138-242
Teressa[2]	119	238-417
Bompoka[2]	26	52-91
Tillanchong[2]	10	20-35

1 *M. n. abbotti*; 2 *M. n. nicobariensis*
\# Lower limit at 2 pairs per mound, upper limit at 3.5 pairs per mound.

800 active mounds in Great and Little Nicobar, and the population of adult breeding birds to be between 3300 and 5750 birds (Table 2, Appendix 1 for map showing important megapode areas).

Dekker (1992) estimated 390 active mounds on Great Nicobar as against this study's 515, although sampling intensity were similar (26 and 30.4 km respectively). The reasons for this difference are that Dekker surveyed three areas while I sampled 19 locations all around the island. In his study the west coast was under sampled (three km at one location); this coast had the least disturbance and the best megapode habitats (I surveyed 12 km at nine locations). His other two transects pass (one partly) through habitat that had been subjected to human activity like road building or quarrying and are not representative of mound abundance. Lastly, by dividing the coast into segments (as in this study), a truer estimate of mounds was arrived at than by a simple arithmetical extrapolation (Dekker 1992).

Seven of nine islets in the Great Nicobar group had habitat suitable for megapodes and the remaining two (Cabra and Pigeon) were too small. Over 50% of the forests of uninhabited Meroe, Treis, Trax, Menchal and Megapode Island have been converted to coconut plantation by the inhabitants of neighbouring islands. Only one active mound each was found on Megapode Island and Meroe, and the high proportion of abandoned mounds was indicative of a dwindled population. A dense ground cover of germinating coconut on Meroe has ruined potential mound building areas. Only Treis and Trax, with four and three active mounds respectively, had a satisfactory megapode population. Less than 10% of Menchal's coast is suitable for megapode as most of the island is rocky. The only level area in Kondul is inhabited and one active mound was found just behind the South Point village. About half of Pilo Milo is inhabited, and the islet is mostly under coconut palms. Megapodes are apparently extinct on this islet, although reports of calls heard indicate that it may still survive. The number of active mounds in the outlying islets in the Great Nicobar group is estimated to be about 23, with an adult breeding population between 90 and 160 birds (Table 2). Thus the population of *M. n. abbotti* is between 3400 and 6000.

Megapodius nicobariensis nicobariensis

M. n. nicobariensis occurs on seven islands of the Nancowry group. On Camorta, Katchall and Trinkat, *M. n. nicobariensis* was patchily distributed with very few locations having active mounds and even fewer where mounds were abundant. For instance, on Camorta, only one location, a small promontory near Kakana village, had a high density of active mounds. Elsewhere in the island, active mounds were either very rare or absent. On Trinkat too very few active mounds were located. At Katchall, considered by Kloss (1903) to be the home of the megapode, though a few mounds were present through much of the coast, only a single location had a high density of mounds. The southern half of Nancowry had mound densities similar to that of Great and Little Nicobar. I estimate that there are over 150 active mounds of *M. n. nicobariensis* in these four islands, and the adult breeding population to be between 600 and 1100 birds (Table 2; Appendix 2 for map showing important megapode areas).

It was only on Teressa and Bompoka that good populations of megapode existed, and the density of active mounds was akin to that of Great and Little Nicobar (Table 3). Tillanchong is mainly hilly with very little level coastal forest, thus megapodes are naturally scarce except in the level forests. The small population that exists is apparently secure. Thus the population of adult breeding birds of *M. n. nicobariensis* is estimated to be between 1200 and 2100 birds and the number of active mounds to be a little over 300.

Loss of population

To assess loss of population, and the reasons behind the reductions, the mean density of mounds and the proportion of abandoned mounds to active mounds for each of the transects traversed were calculated, and comparisons made among islands.

The densities of active mounds are similar for six islands, Great and Little Nicobar, Trax, Nancowry, Teressa and Bompoka which ranged between 30 and 36 mounds per km² (Table 3). On all other islands, density ranged between 3 and 22 mounds per km² (Table 3). In the best habitats active mounds were encountered at least once every 200m, and similar densities have been reported for *M. reinwardt* (Lincoln 1974, Crome & Brown 1979) and for *M. cumingii* (Stuebing & Zazuli 1986). The significantly lower densities in *M. n. nicobariensis* in Camorta, Trinkat and Katchall and of *M. n. abbotti* in the outlying islets thus posed a question. Was lower number of mounds encountered in the northern subspecies natural or has there been a loss or reduction in populations?

Reduction in populations is best indicated by the proportion of abandoned mounds. The two islands with the least damage to coastal forests are Great and Little Nicobar, of which the former had a greater proportion of undisturbed coast. All other islands have undergone considerable conversion of forest to coconut plantations. The proportion of abandoned mounds to active ones in the other islands was between 1.6 to 2.3 times that of Great Nicobar, and 1.2 to 1.6 times of Little Nicobar

Table 3. Summary of census data of megapode mounds

	M. n. abbotti									*M. n. nicobariensis*						
	GN	MI	LN	PM	MR	TR	TA	MN	KN	CM	TT	NN	KT	TS	BP	TI
No. of active mounds	66	1	49	0	1	4	3	1	3	8	2	14	14	33	7	8
No. Type A	20	1	23	0	1	3	1	1	0	7	2	9	11	18	6	4
No. Type B	25	0	14	0	0	0	0	0	1	1	0	2	1	3	0	2
No. Type C	21	0	12	0	0	1	2	0	2	0	0	3	2	12	1	2
No. Abandoned	50	3	78	4	14	14	13	0	5	44	16	15	29	113	25	14
Mean % Abandoned mounds	40	75	57	100	93	78	81	0	63	82	90	53	70	72	78	67
Mean mound density (km²)	33	10	36	-	3	16	30	7	15	10	4	30	22	30	32	13
% mounds with signs of egg collection	7.5	0	2	-	0	0	0	0	0	0	0	0	0	0	0	0
% mounds with snares on them	12	0	18	-	0	0	0	0	0	0	0	8	0	0	14	38
% mounds with monitor lizard signs	18	0	18	-	0	0	0	0	0	25	0	8	0	3	28	13
No. of active mounds (extrapolated)	515	2	311	0	1	4	3	2	11	20	8	60	69	119	26	13

GN=Great Nicobar; MI=Megapode Island; LN=Little Nicobar; PM=Pilo Milo; MR=Meroe; TR=Treis; TA=Trax; MN=Menchal; KN=Kondul; CM=Camorta; TT=Trinkat; NN=Nancowry; KT=Katchall; TS=Teressa; BP=Bompoka; TI=Tillanchong

(Table 3). The only exception was Nancowry where the proportion of abandoned mounds was similar to that of Great and Little Nicobar.

The highest number of abandoned mounds were present in those areas where primary forest had been converted into coconut plantations. In one plantation on Camorta, of the 16 mounds seen in a 1.5 km transect, 14 (87.5%) were abandoned, in another on Teressa 56 abandoned mounds and 4 active ones were seen in 2.75 km, and in very old plantations only traces of abandoned mounds were visible. However, where there was a mosaic of coconut and forest, or the ground vegetation was not cleared, megapodes built mounds. Megapodes apparently abandon pure stands of coconut because they require sufficient ground and middle storey vegetation cover, and mounds become unworkable due to dead coconut fronds covering mounds, and nuts falling and germinating on mounds.

Figure 6. An abandoned mound in a coconut plantation.

Teressa and Bompoka are exceptions because while mound densities are similar to that in Great and Little Nicobar, they have a significantly greater proportion of abandoned mounds (Table 3). Though much of the coast has been converted to coconut in Teressa and Bompoka, there is adequate interspersion of natural habitat within coconut plantations and large tracts of optimal megapode habitat for it not to reflect on mound density. But as several large tracts of prime megapode habitat has been converted to coconut plantations, a high proportion of abandoned mounds are present.

The first signs of a declining population is perhaps a high proportion of abandoned mounds, followed by a decline in the density of active mounds culminating in a loss of population. This can be seen as a continuum in the larger islands (Table 3), which also corresponds to the availability and quality of habitat. Great Nicobar had a high density of active mounds and the least proportion of abandoned mounds while Little Nicobar had a high mound density but a greater proportion of abandoned mounds. Teressa and Bompoka had high mound densities but high proportions of abandoned mounds, Katchall had a lower mound density and a high proportion of abandoned mounds, and Camorta and Trinkat had both low mound densities and high proportions of abandoned mounds.

Threats

The main threats to the Nicobar Megapode are hunting of birds for meat and egg collection, predation and habitat loss.

Hunting and egg collection

The Nicobarese do not hunt or collect eggs of this megapode extensively because megapodes have spiritual and medicinal values. There were, however, inter and intra island differences. In some villages hunting or egg collection is prevalent (e.g. Tahiyuol, Little Nicobar), while in others it is not (e.g. Pilo Pakka, Little Nicobar). Greatest hunting pressure was on the west coast of Little Nicobar and was rare or uncommon over much of the Nancowry group. Continued adherence to traditional values resulted in lesser levels of exploitation which explained the continued

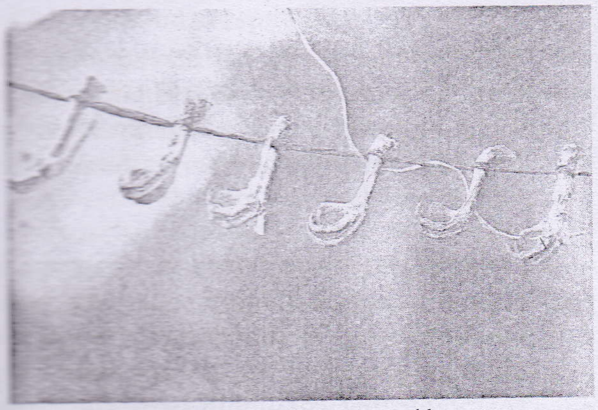

Figure 7. Legs of megapode strung up like a streamer at Tahiyuol on Little Nicobar.

Figure 8. The increasing use of airguns is proving to be a threat to the Nicobar Megapode and other avifauna.

existence of the megapode on Kondul. Where traditional values have been eroded (as by the complete domination of Christianity), localised heavy to excessive hunting pressures may exist. At Tahiyuol 71 legs, presumably of 36 megapodes, had been strung up, these having been shot over the week of a full moon. Such hunting pressures,

Figure 9. Although the eggs of the Nicobar Megapode are eaten, egg collection is apparently not a major threat.

however, were exceptional and was seen only at two locations (Tahiyuol and Pilo Milo). Megapodes are also shot on Meroe and Treis, thus seriously threatening already depleted populations.

Megapode eggs are apparently not an important source of food. Thus, unlike other species where high egg collection pressures exist (Bishop 1978, Todd 1983, Stuebing & Zazuli 1986, Dekker & Wattel 1987, Jones 1989), a low number of mounds had been excavated for eggs (Table 3). The Nicobarese and Shompen do collect eggs but apparently not all Nicobarese collect (or eat?) megapode eggs, and egg collection is only done occasionally. Bompoka is an exception and megapode eggs from there are gifted to people on neighbouring Teressa.

Localised heavy hunting pressures on the megapode by Nicobarese is a recent phenomenon because of the popularisation of airguns. The traditional method, with a cross bow, was rare and I saw it being used only on Bompoka and at one location in Katchall. Most Nicobarese do not use snares, and its use is even resented because pigs and chicken get caught or injured by the nylon nooses. Mainlanders, particularly labourers on construction projects, trap megapodes. High hunting pressures by mainlanders existed on Great Nicobar while work on Project Yatrik (which opened up the island to colonisation) was under way. With the phasing out of the project, and the better implementation of Wildlife Protection laws, hunting pressures on megapodes have declined. I did not come across any sign of mainlanders digging up mounds for eggs.

Figure 10. Thai poachers snare the megapode and have severely depleted populations on the north-eastern coast of Great Nicobar.

Very high hunting pressure, albeit localised, was from Thai poachers who camp in isolated parts of Tillanchong, Great and Little Nicobar. Snares for megapode and wild pig *Sus scrofa nicobarica* had been extensively placed in the north-eastern coast of Great Nicobar and most mounds near Thai camps had snares on them. Several active mounds that were infrequently worked upon was also indicative of a population that had suffered recent losses. About 5% of Great Nicobar's coast is affected in this manner.

Predation

Having evolved in habitats that were free of large carnivores, megapodes are particularly vulnerable to predators (Dekker 1989). In the Nicobars, introduced wild predators are absent. Only the monitor lizard *Varanus salvator*, the reticulate python *Python reticulatus*, and species of raptors are potential predators of megapodes and their

Figure 11. Monitor Lizards burrow into Megapode mounds both to eat eggs as well as to lay their own.

eggs. The monitor lizard excavate mounds both for preying on eggs and to lay its own (cf Dekker 1992). However, as monitor lizards are extensively hunted for meat, the numbers of this predator are kept in check.

Dekker (1992), suggested that cats and dogs pose a threat to megapodes in the Nicobar islands. My observations were contrary to this, the most striking of which was an active type 'A' mound that was within 30 m of an inhabited hut, and at night the megapodes roosted on an adjacent tree. This household had five dogs and four cats. Todd (1983) also stated that in the 100 odd years that cats have been resident on Niuafo'ou extinction of *M. pritchardii* has not taken place. With the exception of Meroe, dogs and cats are currently not a threat to the Nicobar Megapode. Cats were released on Meroe in 1991 to control rats that were seriously damaging the coconut crop. The most visible change since then, is in a flush of germinating coconut palms, forming a dense ground cover. As a result, the area available for mound building is greatly reduced and because of the dense ground cover, the cursorial megapode would be increasingly incapable of avoiding predators.

Habitat loss

The primary threat to most species of megapodes is loss of habitat (e.g. Bishop 1978, Dekker 1990), and this is true for the Nicobar Megapode as well. Demographic changes in the Nicobars have resulted in widespread loss of habitat, this being most acute in the Nancowry group of islands.

The Nicobarese subsist on coconut and have converted coastal forests abutting their villages into coconut plantations and have clear felled forest to plant banana, papaya and tuber-bearing plants. As tribal populations are the highest in the Nancowry group, most damage has occurred there. A 35 km long strip of forest along the southeastern coast has been depleted on Great Nicobar due to settlement of mainland Indians. Over 600 ha. of primary forests were replaced with rubber plantations on Katchall. Expanding townships and villages, roads, airstrips, and infrastructure for defence establishments have all resulted in the loss of habitat. The single biggest threat to megapodes is the loss of habitat.

Conservation perspectives

The long-term perspective for the Nicobar Megapode is bleak because of the persisting loss of habitat. A growing tribal population and the resultant conversion of primary forest to coconut and other plantations continues to encroach into megapode habitat. The problem is most acute in the Nancowry group where suitable habitat, both for megapodes and humans is considerably less than in the Great Nicobar group. Control over habitat loss due to tribals is not possible in the Nicobars, not even where areas have been declared as protected reserves, because the tribals are exempt from Forest and Wildlife laws. The population of the ethnic tribes inhabiting the Great Nicobar group is low and hence an immediate threat of a significant alteration of primary forest is minimal. As further mainlander settlement has been stopped on Great Nicobar, the damage has been contained to forests already lost or degraded.

Though megapodes are not being extensively hunted (or their eggs collected) in the Nicobar islands, intensive localised hunting pressures exist and may cause localised rarity or extinction. The situation, however, is not yet alarming.

The most immediate threat in the Nicobars is the proposal to make Great Nicobar a free port and to create a dry dock and refuelling base for international shipping at the mouth of the Galathea river. If and when implemented, all the Nicobar islands will be lost to conservation.

Conclusion

The Nicobar Megapode was considered to be a seriously endangered bird (Jones 1989). This was found to be untrue as has already been documented for the status of this species in Great Nicobar (Dekker 1992). This is particularly the case with the South Nicobar Megapode, which in places is a common bird. The Nicobar Megapode, as a species, is not under any threat of immediate extinction, and is unlikely to become endangered in the near future.

The status of the northern subspecies *M. n. nicobariensis* gives rise to concern. Though the bird is present on all of the islands where it used to occur, there has been a decline in numbers. This was reflected both in the few number of active mounds and also in the high proportion of inactive mounds present. However, there were certain pockets within each island where megapodes were apparently doing well.

The only real threat to megapodes in the present context is the loss of habitat. This might not be a problem in the Great Nicobar group in the near future, as the islands are thinly populated and are still mostly pristine. In the Nancowry group, however, the situation is very different. Larger human populations and scarcity of land have resulted in megapode habitat being converted to coconut plantations. Though there is no information on the rate of land use change, apparently a significant proportion of the coastal forest cover has already disappeared, and more areas are or will come under coconut plantations. The problem is exacerbated in the Nancowry group (excepting Katchall), as a large amount of the Islands are grassland (over 60% of Trinkat and about 30% of Camorta), and a substantial area of the coast is mangrove. Thus available or optimal habitat for the megapodes is proportionately much less than in the Great Nicobar group. The available habitat is also prime coconut plantation land, and I fear that in a few decades there will be little habitat left for the North Nicobar Megapode to survive in. As the land in the Islands belong to the tribals, and rightly so, controlling or regulating the conversion of forest to coconut will be difficult if not impossible to achieve.

Megapodes are not being extensively hunted (or their eggs collected) in the Nicobar Group of Islands, but localized pressures may be quite high. Unlike other megapode species, egg collection is a far lesser problem than hunting of adult birds. The pressures are localised and once the Thai problem is solved, it will be considerably reduced. The hunting pressures exerted by villages such as Pilo Milo and Tahiyuol may cause localised rarity or even localised extinction of megapodes, but as yet the situation is not alarming.

Figure 12. Most islands of the Nancowry group have very little fresh water. Teressa, however, was a notable exception as there were several streams and rivulets all along the coast. Some, like the waterfall above, strengthen a growing conviction that the future of the Nicobar islands lies in its conservation.

The Status of the Endemic Avifauna of the Nicobar islands

Introduction

Geographically isolated island groups are of particular importance in the conservation planning of a country because the substantial number of endemic species present make a significant contribution to the nation's biodiversity. The Andaman & Nicobar group of islands is no exception. Of the 176 species that are endemic to the zoogeographic subregion of the Indian peninsula and its environs (Ali & Ripley 1983), 14 are endemic to the Andaman and Nicobar islands. Thus, while the Andaman & Nicobar islands account for only 0.2% of the land mass of South Asia, it has approximately 8% of the endemic avifauna of the region, making the islands a high priority area in the conservation of India's avifauna.

A major lacuna in our knowledge about the avifauna of the Andaman & Nicobar islands is the lack of adequate information about the assemblage of avifauna on different islands and their status. A prerequisite to the conservation of the avifauna is the identification of taxa that are threatened, and of the islands or island groups which, if conserved, will result in the preservation of the maximum number of endemic species. This will play a fundamental role in the planning of a protected area network in the Andaman & Nicobar islands.

Methods

The checklist of the avifauna (Table 5; Appendix 3) of the Nicobar islands is based on all confirmed sightings in the field and from a literature review that incorporated information from Abdulali (1964a, 1964b, 1966, 1967, 1971, 1974, 1978); Das (1971), Dasgupta (1976), Ripley (1982), and Ali & Ripley (1983).

The list of endemic avifauna

Taxonomy: The inclusion of species or sub-species as endemic is based on Abdulali (op cit.) even though many of these are not confirmed or accepted. Most disputed classifications of the avifauna in the Andaman & Nicobar islands can be attributed to the paucity of an adequate collection of skins in museums. Till such time this is accomplished, there is a need to include all species / subspecies that have been identified as distinctive in the literature. The current taxonomic status is from Howard & Moore (1991).

The historical status: The population status of each species in literature has been taken from Hume (1874), Butler (1899), and Abdulali (op cit).

Sight records: The relative abundance of a species is indicated by the number of times a species was sighted or heard during this survey. A flock was considered as a single sighting.

Status: The new IUCN criteria for assigning threat status, modified for preparing Red Data Books for birds (Collar *et al.* 1994), have been applied to each species and subspecies endemic to the Nicobar islands. However, due to the lack of quantitative data on population, application of the criteria in the Nicobar group can be misleading as in small inhabited islands almost all species would qualify as either Endangered or Vulnerable. Moreover, many of the criteria call for purely qualitative judgements which were unsatisfactory to this analysis. Thus, numerical thresholds for certain criteria were devised whereby the status of species of avifauna could be judged.

To assess whether a species is threatened, six criteria with various numerical and qualitative thresholds have been defined (Collar *et al.* 1994). Criteria A: Rapid decline; B: Small range, plus any two of: fragmented, declining and fluctuating [habitat]; C: Small population and declining; D1: Very Small or restricted population; D2: Very Small range; and E: Unfavourable PVA (Collar *et al.* 1994). As data on population trends of species in the Nicobar islands is lacking, criteria other than B cannot be effectively applied. Under Criteria B, a continuing decline in area, extent and quality of habitat of a species with an area of occupancy of less than 500 km^2 qualifies it to be classified as endangered and that with an area of occupancy less than 2,000 km^2 as vulnerable.

The two major problems in applying this criteria in estimating loss and rate of loss of habitat were: a) there are no numeric thresholds by which to make this assessment, and b) the absence of data on time frames over which habitat has been lost. I addressed these problems by equating a reduction in area of occupancy with the loss of habitat in the Nicobar islands (i.e. forest that had been cleared or degraded for human use or grasslands that had been planted with trees) irrespective of the time involved and the rate of habitat loss with the rate of human population increase. I then incorporated a numeric threshold for both these factors by which decline in habitat can be judged.

Loss of habitat due to mainlanders was estimated using existing records and visual evaluations (Appendix 4). Three islands have had significant loss of habitat due to mainlanders. The majority of a 35 km long and approximately 2 km wide strip of forest was cleared on Great Nicobar to settle mainlanders, and further areas were cleared to develop other infrastructure. On Katchall about 600 ha of forests were cleared to develop a rubber plantation and further areas were cleared for a township etc. Camorta has undergone habitat loss due to the development of a township. Habitat loss due to Nicobarese was primarily due to the conversion of coastal forest into coconut and other plantations. Typically, a strip of forest not more than 200 m from the beach is cleared for plantation. During the survey I assessed the amount of coastline on each island that was under plantation, and assumed a standard width of 0.5 km to estimate area of habitat loss due to Nicobaris. Thus, a rough estimate of the amount of habitat lost till date could be made (Appendix 4).

Barring loss of habitat due to mainlanders, over 80% of which occurred between 1969 and 1975, the time frame of habitat loss due to Nicobaris cannot be fixed, as the process of converting forest to coconut plantations has continued over several decades. Thus, while it is possible to estimate how much habitat has been lost till date, the time over which this occurred is not known. However, as both tribal and mainlanders are dependent on the natural resources of the islands, the rate of increase of pressure on the forest resources can be related to the rate of increase in human density. The greater the rate of density increase, the greater the increase in pressures on the habitat.

The numerical thresholds incorporated in this analysis are those of criteria C, that is a decline in population of 20% within 10 years qualifies a species as vulnerable and 20% over five years as endangered. I incorporated these values into the assessment of decline in extent and quality of area of occupancy by assuming that where there has been a 20% loss of habitat with a 20% increase in human density over the last 10 years, there has been a decline in area, extent and/or quality of habitat, and that the species should be treated as vulnerable. A doubling of any one of the above two factors, that is a 40% habitat loss or a 40% increase in human density, will qualify a species as endangered.

Though the priority for conservation should be full species endemics, this analysis is concerned with the conservation of all avian taxa unique to the Nicobar islands. Hence, all endemic subspecies are included in the analysis. The status of each species or subspecies has been inferred from Table 5, which gives its area of occupancy (= island group), Appendix 4 which gives the proportion of habitat lost, and Appendix 5 which gives the increase in human density.

Endemic species that were sighted more than 100 times have been considered as not threatened unless undergoing a specific threat like hunting, as sighting frequency is indicative of abundance.

Due to the highly restricted range of most endemics in these islands, and as even a small change in Governmental policy or any other extrinsic factor can result in a collapse in populations, very few can be declared secure when medium (20 years) to long term (50 years) prospects are envisaged. Thus, a species that does not qualify as threatened automatically qualifies as near threatened unless populations (indicated by frequency of sighting) are really very large, and are not subject to pressures like hunting.

Results & Discussion

Endemism

The total number of species and subspecies of avifauna recorded from the Andaman & Nicobar Islands is 270 of which 105 are endemic (Sankaran & Vijayan 1993). The high proportion of endemics (38.9%) however, is due to the very high number of endemic subspecies. Of the endemic 105 species and subspecies, only 14 full species (with 17 subspecies) are endemic. Of the endemics, 82 (or 78.1%) are subspecies of species found on neighbouring mainlands. Of the 14 full species endemic to the Andaman & Nicobar islands, five are exclusive to the Nicobar islands, six to the Andaman islands, and three are common to both.

There are more endemic species exclusive to the Andaman group than the Nicobar islands (Table 4). However, if geographical area is taken into consideration, the ratio of exclusive endemic species or subspecies per sq km is higher in the Nicobars than in the Andamans (Nicobars 0.021 spp. per sq km, Andamans = 0.008 spp. per sq km). Similarly, the ratio of endemics per number of islands is higher in the Nicobar group (Nicobars 1.63 spp. per island, Andamans 0.16 per island).

Thus, while the avifauna of the Nicobars has been considered as an impoverished subset of the Andaman group (Ripley & Beehler 1989), it is clear from the available data that the Nicobars are a high priority area for the conservation of avifauna.

The distribution pattern of the endemic avifauna within the Nicobar group of islands points to the existence of three distinct subgroups: the Car Nicobar, Nancowry and Great Nicobar subgroups (Table 5). The Blyth's Nicobar Parakeet is exclusive to the Great Nicobar group while the

Table 4. Number of Bird species recorded from the Andaman & Nicobar Islands

Total spp. & subspp. recorded from A&N	270
Total spp. & subspp. endemic to A&N	105
Spp. & subspp. endemic to Andaman group	49
Spp. & subspp. endemic to Nicobar group	39
Endemics common to both groups	17
Endemic full spp. (with 17 sub-species)	14
Endemic Subspecies	98

Island group	Total spp.	Exclusive spp.
Andaman	214	126
Nicobars	144	56

Nicobar Bulbul is exclusive to the Nancowry group. The Nicobar Shikra and the Nicobar Megapode are common to both groups. Though Car Nicobar has no full species endemic, there are a few exclusive subspecific endemics.

Status of the Endemic Avifauna

Considerable concern has been expressed about the status of the avifauna in the Andaman & Nicobar islands. Recently, Collar *et al.* (1994) considered four species as globally Vulnerable and 10 species as globally Near Threatened in the Andaman & Nicobar islands. Of the four species considered Vulnerable, two are endemic to the Nicobar group, and six of 10 species considered Near Threatened are present in the Nicobar group, three of which are endemic to the Nicobar islands.

The application of the criteria that designate species as threatened on 45 endemic species and subspecies of the Nicobar islands indicates that 18 species or subspecies endemic to the Nicobar islands are either endangered (1), vulnerable (6), or near threatened (11). Six species and subspecies are data deficient and 21 are of less concern.

Of the species and subspecies that are either Endangered or Vulnerable, four are full species endemics, three of which have subspecies on other island subgroups which are Near Threatened (2) or of less concern (1). Of the Near Threatened species and subspecies, three are subspecies of species endemic to the Nicobar islands. Thus of the five species and their subspecies endemic to the Nicobar group of islands, four are either Endangered, Vulnerable, or Near Threatened. Only one full species endemic, the Blyth's Nicobar Parakeet, is of less concern. Of the three species and their subspecies endemic to both the Andaman & Nicobar islands, two are either Vulnerable or Near threatened. Seven endemic subspecies of species found outside the Andaman & Nicobar islands are either Vulnerable or Near Threatened.

Some species (or subspecies) are threatened or vulnerable in some islands but are of less concern in others. Species, subspecies or populations occurring in the Nancowry or Car Nicobar subgroup are more likely candidates for threatened status than those in the Great Nicobar subgroup.

The list of the endemic avifauna

1. Nicobar Tiger Bittern *Gorsachius melanolophus minor*

Taxonomy: Subspecies separated because it is smaller than *G. melanolophus melanolophus.* Now considered to be *G. melanolophus*, which ranges from India to Greater Sunda. **Historical status:** Apparently uncommon, less than 10 specimens present. **Sight records:** No confirmed sighting, but possibly seen on Tillanchong. **Status:** Data Deficient.

2. Car Nicobar Shikra *Accipiter badius butleri*
   Nicobar Shikra *A. b. obsoletus*

Taxonomy: Now considered to be a full species endemic, *A. butleri*, to the Nicobar islands. *A. b. butleri* is endemic to Car Nicobar, and *A. b. obsoletus* to the Nancowry and Great Nicobar subgroups. **Historical status:** Has been collected on Katchall, Camorta & Great Nicobar. Butler found *A. b. butleri* to be not 'uncommon' on Car Nicobar, the status of *A. b. obsoletus* has not been mentioned. **Sight records:** 20-25. Not sighted on Car Nicobar. **Status:** *A. b. butleri* Endangered [B2c]. *A. b badius* Near threatened.

3. Andaman Pale Serpent Eagle *Spilornis cheela davisoni*
   Nicobar Crested Serpent Eagle *S. c. minimus*
   Great Nicobar Crested Serpent Eagle *Spilornis klossi*

Taxonomy: This species has been reclassified into *S. c. davisoni* and *S. elgini* from the Andamans, and *S. minimus* from the Nicobars. S. minimus occurs as two subspecies, *S. m. minimus* from the central Nicobar islands and *S. m. klossi* from Great Nicobar island. There is apparently only one record of *S. elgini* from the Nicobar, but this may be a case of wrong labelling (Abdulali 1967). **Historical status:** Not numerous. **Sight records:** *S. m. klossi* 30-35 times. *S. m. minimus* no sightings. **Status:** *S. m. klossi* Near threatened. *S. m. minimus* Vulnerable [B2c].

4. North Nicobar Megapode *Megapodius nicobariensis nicobariensis*
   South Nicobar Megapode *M. n. abbotti*

Taxonomy: Originally called *Megapodius freycinet*, is now an endemic full species. **Historical status:** Common. **Sight records:** *M. n. nicobariensis* 45-50; *M. n. abbotti* >150. **Population:** *M. n. nicobariensis* 600-2100 breeding birds and *M. n. abbotti* 3400-6000 breeding birds. **Status:** *M. n. nicobariensis* Vulnerable/ Endangered [B2c, C1]. *M. n. abbotti* Near threatened.

5. Nicobar Bluebreasted Quail *Coturnix chinensis trinkutensis*

Taxonomy: Unchanged. Endemic to the Nancowry and Car Nicobar groups. **Historical status:** Common on Car Nicobar, Trinkat & Camorta. **Sight records:** 12-15. Not sighted on Teressa and Bompoka, but are said to be present there. Grassland habitat not visited on Car Nicobar. **Status:** Of less concern.

6. Button Quail *Turnix tanki albiventris*

Taxonomy: Now considered to be *Turnix tanki tanki*, which is not endemic. **Historical status:** Common on islands with grasslands. **Sight records:** Not specifically identified but quails were flushed several times. **Status:** Of less concern.

7. Andaman Bluebreasted Banded Rail *Rallus striatus obscurior*
   Nicobar Bluebreasted Banded Rail *R. s. nicobariensis*

Taxonomy: The Nicobar subspecies is now considered to be the same as the Andaman one, *Rallus striatus*

Note.
Taxonomy: Recent taxonomic classification from Howard & Moore (1991).
Historical status: From Hume (1874), Butler (1899) and Abdulali (1964a, 1964b, 1966, 1967, 1971, 1974, 1978).
Status: A1c-decline of population due to actual or potential levels of exploitation. A1d-decline due to effects of introduced taxa. B2c-continuing decline in area extent and/ or quality of habitat. C1-continuing decline in population. Data deficient: Inadequate information to make assesment.

obscurior. **Historical status:** Common. **Sight records:** A rail sp. seen once on Camorta and once on Tillanchong. Marshland habitat not surveyed by me. **Status:** Data deficient.

8. Andaman Whitebreasted Waterhen *Amaurornis phoenicurus insularis*
   Whiteheaded Waterhen *A. p. leucocephalus*
   Whiteheaded Waterhen *A. p. midnicobaricus*

Taxonomy: Both *Amaurornis phoenicurus leucocephalus* & *A. p. midnicobaricus* are now not accepted, and all whitebreasted waterhens from the Andaman & Nicobar islands are considered to be *A. p. insularis*. There is, merit in Abdulali's segregation of birds from Car Nicobar as *A. p. leucocephalus*, as those birds have the head down to the nape entirely white, though a few individuals have some dark blotches on the hind neck. **Historical status:** Common. **Sight records:** Great Nicobar >50, Nancowry group 30-35, Car Nicobar 40-50. **Status:** Of less concern.

9. Andaman Pompadour Pigeon *Treron pompadora chloroptera*

Taxonomy: Unchanged. **Historical status:** Abundant. **Sight records:** Great Nicobar group 35-40. Nancowry group 30-35. Car Nicobar 10-12. A common species on many of the Nicobar islands. **Threats:** Extensively hunted with airguns. **Status:** Near threatened.

10. Nicobar Green Imperial Pigeon *Ducula aenea nicobarica*

Taxonomy: Unchanged. Howard & Moore have not mentioned *D. a. andamanica* in their list, which is the subspecies endemic to the Andaman group. **Historical status:** Very common. On some islands 'simply swarming'. **Sight records:** Great Nicobar group >250, Nancowry group 150-200. Car Nicobar 10-15. An exceedingly common pigeon in the Nicobar islands, with islands like Tillanchong teeming with them. **Threats:** Extensively hunted with airguns. On some islands (e.g. Car Nicobar) there has apparently been a severe decline in numbers due to severe hunting pressures. **Status:** Near threatened.

11. Nicobar Woodpigeon *Columba palumboides nicobarica*

Taxonomy: Now not a recognised race, but a single full species endemic *C. palumboides* is recognised from the Andaman & Nicobar islands. **Historical status:** Not common (?). **Sight records:** I found this species almost impossible to differentiate in the field from the Green imperial pigeon. **Threats:** Hunting with airgun. **Status:** Near threatened.

12. Andaman Cuckoo-Dove *Macropygia rufipennis andamanica*
    North Nicobar Cuckoo-Dove *M. r. rufipennis*
    Nicobar Cuckoo-Dove *M. r. tiwarii*

Taxonomy: *Macropygia rufipennis* is a full species endemic from the Andaman & Nicobar islands. *M. r. andamanica* and *M. r. rufipennis* are now considered to be the same and endemic to Andaman & North Nicobars and M. r. tiwarii as endemic to Great Nicobar. **Historical status:** Common. 'Less abundant than in the Andamans'. **Sight records:** Great Nicobar group 10-15, Nancowry group 20-25. Mostly seen in pairs and apparently a naturally scarce species. **Status:** *M. r. rufipennis* Vulnerable [B2c]. *M. r. tiwarii* Of less concern.

13. Nicobar Emerald Dove *Chalcophaps indica augusta*

Taxonomy: Howard and Moore have not mentioned this species from the Nicobar islands and probably consider it the same as the Andaman race *C. i. maxima*. **Historical status:** Common. **Sight records:** 70-75. **Status:** Of less concern / Near Threatened.

14. Nicobar Pigeon *Caloenas nicobarica nicobarica*

Taxonomy: *C. n. nicobarica* is not considered endemic and occurs up to New Guinea islands. **Historical status:** Common (?). 'Breeds in the thousands on Batti Malv'. **Sight records:** Great Nicobar 70-80, Nancowry group 35-40. **Threats:** Hunting by airgun (?). **Status:** Near threatened. **Additional notes:** 3 birds seen drinking sea water from pool left behind by receding tides.

15. Blyth's Nicobar Parakeet *Psittacula caniceps*

Taxonomy: Unchanged. **Historical status:** ? **Sight records:** 150-200. **Status:** Of less concern.

16. Nicobar Redcheeked Parakeet *Psittacula longicauda nicobarica*

Taxonomy: Unchanged. **Historical status:** Extremely common. **Sight records:** >500. **Status:** Of less concern.

17. Andaman Koel *Eudynamys scolopacea dolosa*

Taxonomy: Howard & Moore do not mention this species from the Nicobar islands. **Historical status:** Very common. **Sight records:** 300-350. **Status:** Of less concern.

18. Nicobar Scops Owl *Otus scops nicobaricus*
Taxonomy: Howard & Moore do not record this species from the Nicobars. Abdulali states that 'it appears evident that some form of scops other than *Otus balli* (Andaman Scops Owl) is present in the Nicobars'. **Historical status:** Scarce (?). **Status:** Data deficient.

19. Brown Hawk-Owl *Ninox scutulata obscura*
Taxonomy: Unchanged. **Historical status:** ? **Status:** Data deficient.

20. Nicobar Hawk-Owl *Ninox affinis isolata*
Nicobar Hawk-Owl *Ninox affinis rexpimenta*
Taxonomy: A full species endemic to the Andaman & Nicobar islands. N. a. isolata is present in the Nicobar islands excepting Great Nicobar where *N. a. rexpimenta* is present. **Historical status:** Not very common (?). **Status:** Data deficient.

21. Andaman Greyrumped Swiftlet *Collocalia fuciphaga inexpectata*
Taxonomy: Name changed to *Aerodramus fuciphagus.* Not considered endemic and distribution extends up to Greater Sunda and Timor Islands. **Historical status:** Less common in the Nicobars than in the Andamans. **Sight records:** >100 on Tillanchong, <10 totally on all other islands. **Threats:** Excessive nest collection. **Status:** Vulnerable [A1c]. **Additional notes:** This species, belongs to the 'white nest swiftlet' group, whose nests are made entirely of agglutinated saliva, and are of a very high commercial value in the international market. At Port Blair a kg of nests (one kg normally consists of about 70 nests) fetches between Rs 5000 and 8000 or more. Virtually all colonies are exploited, and nests are collected irrespective of whether there are eggs or chicks in them, with presumably serious effects on the species.

22. Whitebellied Swiftlet *Collocalia esculenta affinis*
Taxonomy: Unchanged. **Historical status:** Abundant. **Sight records:** >100. A common species in most islands, far more numerous than the Andaman Greyrumped Swiftlet. **Status:** Of less concern.

23. Andaman Three-toed Kingfisher *Ceyx erithacus macrocarus*
Taxonomy: Unchanged. **Historical status:** 10 specimens have been collected on Great Nicobar. Apparently common in the Nicobars, particularly Great & Little Nicobars; only 3 records from the Andamans. **Sight records:** Though I boated over 10 km up the Galathea river, and for a couple of kilometres on the Alexandra river, I did not see any. **Status:** Data deficient.

24. Nicobar Storkbilled Kingfisher *Pelargopsis capensis intermedia*
Taxonomy: Now called *Halcyon capensis intermedia.* **Historical status:** A common species on Great & Little Nicobar. Absent in the Nancowry & Car Nicobar groups. Distribution of this species curious as another subspecies is present in the Andaman group. **Sight records:** >75 **Status:** Of less concern

25. Nicobar Whitecollared Kingfisher *Halcyon chloris occipitalis*
Taxonomy: Unchanged. **Historical status:** Present throughout the Nicobar islands. More common in the Nancowry & Car Nicobar group than in the Great Nicobar group. **Sight records:** >100. **Status:** Of less concern. **Additional notes:** Seen nesting in termite (ant ?) nests on trees.

26. Nicobar Greenbreasted Pitta *Pitta sordida abbottii*
Taxonomy: Unchanged. **Historical status:** ?. Endemic only to Great & Little Nicobar. **Sight records:** 25-30. Not common, more often heard than seen. Apparently naturally scarce. **Status:** Of less concern.

27. Nicobar Blacknaped Oriole Oriolus chinensis macrourus
Taxonomy: Unchanged. **Historical status:** Common. **Sight records:** >125. Common in the Nicobars, exceedingly so on Car Nicobar. **Status:** Of less concern.

28. Nicobar Racket-Tailed Drongo *Dicrurus paradiseus nicobariensis*
Taxonomy: Unchanged. **Historical status:** Common. **Sight records:** Great Nicobar group 125-150. Katchall 4-5. Car Nicobar 1. **Status:** Of less concern. **Additional notes:** Curiously distributed in the Nicobar group. Common on Great & Little Nicobar, Megapode island, Kondul, Pilo Milo & Menchal; it is present on Car Nicobar and Katchall, but on no other island of the Nancowry group. Uncommon in the latter two.

29. Small Andaman Drongo *Dicrurus andamanensis andamanensis?*
Taxonomy: Unchanged. **Historical status:** Not recorded from the Nicobars. **Sight records:** 3 individuals in Katchall in the paddy field close to the jetty and 3-4 in Car Nicobar in an area cleared for plantation. Identity to be confirmed. **Status:** ? Excluded from the analysis.

30. Andaman Glossy Stare *Aplonis panayensis tytleri*
Glossy Tree Stare *A. p. albiris*
Taxonomy: The Nicobar race is now considered to be the same as the Andaman one, *Aplonis panayensis tytleri*. **Historical status:** Abundant. **Sight records:** >500. **Status:** Abundant.

31. Nicobar Whiteheaded Myna *Sturnus erythropygius erythropygius*
Katchall Whiteheaded Myna *S. e. katchalensis*
Taxonomy: A full species endemic to the Andaman & Nicobar Islands. Currently classified as *S. e. erythropygius* endemic to Andamans, *S. e. andamanensis* endemic to Car Nicobar and *S. e. katchalensis* endemic to Katchall. **Historical status:** The Whiteheaded Myna was considered to be rare by Hume on Car Nicobar, but Butler found it to be common on that island. The Whiteheaded Myna was introduced to Camorta in the late 1800s, but it has apparently died out. **Sight records:** Katchall 10-12, Car Nicobar 20-25. Common on Car Nicobar but less so on Katchall. **Status:** Near threatened.

32. Andaman Hill Myna *Gracula religiosa andamanensis*
Nicobar Hill Myna *G. r. halibrecta*
Taxonomy: The Andaman & Nicobar birds are now considered to be a single endemic race *Gracula religiosa andamanensis*. **Historical status:** Common (?). **Sight records:** Great Nicobar group 250-300, Nancowry group 12-15. **Status:** Near threatened.

33. Nicobar Pied Cuckoo-Shrike *Coracina nigra davisoni*
Taxonomy: Now called *Lalage nigra davisoni*. **Historical status:** Not uncommon. **Sight records:** <10. Sighted only on Camorta and Katchall. An uncommon or rare species. **Status:** Vulnerable [B2c].

34. Fairy Blue-bird *Irena puella andamanica*
Ali & Ripley quote Butler and include the Nicobars in its distribution, but this species has not been recorded from there by Davison and Abdulali, I am unable to locate Butler's reference, and have excluded this species from the analysis.

35. Andaman Red-whiskered Bulbul *Pycnonotus jocosus whistleri*
Taxonomy: Unchanged. **Historical status:** This species is said to have been introduced into the Nicobars from the Andamans. Davison saw it being released on Car Nicobar and saw a small party on Camorta. **Sight records:** >200. Excepting Tillanchong and Bompoka, they are now present on all Nancowry group islands and Car Nicobar. **Status:** Common. **Additional notes:** There is record of its introduction on only two islands. In the last century it has apparently spread to islands as far as 50 km from the island where it was introduced. Needs to be eradicated from the Nicobar islands.

36. Nicobar Bulbul *Hypsipetes nicobariensis*
Taxonomy: Unchanged. **Historical status:** This full species endemic has been specifically recorded from all islands in the Nancowry group, and from Pilo Milo in the Great Nicobar group. I believe the sight record from Pilo Milo to be erroneous as this species was neither seen by me nor in the past from either Great or Little Nicobar. Said to be common in the past. **Sight records:** Camorta 4-5, Nancowry 1, Katchall 15-20 (1 flock > 100 birds) Tillanchong 1, Teressa 15-20. **Threats:** The introduced Andaman Redwhiskered Bulbul, which has spread throughout the Nancowry group and is very common, has probably resulted in the rarity of the Nicobar Bulbul because of competition for the same ecological niche. **Status:** Vulnerable [A1d,B2c].

37. Paradise Flycatcher *Terpsiphone paradisi nicobarica*
Taxonomy: Unchanged. **Historical status:** Davison found this species rare in both the Andaman & Nicobar islands, but Butler found them to be numerous in the Nicobars. Abdulali did not record it. **Sight records:** 5. **Status:** Near threatened.

38. Car Nicobar Blacknaped Monarch *Monarcha azurea idiochroa*
Nicobar Blacknaped Monarch *M. a. nicobarica*
Taxonomy: Now known as *Hypothymis azurea idiochroa* and *H. a. nicobarica*. **Historical status:** Common. **Sight records:** 90-100. **Status:** Of less concern.

39. Nicobar Ground Thrush *Zoothera citrina albogularis*
Taxonomy: Unchanged. **Historical status:** Butler said they were fairly common throughout the Nicobars, but shy and difficult to procure. Specifically recorded from Trinkat, Nancowry, Camorta and Katchall. **Sight records:** 1 on Katchall. **Status:** Near threatened / Data Deficient.

40. Central Nicobar Olivebacked Sunbird *Nectarinia jugularis klossi*
Car Nicobar Olivebacked Sunbird *N. j. proselia*
Taxonomy: Unchanged. **Historical status:** Common. **Sight records:** >500. **Status:** Of less concern.

41. Nicobar Yellowbacked Sunbird *Aethopyga siparaja nicobarica*
Taxonomy: Unchanged. **Historical status:** Common. **Sight records:** 70-75. **Status:** Of less concern.

42. Nicobar White-eye *Zosterops palpebrosa nicobarica*
Taxonomy: Unchanged. **Historical status:** Common. **Sight records:** >10. **Status:** Of less concern.

43. Nicobar Whitebacked Munia *Lonchura striata semistriata*
Taxonomy: Unchanged. **Historical status:** Common. **Sight records:** <10. **Status:** Of less concern.

Status of Introduced species

Several species of avifauna have been introduced in the Andaman & Nicobar islands. The Andaman group has had a greater number of introductions than the Nicobar group, and of the 12 mainland species introduced, 10 were in the Andaman group and four in the Nicobar group. Additionally, two Andaman endemics have been introduced into the Nicobar islands.

There are several examples of introduced species causing extinction or rarity of endemic species in island ecosystems (e.g. Atkinson 1989, Olson 1989, Carew-Reid 1990, Baker 1991). It is crucial to the long-term survival of several endemic species of the Nicobar islands that the introduced species are either eradicated from the islands or their populations are controlled.

Blue Rock Pigeon : Introduced to Car Nicobar in 1898. Not widespread, but domestic strains are common around habitations in Car Nicobar. Less than a 100 are present on Great Nicobar.

House Crow: *Corvus macrorhynchos* was introduced into the penal settlement at Camorta (*c.* 1890) as was *Corvus splendens* where they both died out. Now the only island where the House Crow is present is on Car Nicobar. (year of introduction ?), where it is common around habitations, but absent or scarce in the forest.

Andaman Whiteheaded Myna: Year of introduction into Camorta unknown. I did not see this species there.

Indian Myna: Introduced in 1867, first introduced into Port Blair and from there to Camorta. This species has apparently died out and I did not see it on Camorta.

Andaman Redwhiskered Bulbul: Year of introduction in Camorta unknown. In the 100 odd years of its presence it has spread to Nancowry, Trinkat, Katchall, Teressa, and Car Nicobar where it is very common at places.

House Sparrow: Was introduced in 1895 into Car Nicobar where it is now common.

Conclusion

About 36% of the endemic species and subspecies present on the Nicobar islands are either endangered (2%), vulnerable (12%) or near threatened (22%), eliciting grave concern about their long-term survival. While there is still adequate habitat available for most species, the trend of increasing human pressure on natural resources, particularly because the limits on the resource base is so acute, will soon result in the disappearance of populations and subsequently of species. Conservation measures need to be taken to ensure that adequate habitat is preserved to ensure that the endemic avifauna of the Nicobar islands survive.

Table 5. Distribution of endemic avifauna in the Nicobar group of islands

	GN	MI	LN	PM	MR	TR	TA	MN	KN	CA	CM	TR	NN	KT	TS	BP	TI	CN	FE	SE
Nicobar Tiger Bittern	#									#		#		#						4
Nicobar Shikra	+		+	+							+			+	+	+	+	#	@	1,4
Nicobar Crested Serpent Eagle	+		+				+				#	#	#	#	#				@	2,3
Nicobar Megapode	+	+	+		+	+	+	+	+		+	+	+	+	+	+	+		@	2,3
Nicobar Bluebreasted Quail											+	+	+					#		4
Button Quail											#	#			#			#		5
Bluebreasted Banded Rail													#					#		4
Whitebreasted Waterhen	+							+			+	+	+	+	+		+	+		1,4
Andaman Pompadour Pigeon	+		+	+					+		+	+	+	+	+	+	+	+		5
Nicobar Green Imperial Pigeon	+		+	#	+	#	#	+	+		+	+	+	+	+	+	+	+		4
Nicobar Woodpigeon	#		?								#	#	#					#	*	4
Nicobar Cuckoo-dove	+	+	+	+							+	+	+	+	+	+	+		*	4
Nicobar Emerald Dove	+		+								+	+	+	+	+	+	#	+		4
Nicobar Pigeon	+			#	+		+				#		+		+	+	+	#		5
Blyth's Nicobar Parakeet	+		+					+	+										@	3
Nicobar Redcheeked Parakeet	+		+	+	+	+	+	?	?		+	+	+	+	+	+	+	+		4
Andaman Koel	+	+	+	+	+	+	+	+			+		+	+	+	+	+	+		5
Nicobar Scops Owl	#										#									4
Nicobar Brown Hawk-owl											#			#				#		5
Nicobar Hawk-owl	#										#	#						#	*	4
Andaman Greyrumped Swiftlet	+		+								+		+		+	+	+	#		5
Whitebellied Swiftlet	+		+	+							+		+	+	+	+		+		5
Andaman Three-toed Kingfisher	#		#																	5
Nicobar Storkbilled Kingfisher	+		+	+	+						?									3
White-collared Kingfisher	+										+	+	+	+	+	+	+	+		4
Nicobar Greenbreasted Pitta	+		+	+																3
Nicobar Blacknaped Oriole	+	+	+	+							+	+	+	+	+	+	+	+		4
Nicobar Racket-tailed Drongo	+	+	+	+					+					+				+		4
Andaman Glossy Tree Stare	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+		5
Nicobar Whiteheaded Myna														+				+		1,2
Nicobar Hill Myna	+		+						+		+	+	+	+						4
Nicobar Pied Cuckoo-shrike											+	#		+						2
Andaman Red-whiskered Bulbul											+	+	+	+	+			+		5
Nicobar Bulbul											+	#	+	+	+	#	+		@	2
Paradise Flycatcher	+										+	#	#	+						5
Nicobar Blacknaped Monarch	+		+		+				+		+		+	+	+	+	+	+		1,4
Nicobar Ground Thrush	#										#		#	+				#		4
Nicobar Olivebacked Sunbird	+	+	+	+		+	+		+	+	+	+	+	+	+	+	+	+		1,4
Nicobar Yellowbacked Sunbird	+		+!	+	#				+											3
Nicobar White-eye	+											#	+	+	+			+		5
Nicobar Whitebacked Munia											+	+		+				#		4
Total number of endemics	32	7	22	15	9	6	8	6	10	1	32	23	26	28	22	17	18	27		

Key: GN Great Nicobar, MI Megapode Island, LN Little Nicobar, PM Pilo Milo, MR Meroe, TR Treis, TA Trax, MN Menchal, KN Kondul, CA Cabra, CM Camorta, TR Trinkat, NN Nancowry, KT Katchall, TS Teressa, BP Bompoka, TI Tillanchong, CN Car Nicobar.

FE: @ = Full species endemic to the Nicobar islands; * = Full species endemic to the Andaman & Nicobar islands.

+ = Sighted by me; # = In literature, not seen by me.

SE: Subspecies endemic to: 1=Car Nicobar group, 2=Nancowry group, 3=Great Nicobar group, 4=two or more Nicobar island groups, 5=common to Andaman islands.

Figure 13. There can be no greater case made for the preservation of Great Nicobar than that of the Shompen (above), a tribe of hunter-gatherers who number barely 150. The loss or degradation of their forests can only result in the extinction of this tribe.

Conserving the Nicobar islands

Introduction

Biodiversity is the total variety of life on earth, and is highly threatened; in the economic sense biodiversity represents unimaginable wealth, in the ethical sense it is priceless (ICBP 1994). Where avian endemism is pronounced, there appears to be a high degree of endemism in other life forms (ICBP 1994), and therefore Endemic Bird Areas are of critical importance. Of the 27 major endemic Bird Areas in Asia (and of 221 in the world) the Nicobar islands is one, and thus is an important component of the biological wealth of India.

Although as much as 80% of the Nicobar islands are still covered by primary forest, and at least 60% is still relatively undisturbed, the trend over the last decade gives rise to grave concern. Three major issues need to be addressed immediately. First, the kind of development programmes that the islands are increasingly being subjected to and second, the growth of human population, particularly that of mainlanders. The third issue is the planning and implementation of a protected area network in the Nicobar islands, whereby the survival of the endemic species of the islands effectively ensured.

Important Islands / Island Groups

The primary difficulty while planning the conservation of islands is in the identification of islands or island groups that need action on a priority basis, as different islands, or island groups have their own distinct flora and fauna, all of which merit preservation. The only way to ensure their long-term survival is by developing conservation programmes for important islands and island groups, setting aside areas as wildlife reserves, where all but the barest of human use is excluded. Islands and island groups have been prioritised for conservation based on the number of endemic species and subspecies and also the number of Threatened or Near Threatened taxa.

Island Groups: From the data available (Tables 6 & 7), it is apparent that all three island groups are crucial to the endemic avifauna of the Nicobar islands, as all island groups have unique taxa. However, the Nancowry group of islands must perforce take first priority, as it not only has the highest number of endemic species and subspecies, but also the highest number of vulnerable taxa (Tables 6 & 7). Of second priority is the Great Nicobar group, as it also possesses a high number of endemics and the highest number of Near Threatened taxa (Table 6 & 7). The Car Nicobar group has the third priority because the island has the least number of endemics, only one of which is threatened.

Islands: The most important island for conservation in the Nicobar islands is Great Nicobar, as it has the highest number of endemic taxa (Table 5 & 7). It is also the largest island in the Nicobars, and large island size decreases the probability of extinction (Adler 1994). Three islands of the Nancowry group, Camorta, Katchall and Nancowry

Table 6. Number of endemic avifauna species and subspecies according to island groups.

Island groups	A	B	C	D	E
Great Nicobar	32	1	5	17	9
Nancowry	36	1	4	19	12
Car Nicobar	27	0	5	10	11

A Total no. of endemics present
B Endemic species exclusive to the subgroup
C Endemic subspecies exclusive to the subgroup
D Endemic species/subspecies common to other Nicobar Islands
E Endemic species/subspecies common to Andaman Islands

Table 7. Number of Endangered, Vulnerable, and Near Threatened avifauna species according to island group.

Island group	En	Vu	NT
Great Nicobar	0	0	10
Nancowry	0	6	9
Car Nicobar	1	1	6

En - Endangered; Vu - Vulnerable; NT - Near Threatened are ranked as second highest on the priority list, despite their inequality in number of endemics, because the conservation of these three islands will benefit all endemic species occurring in the Nancowry group. The only endangered bird, the Car Nicobar Shikra, in the Nicobar group of islands is on Car Nicobar, thus qualifying it as the third priority island.

Developing a Protected Area Network

In their monograph on planning a protected area network for India, Rodgers and Panwar (1988) state 'The scale of biological value in the Andaman & Nicobar islands is so great, that all protected area proposals must be seen as a major priority'. To ensure the long-term survival of the endemic avifauna of the Nicobar Islands it is imperative that a protected area network be developed whereby the habitats of most endemic taxa receive protection.

Existing Protected Areas

Only four of the 24 islands in the Nicobar group have Protected Areas. Batti Malv (2 sq km), Tillanchong (17 sq km) and Megapode Island (0.25 sq km), all uninhabited, are Wildlife Sanctuaries. Great Nicobar is a Biosphere Reserve (885 sq km), with two core areas; the Campbell Bay National Park (426.23 sq km), and the Galathea National Park (110 sq km). A part of Great Nicobar has been designated as a Tribal Reserve (119 sq km) for the Shompen (Pande *et al.* 1991), but much of this falls within the Biosphere Reserve.

Proposed Protected Area Network in the Nicobar group of islands

The existing protected area network in the Nicobar islands is inadequate for two reasons. Firstly, island groups which have both a large number of Andaman & Nicobar endemics and exclusive endemics are not adequately protected, and secondly, the design of the existing Great Nicobar Biosphere Reserve is flawed. I propose the creation of the Nancowry Biosphere Reserve, the redesigning of the Great Nicobar Biosphere Reserve and the inclusion of offshore waters into the two Biosphere Reserves.

Creation of the Nancowry Biosphere Reserve: Even though the Nancowry group has the highest number of endemics and is first on the priority list, only uninhabited Tillanchong island is protected as a Wildlife Sanctuary. Thus, only less than 3% of the area of the Nancowry group is protected. There is a need for a Biosphere Reserve in the Nancowry group, that encompasses all islands within the group. The core areas of the proposed Nancowry Biosphere Reserve should be the three islands that are of high priority, (Camorta, Katchall, and Nancowry), by whose conservation most endemic species in the Nicobar islands will be benefited (Fig. 14). Tillanchong, already a Wildlife Sanctuary, can form the fourth core area (Fig. 14).

Redesigning the Great Nicobar Biosphere Reserve: Although a little over 50% of Great Nicobar has been protected as National Parks and about 85% as Biosphere Reserve (885 sq km) (Fig. 15), this is inadequate. The buffer zones of Biosphere Reserves are designated as areas of multiple use. Although less than 10% of Great Nicobar is under human use, 35% of Great Nicobar has been designatedas a buffer zone. Moreover, the National Parks protect only the central portion and less than 15% of the coastal areas of Great Nicobar. The National Parks also leave unprotected a broad strip of primary undisturbed forest between them through which the East-West road passes.

The aparent flaws in the design of the National Parks on Great Nicobar are:

a) On islands, particularly hilly ones, the first area to be destroyed are coastal forests. This habitat, crucial to the survival of the Nicobar megapode is insufficiently protected (Fig. 14).
b) The southern tip of Great Nicobar, which is unprotected, comprises the largest uninhabited flat coastal forest in the Nicobar group and harbours large populations of species such as the Great Nicobar Crested Serpent Eagle, Nicobar Megapode, Blyth's Nicobar Parakeet and the Nicobar Pigeon.
c) The central portion of Great Nicobar is also unprotected.

About 40% of the coast of Great Nicobar and most of the southern tip and the central portion is uninhabited. These relatively undisturbed primary forests must be protected because any future change in policy can result in these areas being destroyed. Thus, a single National Park must be created in Great Nicobar merging the two existing ones and including the southern tip of the Island (Fig. 15). The buffer zone on the west coast can cover the areas used by the Nicobarese, and that on the east the areas where mainlanders have been settled.

The management of the buffer zones of the proposed National Park can follow two strategies according to the inhabitants of the zones. Those areas where the Nicobarese live must be left strictly alone because they interact with the forests in a relatively non-destructive manner. In the buffer zone on the east coast, which the mainlanders inhabit, programmes of afforestation and sustainable use of resources can be implemented. This will be necessary because in the future, with increasing human populations, there will be a great deal of pressure on the limited resources of the island.

The design of the Great Nicobar Biosphere reserve is inadequate also because it only covers absolutely pristine areas where the influence of mainlanders is non-existent and the influence of the tribals minimal. On Great Nicobar, the tribal populations are very small (fewer than 450 people, and most hamlets have barely 2 or 3 families), and it was evident that the pressures that they exert on the forests were well within sustainable limits. Thus, the existing Biosphere Reserve does not address the real needs which is

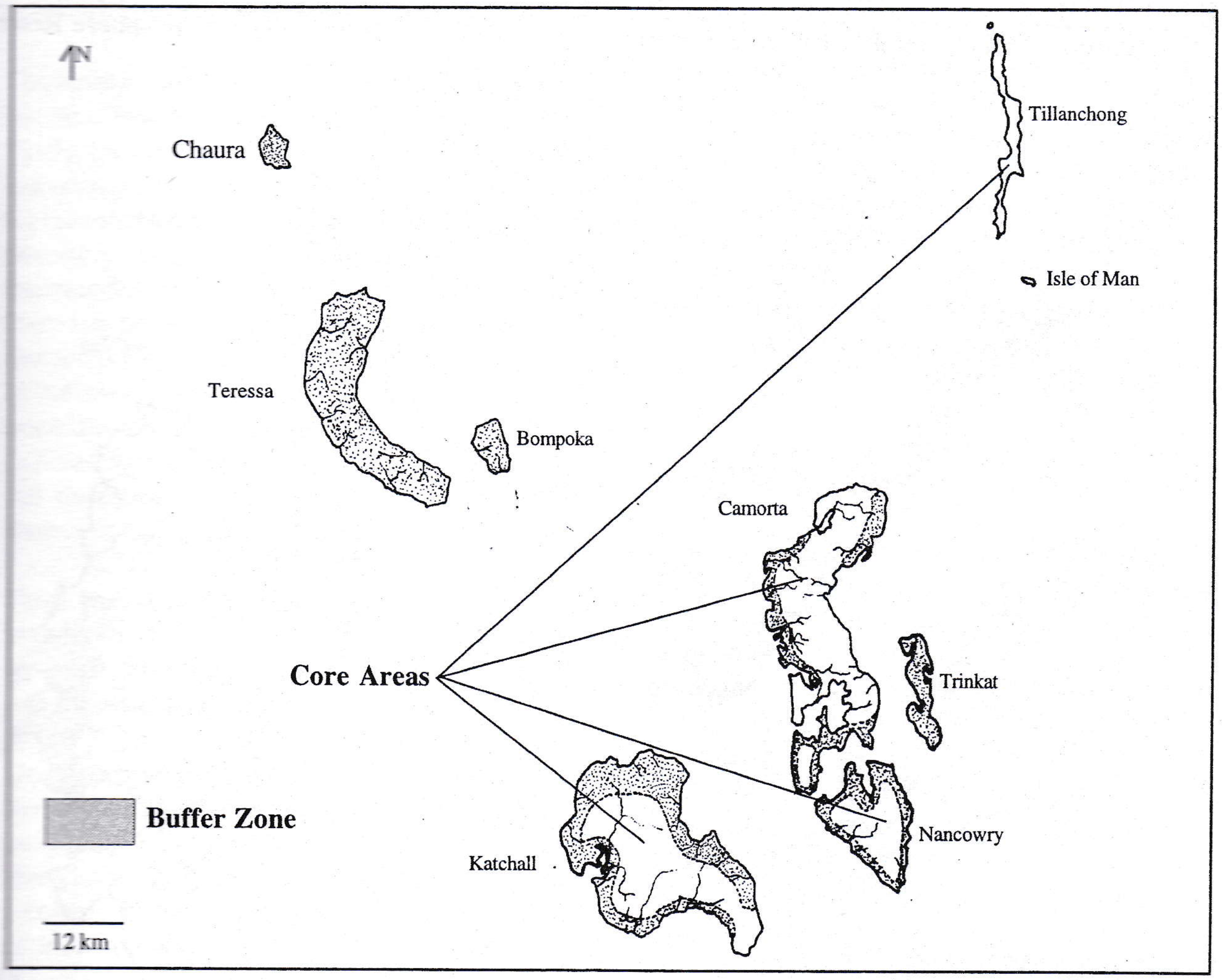

Figure 14. Proposed Nancowry Biosphere Reserve

cover areas that are used to a larger extent by man. The proposed Biosphere Reserve should cover the other Islands in the Great Nicobar Group, namely Kondul, Pilo Milo, Little Nicobar, Meroe, Treis, Trak and Menchal. Little Nicobar, currently unprotected, can have a satellite core zone as well (Fig. 15). The designation of Little Nicobar as a National Park has also been recommended by Rodgers & Panwar (1988).

Conserving offshore waters: The seas around each island are very rich in marine life and resources, many of which are of very high commercial value. There is, therefore, a greater need to provide some form of protection to offshore waters whereby utilisation of marine resources can be regulated at sustainable levels. The incorporation of the sea up to a distance of two nautical miles from the shore and the waters between islands into the Biosphere Reserves is probably the best solution. Alternately, a Marine National Park comprising the waters between the islands can be formed.

Specific Conservation Issues

Human population: Every document on the Andaman & Nicobar islands records a great deal of concern about the continuous inflow of mainlanders into the island group. All but two islands of the Nicobar islands are designated as tribal areas under the Protection of Aboriginal Tribes Act (1957). Therefore, on all islands, excepting Great Nicobar and Katchall, the presence of mainlanders is to primarily facilitate administration. But the growth in mainlander

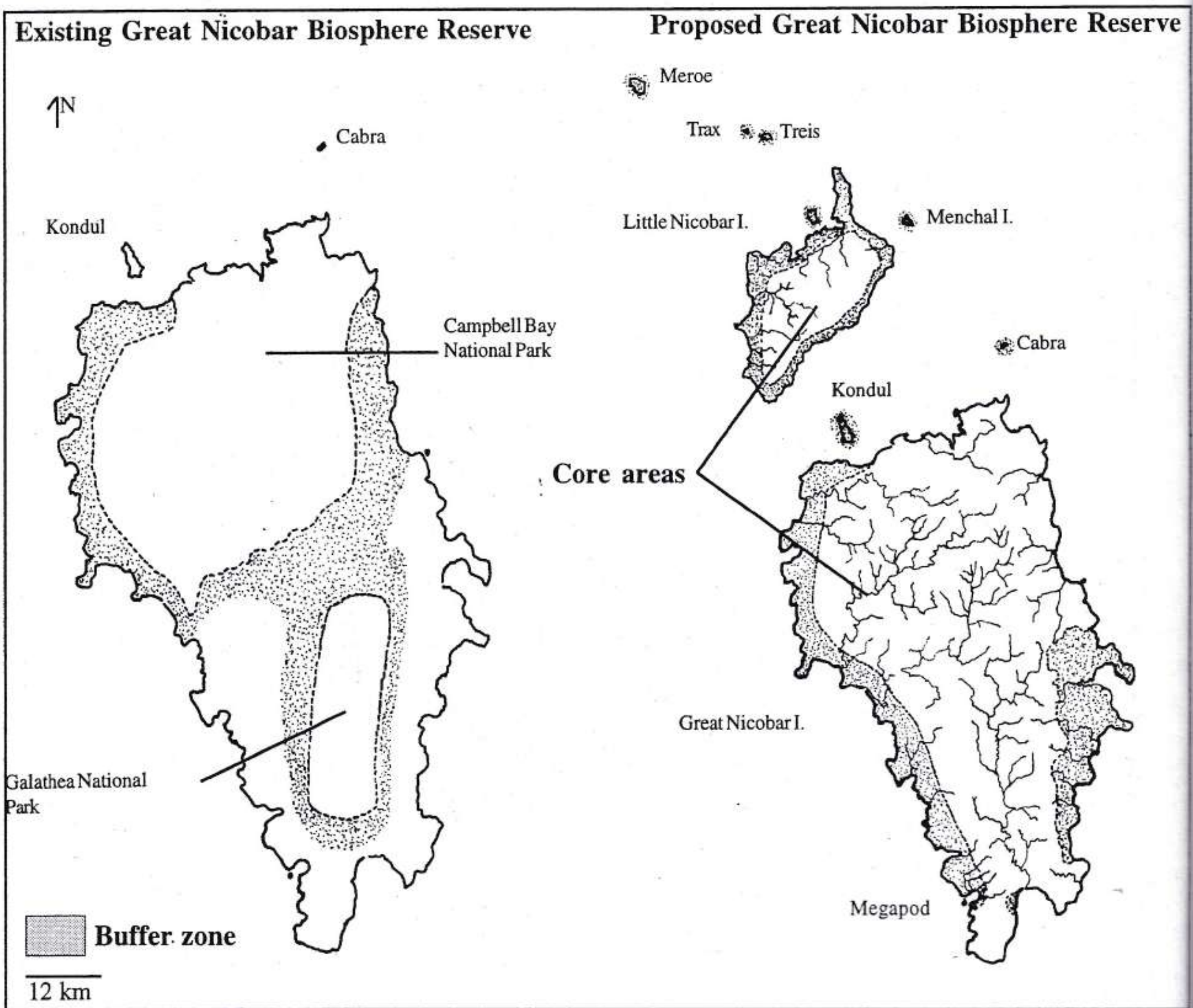

Figure 15. Proposed redesigning of the Great Nicobar Biosphere Reserve

population in the Nicobar islands is not commensurate with the growth of the tribal population. The density of mainlanders has grown from 4.7 per sq km to 7.3 per sq km between 1981 and 1991, an increase of 55%, whereas for the same decade the density of Tribals has increased from 10.8 per sq km to 12.8 per sq km, an increase of only 18.5% (Fig. 16, Appendix 5). The situation is most alarming on islands which are on the priority list for avian conservation where the growth in mainlander population has been greater than 50%, while the growth in tribal population has been less than 20%. The entire appeal against the growth of mainlander population can be illustrated with the case of Camorta. Given the fact that Camorta is a tribal area, and that mainlanders are primarily meant to facilitate the adminstration of the islands, for a population of 1406 tribals, there are 1567 mainlanders. Clearly there is an imbalance between the institutional manpower necessary for administration and the existing manpower and infrastructure.

The rapid growth in mainlander population in the Nicobar islands has three main repercussions. Firstly, there is an increased pressure on natural resources as the people are entirely dependent on fuel wood and building material from the forest. Secondly, as a considerable proportion of the mainlanders is employed by the Government, there has been a rapid expansion in the 'works' that are undertaken, the infrastructure built and in the townships. Thirdly, since the Nicobarese population is also increasing, a rapid growth of mainlander population in the islands will add to the depletion of resources and in the rapid destruction of forests.

Thus, it is imperative that the growth of the mainlander population is checked and if possible *reversed* if the natural resources are to remain within sustainable limits.

Development projects: The immediate threat to the Nicobar islands lies in the kind of development programmes that are being implemented. Like many other remote areas, the Nicobar islands receives a significant subsidy from the Government of India with very little financial return. This

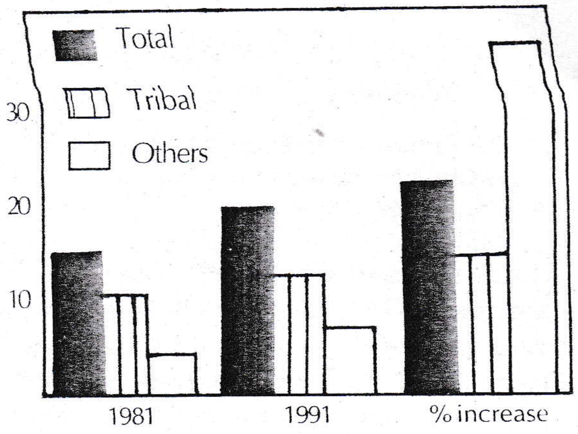

Figure 16. The increasing human population density in the Nicobar group of islands

disparity has resulted in a great deal of pressure on the adminstration to find ways and means by which money can be generated, which in turn has resulted in an acceleration of development. As development essentially means construction, this results in roads being made through undisturbed forests, construction of jetties to service small islands, diesel generated electricity grids for villages of as few as 19 houses and so on. An indicative example is the road from Camorta jetty to Pilpillow village, a distance of about 30 km. When completed, the road will cost the exchequer over one crore rupees. The beneficiaries, a village of 29 households could very well have been provided with a motor boat each at only a cost of Rs 24 lakhs! A more serious problem with indiscriminate development is that many environmentally disastrous schemes are sanctioned, particularly because of the absence of impact assessments by qualified agencies.

In the Nicobars, it is apparent that the kind of development currently underway and envisaged will not only have detrimental effects on the environment but will also result in the erosion of indigenous cultures. For the long-term conservation of the flora and fauna, and of the traditional cultures and lifestyles in the Nicobars a re-thinking on the development of these islands is necessary. Inherent to this is an in depth analysis into the money being spent there, how much of it is really required, and whether the money being spent is really beneficial to the Nicobarese and the Shompen.

Specific projects that need rconsideration

1. The proposed refuelling base and dry dock in Great Nicobar and making Great Nicobar a Free Port.

The most serious threat to the Nicobar islands, particularly Great Nicobar is the twin proposals of making Great Nicobar a free port (an alternate 'Hong Kong') and the building of a refuelling base at the Galathea Bay for international shipping plying the Great Channel. The consequent expansion in mainlander population for the building of necessary infrastructure, trade and other sectors will exert an enormous pressure on the resources of the islands. The worst affected will be the forests and the endemic flora and fauna. More alarming, these projects will have serious adverse repercussions on the shy Scheduled Tribe, the Shompens who hunt and fish in these forests.

Necessary action must be taken to ensure that Great Nicobar is left undisturbed, and that adequate safe guards are put in place which will ensure that such ecologically and socially disastrous projects are never permitted either now or in the future.

2. Roads

Accessability inevitably results in greater levels of exploitation. As the forests in the Nicobar islands are vulnerable to human use a blanket moratorium on the construction of roads in the Nicobar islands needs to be set in place.

Specifically:

a) *Re-alignment of the road leading to the Light House at Indira Point*

Just after 'km 46' on the North-South Road, (0 km = Campbell Bay and 51 km is the light house at Indira point), the road curves along a cliff face for a distance of about 200 m. While GREF, during Project Yatrik, had made a sea wall for part of the distance, sea action on the un-walled part has resulted in the road being cut away. There is a proposal to realign the road in order to by pass this cliff face by constructing a new road through forest further inland. It was understood that the repairing of the existing road, and the shoring of the cliff face is not only possible but will cost only a fraction of that of the new road. This road, from 'km 41' to light house, appears to serve the sole purpose of letting picnickers and other visitors reach the lighthouse situated at the southern tip of India. The cost of loss forest far outweighs the benefits of this road and hence should not be permitted.

b) *The East West Road*

The East West road in Great Nicobar links mainlanders settled on the east coast with Nicobarese on the west coast and runs through Shompen territory. Currently the road is not in use because bridges have broken down and the road is being reclaimed by the forests, but it is likely that the east west road will be made usable in the future. A serious reconsideration must be given as to whether this road is a desirable one, because it gives very easy access to the Nicobarese on the west coast and will bring the mainlanders into greater contact with Shompen. It is likely that greater contact will only have negative effects on the Shompens and the Nicobarese, and thus it would be preferable to leave this road as unusable.

c) *Proposed road in Katchall*

A proposal to construct a new road (about 25 km long) from Katchall jetty to West Bay Katchall along the eastern and southern coast has been proposed. This road passes through the habitat which is amongst the last remnant undisturbed coastal forests in the Nancowry group and where one of the few viable populations of the North Nicobar Megapode exists. As the construction of the road will result in the loss of primary habitat and be detrimental to the threatened North Nicobar Megapode, it is urged that the plans for this road be dropped.

General Issues

Hunting

Hunting is widespread in the Nicobar islands. The tribals are legally permitted to hunt, but an alarming trend in recent times is the increasing use of airguns to shoot pigeons. This has resulted in pigeon populations being severely depleted on several islands. A closed season during the breeding period needs to be immediately effected if the tribals are to 'harvest' pigeons in a sustainable manner.

Although, legally, mainlanders are not permitted to hunt, hunting of the wild boar is prevalent. Apart from wildboar, mainlanders did not appear to hunt other animals on a large scale, nor was there any evidence of hunting crocodiles for their skins in the Nicobar islands. While there is a stricter monitoring of hunting in Great Nicobar (because of the presence of the A.C.F. Wildlife there), there is apparently much less control in the Nancowry group. This needs to be looked into.

The most serious problem however, is from Thai poachers. Three islands are particularly affected, Great Nicobar, Little Nicobar and Tillanchong. While the Thais come to the Nicobars to dive for shells such as Tockus, Nautilus and Turbo they also hunt crocodiles (which are taken back live), collect Edible-nest Swiftlet's nests, and supplement their diet from the forest. A lot of damage is done by the Thais in the areas where they camp. The control of this menace is of primary importance in the Nicobar islands.

Infrastructure for the Forest Department

The infrastructure that the Forest Department currently has in the Nicobars is clearly inadequate. The Wildlife Guards are neither armed, nor does the Department have a single seaworthy vessel. Their mobility and capability of handling conservation issues or patrolling are thus greatly impaired. It is of paramount importance that both these facilities are immediately provided. One readily available source of seaworthy vessels are those confiscated from Thai poachers which can be put to good use by the Forest Department.

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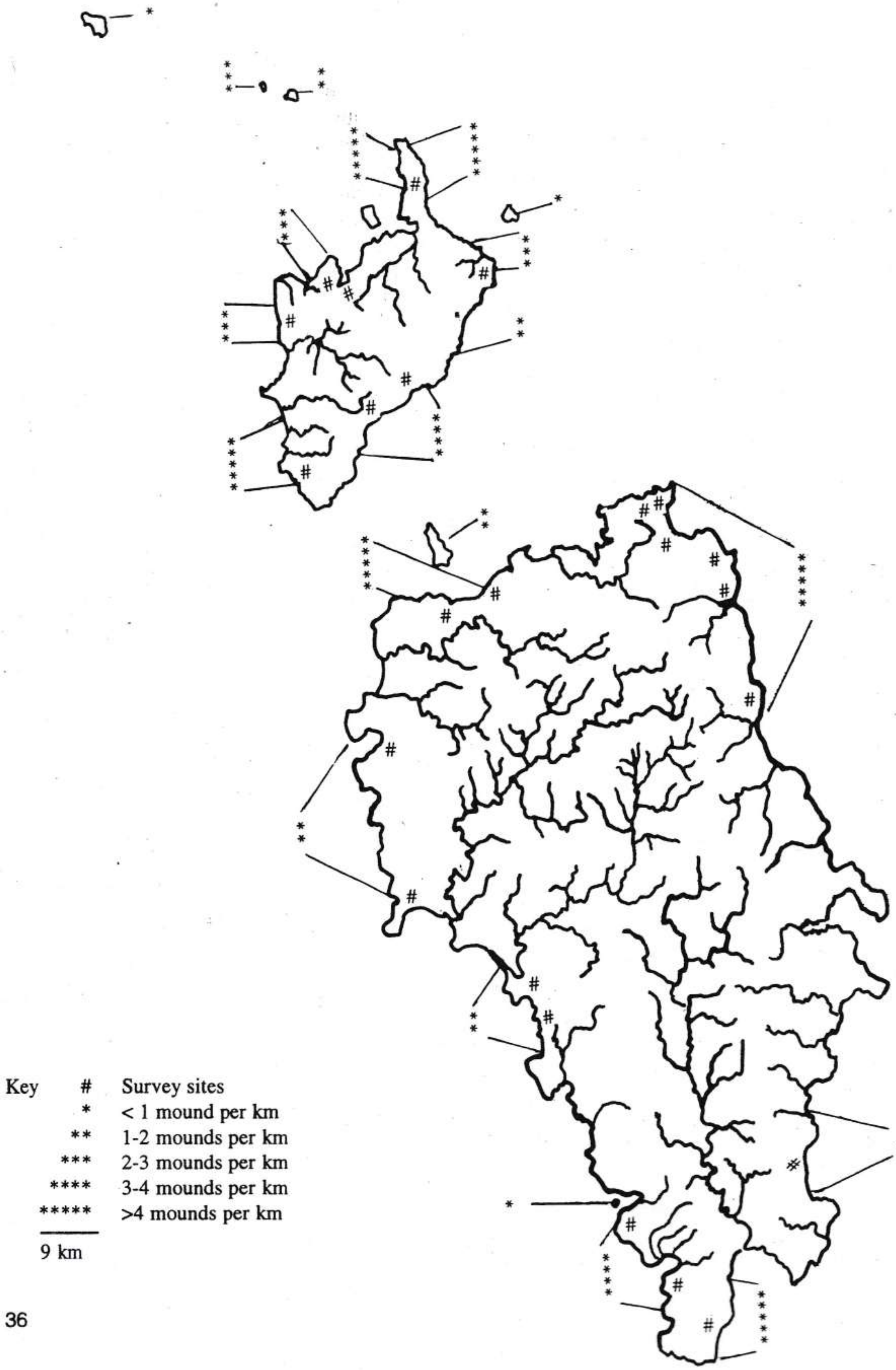
Appendices

1. **Distribution and encounter rate of active mounds in the Great Nicobar group of islands.**



3. The birds of the Nicobars - a review of literature and sightings of this survey

Common name	Species	E	A	Ref.
Red-tailed Tropic-bird	*Phaethon rubricauda rubricauda*			#
Longtailed Tropicbird	*Phaethon lepturus*		+	*
Grey or Spottedbilled Pelican	*Pelecanus philippensis philippensis*			#
Purple Heron	*Ardea purpurea manilensis*		+	#*
Dusky Grey Heron	*Ardea sumatrana sumatrana*			#
Little Green Heron	*Butorides striatus spodiogaster*		+	#*
Indian Pond Heron	*Ardeola grayii*		+	#*
Cattle Egret	*Bubulcus ibis coromandus*		+	#*
Intermediate Egret	*Egretta intermedia intermedia*		+	#*
Little Egret[1]	*Egretta garzetta garzetta*		+	#*
Eastern Reef Heron	*Egretta sacra*		+	#*
Night Heron	*Nycticorax nycticorax nycticorax*			#
Nicobar Tiger Bittern[2]	*Gorsachius melanolophus minor*	+		#
Chestnut Bittern	*Ixobrychus cinnamomeus*		+	#*
Yellow Bittern	*Ixobrychus sinensis*		+	#*
Lesser Whistling Teal	*Dendrocygna javanica*		+	#
Common Teal	*Anas crecca crecca*		+	#
Nicobar Shikra[3]	*Accipiter badius butleri*	+		#
Nicobar Shikra[3]	*Accipiter badius obsoletus*	+		#*
Horsfield's Goshawk	*Accipiter soloensis*		+	#
Whitebellied Sea Eagle	*Haliaeetus leucogaster*		+	#*
Pale Harrier	*Circus macrourus*		+	#
Montagu's Harrier	*Circus pygargus*		+	#
Marsh Harrier	*Circus aeruginosus aeruginosus*		+	#
Andaman Pale Serpent Eagle	*Spilornis cheela davisoni*	+	+	#
Nicobar Crested Serpent Eagle[4]	*Spilornis cheela minimus*	+		#
Great Nicobar Crested Serpent Eagle[5]	*Spilornis klossi*	+		#*
Osprey	*Pandion haliaetus haliaetus*		+	#
Peregrine Falcon	*Falco peregrinus japonensis*			#
North Nicobar Megapode[6]	*Megapodius n. nicobariensis*	+		#*
South Nicobar Megapode[6]	*Megapodius n. abbotti*	+		#*
Nicobar Bluebreasted Quail	*Coturnix chinensis trinkutensis*	+		#*
Indian Yellowlegged Button Quail	*Turnix tanki tanki*		+	#
Button Quail[7]	*Turnix tanki albiventris*	?	+	#
Andaman Bluebreasted Banded Rail	*Rallus striatus obscurior*	+	+?	#
Nicobar Bluebreasted Banded Rail[8]	*Rallus striatus nicobariensis*	+		#
Andaman Whitebreasted Waterhen	*Amaurornis phoenicurus insularis*	+	+	#
Whiteheaded Waterhen[9]	*Amaurornis p. leucocephalus*	+		#*
	Amaurornis p. midnicobaricus	+		#
Water Cock or Kora	*Gallicrex cinerea cinerea*		+	#
Moorhen	*Gallinula chloropus*		+	*
Purple Moorhen	*Porphyrio porphyrio poliocephalus*		+	#*
Grey Plover	*Pluvialis squatarola*		+	#
Golden Plover	*Pluvialis dominica fulva*		+	#*
Large Sand Plover	*Charadrius leschenaultii*		+	#
Kentish Plover	*Charadrius alexandrinus*		+	#*
Lesser Sand Plover	*Charadrius mongolus atrifrons*		+	#*
Whimbrel	*Numenius phaeopus phaeopus*		+	#*
Curlew	*Numenius arquata orientalis*		+	#
Bartailed Godwit	*Limosa lapponica lapponica*			#*
Redshank	*Tringa totanus totanus*		+	#*
Greenshank	*Tringa nebularia*		+	#
Green Sandpiper	*Tringa ochropus*		+	#

Common name	Species	E	A	Ref.
Wood Sandpiper	*Tringa glareola*		+	#
Common Sandpiper[10]	*Tringa hypoleucos*		+	#*
Turnstone	*Arenaria interpres interpres*		+	#*
Pintail Snipe[11]	*Capella stenura*		+	#
Eastern Little Stint	*Calidris ruficollis*		+	#
Little Stint	*Calidris minuta*		+	#*
Sanderling	*Calidris alba*			#
Broadbilled Sandpiper	*Limicola falcinellus*		+	#
Crab Plover	*Dromas ardeola*		+	#*
Great Stone Plover	*Esacus magnirostris magnirostris*		+	#
Large Indian Pratincole	*Glareola pratincola maldivarum*		+	#*
Roseate Tern	*Sterna dougallii korustes*		+	#
Eastern Blacknaped Tern	*Sterna sumatrana sumatrana*		+	#*
Large Crested Tern	*Sterna bergii*			#*
Indian Lesser Crested Tern	*Sterna bengalensis bengalensis*		+	#
Noddy Tern	*Anous stolidus pileatus*		+	#*
Andaman Pompadour Pigeon	*Treron pompadora chloroptera*	+		#*
Nicobar Green Imperial Pigeon	*Ducula aenea nicobarica*	+		#*
Pied Imperial Pigeon	*Ducula bicolor*		+	#*
Blue Rock Pigeon	*Columba livia*			#*
Nicobar Woodpigeon[12]	*Columba palumboides nicobarica*	+		#*
Andaman Cuckoo-Dove 13	*Macropygia rufipennis andamanica*	+	+	#
North Nicobar Cuckoo-Dove	*Macropygia rufipennis rufippenis*	+		#*
Nicobar Cuckoo-Dove	*Macropygia rufipennis tiwarii*	+		H*
Burmese Spotted Dove	*Streptopelia chinensis tigrina*			#
Nicobar Emerald Dove[14]	*Chalcophaps indica augusta*	+		#*
Nicobar Pigeon[15]	*Caloenas nicobarica nicobarica*	?	?	#*
Blyth's Nicobar Parakeet	*Psittacula caniceps*	+		#*
Nicobar Redcheeked Parakeet	*Psittacula longicauda nicobarica*	+		#*
Indian Lorikeet	*Loriculus vernalis vernalis*		+	#
Brainfever Bird	*Cuculus varius*		+	*
Indian Cuckoo	*Cuculus micropterus micropterus*		+	#*
Small Cuckoo	*Cuculus poliocephalus*			*
Himalayan Cuckoo	*Cuculus saturatus saturatus*		+	#
Indian Drongo-Cuckoo	*Surniculus lugubris*			#
Emerald Cuckoo	*Chalcites maculatus*		+	#*
Andaman Koel	*Eudynamys scolopacea dolosa*	+		#
Andaman Crow Pheasant	*Centropus sinensis andamanensis*		+	#
Nicobar Scops Owl[16]	*Otus scops nicobaricus*	+		#
Brown Hawk-Owl	*Ninox scutulata obscura*	+	+	#
Nicobar Hawk-Owl	*Ninox affinis isolata*	+		#
	Ninox affinis rexpimenta	+		#
Spotted Wood Owl	*Strix selaputo*			#
Fish Owl	*Ketupa javanensis* (= *Bubo ketupa*?)			#
Andaman Greyrumped Swiftlet[17]	*Collocalia fuciphaga inexpectata*	+		#*
Whitebellied Swiftlet	*Collocalia esculenta affinis*	+	+	#*
Brownthroated Spinetail Swift[18]	*Chaetura gigantea indica*		+	#
Indian Small Blue Kingfisher	*Alcedo atthis bengalensis*		+	#*
Andaman Three-toed Kingfisher	*Ceyx erithacus macrocarus*	+	+	#
Three-toed Kingfisher	*Ceyx erithacus erithacus*		+	#
Nicobar Storkbilled Kingfisher[19]	*Pelargopsis capensis intermedia*	+		#*
Blackcapped Kingfisher	*Halcyon pileata*		+	#*
Nicobar Whitecollared Kingfisher	*Halcyon chloris occipitalis*	+		#*
Bluetailed Bee-eater	*Merops philippinus philippinus*		+	#*

Commonname	Species	E	A	Ref.
Nicobar Greenbreasted Pitta	*Pitta sordida abbottii*	+		#*
Swallow	*Hirundo rustica gutturalis*		+	#*
Brown Shrike	*Lanius cristatus cristatus*		+	#
Philippine Shrike	*Lanius cristatus lucionensis*		+	#*
Nicobar Blacknaped Oriole	*Oriolus chinensis macrourus*	+		#*
Grey or Ashy Drongo	*Dicrurus leucophaeus*	?		#
Crowbilled Drongo	*Dicrurus annectans*			#
Nicobar Racket Tailed Drongo	*Dicrurus paradiseus nicobariensis*	+		#*
Andaman Glossy Stare	*Aplonis panayensis tytleri*	+	+	#
Glossy Tree Stare[20]	*Aplonis panayensis albiris*	+		#*
Nicobar Whiteheaded Myna[21]	*Sturnus erythropygius erythropygius*	+		#*
Katchall Whiteheaded Myna	*Sturnus erythropygius katchalensis*	+		#*
Daurian Myna	*Sturnus sturninus*			#
Indian Myna	*Acridotheres tristis tristis*		+	#
Andaman Hill Myna	*Gracula religiosa andamanensis*	+	+	#
Nicobar Hill Myna[22]	*Gracula religiosa halibrecta*	+		#*
Nicobar Pied Cuckoo-Shrike[23]	*Coracina davisoni nigra*	+		#*
House Crow	Corvus splendens			*
Ashy Minivet	*Pericrocotus divaricatus*		+	*
Fairy Bluebird[24]	*Irena puella andamanica*	+	+	#
Andaman Redwhiskered Bulbul	*Pycnonotus jocosus whistleri*	+	+	#*
Nicobar Bulbul	*Hypsipetes nicobariensis*	+		#*
Olive Flycatcher	*Rhinomyias brunneata nicobarica*		?	#*
Paradise Flycatcher	*Terpsiphone paradisi nicobarica*	+	+	#*
Car Nicobar Blacknaped Monarch[25]	*Monarcha azurea idiochroa*	+		#*
Nicobar Blacknaped Monarch[25]	*Monarcha a. nicobarica*	+		#*
Malay Streaked Fantail Warbler	*Cisticola juncidis malaya*			#*
Pallas's Grasshopper Warbler	*Locustella certhiola centralasiae*		+	#
Streaked Grasshopper Warbler	*Locustella lanceolata*		+	#
Thickbilled Warbler	Phragamaticola *aedon aedon*	+		#
Palelegged Leaf Warbler	*Phylloscopus tenellipes*			#
Indian Blue Rock Thrush	*Monticola solitarius pandoo*		+	#
Nicobar Ground Thrush	*Zoothera citrina albogularis*	+		#
Redthroated Pipit	*Anthus cervinus*		+	#
Forest Wagtail	*Motacilla indica*		+	*
Greyheaded Yellow Wagtail	*Motacilla flava thunbergi*		+	#
Blueheaded Yellow Wagtail	*Motacilla flava beema*		+	#
Grey Wagtail	*Motacilla c. caspica* (*c. cinerea*)		+	#*
Nicobar Olivebacked Sunbird	*Nectarinia jugularis klossi*	+		#*
Car Nicobar Olivebacked Sunbird	*Nectarinia jugularis proselia*	+		#*
Nicobar Yellowbacked Sunbird	*Aethopyga siparaja nicobarica*	+		#*
Nicobar White-eye	*Zosterops palpebrosa nicobarica*	+	+	#*
House Sparrow	*Passer domesticus*		+	#*
Nicobar Whitebacked Munia	*Lonchura striata semistriata*	+		#*
Yellowbreasted Bunting	*Emberiza aureola aureola*			#

n.b. Sightings during this survey only at the species level.

Key: E = (+) endemic to Andaman & Nicobar Islands, A = (+) occurs in the Andaman group also; Ref. = # from literature * sighted during this survey.

Source: Abdulali (1964a, 1964b, 1966, 1967, 1971, 1974, 1978), Das (1971), Dasgupta (1976), Ripley (1982). Ali & Ripley (1983).

Notes on species in Appendix 3. Given below are changes in names and current taxonomic classifications in Howard & Moore (1991). The numbers below correspond to those against species in Appendix 3.

1 Name changed to *Egretta garzetta schistacea.*
2 Not accepted; consider it to be *Gorsachius melanolophus,* which does not have any sub-species and which ranges from India to Greater Sunda.
3 Name changed to *Accipiter butleri butleri* and *Accipiter butleri obsoletus*
4 The Crested serpent eagle found in the Nicobar islands is now a single endemic species with two sub-species. *Spilornis minimus minimus* in the North Nicobar islands and *Spilornis minimus klossi* from Great Nicobar.
5 *Spilornis minimus klossi* on Great Nicobar.
6 Originally called *Megapodius freycinet.*
7 Not accepted; considered to be *Turnix tanki tanki,* which is found on mainland India.
8 Not accepted; considered to be *Rallus striatus obscurior,* the same as the Andaman race.
9 Do not accept both *Amaurornis phoenicurus leucocephalus* & *A. p. midnicobaricus.*
10 *Actitis hypoleucos.*
11 *Gallinago stenura.*
12 Do not differentiate *Columba palumboides* into sub-species. Instead a single species endemic to both Andaman & Nicobar islands.
13 Not accepted; consider *Macropygia rufipennis rufipennis* as endemic to Andaman & North Nicobars and *M. r. tiwarii* as endemic to Great Nicobar
14 Do not accept this subspecies and presumably consider it the same as *Chalcophaps indica maxima* of the Andaman group.
15 *Caloenas nicobarica nicobarica* is not endemic and occurs up to New Guinea islands.
16 Do not accept. Presumably consider the Nicobar birds as the same as those from Andamans *Otus scops modestus.*
17 Name changed to *Aerodramus fuciphagus.* Also not considered endemic and is distributed up to Greater Sunda and Timor Islands.
18 Now called *Hirundapus gigantea indicus.*
19 Now called *Halcyon capensis intermedia.*
20 Do not accept and consider Nicobar birds the same as *Aplonis panayensis tytleri* from the Andamans.
21 Consider *Sturnus erythropygius erythropygius* as endemic to Andamans, and *S. e. andamanensis* as endemic to Car Nicobar.
22 Do not accept. Consider Andaman & Nicobar birds as a single endemic race *Gracula religiosa andamanensis.*
23 Call it *Lalage nigra davisoni.*
24 Do not mention this species for Andaman & Nicobar islands!
25 Call it *Hypothymis azurea idiochroa* and *H. a. nicobarica.*

4. A rough estimate of habitat loss in the Nicobar group of islands.

	Area (sq km)	Forest (sq km)[1]	Forest loss (sq km)[2] Mainlander	Forest loss (sq km)[2] Nicobari	% habitat loss Forest	% habitat loss Grassland
Car Nicobar	126.9	124	5	50	45	0
Batti Malv	2.1	2	0	0	0	-
Chaura	8.2	8	0	6	73	-
Teressa	101.4	40	0	15	37	<5
Bompoka	13.3	10	0	2	20	-
Tillanchong	16.82	16	0	1	6	-
Katchall	174.4	174	10	20	17	-
Camorta	188.2	115	3	15	16	<4
Nancowry	66.9	54	0	10	18	0
Trinkat	36.3	15	0	10	65	0
Great Nicobar	1045.1	1045	75	15	9	-
Little Nicobar	159.1	159	0	12	8	-
Kondul	4.6	4	0	1.5	33	-
Pilo Milo	1.3	1	0	1	77	-
Megapode I.	0.13	0.1	0	0.05	50	-
Meroe	2	2	0	0.8	40	-
Treis	0.5	0.5	0	0.3	50	-
Trax	0.2	0.2	0	0.1	50	-
Menchal	1.5	1.5	0	1	67	-
Car Nicobar Group	129	126	5	50	44	-
Nancowry Group	605.52	432	13	79	21	3
Great Nicobar Group	1214.43	1213	75	32	9	-
Nicobar group	1948.95	1771	93	161	14	3
Nancowry + Great Nicobar groups	1819.95	1645	88	111	123	
Nancowry + Car Nicobar groups	734.52	558	18	129	263	

n.b.

1. This figure is hypothetical (i.e. area of forest prior to colonisation) and is used to assess % loss of forest till date on each island. Area under forest for islands without grasslands was considered to be the entire island. On islands with grasslands, forest cover is area of island minus that under grassland (rough estimate).

2. Estimates of habitat loss and forest cover are very crude approximations and must be treated as such. See methods for details of assessing habitat loss due to mainlanders and Nicobaris.

[-] Habitat not present on the island.

5. Changes in human population in the Nicobar islands between 1981 and 1991.

	1981 population census			1991 population census			1991 density (sqkm)			Density/sqkm		
	Total	Tribal	Others	Total	Tribal	Others	Total	Tribal	Others	1981	1991	%increase
Car Nicobar	15486	13514	1972	19336	15781	3555	152.4	124.4	28	122	152	24.6
Chaura	1118	1114	4	1225	1196	29	149.4	145.9	3.5	136	149	9.6
Teressa	1217	1165	52	1779	1617	162	17.5	15.9	1.6	12	18	50
Bompoka	53	50	3	51	51	0	3.8	3.8	0	4	4	0
Katchall	3702	2084	1618	5072	2491	2581	29.1	14.3	14.8	21	29	33.3
Camorta	2256	1269	987	2973	1406	1567	15.8	7.5	8.3	12	16	33.3
Nancowry	711	621	90	1014	907	107	15.2	13.6	1.6	11	15	36.4
Trinkat	378	377	1	350	350	0	9.6	9.6	0	10	9.6	0
Great Nicobar	4976	474	4502	6831	536	6295	6.5	0.5	6.0	5	7	40
Little Nicobar	298	298	0	308	295	13	1.9	1.9	0.1	2	2	0
Kondul	143	129	14	147	139	8	32	30.2	1.7	31	32	3.2
Pilo Milo	89	89	0	122	109	13	93.8	83.8	10	68	94	40.6
Car Nicobar Group	15486	13514	1972	19336	15781	3555	150	122	28	120	150	25
Nancowry group	9435	6680	2755	12464	8018	4446	21	13	7	16	21	31.3
Great Nicobar Group	5506	990	4516	7408	1079	6329	6	1	5	5	6	20
Nicobar islands	30427	21184	9243	39208	24878	14330	20.1	12.8	7.4	15.6	20.1	28.8

*Source: Government of India Census

About SACON

Sálim Ali Centre for Ornithology and Natural History (SACON) is a society registered under the Society Registration Act, 1960. The objectives of SACON are : (1) to study India's biological diversity so as to promote its conservation and sustainable use; (2) to study the ecology of the Indian avifauna with special reference to its conservation; (3) to foster the development of managers; and (4) to function as a regional nodal agency for the dissemination of information on biodiversity and its conservation. The centre is an autonomous Centre of Excellence, aided by the Ministry of Environment and Forests, Government of India. The administration of SACON is vested in the Governing Council which includes the Secretary, and Financial Advisor to the Ministry of Environment and Forests, Government of India. SACON's research activities are moderated by a Research Advisory Council, constituted by renowned wildlife scientists, forest managers and policy makers.

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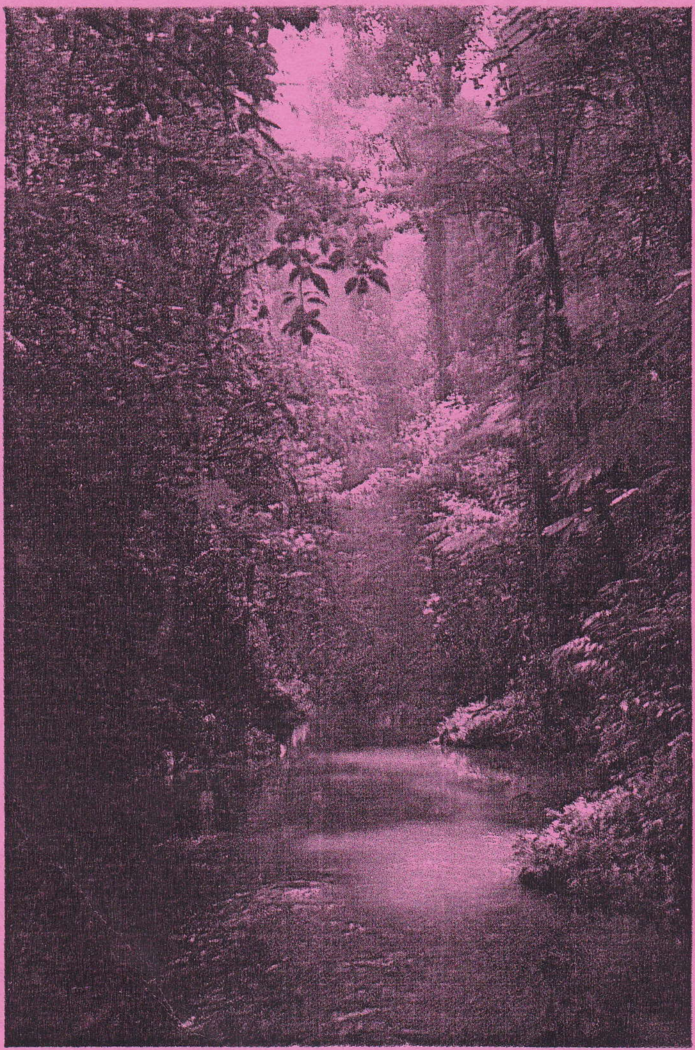

ANNEXURE A17

Chapter 3

Distribution and Speciation of Megapodes (Megapodiidae) and Subsequent Development of their Breeding Behaviour

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Abstract Megapodes (Megapodiidae), the most peculiar of all Galliformes, are of Gondwana origin. On the Australian plate they shifted from normal avian incubation to their aberrant strategy of incubating eggs in mounds of sand and leaf litter where heat is generated by microbial decomposition. From here, they spread through the Indonesian archipelago and eastwards into Polynesia, resulting in rapid speciation and the use of alternative heat sources for the incubation of their eggs.

1. Introduction

The distribution of megapodes (Aves, Galliformes, Megapodiidae), as well as their unique breeding behaviour, have led to conflicting theories as to their geographical origin and reproductive history. Olson (1980), and authors therein, assumed that megapodes reached Australia from southeast Asia, probably by the Miocene. He explained their current absence on the mainland of southeast Asia by competitive exclusion with pheasants (Phasianidae). However, since Olson's publication, a fossil of what was considered to be a megapode from Eocene-Oligocene deposits of France has been re-identified as representing a separate extinct family Quercymegapodiidae

W. Renema (ed.), Biogeography, Time, and Place: Distributions, Barriers, and Islands, 93–102

(Mourer-Chauviré, 1992), leaving no evidence for the former presence of megapodes outside Australasia. Since this publication by Mourer-Chauviré was overlooked by Newton (2003: 137–138; 160), the theory that megapodes reached Australia from southeast Asia still stands in recent literature. Alternatively, Cracraft (1973, 1980) proposed a Gondwana origin for the Galliformes and suggested that modern megapodes were present in Australia from the time of the breakup of Gondwana. Dekker (1989, 1990) considered predation by carnivores, especially Felidae and Viverridae, as a key factor explaining the absence of these birds from the mainland of southeast Asia and the Greater Sunda islands. Recent findings of a fossil (*Ngawupodius*) from the Late Oligocene at Lake Pinpa, Central Australia, now represents the earliest fossil record of the Megapodiidae (Boles and Ivison, 1999), supporting the theory of a Gondwana origin for the megapodes.

Various authors (e.g., Frith, 1962; Immelmann and Sossinka, 1986) considered the so-called burrow-nesting strategy, in which megapodes bury their eggs in holes in warm sand, as the original breeding strategy. However, Clark (1960, 1964a, b) and Dekker and Brom (1992) suggested that burrow-nesting has been derived from mound-building, in which megapodes bury their eggs in self-made mounds of decomposing, heat-generating leaflitter. The latter view was supported by recent workers. Starck (1993: 285) considered megapodes "a monophyletic taxon of Galliform birds with the superprecocial development as a derived character complex characterizing the taxon" and stated that "the breeding biology is derived from "normal" avian incubation and not from sauropsid ancestors". Later, Starck and Sutter (2000: 542) wrote "that megapode development does not differ substantially from galliform precocity". Booth and Jones (2001: 192) (unaware of Boles and Ivison, 1999) were of the opinion that "megapodes almost certainly evolved from a galliform ancestor, as early as the Pliocene … and this probably had a ground nest with large clutches of synchronously hatching, highly precocial chicks commonly seen in extant galliforms".

Although some of these discussions are recent, all were published when no phylogenies based on nuclear and mitochondrial DNA sequences were available. These were first published by Birks and Edwards (2002). The relationships within the genus *Megapodius* might prove to be crucial to the discussion. The phylogenies of Birks and Edwards will form the basis for this discussion about the geographical origin and reproductive history of the family.

2. Megapode Phylogenies and Other Relevant Publications

After the publications by Mourer-Chauviré (1992), in which she no longer considered a fossil from Eocene-Oligocene deposits of France to be that of a megapode, and that of Boles and Ivison (1999), who confirmed the presence of the Megapodiidae in Australia as early as the Late Oligocene, there is general agreement that megapodes were isolated in Australo-Papua for an extended period. A Gondwana origin would in fact link the Megapodiidae with the South American cracids (Family Cracidae), which are by some considered the sister-group of the megapodes. Sibley and Ahlquist (1990) placed the megapodes and cracids together in the order Craciformes. However, research based on 102 morphological characters, including 89 based on osteology, made Dyke et al. (2003) consider a monophyletic Megapodiidae to be the sister-group to all other Galliformes and to be the most basal clade within the order. The recovery, by Sibley and Ahlquist (1990), of a single clade comprising both Megapodiidae and Cracidae is not supported by a single morphological character (Dyke et al., 2003).

Brom and Dekker (1992: 15, Fig. 5) published a phylogeny of the Megapodiidae based on traditional, mainly morphological characters (see also Jones et al., 1995). Seven years later, Mey (1999: 30, Fig. 5) published a phylogeny of the megapodes based on the phylogeny of the chewing lice found on them. Birks and Edwards (2002), who sequenced nuclear and mitochondrial DNA, included in their studies 15 of the 22 extant species representing all seven genera. Their phylogeny, which included representatives of other Galliform families as outgroups, shows an early split in megapodes, leading to two major clades: (1) *Alectura*, *Aepypodius*, *Leipoa*, *Talegalla* and *Macrocephalon* and (2) *Eulipoa* and *Megapodius*. It is largely congruent with the phylogeny by Mey (1999), but differs from the one published by Brom and Dekker (1992), in which *Leipoa*, *Talegalla*, *Macrocephalon*, and *Megapodius* (including *Eulipoa*) form a clade.

Of the 13 species within the most widely dispersed genus *Megapodius*, which includes species exhibiting all the different breeding strategies, no less than nine species (totalling 14 populations or subspecies) were sampled by Birks and Edwards (2002). Additional morphological studies by Roselaar (1994: 21) add to this and together they offer great opportunities for a renewed discussion on the historical distribution, dispersal and evolution of the unique reproductive systems within megapodes. The relationships within the genus *Megapodius* do show some remarkable results (for details, see Birks and Edwards, 2002): *M. tenimberensis* from Tanimbar and *M. cumingii* from Sulawesi and the Philippines are an early split (*M. bernsteinii* (Sula Islands), which was not included in the analyses, might fit with these (Roselaar, 1994), as might *M. nicobariensis*). *Megapodius eremita* from the Solomon Islands and *M. layardi* from Vanuatu are not close relatives as was previously suggested based on distribution: they represent descendents of different waves of dispersal. Furthermore, *M. layardi* and *M. pritchardii* from Niuafo'ou, Tonga, are sister-taxa. Some of the conclusions by Birks and Edwards (2002) are congruent with Roselaar (1994).

3. Possible Scenario of Current Distribution and Breeding Strategies

3.1. Distribution

The position of the Australian continent during the Late Oligocene (Fig. 1) is the starting point for the discussion as it was there and then that we know of the earliest occurrence of megapodes: the recently discovered, extinct, megapode *Ngawupodius minya* (Boles and Ivison, 1999).

During the Oligocene, the Australian continent was well isolated, slowly drifting north and colliding with New Guinea. In the Early Miocene, New Guinea

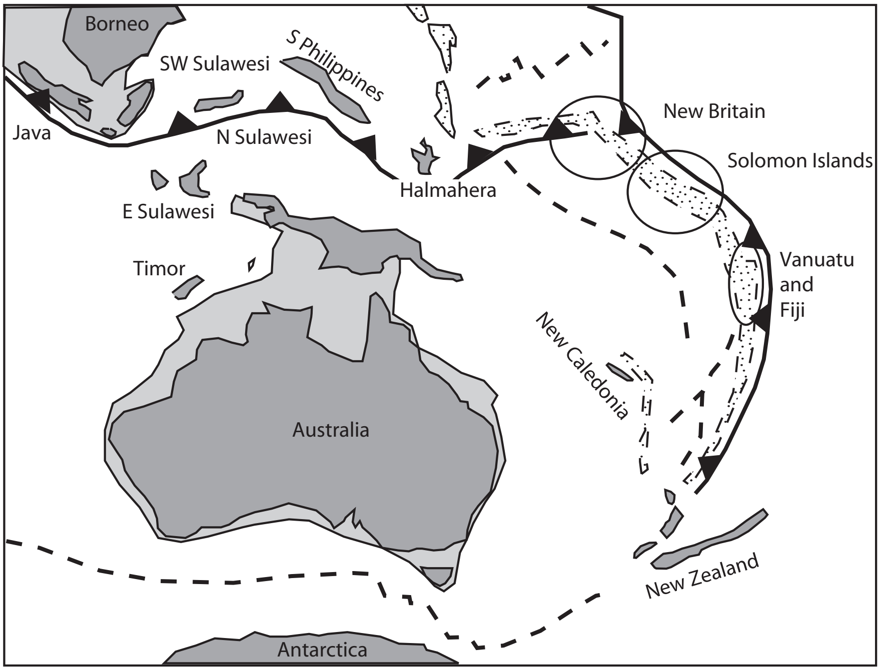

Fig. 1 Position of the Australian continent during the Oligocene (34–24 Ma) (after Hall, 1998)

was a series of islands on the northern edge of the Australian plate. During the Middle Miocene, from about 15 Ma, larger parts of New Guinea were uplifted to above sea level. Northern Australia had a warm, wet climate, which became gradually cooler and drier by the Late Miocene. During the Pliocene, 5.3–1.8 Ma there was an overall cooling of sea and land temperatures, and Australia collided with the Timor region. Active dispersal of animals, including that of megapodes, which began to gain their modern appearances, took place using islands as stepping stones as the Australian continent continued to approach the Asian continent. During the past 10,000 years the position and climate of Australia has changed little.

The earliest known fossil occurrence of the Megapodiidae was, until the discovery of the tiny *Ngawupodius minya* by Boles and Ivison (1999), from the Pliocene of Australia and relates to (what was until recently considered) a single extinct genus *Progura* (but see below). The Pleistocene fossil record of megapodes from Australia is dominated by this megapode, which was bigger than any of the extant taxa and most likely a poor flyer. Initially believed to include two species, *P. gallinacea* and *P. naracoortensis*, it was subsequently considered to represent a single species *P. gallinacea*. Differences in size were explained by sexual dimorphism (Boles and Ivison, 1999: 200; Steadman, 1999: 9) but are now seen as representing individual variation or stage of maturity (W. Boles, 2004, unpublished). Boles

(2004, unpublished) thus synonymized *Progura* with *Leipoa* stating "*Progura* is not separable from *Leipoa* and the differences between *P. gallinacea* and *L. ocellata* are mainly quantative (size), with qualitative differences so small that it is doubtful that these represent distinct species. *P. gallinacea* appears to be the megafaunal version of *L. ocellata. P. gallinacea* becomes either *Leipoa gallinacea* (if the two are kept as separate species) or *Leipoa ocellata gallinacea* (if considered temporal subspecies of a single species)". The record of the modern *L. ocellata* from the Victoria Fossil Cave, which was based on a damaged skeleton of a chick, is not valid, leaving no evidence of modern *L. ocellata* elsewhere in the Pleistocene or earlier (W. Boles, 2004, unpublished).

Outside Australia, only few fossil remains involving megapodes other than *Megapodius* species, are known. These are late Quaternary cave deposits in Irian Jaya containing the extant *Aepypodius arfakianus* (Aplin et al., 1999) and late Pleistocene-Holocene deposits in Fiji containing *Megavitiornis altirostris*, a large, quite unusual extinct megapode (Worthy, 2000). *Sylviornis neocaledoniae*, a large and flightless extinct bird from New Caledonia, once believed to be either a ratite (Poplin, 1980) or a megapode (Poplin et al., 1983), is no longer considered a megapode but better placed in a family of its own (for a summary, see Jones et al., 1995: 23). The fossil record as summarized here, with ancestral megapodes restricted to the Australian landmass (including New Guinea) and (recently) Fiji, makes it most likely that the unique incubation strategy has developed here.

No fossils are known from New Zealand, which separated from Gondwana *c*. 85 Ma. All fossil records in Polynesia are from the Holocene, representing species of the genus *Megapodius* which were exterminated from islands after the arrival of the Polynesians. The Polynesian megapode *Megapodius pritchardii*, which was long believed to have been introduced to Niuafo'ou (Tonga), is in fact a relic of a once much wider distribution. Fossil remains of this species have been found on Foa and Eua (Tonga) and it is suggested that it occurred on perhaps as many as 100 individual islands in the region (Steadman, 1999: 13). Steadman (1999) discussed the biogeography and extinction of megapodes in Oceania, from which at least five different extinct species (all *Megapodius*) are now known. He estimated that at least as many species have gone extinct as still exist today: "if not for people, the figure of 22 living species of megapodes would increase to 45–55 species" (Steadman, 1999: 16).

Although many of the present day megapodes, including all *Alectura*, *Aepypodius*, *Leipoa*, and *Talegalla* species which are restricted to Australia or New Guinea and *Macrocephalon maleo* from Sulawesi, are poor flyers, the smaller *Eulipoa wallacei* from the Moluccas and all *Megapodius* species are strong flyers. They can easily cover vast areas of open water, even at the chick stage. It is therefore no coincidence that species of *Megapodius* are widely distributed and occur on islands in the Pacific, eastern Indonesia, the Philippines, and the Mariana and Nicobar islands. *Macrocephalon*, *Eulipoa*, and *Megapodius* will have colonized these islands from the Australian plate in different waves. Also within the genus *Megapodius*, different waves of dispersal have taken place. For a map of the current distribution of the family, see Jones et al. (1995: 21).

Roselaar (1994: 21) was of the opinion that “the present-day distribution of *Megapodius* with a single species on each group of islands is apparently not due to fragmentation of the range of a once widespread species, but is more likely the result of a long history of colonizations and extinctions by a number of species”. He believed that “a history of invasions and extinctions by various species of *Megapodius* may explain some of the peculiarities in their present-day distribution.” Furthermore, he considered *M. reinwardt* to be a recent successfully spreading species.

3.2. Breeding Strategies

Megapodes exploit three different sources of heat for the incubation of their eggs. Those that build mounds use rotting vegetation for incubation, while burrow-nesters dig holes in volcanically heated soil or in sun-exposed warm sand in which they bury their eggs. All seven species of the genera *Alectura* (1), *Aepypodius* (2), *Leipoa* (1), and *Talegalla* (3), which are restricted to either Australia or New Guinea, are strict mound-builders. *Macrocephalon maleo* from Sulawesi and *Eulipoa wallacei* from the Moluccas are strict burrow-nesters and do not build mounds. Within the widely distributed genus *Megapodius* some species are strict burrow-nesters, others build mounds, while a few species can do both. Figure 2 shows the incubation strategies superimposed on the cladogram by Birks and Edwards (2002). Figure 3 shows the same for the genus *Megapodius*, superimposed on a map of their current distribution. The four *Megapodius* species not sampled by Birks and Edwards (*M. decollatus* from New Guinea, *M. geelvinkianus* from the Geelvink islands, *M. bernsteinii* from the Sula Islands and *M. nicobariensis* from the Nicobars) are all strict mound-builders.

Burrow-nesting megapodes, those using heat sources other than rotting vegetation, all live on islands and are not found in Australia and New Guinea. They occur in places which have been colonized by active dispersal (flight), as many of these islands have always been isolated. It suggests that burrow-nesting developed secondarily when new habitats, some of volcanic origin or with sun-exposed beaches, were invaded. These new, often tropical habitats led to a radiation in breeding behaviour and speciation within the genus *Megapodius*. Heat necessary for the incubation of their eggs did not have to be produced by the arduous task of raking together large mounds of leaves in which birds dig a hole and bury their eggs – heat was “simply” there. They shifted from building and maintaining mounds to the simple task of digging a hole in warm sand. The increase in relative size and yolk content of the eggs in burrow-nesting species compared to that of their mound-building relatives (Dekker and Brom, 1992), which results in even larger and more precocial (superprecocial *sensu* Starck, 1993) chicks in burrow-nesters, is an indication that burrow-nesting is derived from mound-building.

When the Australian plate moved closer to Asia and sea levels changed, islands could have acted as “stepping stones” and inter-island distances might have alternately decreased and increased. Ancestral megapodes were thus able to reach

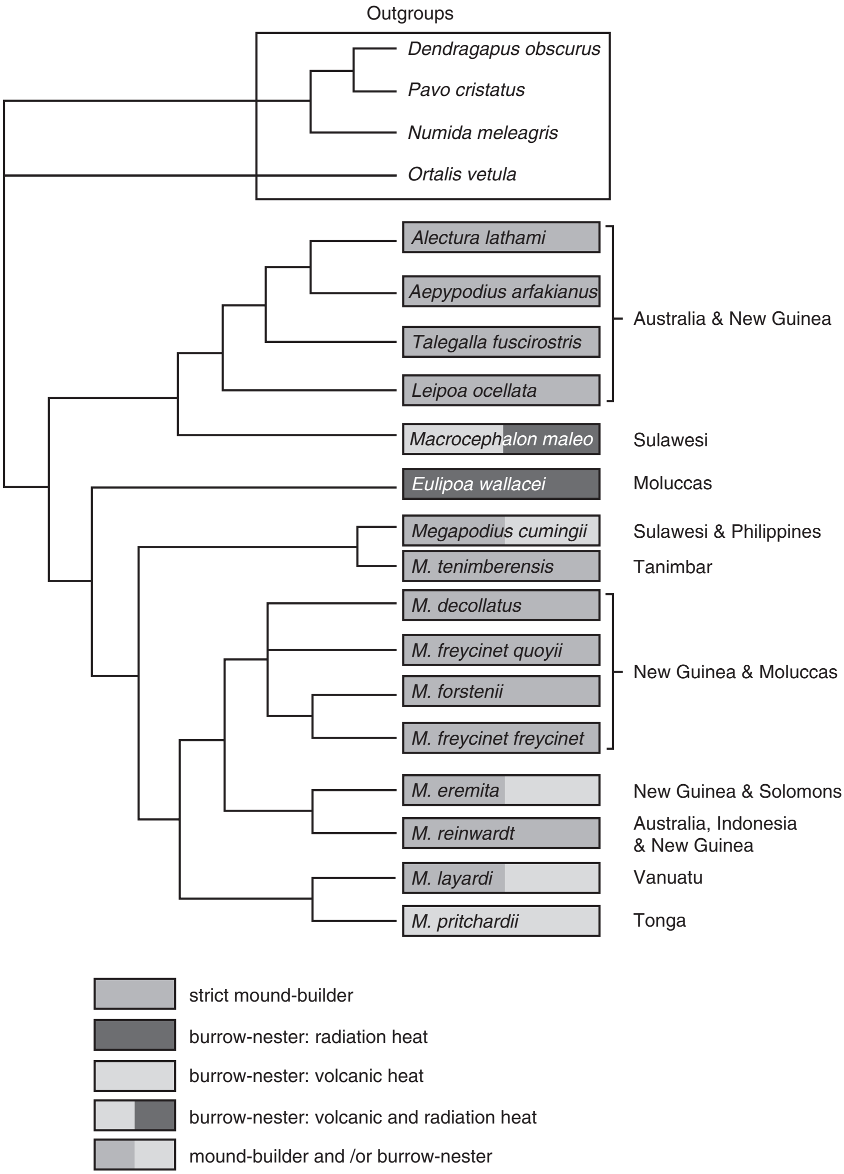

Fig. 2 Phylogenetic tree of the family Megapodiidae (redrawn from Birks and Edwards, 2002) showing the incubation strategies exhibited by the different taxa.

new habitats, passively and actively, where they became isolated. This led to a diversification in taxa as well as reproductive strategies. Their move westwards to the mainland of southeast Asia was subsequently halted by the presence of carnivore predators (Dekker, 1989) or – as suggested by Olson (1980) – by competition with

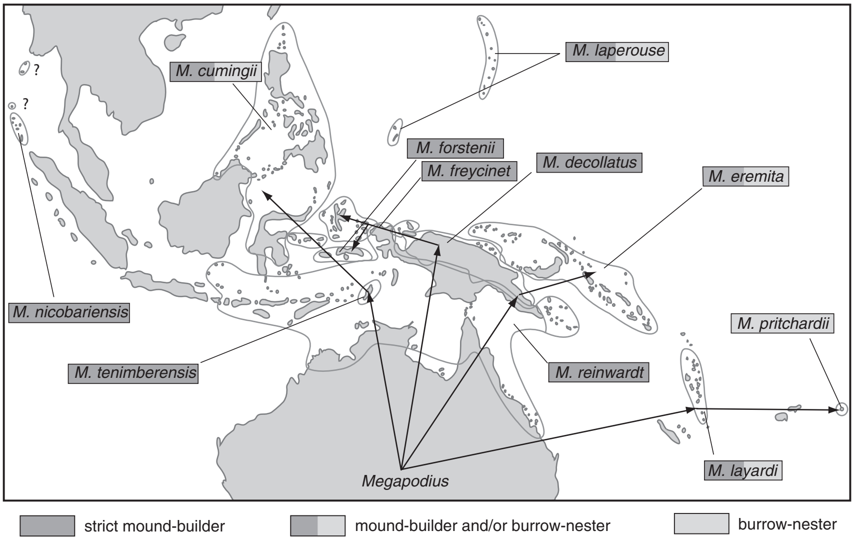

Fig. 3 Cladogram of the genus *Megapodius* superimposed upon a map of the region.

phasianids, or both. The absence of megapodes from the Greater Sunda Islands, either primarily or secondarily, can be explained in a similar way. The presence of *M. cumingii* on small islands off Borneo and of *M. nicobariensis* on the Nicobars (this species is not included in Fig. 2, but most likely closely related to *M. cumingii*) seems a relic and would suggest that megapodes once did occur on the Greater Sunda Islands from which they disappeared either through predation or competition. This has, however, not (yet) been substantiated by fossil evidence. Looking eastwards into the Pacific, we know through the work by Steadman (1999) that most islands in western Polynesia were once inhabited by megapodes and that Man is largely responsible for their absence now. The easternmost islands ever reached were Niue (Tonga) and American Samoa. The distance between the Pacific islands as well as the fact that these islands become more and more remote from the source of the "megapode origin" diminishes the chance for individual megapode taxa to reach a certain island. This might have stopped further spreading of megapodes across the Pacific.

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3~~6~~4 ANNEXURE A18

Impact of the 2004 tsunami on the Vulnerable Nicobar megapode Megapodius nicobariensis

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Impact of the 2004 tsunami on the Vulnerable Nicobar megapode *Megapodius nicobariensis*

K. Sivakumar

Abstract The small, isolated populations of the Nicobar megapode *Megapodius nicobariensis*, currently categorized as Vulnerable on the IUCN Red List, on the Nicobar islands in the Indian Ocean have declined by c. 70% since 1994. The 2004 tsunami is believed to be the major cause of this decline. The populations of megapodes on the islands of Megapode and Trax were wiped out by the tsunami. I estimate from a 2006 survey that 395–790 breeding pairs of the Nicobar megapode now survive on the coasts of the various islands compared to 2,318–4,056 pairs in 1994. The tsunami also adversely influenced nest-site selection and mound-nest ecology: > 50% of mounds were found closer to the shore in 2006 than in 1994, probably because of loss of suitable habitat, and they may become inundated with seawater during high tides. Most of the mound-nests found were constructed after the tsunami and were significantly smaller in volume than those present in 1994. Restoration of suitable habitat is critical for the long-term viability of the Nicobar megapode. However, post-tsunami impacts such as the creation of large-scale plantations in coastal areas, which are encroaching upon megapode habitat, may be severe. Because of the decline in numbers and habitat destruction and hunting the Nicobar megapode probably now qualifies for categorization as Endangered on the IUCN Red List.

Keywords Coastal biodiversity, habitat selection, isolated population, *Megapodius nicobariensis*, Nicobar islands, Nicobar megapode

Introduction

Isolated populations of rare species may be disproportionately affected by both stochastic and deterministic factors such as hurricanes, fires, changes in habitat quality, inbreeding and genetic drift (Soulé, 1987; Burgman et al., 1993). To conserve such species there is a need to assess the impacts of such factors on the long-term survival of individual populations (Karen, 1998). An earthquake with a magnitude of 9.15, with its epicentre at 3.29° N and 95.94° E off the coast of Sumatra and with a focal depth of 30 km, occurred on 26 December 2004 at 06.29. It triggered a tsunami that, amongst other effects, engulfed the entire low-lying coastal forests of the Nicobar islands in the Bay of Bengal. The waters, which took several days to recede, devastated the people and wildlife of the Nicobar islands (Sankaran, 2005). This was the first recorded major natural catastrophe for the islands.

One species expected to have been adversely affected by the tsunami is the Nicobar megapode *Megapodius nicobariensis*. The megapodes utilize external sources of heat to incubate their eggs (Jones et al., 1995). The Nicobar megapode, a mound nesting bird, is endemic to the Nicobar Islands, separated from its nearest congener by a distance of > 1,500 km (Lister, 1911; Olson, 1980). There are two subspecies: *M. n. nicobariensis* on the Nancowry group of Islands north of the Sombrero channel and *M. n. abbotti* on the Great Nicobar group of islands south of the channel (Hume & Marshall, 1878; Abdulali, 1964; Ali & Ripley, 1983; Fig. 1). The species builds three types of mounds: A, built in open areas away from trees; B, built against a living tree base; C, built on or around a dead log or stump (Dekker, 1992; Sankaran, 1995b; Sankaran & Sivakumar, 1999; Sivakumar, 2000) and the sources of heat that create suitable incubation conditions vary with mound type, location and dimensions (Jones, 1987; Bowman et al., 1994; Palmer et al., 2000; Sinclair, 2002; Sinclair et al., 2002; Sivakumar & Sankaran, 2003).

Historically the Nicobar megapode occurred on all Nicobar Islands (Hume, 1874; Kloss, 1903; Dekker, 1992; Sankaran, 1995a,b) except Car Nicobar (Butler, 1899), Chaura (Abdulali, 1967) and Bati Malv (Sankaran, 1995a). There are a few records of megapodes from the Andaman group of islands (Hume, 1874; Butler, 1899; Sewell, 1922) and from the Coco Islands further north (Kloss, 1903; Abdulali, 1964). None of the records from the Andaman group are of recent origin and the species is now believed to be absent there (Sankaran, 1995a,b). In 1994 the population of *M. n. abbotti* was estimated to be 3,400–6,000 and the number of active mounds 849 (Sankaran, 1995a). The population of breeding adults of *M. n. nicobariensis* was estimated to be 1,200–2,100 and the number of active mounds c. 300 (Sankaran, 1995a). Habitat loss, hunting and egg collection are considered the major threats to the megapodes (Jones et al., 1995; Sivakumar & Sankaran, 2003).

The 1994 survey of the Nicobar megapode (Sankaran, 1995b) was the only one made before the tsunami. I therefore took this as a baseline for comparison with the status and distribution of the megapode in 2006, one nesting season after the tsunami. Post-tsunami restoration, especially of coastal habitat, is still required in the Nicobar

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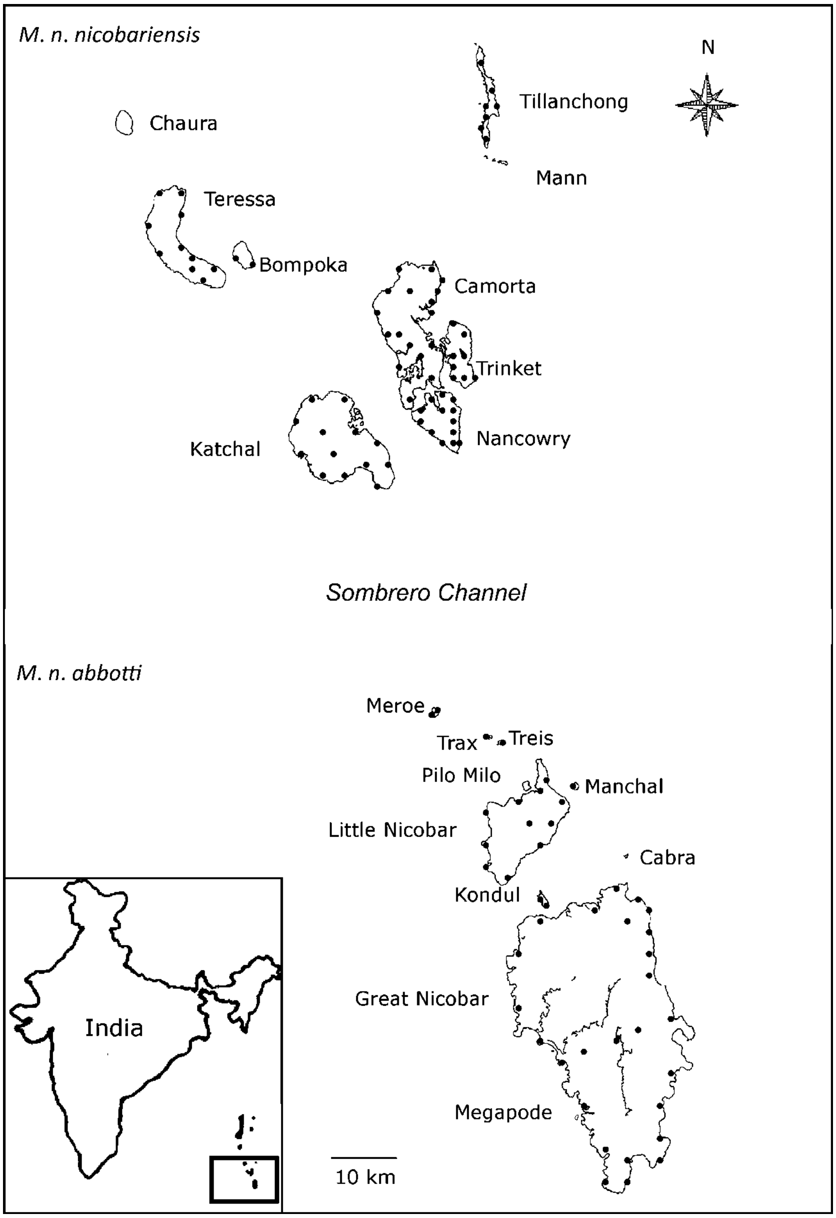

FIG. 1 *Megapodius nicobariensis* occurs as two subspecies: *M. n. nicobariensis* on the Nancowry island group north of the Sombrero channel and *M. n. abbotti* on the Great Nicobar island group south of the channel. The locations of the transects on each island are indicated as black circles. The inset indicates the location of the islands in the Bay of Bengal.

islands. However, any ill-planned restoration could adversely affect the coastal-living megapodes. I therefore studied the post-tsunami conservation status of the coastal populations of the Nicobar megapode to provide information to support appropriate conservation action.

Study area

The Nicobar Islands can be subdivided into three subgroups based on ornithological affinities (Sankaran, 1995a). To the south lies the Great Nicobar group consisting of two islands > 100 km^2, nine islets > 5 km^2 in area, and a few rocks. Among them, Great Nicobar, Little Nicobar, Kondul and Pilo Milo are inhabited, and Meroe, Treis, Trax, Menchal, Megapode, Cabra and Pigeon are uninhabited. Fifty-eight km north of the Great Nicobar group is the Nancowry group (Fig. 1) comprising three islands >100 km^2, two of 36 and 67 km^2, three < 17 km^2, two small islets and a few rocks. Except islets, all other islands of the Nancowry group are inhabited. The northernmost subgroup comprises Batti Malv and Car Nicobar, which are 88 km north of the Nancowry group. Batti Malv is uninhabited and Car Nicobar has a population of > 19,000 people (Sankaran, 1995b).

Two groups of indigenous people inhabit the Nicobar Islands, along with settlers from the Indian mainland. The Shompen, who now number < 150, are a semi-nomadic hunter-gather tribe who inhabit the forests of the central uplands. The Nicobarese, who have several settlements along the coast, constitute the largest tribal group of > 27,000 people. The entire population of coastal-living Nicobarese, including settlers, were adversely affected by the tsunami and these people still need to be provided with new housing and, in most cases, alternative livelihoods.

Methods

This study was carried out during February–May 2006. Because the Nicobar megapode is shy and cryptic and therefore difficult to see in the forest whereas nesting mounds are stationary, inanimate and represent breeding signs, the easiest way to estimate and monitor a megapode population is by counting the number of active mounds (Dekker, 1992; Sankaran, 1995b; Sivakumar & Sankaran, 2003). Surveys conducted in 1994 (Sankaran, 1995b) also utilized mound counts, thus facilitating a pre-tsunami comparison with the data collected in 2006.

The coastlines of the 15 islands on which the species was reported in 1994 were surveyed for mounds using a standardized survey protocol (Sankaran, 1995b). To estimate the total number of active mounds the coastline of each island was divided into suitable and unsuitable coastal habitat for mound building. Coastal habitat suitable for mound building has a sandy-loam substratum and littoral forests (Sivakumar, 2000). The extent of these two coastal habitat types was measured using satellite images (from 2006) and vegetation maps (Sankaran, 2005).

Variable width transects of 10–600 m were used to count all the mounds present within a surveyed area (the low lying coastal littoral forests are of varying width). Transect length and distance between transects was determined by island size but was uniform for an island. The mean length of a transect was 2 km but in some islands, the entire coast was surveyed because the total coastline was < 2 km. The census was carried out with seven observers walking at 20-m intervals parallel to the shore; for transects > 140 m wide we walked the transect more than once to cover the entire width. The interior forests of Great Nicobar, Little Nicobar, Camorta, Katchal and Teressa islands were surveyed, by seven observers, with 1-km transects of 140 m width and 1 km long. The total number of active and abandoned mounds, mound size, green canopy cover over mound, and the distance between high tide mark and mounds were recorded.

Active mounds were identified by signs of recent digging by megapodes or by whether the soil was compact and hard, with vegetation growth (i.e. an abandoned mound) or loose and easily penetrable with a stick (i.e. an active mound; Sankaran, 1995b).

Because the distribution of mounds was not uniform (Sankaran, 1995b) the suitable and unsuitable segments of coastal areas were surveyed separately. A total of 328 km of coastal habitat was identified as suitable, of which 157.5 km were sampled in 80 transects (68 of 2 km, 10 < 2 km, and two > 2 km). Of the 358.8 km of unsuitable coastal habitat, 77.9 km were surveyed in 39 transects (29 of 2 km, five > 2 km and five < 2 km). On most islands mound distribution was not uniform and therefore mound abundance, *D*, on an island was estimated using the following formula:

$$D = \left(\frac{N}{S_a}\right) H_a,$$

where N = total number of mounds found in S_a, a = habitat type (suitable or unsuitable), S = total length of coastal area sampled in habitat a and H = total length of coastal area available for habitat a. Standard error of the mean number of mounds present per km of coast of an island was estimated when there were > 2 transects on an island (Table 2).

Up to 20% of the megapodes are estimated to live in the interior forests of the islands (Dekker, 1992), which comprise 72% of the total area of the islands. Because of the difficulty in working in such forests survey intensity was lower, with 11 transects on Great Nicobar, four each on Little Nicobar and Camorta, three on Katchal, and two each on Teressa and Nancowry islands.

Basal circumference, height and diameter of mounds were measured. As mounds are uneven in shape and have a cone-like appearance, volume was calculated approximately using the equation for the volume of a cone: $1/3\pi r^2 h$, where r is the radius and h the height (Sivakumar & Sankaran, 2003).

More than one pair of megapodes may use a mound. Sankaran (1995a) used two pairs per mound for the lower limit and 3.5 pairs as the upper limit but Sivakumar (2000) observed that a mean of 2.5 pairs used a mound. Most of the mounds that I observed were < 1 year old (based on their size and the fact that most mounds were washed away by the tsunami) and too small to accommodate more than two pairs (Sivakumar & Sankaran, 2003). Thus, for the population estimate I used one and two pairs as the lower and upper limits, respectively.

Results

In 2006 I found the Nicobar megapode on all but two islands (Trax and Megapode) from where it had been reported in 1994 (Sankaran, 1995a). Comparing the distribution of mounds from the shore inland there were significant differences between 1994 (Sankaran, 1995a) and 2006 (Wilcoxon signed ranks test, $Z = -2.934$, $P < 0.005$; Fig. 2). In 2006 > 90% of mound nests were within 30 m of the shore and, of these, c. 16% of mounds were within 5 m of the shore.

I found significantly fewer active mound nests than reported in 1994 (paired sample *t*-test, $t = 2.061$, df = 14, $P < 0.05$). Based on an estimated total of 394 active mounds (Table 1), I estimate that 394–788 breeding pairs of Nicobar

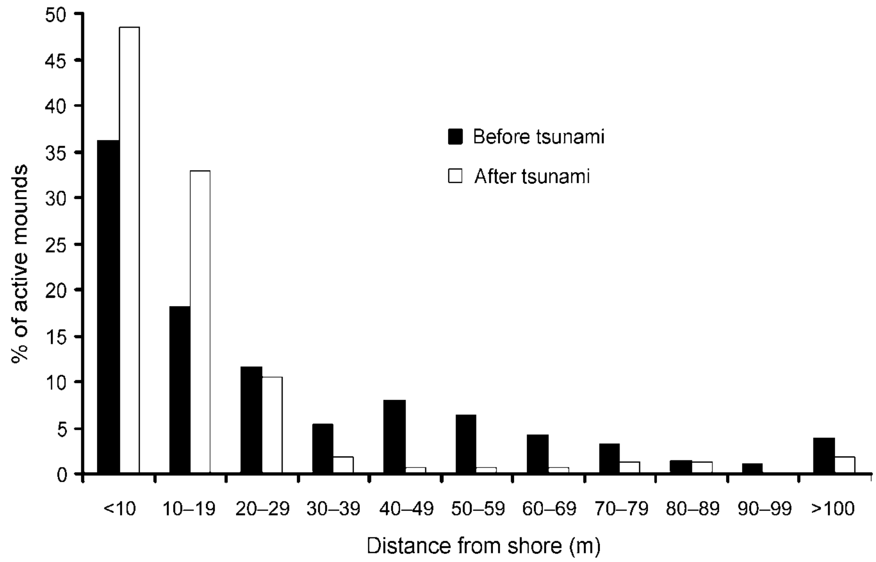

FIG. 2 Distance of active Nicobar megapode mound nests from the shore in 1994 (before the tsunami) and in 2006 (after the tsunami).

megapode now occur on the coastal habitat of the islands, which is < 70% of the numbers reported in 1994.

Suitable coastal habitat for *M. n. nicobariensis* on the Nancowry island group (Fig. 1) shrank after the tsunami and only 37% of the coastal habitat is now available for mound building, with an estimated 97 active mounds and thus 97–194 breeding pairs. I did not find any active nest mounds in unsuitable coastal habitat (coconut plantations, mangroves, human habitation and cliffs). The islands of Tillanchang and Trinket, despite their relatively small size,

TABLE 1 Summary of the survey of the two subspecies of Nicobar megapode *Megapodius nicobariensis* carried out on 14 islands (Fig. 1) in 2006 in suitable and unsuitable habitat for mound building (see text for definitions), with total length of the coast of each island, length of coast surveyed and number of transects used, number of active mounds found, estimated total number of active mounds (extrapolated to the whole coast, see text for explanation), and estimated number of active mounds per km (with SE; suitable habitat only).

	Suitable coastal habitat					Unsuitable coastal habitat			
Island	Length (km)	Length surveyed, km (no. of transects)	Active mounds	Estimated total active mounds	Active mounds ± SE (km^{-1})	Length (km)	Length surveyed, km (no. of transects)	Active mounds	Estimated total active mounds
***M. n. abbotti* (Great Nicobar island group)**									
Great Nicobar	130	42.5 (20)	64	195.8	1.46 ± 0.24	83	12 (6)	1	7
Kondul	1	1 (1)	1	1.0		6.5	2 (1)	0	0
Little Nicobar	55	17.5 (9)	25	78.6	1.46 ± 0.39	23	6 (2)	1	4
Megapode	0	0	0	0		0	0	0	
Menchal	1	0.5 (1)	3	6.0		2.3	1 (1)	0	0
Meroe	2	2 (1)	2	2.0		3.3	1 (1)	0	0
Pilo Milo	0	1.5 (1)	0	0		3	3 (1)	0	0
Trax	0.1	0.1 (1)	0	0		1.2	1.2 (1)	0	0
Treis	2	2 (1)	3	3.0		0.7	0.7 (1)	0	0
Subtotal	191	67 (35)	98	286	155 ± 0.67	123	27 (14)	2	11
***M. n. nicobariensis* (Nancowry island group)**									
Nancowry	17	16 (8)	7	7.4	0.44 ± 0.20	27.3	10 (5)	0	0
Katchal	30	14 (7)	4	8.6	0.29 ± 0.18	48	12 (6)	0	0
Camorta	35	21 (11)	4	6.7	0.23 ± 0.10	77.5	12 (6)	0	0
Tillanchang	15	9 (5)	16	26.7	1.80 ± 0.12	27	6 (2)	0	0
Trinket	15	11.5 (6)	20	26.1	1.75 ± 0.51	15	4 (2)	0	0
Teressa	20	16 (7)	7	8.8	0.46 ± 0.22	33.3	6 (3)	0	0
Bampoka	5	2 (1)	5	12.5		7.8	1 (1)	0	0
Subtotal	137	90.5 (45)	63	96.8	1.05 ± 0.35	236	51 (25)	0	0
Total	328	157.5 (80)	161	383	1.32 ± 0.39	358.8	77.9 (39)	2	11

Table 2 Estimated total number of active mounds and breeding pairs of the two subspecies of Nicobar megapode in 1994 (Sankaran, 1995b) and 2006 (this study; number of active mounds is a sum of the estimated total number of active mounds in suitable and unsuitable habitat from Table 1).

Island	Estimated no. of active mounds in 2006	Estimated no. of active mounds in 1994	Estimated no. of breeding pairs in 2006 (range)	Estimated no. of breeding pairs in 1994 (range)
***M. n. abbotti* (Great Nicobar island group)**				
Great Nicobar	203	515	203–406	1,030–1,803
Kondul	1	11	1–2	22–39
Little Nicobar	82	311	82–164	622–1,089
Megapode	0	2	0	4–7
Menchal	6	2	6–12	4–7
Meroe	2	1	2–4	2–4
Pilo Milo	0	0	0	0
Trax	0	3	0	6–11
Treis	3	4	3–6	8–14
Subtotal	297	849	297–594	1,698–2,972
***M. n. nicobariensis* (Nancowry island group)**				
Nancowry	7	60	7–14	120–210
Katchal	9	69	9–18	138–242
Camorta	7	20	7–14	40–70
Tillanchang	27	10	27–54	20–35
Trinket	26	8	26–56	16–28
Teressa	9	119	9–18	238–417
Bampoka	13	26	13–26	52–91
Subtotal	98	312	98–196	624–1,092
Total	394	1,161	395–790	2,322–4,064

now hold nearly 50% of the population of this subspecies. The megapode populations on the larger islands of Camorta, Katchal, Teressa and Nancowry was estimated to be c. 63 breeding pairs, 88% less than estimated in 1994 (Table 2).

M. n. abbotti occurs on all of the islands of the southern Great Nicobar group (Fig. 1) except for Pilo Milo, Megapode and Trax where the megapode now appears to be extinct (megapodes were not found on Pilo Milo in 1994). Of the 314-km coast 61% contains suitable habitat, and I found a total of 286 active mounds. In unsuitable coastal habitat I found 11 active mounds. I estimate that 297–594 breeding pairs occur on the coastal habitat of these islands. I found the largest population of this subspecies on Great Nicobar, with an estimated 203–406 breeding pairs. The second largest population is on Little Nicobar. These two islands are the largest in this group and provide breeding habitats for 96% of the total population of the subspecies.

There was a significance difference in the composition of mound types between 1994 and 2006 ($\chi^2 = 35.4$, df = 2,

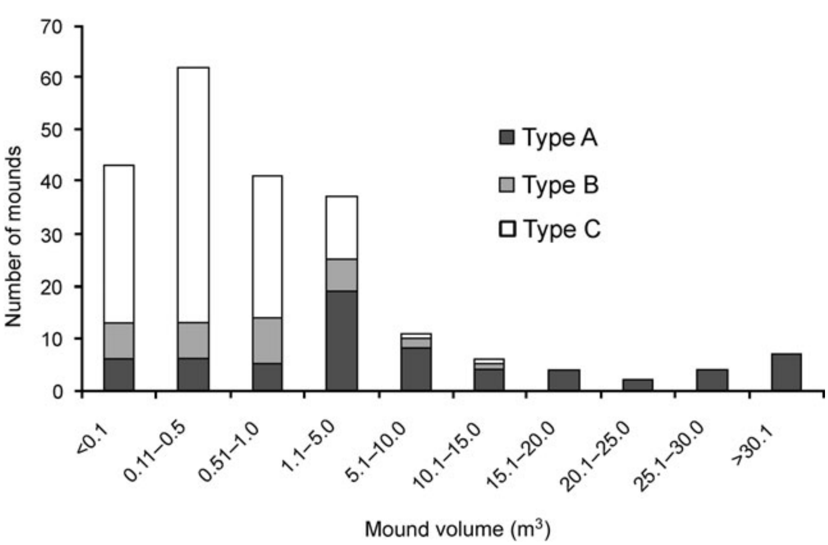

Fig. 3 Frequency distribution of mound nest volume of the three mound types (see text for details) of the Nicobar megapode.

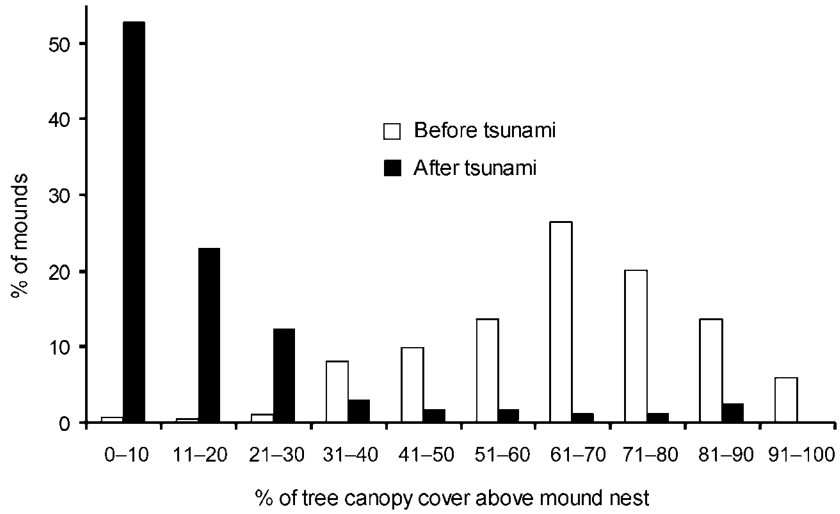

FIG. 4 Percentage of tree canopy cover above Nicobar megapode mound nests in 1994 (before the tsunami) and in 2006 (after the tsunami).

$P < 0.001$). In 2006 and 1994, respectively, 11 and 21% were Type A, 17 and 41% Type B, and 72 and 37% Type C. Mounds varied in volume (0.01–71.45 m^3). Of the 217 observed mounds, the majority (84%) were $< 5\ m^3$ and 67% were $< 1\ m^3$. Less than 6% of mounds were $> 20\ m^3$ and all of these were type A. Because most of the mounds were new and constructed after the tsunami the mean volume ($3.78 \pm$ SE $0.62\ m^3$) was smaller than in 1994 ($6.34 \pm$ SE $0.16\ m^3$; Wilcoxon signed ranks test, $Z = -2.497$, $P < 0.05$). Type A mounds were generally of a greater range of volumes than Types B and C, which were generally small in size (Fig. 3). Green canopy cover above mounds was significantly less in 2006 than in 1994 (Wilcoxon signed ranks test, $Z = -2.090$, $P < 0.05$; Fig. 4).

Of the 26 transects surveyed in the interior of the islands, mounds were found only on three transects, one on the southern tip of Great Nicobar, and two mounds from two different locations on Camorta. These mounds were not included in our population estimates.

Discussion

The major reason for the decline of the Nicobar megapode since 1994 appears to be the tsunami, which washed away both suitable habitat and nest mounds. In addition, the tsunami appears to have been the cause of the extirpation of the megapode on the islands of Megapode and Trax. Megapode was fully submerged for 3 weeks after the tsunami and the coastal areas of Trax were fully inundated. The Nicobar megapode appears preferentially to build mound nests in coastal areas because of the sandy-loam substratum there (Sivakumar, 2000; Sivakumar & Sankaran, 2003). Compared to the previous survey (Sankaran, 1995b) the mounds were closer to the shore, possibly because the tsunami reduced the extent of suitable coastal habitat. These mounds, which were built near to the high tide mark, could be affected by abnormally high tides or waves. Maintaining mound temperature at a constant rate is important for successful egg incubation (Sivakumar & Sankaran, 2003), and any influence of the nearby sea water on incubation temperature could adversely affect the hatching success of these mounds and lead to further population declines. I observed that human threats to the megapode, such as habitat degradation, hunting and egg collection, continue in the Nicobar islands.

I found the largest population of *M. n. nicobariensis* on Tillanchang despite its smaller size, and the population there is approximately the same size as in 1994. Tillanchang is the only Wildlife Sanctuary within the range of this subspecies, although I observed evidence of megapode hunting there. Because the intensity of the tsunami waves was diminished by the islands of Camorta, Katchal and Chaura before reaching Tillanchang, the impact of the tsunami was less on this island. However, the tsunami caused a drastic change in the number of mounds on all other islands (Table 2). As the earthquake occurred south of the Great Nicobar island group the tsunami waves arrived there first, and this may explain the 65% decrease in the population of *M. n. abbotti* on this island group compared to 1994.

The sources of heat that create suitable incubation conditions within a mound nest vary with mound type, location and size (Bowman et al., 1994; Palmer et al., 2000; Sinclair, 2002; Sinclair et al., 2002; Sivakumar & Sankaran, 2003). Type A mounds are larger in size and normally used by > 3 pairs (Sivakumar & Sankaran, 2003) but the number of such mounds was greatly reduced by the tsunami. I saw a greater number of type C mounds, probably because of the availability of dead trees after the tsunami; type C mounds may become type A once the tree decomposes fully (Sivakumar & Sankaran, 2003). Types B and C are normally smaller in size and accommodate fewer birds (Sivakumar & Sankaran, 2003). The active mounds were mostly small in volume (Fig. 3), indicating that they were constructed after the tsunami.

The temperature generated through fermentation of vegetative material inside a mound probably aids incubation (Sivakumar & Sankaran, 2003) although ambient temperature may also have an influence (Jones, 1987; Sinclair, 2002; Sinclair et al., 2002). The reduced green canopy cover above mounds in 2006 compared to 1994 means that more direct sunlight is now falling on the mounds, which may therefore warm up more quickly (Sinclair, 2002; Sinclair et al., 2002). If temperatures become too hot this could have a detrimental effect on egg development.

The Nicobar megapode is included in Schedule I of the Indian Wildlife (Protection) Act, 1972 and is categorized as Vulnerable on the IUCN Red List (BirdLife International, 2008). However, as the population has decreased by c. 70% since 1994 and habitat destruction and hunting are still adversely affecting the species it probably qualifies for categorization as Endangered based on criteria (IUCN, 2001) A1acd, i.e. a reduction in population size (A), with an estimated reduction of $\geq 70\%$ over the last 10 years (1) based on direct observation (a), an index of abundance (b) and a decline in extent of occurrence (c).

Island ecosystems are known for their resilience because of the possibilities for restoration by recolonization (Gunderson, 2000; Elmqvist et al., 2003). In this context, habitat restoration will be crucial for the long-term viability of the Nicobar megapode populations. There are currently two National Parks and two Wildlife Sanctuaries within the range of the megapode. Both National Parks are on Great Nicobar. Although these Parks offer some protection to *M. n. abbotti*, large extents of potential coastal habitat, especially along the west coast, are outside protected areas. The Wildlife Sanctuary of Megapode Island was completely submerged by the tsunami and no megapodes survived. Tillanchang Wildlife Sanctuary, which includes the whole of the island, is the only protected area that protects *M. n. nicobariensis.* Overall $< 5\%$ of the range of this subspecies is protected.

The tsunami washed away most of the planted as well as wild coastal coconut *Cocos nucifera* and areca nut *Areca catechu* palms and re-establishment of these plantations is important for the future survival of the islands' people. However, in the absence of appropriate planning the ongoing planting may encroach upon the coastal habitat of the Nicobar megapode.

Following the tsunami hunting pressure on the megapode has increased. Although the Nicobarese attach traditional cultural values to megapodes (the species is a symbol of love because of its monogamous breeding behaviour), scarcity of animal protein has forced them to hunt the species. A conservation education programme addressing this issue needs to be initiated. The two aboriginal tribes, the Nicobarese and Shompens, are exempt from the Indian Wildlife (Protection) Act, 1972. Considering the changing lifestyle of these two peoples (Math et al., 2006) either this immunity needs to be reviewed or the tribes need to be involved in the conservation and management of both the megapode and the islands' protected areas.

The Andaman & Nicobar Forest Department has already adopted some of the recommendations of this study, such as inter-departmental coordination in the re-establishment of coconut plantations so as to avoid plantation in prime megapode habitat. In addition, the Department has agreed, in principle, to initiate a programme to eradicate introduced cats and dogs, known to predate the megapode (Sivakumar, 2000), from the coastal areas of the Nicobar islands. The Department has also initiated a long-term monitoring programme of the habitat of the megapode.

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Biographical sketch

K. Sivakumar's research interests include avian ecology, island ecology, marine biology, invasive species and Antarctic wildlife. He has studied the ecology of the Nicobar megapode, red jungle fowl and olive ridley marine turtle, the mammals of Antarctica, and fishes of the Trans-Himalayas and the River Ganges. He has a particular interest in the avian fauna of island ecosystems and has been involved in the assessment of the conservation status of the threatened fauna of India. As well as being a member of the Wildlife Institute of India, he is the scientist in charge of the National Institute for Coastal and Marine Biodiversity.

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THE DISTRIBUTION, STATUS AND CONSERVATION OF THE NICOBAR MEGAPODE *Megapodius nicobariensis*

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Abstract

The mound-nesting Nicobar megapode occurs as two subspecies Megapodius nicobariensis nicobariensis *and* M. n. abbotti, *both endemic to the Nicobar Islands. Thought to be endangered, this survey found it on almost all Nicobar islands where it historically occurred and concluded that, as a species, it was currently not threatened, and has probably become extinct only on inhabited Pilo Milo island. While* M. n. abbotti *is secure other than on small outlying islets,* M. n nicobariensis *is threatened on all but three islands of its range. Loss of population in* M. n. nicobariensis *was indicated both by significantly lower mound densities and by a higher proportion of abandoned to active mounds, when compared with* M. n. abbotti. *Data were collected for 127 active mounds of* M. n. abbotti *and 85 active mounds of* M. n. nicobariensis, *and it was estimated that 849 and 312 active mounds, respectively are present, the population of the species being between 4500 and 8000 adult birds.*

Though hunting and collection of eggs exists, the main threat to megapodes is loss of habitat, mainly due to conversion of coastal forest, the megapode's primary nesting habitat, to coconut plantations. Expanding urbanization and construction of coastal roads are other serious problems. The single largest threat is a proposal to make Great Nicobar a free-trade port which, if implemented, will destroy the Andaman and Nicobar islands.

Keywords: megapodes, Nicobar megapode, Andaman and Nicobar islands.

INTRODUCTION

The family Megapodidae consists of 19 species in six genera, most of which are island forms occurring in Australia, New Guinea, eastern Indonesia, the Philippines, Niuafo'ou (Tonga), the Palau and Mariana islands and the Nicobar islands in India (Dekker, 1990). Throughout their distribution, megapodes are threatened by habitat destruction, introduction of predators, and over-exploitation of their eggs (Dekker, in press), and nine of these 19 species are threatened (Jones, 1989; Jones & Birks, 1992).

The Nicobar megapode *Megapodius nicobariensis* was considered to be seriously endangered (Jones, 1989; Jones & Birks, 1992), and has featured in several lists of endangered species (e.g. Collar & Andrew, 1988). The megapode is therefore protected under Schedule I of the Indian Wildlife Protection Act (1972) whereby hunting and trade is prohibited. The ethnic tribes of the Nicobar islands (Nicobareses and Shompen) are exempt from the Act. In 1988, the extinction of the megapode from Kondul was reported, a population of less than 400 birds from Great Nicobar was estimated and the extinction of this species was predicted in the next 10 years (Anon., 1988). However, Dekker (1992) estimated the population of *M. n. abbotti* at about 780 breeding pairs (if not more) in the coastal area of Great Nicobar and concluded that it was not threatened there. The status of the species on other islands, however, was still unknown.

The purpose of the paper is to document precisely the present distribution and status of the Nicobar megapode (*M. n. nicobariensis* and *M. n. abbotti*) and to identify threats to this species.

Study area

The Andaman and Nicobar islands (latitudes 6°45' and 13°41' and longitudes 92°12' and 93°57') in the Bay of Bengal arch from Arakan Yoma in Mayanmar in the north to Sumatra in Indonesia in the south (Saldanha, 1989; Dagar *et al.*, 1991). The islands cover an area of 8249 km^2, with a total coastline of 1962 km—the Andaman group with more than 325 islands (21 inhabited) covering 6408 km^2, and the Nicobar group (Fig. 1) with over 24 islands (12 inhabited) with an area of 1841 km^2 (Singh, 1981; Saldanha, 1989).

The Nicobar islands can be subdivided into three distinct subgroups. To the south the Great Nicobar group consists of two islands over 100 km^2 in area, nine islets of less than 5 km^2, and a few rocks. Four islands are inhabited. The human population on Great Nicobar (6831 people) has both tribal (8%) and mainland Indians including settlers. The tribals are thinly distributed along the southern, western and northern coasts. Of the mainlanders, 55% are in the township Campbell Bay midway up the east coast, and the remainder pursue agrarian livelihoods along the southeastern coast. Little Nicobar has no mainland settlers and the tribals are distributed all around the island. Kondul and Pilo Milo

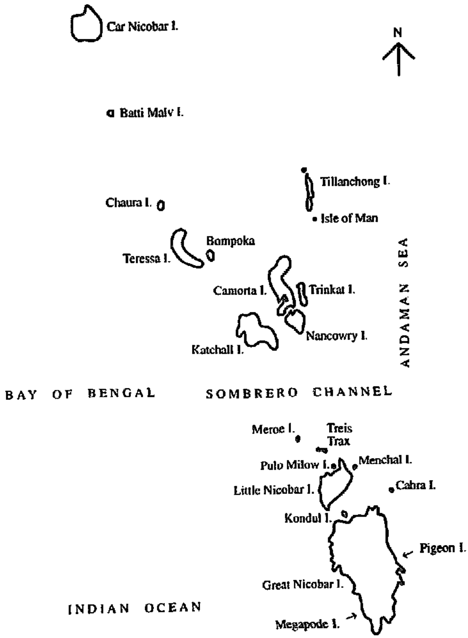

Fig. 1. The Nicobar group of Islands.

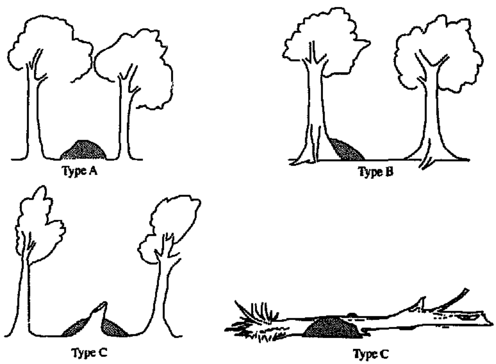

Fig. 2. Mound types in the Nicobar megapode.

Table 1. Summary of details of islands in this survey

Island	Area (km^2)	Coastline (km)	No of transects	Transects (km)	% coast surveyed	Survey days	Population	
							Tribal	Mainlander
Great Nicobar	1045·1	213	19	30·4	14	56	536	6295
Little Nicobar	159·1	78	12	12·7	16	18	295	13
Megapode Island	0·125	2·4	1	1·0	42	1	0	0
Meroe	<3	5·25	1	5·25	100	3	0	0
Treis	<1	2·7	1	2·7	100	0·5	0	0
Trak	<0·2	1·2	1	1·2	100	0·25	0	0
Menchal	<2	3·3	1	1·5	46	2	0	0
Kondul	4·6	7·5	1	2	27	2	139	8
Pilo Milo	1·3	3·0	1	2·5	83	2	109	13
Camorta	188·2	112·5	8	12·2	11	17	1406	1567
Trinkat	36·3	30	2	4·0	23	5	350	0
Nancowry	66·9	44·3	4	10·25	7	4	907	107
Katchall	174·4	78·0	3	8	10	8	2491	2581
Teressa	101·4	53·25	5	11·95	22·4	12	1617	162
Bompoka	13·3	12·75	1	2·2	17·3	2	51	0
Tillanchong	16·82	42	4	6·2	14·8	7	0	0

are inhabited islets; Meroe, Treis, Trax, Menchal, Megapode, Cabra and Pigeon are uninhabited.

The Nancowry group (middle Nicobar islands), 58 km north of the Great Nicobar group, consists of three islands larger that 100 km^2, two of 36 and 67 km^2, three less than 17 km^2, two small islets and a few rocks. Seven islands in the Nancowry group are inhabited, with a population of 12,464 comprised of both tribals (64%) and mainlanders. The tribals are distributed all around the islands. Mainlanders do not own land in the nancowry group, and about 80% are either employed by various government agencies, tribal co-operative societies or trade sectors. Twenty percent of mainlanders in the Nancowry group are Sri Lankan repatriates who have been settled on Karchall and who work on the 600-ha rubber plantation. Tillanchong is the only uninhabited island of the group.

The northernmost subgroup, composed of Batti Malv and Car Nicobar, is 88 km north of the Nancowry group. Batti Malv is uninhabited and Car Nicobar has a population of over 19,000 people, 80% of whom are tribals. The mainlanders are mainly employed in government and trade sectors.

The habitat characteristics of the islands vary. In the Great Nicobar group, all islands are completely forested. A small proportion of the coast of the larger islands is mangrove. In the Nancowry group of islands, the central portion of all islands, except Katchall and Tillanchong, are grasslands (over 60% of Trinkat and Teressa, 30–50% of Camorta and at least 20% of Nancowry and Bompoka), often extending to the coast itself. Within the grasslands there are patches of forest. A substantial amount of the coastline of Camorta, Trinkat and Nancowry is mangrove. Thus habitat available for the megapode is considerably less in the Nancowry group than in the Great Nicobar group.

Four islands in the Nicobar group have areas protected as wildlife preserves, and most islands are tribal reserves. Tillanchong, Batti Malv and Megapode Island, all uninhabited, are Wildlife Sanctuaries. Great Nicobar is a Biosphere Reserve (885 km^2), whose two core areas are National Parks (536 km^2).

The mound of the Nicobar megapode

The Nicobar megapode builds mounds of sand, loam, coral bits and rotting vegetation within which eggs are laid. Mounds vary in height from 10 cm to 2·1 m and in basal circumference from 7 to 45 m. Basically three types of mounds are built by the Nicobar megapode and have been described by Dekker (1992) as: type 'A' mounds or true mounds, regular in shape and built on an open spot away from trees; type 'B' mounds, irregular in shape, built against the buttress or stem of a large living tree; type 'C' mounds, also irregular in shape but built against, around, under or over a dead rotting tree stump or log (Fig. 2).

Mounds are usually made close to the shore but may also be present some distance inland (Hume & Marshall, 1878; Baker, 1930). This preference for nesting near the beach is common to at least one other species, *M. freycinet* (Stuebing & Zazuli, 1986). Of the 188 active mounds for which measurements were taken during this study, 97% were found within 100 m (80% within 60 m) of the beach. A few mounds were further inland (as far as 15 km inland on Great Nicobar), but these were difficult to find because of hilly terrain and much lower densities.

METHODS

The historical distribution of the Nicobar megapode was learnt from literature and this was followed by a survey of the Nicobar group of islands from 10 December 1992 to 5 April 1993, and 20 December 1993 to 31 March 1994. The coastline of 17 islands was sampled by walking around each island so that the entire range of this species was covered. Distances between sampling sites varied between 5 and 8 km on larger islands and the entire coast of small islands was surveyed (Table 1).

As mounds are stationary, inanimate and represent breeding, the best way to estimate and monitor megapode populations is by assessing the number of active mounds (those in use), identified by signs of recent digging. When such signs were not obvious, as when rains obliterated marks, the state of a mound was identified by checking whether the soil was compact and hard (abandoned) or if the soil was loose and easily penetrable with a stick (active). A mound that was not active (i.e. not in use) was considered abandoned. I preferred this classification over Dekker (1992), who called such mounds inactive, because 'inactive' implies that a mound is periodically inactive and active, while in reality most abandoned mounds had not been used for considerable periods, were in stages of obliteration, and often had vegetation growing on them. This indicated that in the Nicobar megapode, few if any mounds are brought back into use after being abandoned.

As mounds are predominantly placed in a narrow strip of forest along the seashore (Dekker, 1992; this study), the survey concentrated on forests abutting the beach. The census consisted of two observers walking between 30 and 50 m abreast parallel to the seashore, with the observer closest to the sea about 20–30 m from the beach. As mounds within 20 or 30 m of the observer are easily located, most mounds within a belt of forest about 100 m wide starting from the beach were thus counted. The length of this modified belt transect was about 1·5–2 km (av. 1·7 km, SD = 1·3 km, range 0·2–8 km, n = 64). Only three transects were less than 0·5 km, in terrain where available habitat was limited to the length of the transect, e.g. small bays amidst cliffs. The data from such transects have not been appended to other transects.

The census data consisted of three parameters: (a) length of the transect; (b) distance between mounds; and (c) distance between the mound and the beach. I calculated mound density (per km^2) by the equation, $D = m/l \times w$, where m = number of active mounds, l = length of transect (km) and w = width (100 m) as 97% of mounds in coastal forests were found within 100 m of the beach. Mounds beyond 100 m from the beach were excluded from the estimates.

To estimate the total number of active mounds, the coastline of each island was divided into segments based on similarity of habitat. This was necessary because the distribution of mounds was not uniform and they were not present or were very rare where cliffs or mangrove swamps abutted the shore or the forest was low-lying and periodically inundated (e.g. dominated by *Areca* or *Pandanus* palms), or the forest has been replaced by coconut. Thus, a segment was based on judging overall similarities in habitat and its suitability for megapodes. The total number of mounds for the forest abutting the coast (probably comprising 75% of mounds in Great and Little Nicobar, Katchall, Bompoka and Tillanchong, and over 90% of Camorta, Trinkat, Nancowry, and Teressa) was then calculated by the equation:

$$\sum_{i=1}^{n} \frac{M_i}{L_i} \times S_i,$$

where n = number of segments, $_i$ denotes a particular segment, S_i = length of segment, L_i = total length of transects within a segment, M_i = total number of active mounds within L_i.

Megapodes also occur in the forests in the interior of the islands, and in the larger fragments of forests within grasslands in the Nancowry group. These populations have not been considered in my estimates.

Measurements of distances were approximate. Distances in the field were measured using a pedometer set at 45 cm, arrived at by comparing strides taken to survey 1·5 km of megapode habitat abutting a metal road, and on the road. Distances between the mound and the beach were measured either by pacing, or visual estimates. Coastlines were measured from 1:150,000 scale hydrographic charts. Signs of predation, both natural and human, were recorded for every active mound seen.

RESULTS AND DISCUSSION

Distribution

M. nicobariensis, endemic to the Nicobar islands, is geographically isolated, with its nearest congeneric about 1600 km away (Olson, 1980). Two subspecies are recognized — *M. n. nicobariensis*, present on the Nancowry group of islands north of the Sombrero Channel, and *M. n. abbotti*, on the Great Nicobar group of islands to the south (Ali & Ripley, 1983; Fig. 1). As the two subspecies have significant dialectic differences in their vocalizations, subspecific identification is possible in the field (this study).

The Nicobar megapode occurred on most Nicobar islands (Hume, 1874; St John, 1899; Kloss, 1903) but was not found on Car Nicobar (Butler, 1899) and Chaura (Abdulali, 1967). There were a few records from the Andaman group of islands (Hume, 1874; Butler, 1899; Sewell, 1922) and from the Coco islands further north (Kloss, 1903; Abdulali, 1964). None of the records from the Andaman group are of recent origin and the species is believed to be absent there.

Three theories have been put forward for the absence of megapodes from the Andaman islands. Kloss (1903) believed that megapodes were introduced to the Nicobars by the Malays and explained their absence from the Andamans because voyagers were deterred from those islands by hostile natives, thus preventing their introduction. Olson (1980) suggests that megapode distribution is a result of competitive exclusion by other galliforms, but as wild galliforms are absent in the Andamans, this does not explain their absence there. Dekker (1989) argued that because mound-nesting megapodes are unable to survive in the presence of large carnivores, their absence in the Andamans might be explained by the introduction of the palm civet *Paguma hermaphroditus* and masked palm civet *P. larvata* (Kloss, 1903; Dekker, 1992), and considers the Nicobar megapode as a relict population. However, of the two civets in the Andamans only *P. hermaphroditus* is introduced; *P. larvata tytleri* is a subspecific endemic, and it is therefore possible that megapodes were not able to colonise the Andamans at all.

Whether the megapode existed in the Andaman group needs confirmation as there are no specimens from those islands and shooting records appear to be hearsay. It is possible that the mound reported by Hume (1878) was a nest of the king cobra *Ophiophagus hannah*, a likely error if one had not seen a megapode mound before. Spot sampling in South Andamans failed to reveal old mounds (this study), traces of which can be present for over 1000 years (Stone, 1991). Many taxa are exclusive either to the Nicobars or the Andamans and this is probably also true for the Nicobar megapode. Tangible evidence, in the form of abandoned mounds, is needed before we can conclude that this species indeed existed in the Andaman group of islands.

I found the Nicobar megapode to be present on all but one island (Pilo Milo, where it is probably extinct) in the Nicobars from where it had been reported. It may have existed on Car Nicobar (78 km north of Teressa, the nearest megapode population) a century ago (Kloss, 1903; this study) but I found no traces of mounds. Chaura is only 11.5 km from Teressa and considering the megapode's occurrence on the more remote Tillanchong there is no reason why it should not have existed there. Even if it did occur in the past, both Car Nicobar and Chaura are much too densely populated for the species to exist there now.

Status

Crucial to a population estimate is the number of pairs that use a mound in a year, whether larger mounds attract more pairs, differences in types of mounds and in the number of pairs using them, presence of mound tenacity, egg-laying frequency, number of eggs laid and duration of reproductive period. This information is as yet unavailable and any population estimate will be tenuous. Thus, the best indicator of the status of megapodes is an estimate of the number of active mounds in an island. However, Dekker (1992) estimated an average of two pairs per mound (for all three types), and emphasized that this was an absolute minimum, indicative of the breeding population for the month of March only. As the breeding is said to be through the year (Ali & Ripley, 1983), the actual number of pairs that use a mound in a year would be more (cf. Dekker, 1992). That more than two pairs use the same mound was also evident from trappers who had snared several birds from the same mound. In two other mound-building megapodes, a maximum of four and five pairs have been estimated as using the same mound (Rand & Gillard, 1967; Stuebing & Zazuli, 1986). Thus for the population estimate, I used two pairs per mound for the lower limit and 3·5 pairs per mound for a conservative upper limit (the mean of the minimum of pairs per mound for *M. nicobariensis* and the maximum recorded for megapodes in the literature).

Megapodius nicobariensis abbotti

On Great Nicobar, *M. n. abbotti* was believed to have disappeared from all areas colonised by mainlanders (Dekker, 1992). However, megapodes still survive there and four active mounds were located over a distance of 11 km. In areas not colonised by mainlanders, active mounds were present in all forests abutting the shore, as was the case with all of that part of Little Nicobar which has no mainland settlers. I estimated over 800 active mounds in Great and Little Nicobar and a population of adult breeding birds between 3300 and 5750 birds (Table 2).

Dekker (1992) estimated 390 active mounds on Great Nicobar as against this study's 515, though sampling intensities were similar (26 and 30·4 km, respectively). Dekker, however, surveyed three areas, whereas I sampled 19 locations all round the island. In his study the west coast was under-sampled (3 km at one location); this coast had the least disturbance and the best megapode habitats (I surveyed 12 km at nine locations). His other two transects pass (one partly) through habitat that had been subjected to human activity such as road building or quarrying and are not representative of mound abundance. Lastly, by dividing the coast into segments (this study) a truer estimate of mound numbers was obtained than by a simple arithmetical extrapolation (Dekker, 1992).

Seven of nine islets in the Great Nicobar group had habitat suitable for megapodes and two (Cabra and Pigeon) were too small. Over 50% of the forests of uninhabited Meroe, Treis, Trak, Menchal and Megapode Island have been converted to coconut plantation by the inhabitants of neighbouring islands. On Megapode Island and Meroe only one active mound each was found and a high proportion of abandoned mounds was indicative of a dwindling population. A dense ground cover of germinating coconut on Meroe has ruined potential mound-building areas. Only Treis and Trax, with four and three active mounds each, had a satisfactory megapode population. Less than 10% of Menchal's coast is suitable for megapode as most of the island is rocky. Only one active mound was found there. The only level area in Kondul is inhabited and of the three active mounds found, one was just behind the South Point village. About half of Pilo Milo is inhabited, and the islet is mostly under coconut palms. Megapodes are apparently extinct on this islet, though reports of calls heard indicate that it may still survive. The number of active mounds in the outlying islets in the Great Nicobar group is estimated to be 23, with an adult breeding population between 90 and 160 birds (Table 2). Thus the population of *M. n. abbotti* is between 3400 and 6000 birds.

Megapodius nicobariensis nicobariensis

M. n. nicobariensis occurs on seven islands of the Nancowry group. On Camorta, Katchall and Trinkat, it was patchily distributed, with very few locations having active mounds and even fewer where mounds were abundant. For instance, on Camorta, only one location,

Table 2. Population estimate of the Nicobar megapode

	Estimated no. of active mounds	Estimate of number of breeding pairs (range)[a]
M. n. Abbotti	849	1698–2972
Great Nicobar	515	1030–1802
Little Nicobar	311	622–1088
Megapode Island	2	4–7
Pilo Milo	0	0
Meroe	1	2–4
Treis	4	8–14
Trak	3	6–11
Menchal	2	4–7
Kondul	11	22–39
M. n. nicobariensis	312	624–1093
Camorta	20	40–70
Trinkat	8	16–28
Nancowry	60	120–210
Katchall	69	138–242
Teressa	119	238–417
Bompoka	26	52–91
Tillanchong	10	20–35

[a]Lower limit at two pairs per mound, upper limit at 3·5 pairs per mound.

a small promontory near Kakana village, had a high density of active mounds. Elsewhere in the island, active mounds were either very rare or absent. Very few active mounds were located on Trinkat. At Katchall, considered by Kloss (1903) to be the home of the megapode, a few mounds were distributed through much of the coast, but only a single location had a high density. The southern half of Nancowry had mound densities similar to that of Great and Little Nicobar. I estimated over 150 active mounds of *M. n. nicobariensis* in these four islands, and an adult breeding population of between 600 and 1100 birds (Table 2).

It was only on Teressa and Bompoka that good populations of megapode existed, with a similar density of active mounds as that of Great and Little Nicobar (Table 3). Tillanchong is mainly hilly with very little level coastal forest; thus megapodes are naturally scarce except in the level forests. The small population that exists is apparently secure. Thus the total population of adult breeding birds of *M. n. nicobariensis* is estimated to be between 1200 and 2100 birds and the number of active mounds to be a little over 300.

Population loss

To assess which islands have undergone population loss, and the reasons behind the reductions, the mean density of mounds and the proportion of abandoned to active mounds for each of the transects traversed were calculated, and comparisons made between islands.

The densities of active mounds are similar for six islands, Great and Little Nicobar, Trax, Nancowry, Teressa and Bompoka, where densities ranged between 30 and 36 mounds km^2 (Table 3). In all other islands, densities ranged between 3 and 22 mounds km^2. In the best habitats, active mounds were encountered at least once every 200 m, and similar densities have been reported for *M. reinwardt* (Lincoln, 1974; Crome & Brown, 1979) and for *M. cumingii* (Stuebing & Zazuli, 1986). The significantly lower densities in *M. n. nicobariensis* in Camorta, Trinkat and Katchall and of *M. n. abbotti* in the outlying islets of the Great Nicobar group thus poses the question whether the lower number of mounds encountered for the northern subspecies is natural or whether there has been a loss or reduction in the populations.

Reduction in the populations is best indicated by the proportion of abandoned mounds. The two islands with the least damage to coastal forests are Great and Little Nicobar, of which Great Nicobar had a greater proportion of undisturbed coast. All other islands had

Table 3. Summary of census data of megapode mounds

	M. n. abbotti									*M. n. nicobariensis*						
	GN	MI	LN	PM	MR	TR	TA	MN	KN	CM	TR	NN	KT	TS	BP	TI
No. of active mounds																
Type A	20	1	23	0	1	3	1	1	0	7	2	9	11	18	6	4
Type B	25	0	14	0	0	0	0	0	1	1	0	2	1	3	0	2
Type C	21	0	12	0	0	1	2	0	2	0	0	3	2	12	1	2
Total	66	1	49	0	1	4	3	1	3	8	2	14	14	33	7	8
No. of abandoned mounds	50	3	78	4	14	14	13	0	5	44	16	15	29	113	25	14
Mean % abandoned mounds	40	75	57	100	93	78	81	0	63	82	90	53	70	72	78	67
Mean mound density (km^2)	33	10	36	—	3	16	30	7	15	10	4	30	22	30	32	13
% mounds with signs of egg collection	7·5	0	2	—	0	0	0	0	0	0	0	0	0	0	0	0
% mounds with snares	12	0	18	—	0	0	0	0	0	0	0	8	0	0	14	38
% mounds with monitor lizard signs	18	0	18	—	0	0	0	0	0	25	0	8	0	3	28	13
No. active mounds (extrapolated)	515	2	311	0	1	4	3	2	11	20	8	60	69	119	26	13

GN, Great Nicobar; MI, Megapode Island; LN, Little Nicobar; PM, Pilo Milo; MR, Meroe; TR, Treis; TA, Trak; MN, Menchal; Kn, Kondul; CM, Camorta; TR, Trinkat; NN, Nancowry; KT, Katchall; TS, Teressa; BP, Bompoka; TI, Tillanchong.

undergone considerable conversion of forest to coconut plantations. The proportion of abandoned to active mounds in the other islands was between 1·6 and 2·3 times that of Great Nicobar, and 1·2–1·6 times that of Little Nicobar (Table 3). The only exception was Nancowry where the proportion of abandoned mounds was similar to Great and Little Nicobar.

The highest number of abandoned mounds were present in those areas where primary forest has been converted into coconut plantations. In one plantation on Camorta, of the 16 mounds seen in a 1·5-km transect, 14 (87·5%) were abandoned, in another on Teressa 56 were abandoned and four active mounds were seen in 2·75 km, and in very old plantations only traces of abandoned mounds were visible. However, where there was a mixture or mosaic of coconut and forest, or the ground vegetation was not cleared, megapodes built mounds. They apparently abandon pure stands of coconut because they require sufficient ground and middle-storey vegetation cover, and probably also because mounds become unworkable due to the cover of dead coconut fronds, and falling and germinating nuts.

Teressa and Bompoka are exceptions because while mound densities are similar to that in Great and Little Nicobar, they have a significantly greater proportion of abandoned mounds (Table 3), since much of the coast on these islands has been converted to coconut. There is, however, an adequate interspersion of natural habitat within the plantations and large tracts of optimal megapode habitat.

The first sign of a declining population is perhaps a high proportion of abandoned mounds, followed by a decline in the density of active mounds and culminating in population loss. This can be seen as a continuum in the larger islands (Table 3), which also corresponds to the availability and quality of habitat. Great Nicobar had a high density of active mounds and the least proportion of abandoned mounds while Little Nicobar had a high mound density but a greater proportion of abandoned mounds. Teressa and Bompoka had high mound densities but high proportions of abandoned mounds, Katchall with a lower mound density and a high proportion of abandoned mounds and Camorta and Trinkat with both low mound densities and high proportions of abandoned mounds.

Threats

The main threats to the Nicobar megapode can be classified into hunting of birds for meat and egg collection, predation and habitat loss.

Hunting and egg collection

Because megapodes have spiritual and medicinal values attached to them, the Nicobarese do not hunt or collect eggs of this species extensively. There were, however, inter- and intra-island differences. In some villages hunting or egg collection is present (e.g. Tahiyuol, on Little Nicobar), while in others it is not (e.g. Pilo Pakka, also on Little Nicobar). Hunting was greatest on the west coast of Little Nicobar and rare or uncommon over much of the Nancowry group, particularly Kondul, where continued adherence to traditional values resulted in lesser levels of exploitation. Where traditional values have been eroded (as by the complete domination of Christianity), localised heavy to excessive hunting pressures may exist. At Tahiyuol, 71 legs, presumably of 36 megapodes, had been strung up and shot during the week of a full moon. Such hunting pressures, however, were exceptional, and in the entire range of the species were seen only at two locations (Tahiyuol and Pilo Milo). Megapodes are also shot on Meroe and Treis, thus seriously threatening already depleted populations.

Megapode eggs are apparently not an important source of food. Thus, unlike other species where high egg collection pressures exist (Bishop, 1978; Todd, 1983; Stuebing & Zazuli, 1986; Dekker & Wattel, 1987; Jones, 1989), a low number of mounds had been excavated for eggs (Table 2). The Shompen and some Nicobarese do occasionally collect eggs (but apparently all Nicobarese do not collect (or eat?) megapode eggs and egg collection is only done occasionally.) Bompoka is an exception, and megapode eggs from there are gifted to people on neighbouring Teressa. Localised, heavy hunting pressures on the megapode by Nicobarese are a recent phenomenon, because of the popularisation of airguns. The traditional method, with a cross bow, was rare and I saw it being used only on Bompoka and at one location in Katchall. Most Nicobarese do not use snares, and its use is even resented because pigs and chicken get caught or injured by the nylon nooses.

Mainlanders, particularly labourers on construction projects, trap megapodes, e.g. on Great Nicobar while work on Project Yatrik (which opened up the island to colonisation) was under way. With the phasing out of the project, and the better implementation of Wildlife Protection laws, hunting pressures have declined. I did not come across any sign of mainlanders digging up mounds for eggs.

Very high hunting pressure, albeit localised, was from Thai poachers who camp in isolated parts of Tillanchong, Great and Little Nicobar. Snares for megapode and wild pig *Sus scrofa nicobarica* had been placed extensively in the northeastern coast of Great Nicobar and most mounds near Thai camps had snares on them. Several active mounds where building was infrequent were also indicative of a population that had suffered recent losses. About 5% of Great Nicobar's coast is affected in this manner. Thai poachers also collect eggs.

Predation

Having evolved in habitats free of large carnivores, megapodes are particularly vulnerable to predators (Dekker, 1989). In the Nicobars, introduced wild predators are absent. Only the monitor lizard *Varanus salvator*, the reticulate python *Python reticulatus* and species of raptors are potential predators of megapodes and their eggs. The monitor lizard excavates mounds both to prey on eggs and to lay its own eggs (cf. Dekker, 1992). However, this is not a problem and as monitor lizards are extensively hunted for meat, the numbers of this predator are kept in check.

Dekker (1992) suggested that cats and dogs pose a threat to megapodes in the Nicobar islands. I made a few observations that were contrary to this, the most striking of which was an active type 'A' mound within 30 m of an inhabited hut with five dogs and four cats. At night the megapodes roosted on an adjacent tree. Todd (1983) also stated that in the 100-odd years that cats have been resident of Niuafo'ou, *M. pritchardii* has not become extinct. Dogs and cats are currently not a threat to the Nicobar megapode, except on Meroe, where cats were released in 1991 to control a very high population of rats that were seriously damaging the coconut crop. The most visible change on Meroe since then has been a flush of germinating coconut palms, 1·5–2 m high, forming a dense ground cover, greatly reducing the area available for mound building. Because of the density of ground cover, the essentially cursorial megapode will also be increasingly incapable of avoiding predators.

Habitat loss

The primary threat to most species of megapodes is loss of habitat (e.g. Bishop, 1978; Dekker, 1990), and this is also true for the Nicobar megapode. Demographic changes in the Nicobars have resulted in widespread loss of habitat, being most acute in the Nancowry group of islands.

The Nicobarese subsist on coconut and have clear-felled forest to plant banana, papaya and tuber-bearing plants. As tribal populations are the highest in the nancowry group, most damage has occurred there. An approximately 35-km long strip of forest along the southeastern coast has been depleted on Great Nicobar due to settlement of mainland Indians. Over 600 ha of primary forests were replaced by rubber plantations on Katchall. Expanding townships and villages, roads, airstrips and infrastructure of defence establishments have all resulted in the loss of habitat, which is the single biggest threat to megapodes.

Conservation perspectives

The long-term perspective for the Nicobar megapode is bleak due to persisting loss of habitat. The problem is most acute in the Nancowry group where suitable habitat, both for megapodes and humans is considerably less than in the Great Nicobar group. Control over habitat loss due to tribals is not possible in the Nicobars, even where areas have been declared as protected reserves, because the tribals are exempt from Forest and Wildlife laws. The population of the ethnic tribes inhabiting the Great Nicobar group is low, and an immediate threat of significant alteration of primary forest is minimal. As further mainlander settlement has been stopped on Great Nicobar, the damage has been contained to forests already lost or degraded.

Though megapodes are not being extensively hunted (or their eggs collected) in the Nicobar Group of Islands, intensive localised hunting pressures exist and may cause localised rarity or extinction. The situation, however, is not yet alarming.

The most immediate threat in the Nicobars is the proposal to make Great Nicobar a free port and to create a dry dock and refuelling base for international shipping at the mouth of the Galathea river. If and when implemented, all the Nicobar islands will be lost to conservation.

The Nicobar megapode, as a species, is not endangered. The only two criteria (IUCN criteria for threatened status; Collar et al., 1994) for which the species qualifies are B2c (continuing decline in area, extent and quality of habitat) and C1 (decline over the last 10 years may be greater than 20%, though there are no data for this). The species should therefore not be classified as threatened, but as it qualifies for one of the B codes, I propose that it be classified as vulnerable and its status be periodically re-evaluated.

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ANNEXURE A20

Preliminary results of an ongoing study of the Nicobar megapode Megapodius nicobariensis Blyth

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Preliminary results of an ongoing study of the Nicobar megapode *Megapodius nicobariensis* Blyth

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Sankaran R. & K. Sivakumar. Preliminary results of an ongoing study of the Nicobar megapode *Megapodius nicobariensis* Blyth.
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Key words: Megapodiidae; Nicobar megapode; *Megapodius nicobariensis*; incubation mounds; social organization; pair-bond.
Data collected during an ongoing study on incubation mounds and the social organization of the Nicobar megapode *Megapodius nicobariensis* Blyth, 1846, are reviewed. Microbial decomposition of organic matter in mounds is likely to be the major source of heat production within incubation mounds of the Nicobar megapode, though a direct relation between the rate of organic activity and the temperature could not be shown. The size of a mound was found to be the most important factor in the stabilization of incubation temperatures at optimal levels. Data on the social organization of the Nicobar megapode are presented. The use of mounds by multiple pairs, territorial behaviour, extra-pair copulations and the break-up of pairs are highlighted. The mating system in the Nicobar megapode is briefly discussed.

Introduction

The Nicobar megapode *Megapodius nicobariensis* Blyth, 1846, is a monomorphic mound building megapode, endemic to the Nicobar Islands in the Bay of Bengal. It is separated from its nearest congeneric for about 1600 km (Olson, 1980). Two subspecies are recognized: *M. n. nicobariensis* Blyth, 1846, which is found in the Nancowry group north of the Sombrero Channel and *M. n. abbotti* Oberholser, 1919, from the Great Nicobar group lying south of it (Hume & Marshall, 1878; Abdulali, 1964; Ali & Ripley, 1983; Jones et al., 1995; fig. 1), a separation which conforms to other avifaunal assemblages in the Nicobar islands (Sankaran, 1997). The Nicobar megapode was considered to be seriously endangered (Collar & Andrew, 1988; Jones, 1989; Jones & Birks, 1992). However, a survey of Great Nicobar indicated that *M. n. abbotti* was not threatened (Dekker, 1992; Dekker & McGowan, 1995), and based on population estimates of the Nicobar megapode on all the Nicobar islands between 1992 and 1994, Sankaran (1995a, b, 1998) concluded that *M. n. nicobariensis* is vulnerable and *M. n. abbotti* near threatened, and designated the species as vulnerable.

Studies by Dekker (1992) and Sankaran (1995a, b) have described the incubation mounds of the Nicobar megapode. Sivakumar & Sankaran (in press) have quantified site and habitat selection of mounds as well as mound use patterns in this species. This paper presents the preliminary results of an ongoing ecological study of the Nicobar megapode which was initiated in 1995, and focuses on two aspects: incubation conditions within mounds and social organization. Specific questions include:

— do heat sources (microbial decomposition or solar radiation) that create suitable incubation conditions in a mound vary with mound dimensions? Which source provides the most stable incubation conditions?

— do heat sources and mound dimensions have a bearing on the number of pairs that use a mound, the number of eggs laid, and hatching success?

— what relation do home range and/or territory of a pair have to the location of the mound it uses?
— do home range and territory vary between breeding and non-breeding phases?
— how are pair bonds formed, and how permanent are they ?

In this paper, we present our preliminary findings based on data collected over two breeding seasons. A more detailed treatment will follow later, when data have been collected over more breeding seasons.

Study Area

The Andaman and Nicobar Islands (6°45′ to 13°41′ latitude, 92°12′ to 93°57′ longitude) in the Bay of Bengal arch from Arakan Yoma in Mayanmar in the north to Sumatra, Indonesia, in the south (Saldanha, 1989; fig. 1). The islands cover an area of 8,249 km^2, with a total coastline of 1962 km. The Andaman group with more than 325 islands (21 inhabited) cover an area of 6,408 km^2, the Nicobar group with over 24 islands (13 inhabited) cover an area of 1,841 km^2 (Singh, 1981; Saldanha, 1989).

We have been studying the ecology of the Nicobar megapode since January 1996 at the southern tip of Great Nicobar (fig. 2). Our study area lies on the coast, is about 4 km long, and is bisected by a disused metal road which ends at the light house at Indira Point. The intensive study area is a narrow strip of forest between 40 and 300 m wide, that is bounded by the beach to the east and by either wetlands or forests that are inundated during the monsoons to the west. The soil within this strip of forest is sandy and loamy, and the dominant trees are *Barringtonia asiatica*

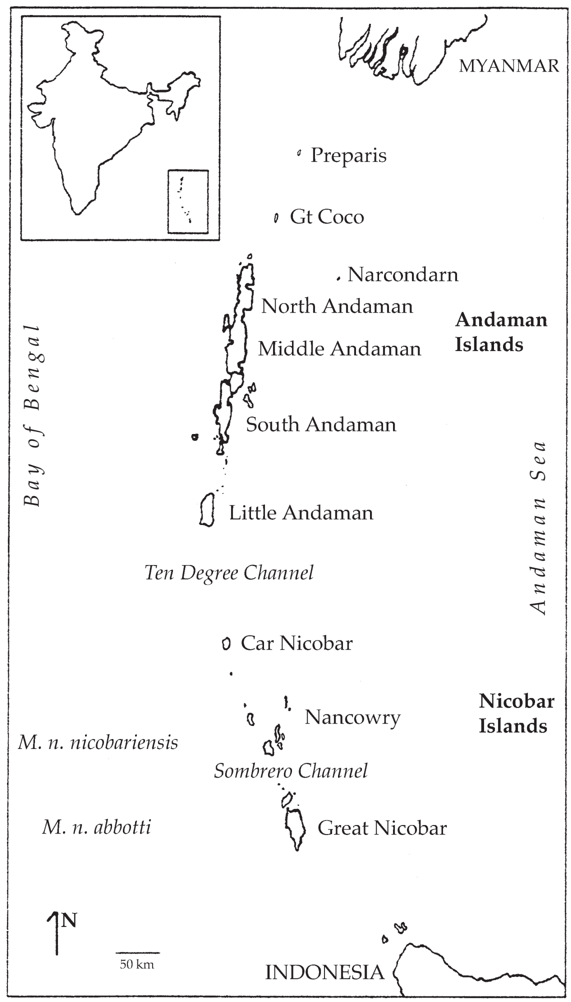

Fig. 1. The Andaman & Nicobar Islands showing the distribution of the two subspecies of the Nicobar megapode *Megapodius nicobariensis*.

Kurz., *Terminalia bialata* Steud., *Terminalia catappa* L., *Syzygium samarangense* (Blume) Merrill & Perry, *Thespesia populnea* Soland. ex. Correa, and *Macaranga* spp. The study area has dense stands of *Pandanus tectorius* Parkinson ex J.P. du Roi and *P. odoratissimus* L. in patches, and the road is fringed by stands of *Leea angulata* Korth. ex Miq., *L. grandifolia* Kurz., and *Draceana* spp. There are a few patches where the ground is open and with little vegetation. The soil of the forest type to the west of this coastal forest, is wet and clayey and covered with *Areca* spp. as well as trees like *Ixora barbata* Roxb., *Pongamia pinnata* Pierre, *Alstonia kurzii* Hook.f., *Aisandra butyracea* (Roxb.) Baehni, *Myristica irya* Warb., *M. andamanica* Hook.f., and *Celtis timorensis* Span.

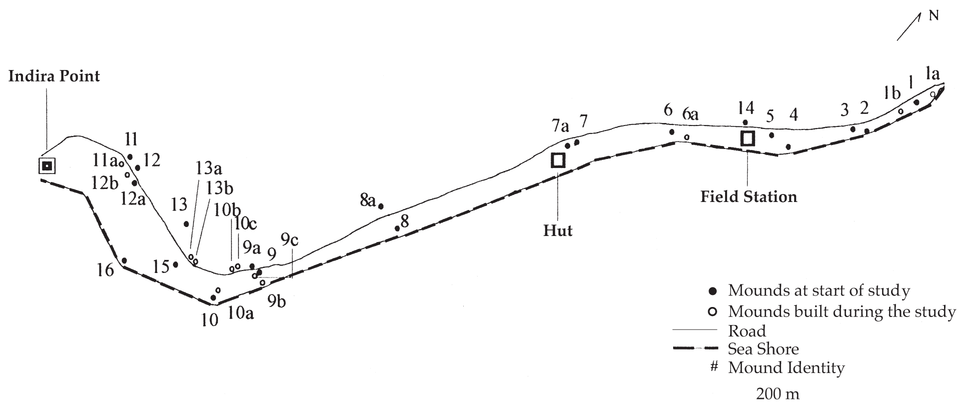

Fig. 2. The southern tip of Great Nicobar island where the ecology of the Nicobar megapode is being studied. The figure shows the location of incubation mounds that were present at the start of the study in January 1996, and the mounds that were subsequently newly built.

Methods

Incubation conditions within mounds

The basal circumference, height and diameter of mounds were measured once a month. The mound size, expressed in m^3, is derived from the equation for the volume of a cone: $1/3\pi r^2 h$, where r is the radius and h the height.

In 1996 we implanted four temperature probes, at depths between 20 and 75 cm, in seven mounds that were selected for intensive studies. However, after about two months these probes malfunctioned, probably due to high humidity and rainfall. In 1997, we used a temperature probe placed at the tip of a 1 m long steel tube which was inserted to depths of 30, 60 and 90 cm. The temperature of all mounds in our study area was measured once a month and for the target mounds once every ten or 15 days.

Microbial activity was measured indirectly using a soil respirometer (PP Systems EGM-1 Environmental Gas Monitor with a SRC-1 Soil Respiration System), assuming that in those mounds where organic activity was high, greater amounts of CO_2 would be emitted. The soil respirometer measures CO_2 changes in a fixed volume over a known period of time and fits a quadratic equation to the data to arrive at a SR value which is the soil respiration rate in g CO_2/m^2/hour.

The intensity of light falling upon a mound at different times of the day was measured using a Lux meter. Both soil respiration and light intensity were measured at least once in a fortnight for seven mounds which were under intensive study. The temperature, soil respiration, and light intensity data presented here are means of all data points. Temporal variations are not dealt with in this paper.

All mounds in the study area were visited twice a day, when we recorded any activity, allowing us to identify whether and when eggs were laid in a particular mound. Whenever possible, a newly laid egg was located by digging into the mound, and the egg was marked. The egg was monitored by relocating it once every 15 days. Incubation temperatures near the egg were measured once every 15 days.

Territory & social organization

We observed megapodes mostly on the mound and opportunistically away from the mound using the focal animal sampling method (Altmann, 1974). We colour-marked 23 birds, which represented 16 paired and two unpaired birds. Their positions were plotted on detailed maps of the study area. All sightings, calls and fights were plotted on this map.

Results

Incubation conditions within mounds

The size of mounds

The size of a mound varies during the season. Between January and June 1996, eight mounds increased in size, four decreased, and nine showed no change (n = 21;

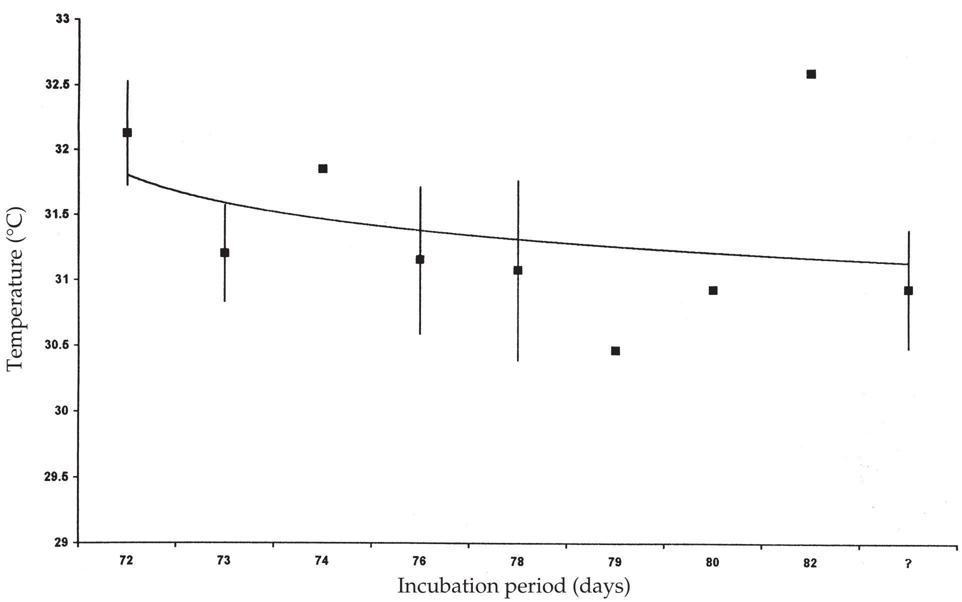

Fig. 3. Relation between core mound temperature (°C) and incubation period (days) of eggs of the Nicobar megapode.

Table 1. The history of 27 incubation mounds of the Nicobar megapode.

Mound	Months during which the mound was active												Size of the mound (m^3)			
ID	1996						1997						1996		1997	
	J	F	M	A	M	J	J	F	M	A	M	J	Jan	June	Jan	June
1	—	—	—	—	—	—	—	—	—	—	—	—	0.4	0.4	0.6	0.3
1a										—	—	—				0.8
1b										—	—	—				1.3
2	—	—	—	—	—	—	—	—					0.4	0.4	0.4	0.4
3	—	—	—	—	—	—	—	—	—	—	—	—	4.1	2.8	1.4	3.2
4	—	—	—	—	—	—	—	—	—	—	—	—	6.5	6.9	7.9	14.7
6	—	—	—	—	—	—	—	—	—	—	—	—	0.8	0.7	0.8	1.8
6a						—	—	—	—	—	—	—	0.1	0.2	0.3	0.2
7	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	0.1	0.5
7a	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.8	0.8	0.8
8	—	—	—	—	—	—	—	—	—	—	—	—	4.5	4.0	3.7	6.2
8a		—	—										0.1	0.1	0.1	0.1
9	—	—	—	—	—	—	—	—	—	—	—	—	5.2	5.6	2.1	7.3
9a	—	—	—	—	—	—	—	—	—	—	—	—	0.2	0.2	0.2	2.2
9b				—	—	—	—	—	—	—	—	—	0.1	0.1	0.1	0.1
9c									—	—	—	—	0.1	0.1	2.2	
10	—	—	—	—	—	—	—	—	—	—	—	—	25.6	28.1	25.6	24.1
10a												—		0.2	0.2	4.4
11	—	—	—	—	—	—	—	—	—	—	—	—	0.2	0.2	0.2	0.3
11a		—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	0.1	0.1
12	—	—	—	—	—	—	—	—	—	—	—	—	0.8	0.8	0.9	4.3
12a	—	—	—	—	—	—	—	—	—	—	—	—	0.9	1.5	1.6	5.7
12b									—	—	—	—			2.3	7.1
13	—	—	—	—	—	—	—	—	—	—	—	—	11.1	12.8	13.3	13.1
13a										—	—	—			1.8	1.8
13b										—	—	—			0.4	0.5
14	—	—	—	—	—	—	—	—	—	—	—	—	6.5	5.9	8.8	4.2

table 1). Between January and June 1997, 13 mounds increased in size, four decreased, and seven showed no change (n = 24; table 1). Of the 15 mounds which were active over the entire study period from January 1996 to June 1997, 11 mounds increased in size, and four decreased (table 1). Overall, of the 22 mounds for which size has been monitored for 1996 and 1997, 15 mounds have become larger in volume by 1.5 to nearly 25 times between January or June 1996 and June 1997, three have become smaller, and four mounds showed no size change (two of which had been abandoned during the course of the study).

Incubation temperature

We monitored the temperature near 26 eggs in 12 mounds, and recorded the incubation period for 23 eggs. Three eggs did not hatch. The shortest incubation period was 72 days (fig. 3). The mean temperature near eggs hatching on the 72nd day was 32.1°C.

The effect of mound size on incubation temperature

We studied the effect of mound size on the temperature in 27 mounds (fig. 4). Mound size varied from 0.006 m^3 to 24.27 m^3 (x = 3.48 m^3). We found that small mounds (< x) are more likely to have a variable, more fluctuating temperature, ranging from 29.2-34.4°C (x = 31.4 ± 0.35°C, n = 19), than larger mounds (> x) where the temperatures range from 31.9-35.0°C (x = 33.4 ± 0.34°C, n = 8).

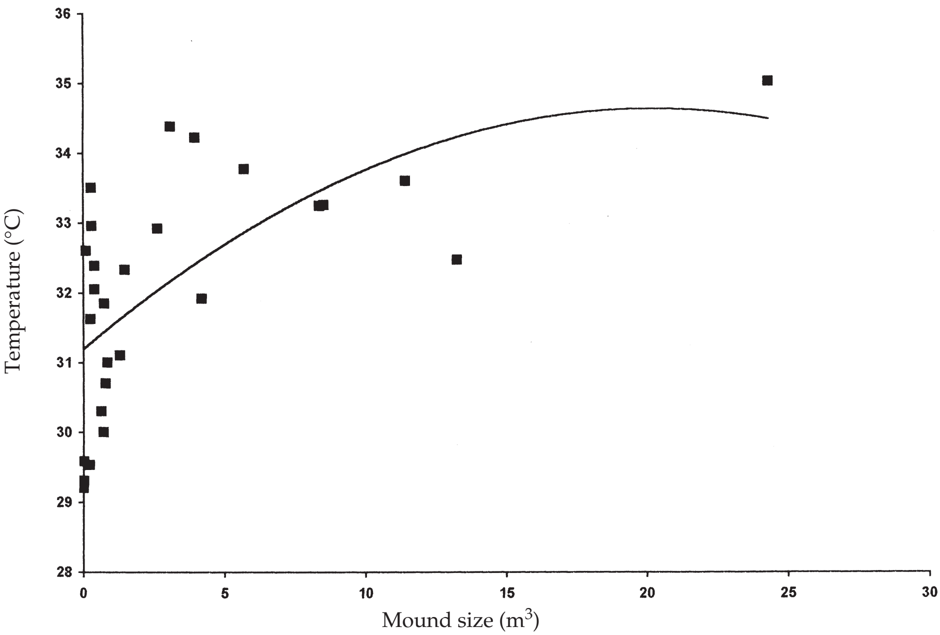

Fig. 4. Relation between mound size (m^3) and temperature (°C) in mounds of the Nicobar megapode.

The role of light intensity and soil respiration on the incubation temperature

Solar radiation does not seem to play a role of significance in establishing suitable incubation temperatures within the mound of the Nicobar megapode as was evidenced by mound surface temperatures usually being 2-4°C less than the temperature within the core of the mound.

The increase in microbial activity inside a mound and the consequent increase in temperature in the same mound in two different years seems to indicate that microbial activity is the primary source of heat in mounds (table 2). The lack of a clear relation between microbial activity and mound temperature may indicate that while microbial activity is the main source of heat production, it may not play a role in either the optimalization or the stabilization of core mound temperatures. Our data indicate that optimalization and stabilization of mound temperatures are probably governed by mound size (fig. 4).

Egg laying and hatching success

Of the 32 mounds that have been active in the study area in 1996 or 1997, eggs have been laid in at least 30. In 1996, 22 mounds were active and contained eggs. Five

Table 2. Factors influencing mound temperature in the Nicobar megapode. The values are means of all data collected between January and June in each year.

Mound ID	Size (m^3)		Temperature (°C)		Soil respiration ($gCO_2/m^2/h$)		Light intensity (lux)	
	1996	1997	1996	1997	1996	1997	1996	1997
3	3.1	3.1	31.5	34.4	4.1	5.7	1066	3460
8	4.1	8.5	31.5	33.3	5.2	6.5	1748	2640
9	5.4	3.9	35.8	34.2	5.1	6.3	6393	1119
10	27.4	24.3	32.3	35.0	3.7	6.1	7006	5230
13	11.2	13.2	31.4	32.4	6.8	7.4	2893	1170
14	6.2	8.4	31.6	33.2	5.5	6.5	6768	6430

of these mounds were not used for egg laying in 1997: two were abandoned, while in the remaining three megapodes did some digging, albeit rarely.

There is a relation between mound size and the number of eggs in a mound (fig. 5, table 3). Overall, the smallest mounds (<1 m^3) contain the least number of eggs (x = 1.6 ± 0.56 eggs, n = 16), though there are exceptions and two mounds in this sample contained six and eight eggs respectively. Medium sized mounds (1-5 m^3) have a larger number of eggs laid in them (x = 6.7 ± 1.48 eggs, n = 6), while, in general, the largest mounds contained the largest number of eggs (x = 8.2 ± 1.91 eggs, n = 6) (fig. 5).

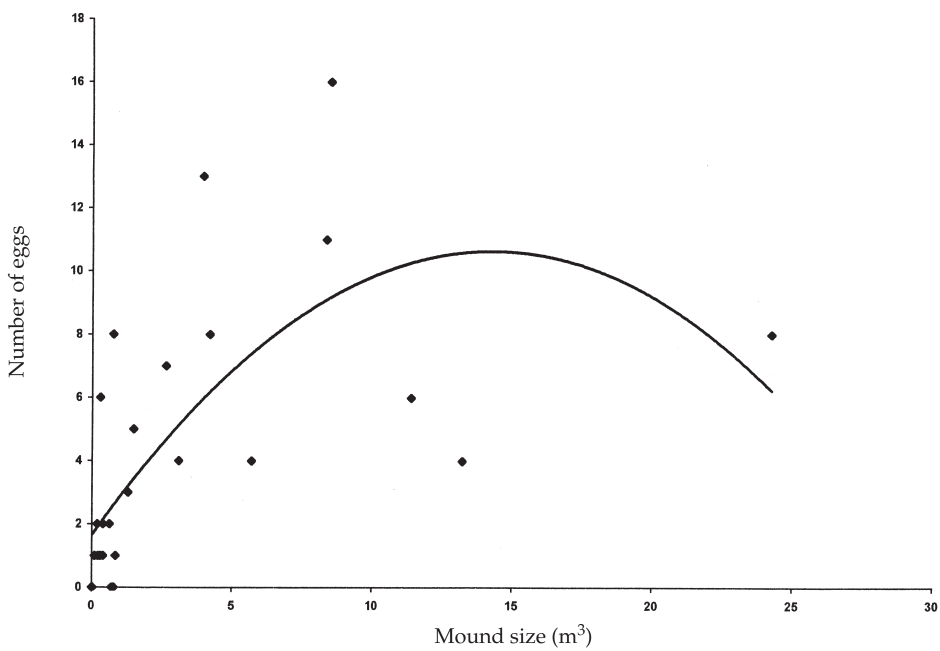

Fig. 5. Relation between mound size (m^3) and the number of eggs in the Nicobar megapode.

Table 3. The number of pairs of Nicobar megapode, the number of eggs laid, and the hatching success in mounds of different sizes. Data only for mounds in which eggs were marked and monitored.

Mound size in m^3 (No. of mounds in size class)	No. of marked (+ unmarked) pairs using the mound [# of mounds]	No. of eggs (mean eggs/) mound	No. of eggs marked and monitored	No. of marked eggs that hatched (%)
<1 (7)	1 (+1), [1]	26 (3.7)	11	10 (90)
1-3 (4)	-	17 (4.3)	11	8 (73)
3-5 (5)	2 (+ ?), [1]	28 (5.6)	17	16 (94)
5-10 (3)	5(+ ?), [3]	34 (11.3)	22	15 (68)
>10 (3)	1(+ 1), [1]	18 (6)	5	2 (40)

Hatching success was recorded in 22 mounds. Our clumped data indicate that the highest hatching success was recorded in small and medium sized mounds (table 3).

Social organization

Our study area has a population of more than 50-60 pairs of megapodes as well as several unpaired birds of both sexes. In 1996 and 1997, 23 megapodes were colour marked, which at the time of capture represented 15 pairs and four unpaired individuals, two of which later paired with each other. Of these 16 pairs, both male and female were colour-marked in five pairs.

Distribution of mounds

At the start of the study in January 1996, there were 18 active mounds in our study area (fig. 2). Between January and June 1996, four new mounds were constructed. Between December 1996 and June 1997, an additional eight mounds were built. Two mounds had been abandoned between June 1996 and December 1996. In September - October 1997 two more mounds were constructed, and by November 1997, 30 mounds were actively used within our study area. Two mounds which were active at the commencement of this study had been abandoned.

While mounds are present throughout the study area, some degree of clustering is discernible (fig. 2). Of the 32 mounds studied, eight clusters can be recognized: one cluster of four mounds, one of three and six of two mounds each. Of the 14 new mounds built, eight were built so as to add on to an existing cluster (n = 2), or form a new cluster (n = 6). There did not appear to be a relationship between the size of a mound, and the propensity for additional mounds to be built so as to form a cluster.

Mound use

At least 65% of the mounds were used by more than one pair. The mean number of pairs per mound is 2.3 ± 0.3 (n = 29). Ten of the smaller mounds were used for egg laying by only one pair each. However, data obtained from colour marked birds indicated that even more pairs used a mound than we had calculated from observations of an unmarked population. Between January and June 1997, six mounds were used by one to five colour marked pairs ($x = 3.0 \pm 0.67$ pairs per mound). This is a minimum value as also unmarked pairs used these mound simultaneously. Of the 16 colour marked pairs, 12 pairs (75%) laid eggs in a single mound only, three pairs (18%) used more than one mound for egg laying, and one pair changed mounds.

Territory

The Nicobar megapode is a strongly territorial species. Typically, a territory has a fairly large exclusive area with a mound at one corner. Here, the territory overlaps with that of other pairs that use the same mound (fig. 6). In case of one particular mound, which was not part of a cluster, one of four colour marked pairs had a particularly large territory which included two mounds (G14/O14 in fig. 6). This pair used both mounds for egg laying. In another case where four mounds occurred in a tight cluster, more than one territory overlapped at the cluster (fig. 7): one of three colour marked pairs used two adjacent mounds (9 and 9c in fig. 7), one pair used three mounds (9, 9a and 9c) and one pair initially used three mounds (9, 9c and 9b) but subsequently shifted to a distant mound (10b in fig. 7). The position of the territory varies between egg laying and non egg laying periods. It appears that territories either shrink to exclude the mound outside the egg laying season or the birds establish a

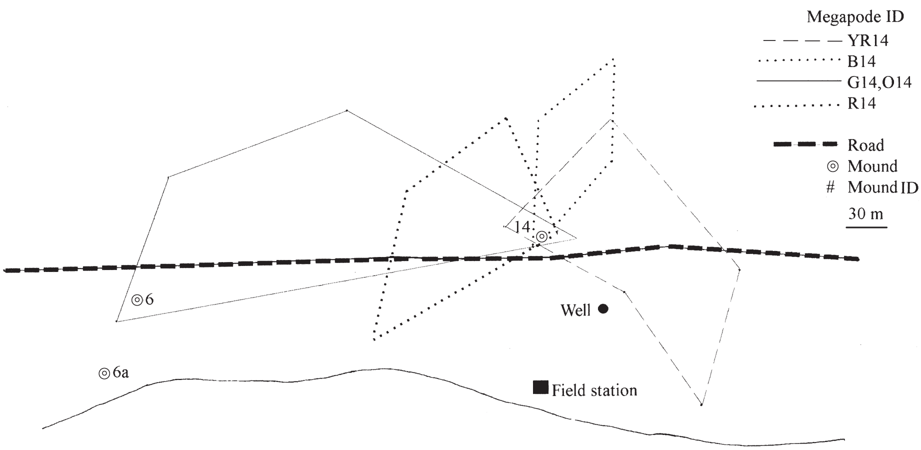

Fig. 6. Most Nicobar megapode incubation mounds are used by more than one pair of birds, whose territories overlap at the mound. Some pairs, like G14, 014, may have large territories that have within them two or more incubation mounds in which the pair may lay eggs.

new territory away from the mound.

Defence of a territory is through frequent duetting, physical fights and chases. The duet (contra Jones et al., 1995) is usually initiated by the female. Up to eight birds may aggregate in a very small area calling aggressively. Physical fights take place between pairs, or between solitary birds and pairs, and is largely sex based. The majority of the territorial disputes which result in physical encounters take place in the areas immediately around the mound and the area of overlap between two or more territories (fig. 7).

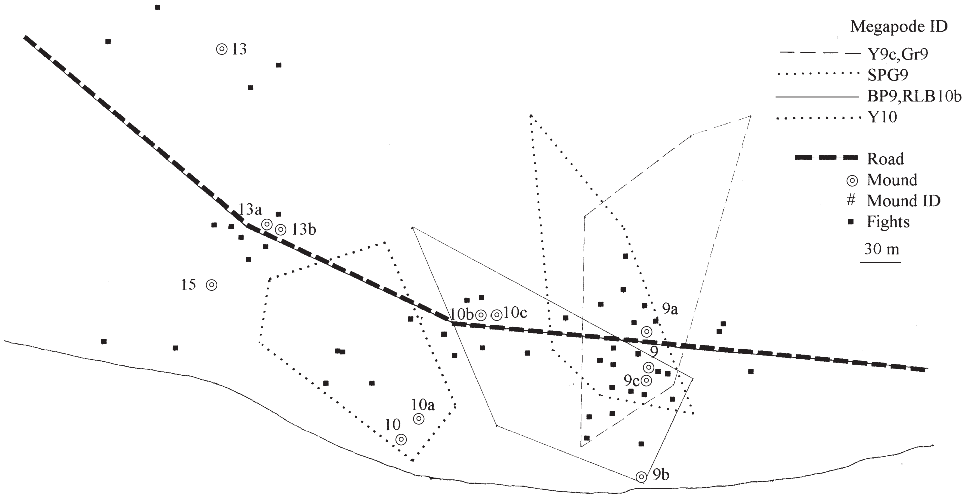

Fig. 7. The territories of four colour marked pairs of the Nicobar megapode. Territories overlap at the incubation mound which may be used by more than one pair, or a pair may use more than one mound present within its territory. The majority of territorial fights take place at or near the mound, and in the area of overlap between two adjacent territories.

There seems to be a strong hierarchy between pairs that use a mound at any given time. This hierarchy is evidenced by the dominant pair (the pair in which both male and female are dominant) usually spending most of the time at the mound, its greater involvement in mound defence and the likelihood of it disrupting other pairs while working on the mound. The defence of a territory requires equal participation of both sexes. However, this hierarchy varies temporally and spatially. The dominant pair maintains its position at the mound apparently only as long as it is laying eggs, subsequent to which its hierarchial position is occupied by either a pair which was already present at the mound, or by a new pair. Subdominant pairs may shift territories to occupy a different mound (BP9 in fig. 7), or may lay eggs in two mounds (GOF8 in fig. 8). Dominant pairs may also lay in more than one mound (G14, 014 in fig. 6). Solitary birds of either sex do not defend territories, but usually attach themselves to a mound, working on it when pairs that use that mound are absent. Solitary birds as a rule do not vocalise in response to duets, but have been recorded calling on occasion during aggressive encounters.

Pair bond, pair formation, copulation & displays

Pairs L8 and P8 which were colour marked in 1996 had, by the commencement of the 1997 season, separated from their original partner. The female of L8 was paired with an unmarked male and laid two eggs in the mound in which she laid eggs in 1996, when along with the male L8, she formed the dominant pair (fig. 8). The male of L8 had paired with an unmarked female who was later ringed as GO8. While paired with male L8, GO8 laid two eggs in the same period and in the same mound in which female L8 laid her eggs (fig. 8). Male L8 and GO8 became the dominant pair. In

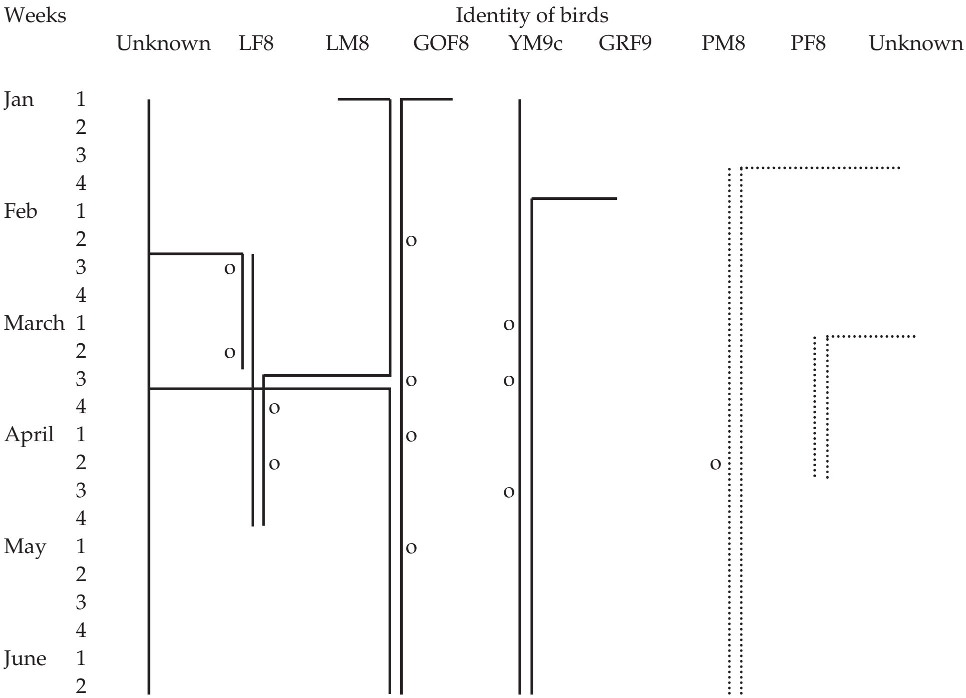

Fig. 8. Pair bonds in the Nicobar megapode in 1997. The tenure of pair bonds is tracked by solid or dashed vertical lines. The solid lines indicate frequent use of a mound and the dashed line indicates infrequent use. The 'o' sign indicates the laying of an egg. F or M in the individual identity indicates sex, and the number indicates the mound used by that individual. Note changes in partners midway through the egg laying period of the female.

March, male L8 and female L8 rejoined and became the dominant pair of the mound again, and together laid two more eggs (fig. 8). GO8 paired with an unmarked male and continued to use the same mound. They became the dominant pair when pair L8 had completed egg laying in April (fig. 8). The male and female P8 who, after their separation, were paired with unmarked birds, did not rejoin.

We only have one instance of a new pair being formed from two colour marked birds that were unpaired when trapped (fig. 8). Male Y9c built a new mound (9c, fig. 7) adjacent to an existing mound where solitary female GR9 had attached herself to (9 in fig. 7). We suspect that, to form a pair, a solitary bird either has to attach itself to a mound or construct a new one. One marked solitary megapode has now remained unpaired for nearly two years, though it had briefly formed a pair for about one week. This solitary male has a home range that included at least three mounds.

Copulation within a pair has been observed three times. On one occasion, a male chased its partner and mated with her repeatedly. On another occasion, a male chased its partner onto a branch and copulated with her on the branch. The third observation was after a fight with another pair, after which the winning male returned to its partner and mated with her.

Extra-pair copulation has also been recorded. On one occasion in 1997, the male of a pair copulated or attempted copulation six times with the female of another pair during a fight which lasted for about 45 minutes, and during which it continually chased the female of the other pair into trees where copulation was attempted. Their respective partners were calling but neither fought or attempted mating. In 1998, extra-pair copulation was seen twice, in both instances it was part of physical fights. The second instance was between nine birds that included three pairs and three unpaired birds, two of which were males. In this instance the fight was initiated between a pair and an unpaired female who was raped by the male. They were then joined by another pair, whose male raped both the paired and unpaired female. These were then joined by two unpaired males, and then by one more pair. Intra-sexual physical fights and inter-pair copulation took place apparently indiscriminately for about an hour. In at least five other instances, rape has been attempted but copulation was not observed by us.

We have not observed any intra-pair displays between a male and female Nicobar megapode. On one occasion a male exposed food two to three times while working on a mound when the female reacted to his signals and ate it. The maintenance and confirmation of the pair bond appears to lie solely in the duetting, the joint defence of territories and mounds, and in the digging of mounds. Pairs may keep in touch by low contact calls, and display anxiety when separated.

Discussion

Incubation conditions within mounds, egg laying and hatching success

Megapode mounds are amongst the largest structures made by any non-colonial bird, and represent the harnessing of the energy produced by microbial respiration (Seymour et al., 1986; Jones, 1989) and/or solar radiation (Frith, 1956). Incubation temperatures in megapode mounds show considerable fluctuation, and while the negative effects of these fluctuations on eggs are largely offset by a variable incubation period (Booth, 1987), there are strategies to balance both heat loss and gain (Jones, 1989; Jones & Birks, 1992). While mound maintenance is thought to play a role in maintaining suitable incubation temperatures, Seymour (1985) proposed, for mounds of the Australian brush-turkey *Alectura lathami* J.E. Gray, 1831, and malleefowl *Leipoa ocellata* Gould, 1840, that heat production and heat loss tend to stabilize mound temperatures at an equilibrium. This is due to the great thermal inertia of mounds once they reach certain dimensions, because they have an adequate moisture content, and because of the regular incorporation of fresh, moist organic material. However, the incubation mound of the Nicobar megapode does not fully fit these assumptions. First, the size of the mound can vary in height from ten cm up to 2.1 m and in basal circumference from seven to 45 m (Sankaran, 1995b). Second, the proportion of organic material in a mound varies (Sivakumar & Sankaran, in press), and third, the gap in the canopy above a mound varies resulting in differences in the amount and duration of sunlight falling on a mound. This might indicate that the heat sources which create suitable incubation conditions within a mound may vary, with some mounds appearing to rely on organic decomposition and others on sunlight.

Solar energy, however, probably does not increase mound core temperatures directly. The canopy above a mound causes direct sunlight to fall on a mound only for very short periods, with the result that both ambient temperature and mound surface temperatures are almost always lower than mound core temperatures. Thus, the role of solar energy is probably restricted to warming the surface of the mound, whereby dissipation of heat is reduced.

Microbial respiration is the primary source of heat harnessed by most mound building megapodes in their mounds (Jones et al., 1995). A clear relation did, however, not exist between mound temperatures and organic activity as evidenced from soil respiration. An overall increase in mound temperatures and soil respiration between years in the same mounds indicated that organic activity is probably the primary source of heat in the mounds of the Nicobar megapode. Microbial respiration, however, does not have a linear relation to the temperature of the mound, and mounds with higher levels of soil respiration did not necessarily have higher temperatures (table 2). Two factors could be responsible for this. First, there might be differences in the amount of heat produced by decomposition due to the kind of leaves and other organic litter added to the mound. Second, the rate of heat loss probably differs between mounds, caused by differences in the proportion of surface area to the volume of mound or to the amount of moisture content within the mound (Jones et al., 1995).

Our observations on the influence of mound size on mound temperatures are consistent with the model of mound homeothermy (Seymour, 1985; Jones et al., 1995). Small mounds show a greater variation in mound temperature than large mounds, with small mounds showing temperatures below, at or above optimal incubation temperatures (32-35°C; Dekker, 1990) while the incubation temperatures of large mounds lay within the optimal incubation temperature range. Thus, while the rate of microbial respiration is independent of size, and small mounds may have higher levels of microbial activity, stabilization at optimal incubation temperatures is consistent only in large mounds. One would therefore expect that eggs in large mounds are more likely to hatch successfully than those in smaller mounds. However, hatching success does not reflect these trends. Small and medium sized mounds had a higher hatching success than the largest mounds. We do not have an adequate explanation for this as yet, though more digging activity in larger mounds, and consequently greater exposure of eggs to the atmosphere is a possible factor.

The optimalization of incubation conditions in large mounds is reflected in an overall trend of a greater number of pairs using these mounds, and consequently, a greater number of eggs laid in them. However, we interpret the exceptions, that is small mounds having a greater number of eggs, or larger mounds having fewer eggs, an indication that size is not the only criterion. The quality of the mound, and the number of pairs using a mound, which appears to be somewhat independent of mound size, are probably other determining factors. The data indicate that medium sized mounds have the largest number of eggs. The smallest mounds probably have physical limitations as to the number of eggs that can be laid in them, and the largest mounds are probably moribund, and hence used by fewer pairs.

Social organization

The social organization of megapodes is poorly understood. Most megapodes, particularly those belonging to the genus *Megapodius*, are believed to be monogamous as most species exhibit features such as monomorphism, highly synchronised behaviours, and duetting (Jones et al., 1995). These characteristics indicate that pair bond in most megapodes is strong therefore excluding the need for and the chance of extra-pair copulations (Jones, 1989). It is also believed that monogamy is inevitable in mound building species since high paternal investment can only be expected if male parental care benefits their own progeny (Jones, 1989). Monogamy in megapodes, however, is an anomaly as female emancipation from parental care, and the presence of resources (the incubation mound) that can be dominated by males, should result in a polygynous mating system (cf. Orians, 1969). Promiscuity has been documented or suspected in some mound building megapodes that exhibit sexual dimorphism (Jones, 1989; Jones et al., 1995), and an instance of polygamy has also been documented for the monomorphic malleefowl which was believed to be strictly monogamous (Weathers et al., 1990; Jones et al., 1995).

Though the Nicobar megapode exhibits characteristics of permanent pair bonds which are consistent with several other species of mound building megapodes (Crome & Brown, 1979; Jones et al., 1995), our finding is that the break up of pairs either between years, or within the breeding season, is prevalent. Moreover, extra pair copulation does occur, and is probably a regular component of the innumerable agonistic interactions. This indicates that the pair bond in this species, and possibly in other mound building megapodes, may be far less permanent than was thought (cf. Jones et al., 1995).

The apparently equal role of both sexes in the defence of a territory and the incubation mound, and the temporal hierarchies that are evident between pairs that use the same mound, indicate that the pair bond in the Nicobar megapode serves the primary function of giving a pair access to an incubation mound, and enabling them to defend this access. Either sex may therefore change partners to improve access to or defence of a mound. That access to a mound appears to be the primary function of the pair bond is also evidenced by the total absence of courtship display that in most other monogamous species serves as precopulatory display and strenghtens or reinforces the pair bond. The lack of courtship display is apparently consistent in most megapodes.

The presence of sexually mature unpaired birds of both sexes for apparently extended periods of time is of particular interest. Megapodes probably remain unpaired due to absence of space within which to establish a territory. This appears to be a key function of pair formation. The frequent fights between solitary birds and pairs, and the intra-sex fights that takes place during such encounters, may indicate that solitary birds attempt to steal mates from existing pairs. Unpaired birds of either sex, however, probably do breed successfully. Unpaired males attempt to forcibly copulate with the females of pairs during agonistic interaction, and unpaired females have been recorded copulating with males of pairs. Also, solitary females have been observed egg laying eggs. It is not known whether unpaired males and females copulate, though a very brief pair bond was formed between two such individuals.

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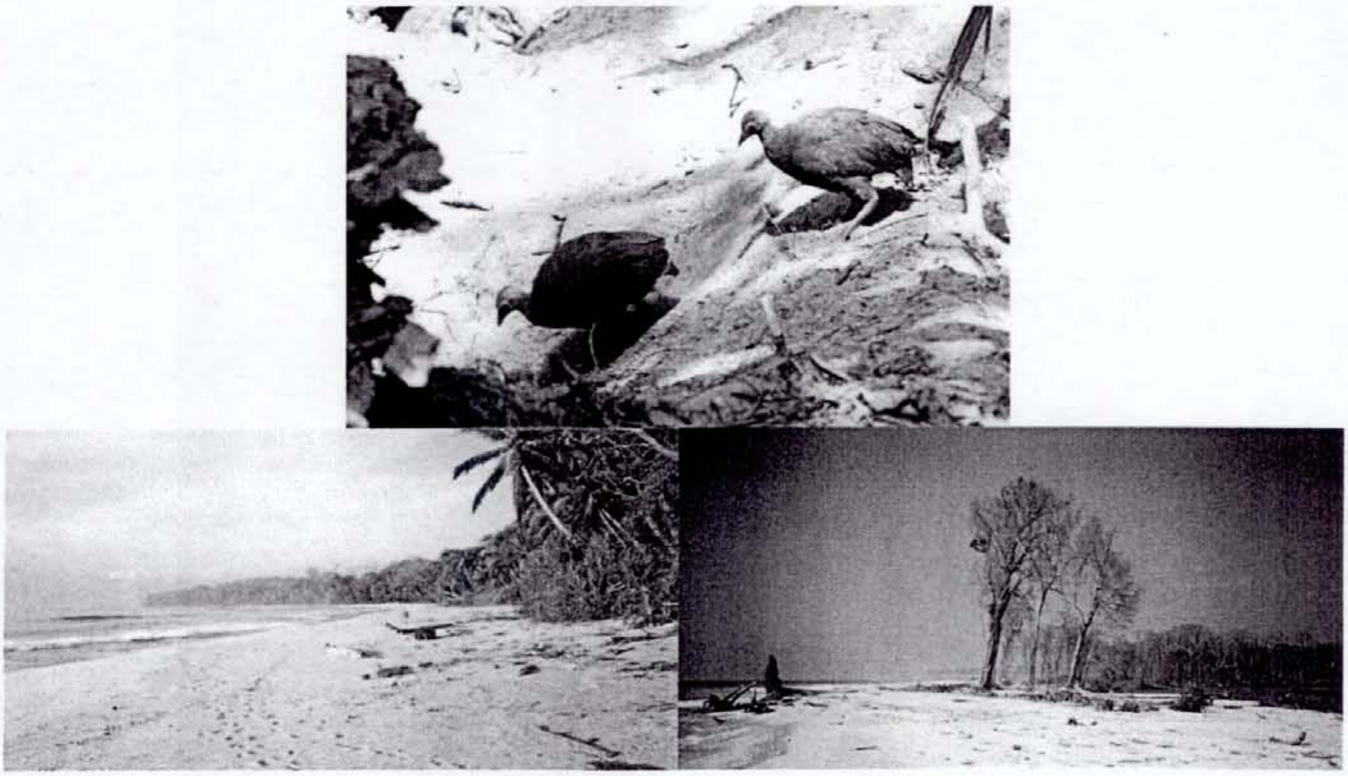
The Nicobar megapode

Status, ecology and conservation: Aftermath tsunami



K Sivakumar

Final Report

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Dehradun

February 2007

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Executive Summary

1. The Wildlife Institute of India conducted a status survey of the Nicobar megapode along with other coastal endangered species in the Nicobar group of islands in an effort to document the adverse impacts on their populations due to tsunami that occurred on 26th December 2004. The endemic Nicobar megapode population showed a dramatic decline (nearly 70%) in the number when compared to previous survey carried out in 1993-94. In 2006, there are approximately 800 breeding pairs in the coastal zones of these island group.
2. There was no evidence of Nicobar megapode in Megapode Island WLS and Trax Island during this survey where megapodes was reported earlier.
3. Crucial megapode habitats such as littoral forests of the island group were adversely affected. The populations of indicator species of the littoral forests *Barringtonia asiatica* and *Terminalia bialata* were severely impacted. However, regeneration of these species was found on the coastal region.
4. The island ecosystem are known for their resilience due to their ability for re-populating habitats and promoting regeneration. However, the restoration of the original biodiversity is possible only if the natural process such as recolonization is facilitated. The aftermath of the tsunami has left the trail of homeless families who need rehabilitation. Finding proper homes and alternate livelihood for them should not undermine ecosystem resilience. Raising plantation crops to generate revenue in the littoral forests should take into account the long term effects of habitat alteration.
5. Significant levels of wildlife habitats have been occupied by the tribals under the leadership of the tribal chiefs (known as Village Captain). Any conservation awareness programme with the help of these Village Captains would be useful for implementing recovery plans of declining species.
6. The Nicobar Division of the State Forest Department needs to be strengthened to facilitate wildlife protection and to take up appropriate wildlife management actions.
7. A total of 37 permanent monitoring plots have been identified and marked (Table 2) for long term monitoring of megapodes and its habitat. With some basic training, forest staff can collect data from these plots and within a weeks time all islands can be surveyed and collected data analyzed for developing appropriate conservation and management measures.

Content

Chapter 1
The Nicobar megapode

1.1. Introduction

The megapodes are a unique group of birds as they utilise external sources of heat to incubate their eggs (Jones *et. al.* 1995). The Megapodiidae, literally meaning big feet after the disproportionately large feet of the birds, were first described to science during Magellan's 1519-1522 expedition to the Far East (Frith 1956 & 1959). The family Megapodiidae consists of 22 species in seven genera, most of which are island forms occurring in Australia, New Guinea and surrounding islands, eastern Indonesia, the Philippines, Niuafo'ou Island, the Palau and Mariana Islands and the Nicobar Islands (Dekker 1989, 1990 & 1992). Thirteen of these 22 species are currently threatened by habitat destruction, introduction of predators and over-exploitation of eggs (Jones *et al.* 1995).

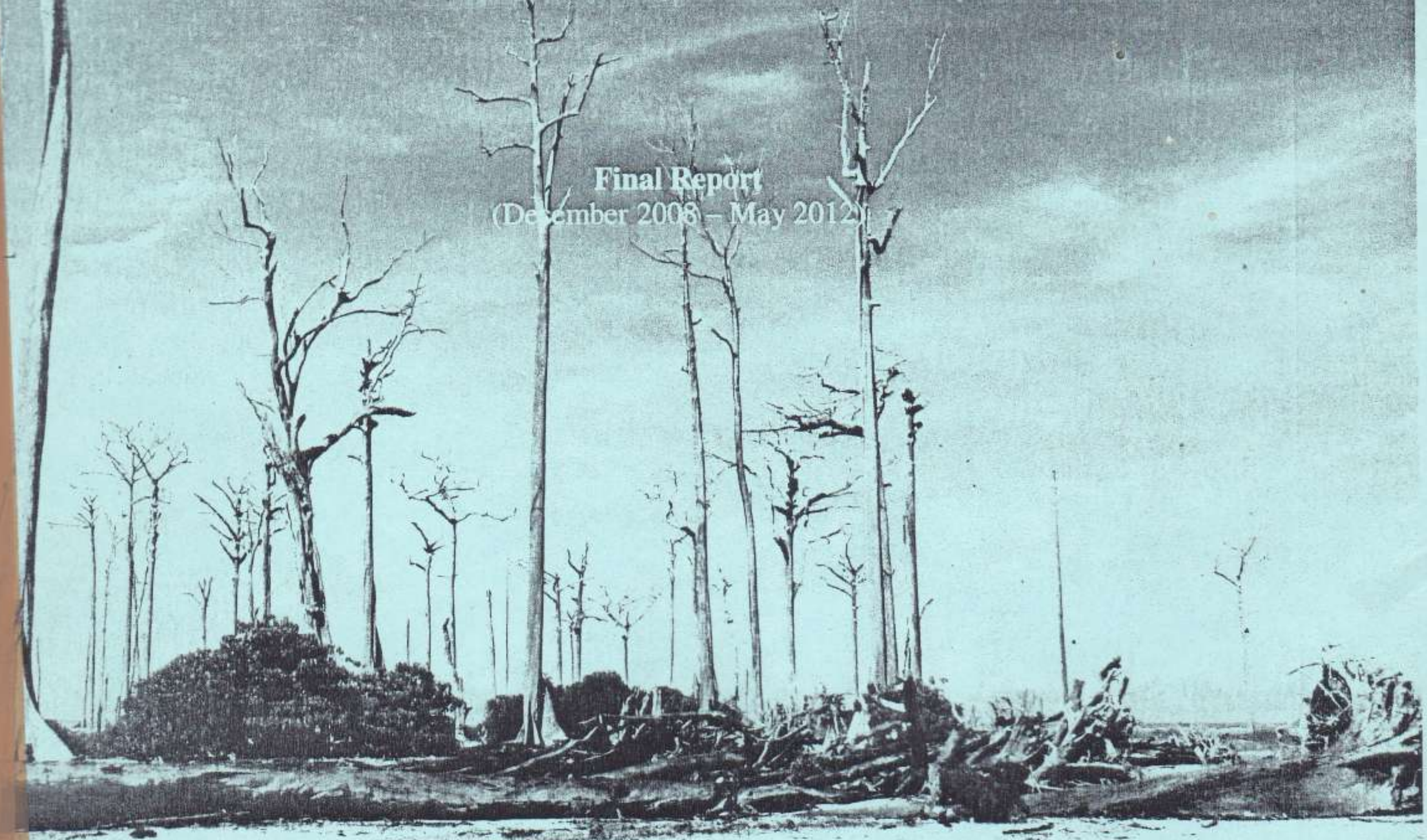
Megapodes are heavy-bodied birds of the forest floor and resemble Galliformes in body shape and plumage. Most megapodes are brown, blackish, or grey in colour. Many have virtually bare areas on their face or neck and this exposed skin may be coloured yellow, blue, or dull red. Megapodes are opportunistic ground foragers, eating a wide variety of food such as insects, seeds, and fallen fruits. Although all are able to fly, and some make considerable flights on a daily basis, most species move primarily by walking (Jones *et al.* 1995).

The taxonomic position of the family Megapodidae is still subject to debate (Jones *et al.* 1995). In the past, megapodes were believed to have more affinities with Charadriiformes, Columbiformes, Passeriformes and even Falconiformes. Later megapodes were included in the order Galliformes along with Guans and Curassows which are sometimes classified under a separate order Craciformes (e.g. Sibley and Monroe, 1990). In 1899, Sharpe divided the Galliformes into several suborders, the "megapodii" was first among them. After studying the osteological, karyological and biochemical properties of egg white proteins of megapodes and other galliformes, Megapodiidae was considered as the sister group of all remaining Galliformes (Jones *et al.* 1995).

The family Megapodiidae contains seven genera : *Megapodius, Macrocephalon, Talegalla, Aepypodius, Alectura, Leipoa* and *Eulipoa*. The genera *Megapodius* and *Eulipoa* have the smallest megapodes and their geographical variation is considerable but most are domestic-chicken-sized birds with short tails and a short pointed nuchal crest (Beehler *et al.* 1986). The monotypic genus *Macrocephalon* is closely related to the genus Megapodius. The *Talegalla* species do not have wattles and are large sized black coloured megapodes. Alectura is considered to be closely related to *Talegalla* and *Aepypodius*, a group known as the Brush-turkeys, each having a bare neck and face that may be brightly coloured (Jones *et al.* 1995). *Alectura* and the two *Aepypodius* species also possess inflatable necksacs or wattles and combs, and have brilliantly coloured heads and necks (Jones *et al.* 1995). The Brush-turkeys are the only group in which sexual dimorphism is evident, with the males

ANNEXURE A22

MONITORING POST-TSUNAMI COASTAL ECOSYSTEM RECOVERY IN THE NICOBAR ISLANDS AND DEVELOPING SITE-SPECIFIC RESTORATION MEASURES



Final Report
(December 2008 – May 2012)

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P. Balasubramanian (June 2010 - May 2012)
Lalitha Vijayan (February 2009 - May 2010)
Ravi Sankaran (December 2008 - January 2009)

CO-INVESTIGATORS

P. Pramod (June 2010 – May 2012)
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SENIOR RESEARCH FELLOWS

A. P. Zaibin
P. Nehru

9/7/12

SACON

Sálim Ali Centre for Ornithology & Natural History

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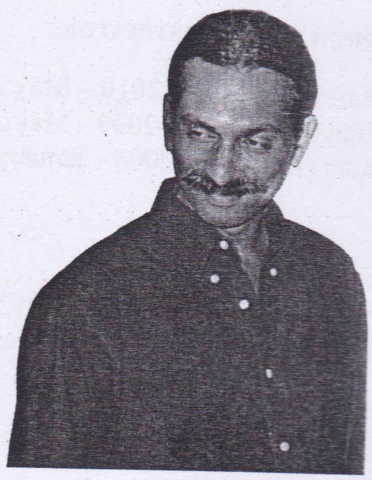


To Dr. Ravi Sankaran (1963 - 2009)

CONTENTS

CHAPTER - VI

NICOBAR MEGAPODE: POST TSUNAMI STATUS AND MOUND ATTRIBUTES

Megapodes (Megapodiidae) are the most peculiar of all Galliformes which show an aberrant strategy of incubating eggs in mounds of sand and leaf litter where heat is generated by microbial decomposition (Dekker 2007). Nicobar Megapode *Megapodius nicobariensis,* endemic to Nicobar Islands, is geographically isolated from its nearest congener about 1,600km away (Olson 1980*). According to Dekker (2007) Nicobar Megapode is probably a relic species and once occurred on the Greater Sunda Islands from which they disappeared either through predation or competition. Historically, Nicobar Megapode occurred on most of the Nicobar Islands, but not on Car Nicobar and Chowra. Sankaran (1995) reported the species from 15 of 17 islands surveyed, thus confirming its occurrence in all islands where it has been historically recorded. The species occurs as two distinct subspecies namely, *Megapodius nicobariensis nicobariensis* in the Nancowry group and *M. n. abbotti* in the Great Nicobar group (Ali & Ripley 1983). Prior to tsunami, the species was found in greatest concentrations in littoral forests due to the propensity of megapodes to build incubation mounds close to the beach (Sankaran 1995b; Sivakumar 1999).

The mega earthquake that triggered the tsunami of December 26, 2004, caused Nicobar Islands to subside in places by nearly 4.75 m (Sekhsaria 2009) destroying vast tracts of littoral forest (Sankaran 2005). Nicobar Megapode was considered as the one of the most severely affected species due to loss of coastal habitats which species preferred to build incubation mounds. Sankaran (2005) conducted a rapid impact assessment of the Nicobars two months after the tsunami to assess the impact of tsunami on Nicobar Megapode and he estimated that nearly 1,100 nesting mounds had been lost. A systematic post-tsunami study in 2006 by Sivakumar (2007) showed nearly 70% decline in the number of individuals when compared to pre-tsunami populations. The present study aimed to assess the present status of Nicobar Megapode in Nicobar Islands where rapid regeneration of coastal ecosystem is under way.

6.1. Methodology

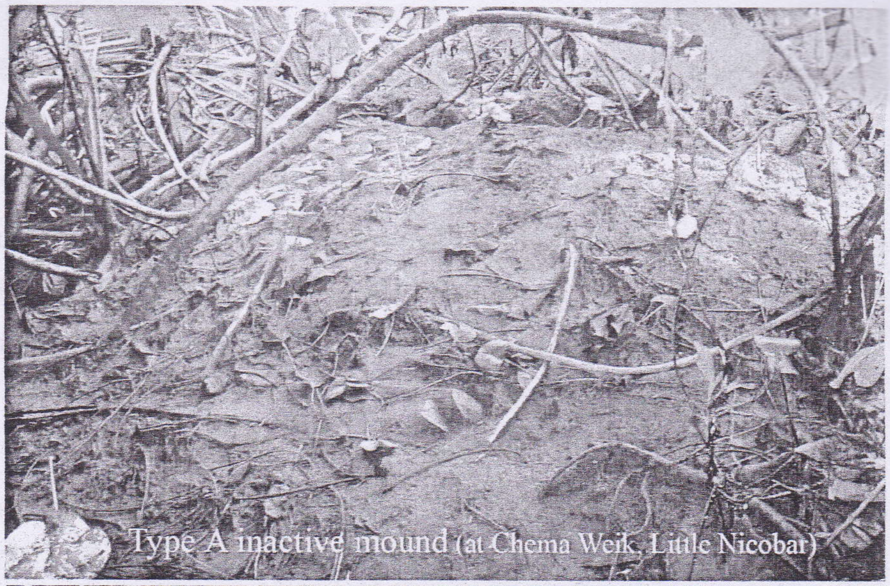
Eight islands in Great Nicobar group and seven in Nancowry group of islands with known *distribution of megapodes* were surveyed both in the tsunami-affected littoral zone and adjacent potential habitats. Selection of sites was *largely based on criteria* such as variation in damage level, terrain, vegetation community, and current and predicted levels of anthropogenic pressures. A reconnaissance field trip was made to Great Nicobar Islands during March-May 2009. Intensive studies were conducted between October 2009 and August 2011.

Sivakumar (2007, 2010) categorized 687 km coastal line of islands as (a) suitable habitat (328 km) and (b) unsuitable habitat (359 km) for megapodes. During the present study, a total of 73 km coastline habitats (34.9 km of suitable habitat and 38.1 km of unsuitable habitat) in 44 sites of 15 islands (Fig. 19) with previously known distribution of megapodes were surveyed. Direct sighting of the species, calls and the presence of its mounds were recorded. Surveys were done mostly from 0600 hrs to 1130hrs.

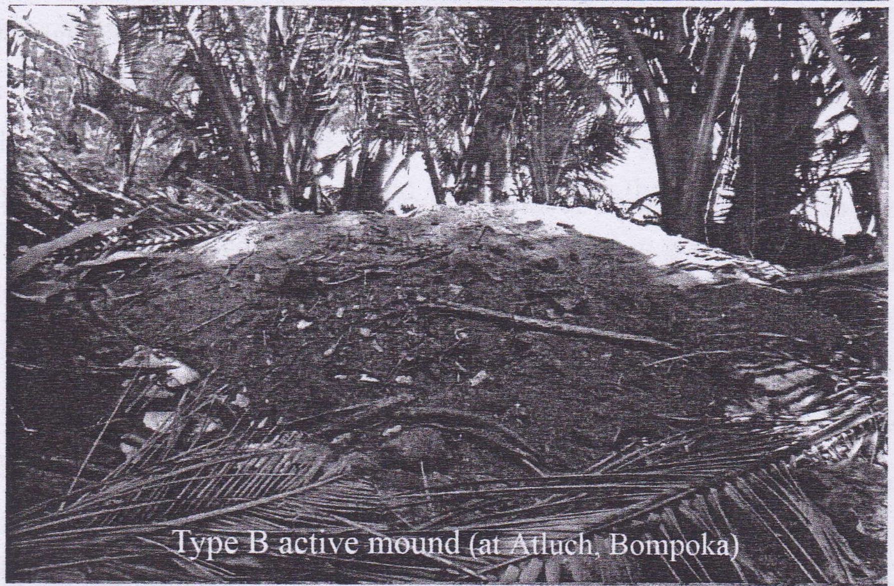
6.1.1. Population status and mound attributes

Enumeration of active mounds was carried out in the previous studies (Sankaran 1995b; Sivakumar 2007) to assess the population of Nicobar Megapode. In the present study also, active mounds were considered for population estimation. Mounds were GPS located during bird point count surveys. The paths taken during the point counts were considered as transects.

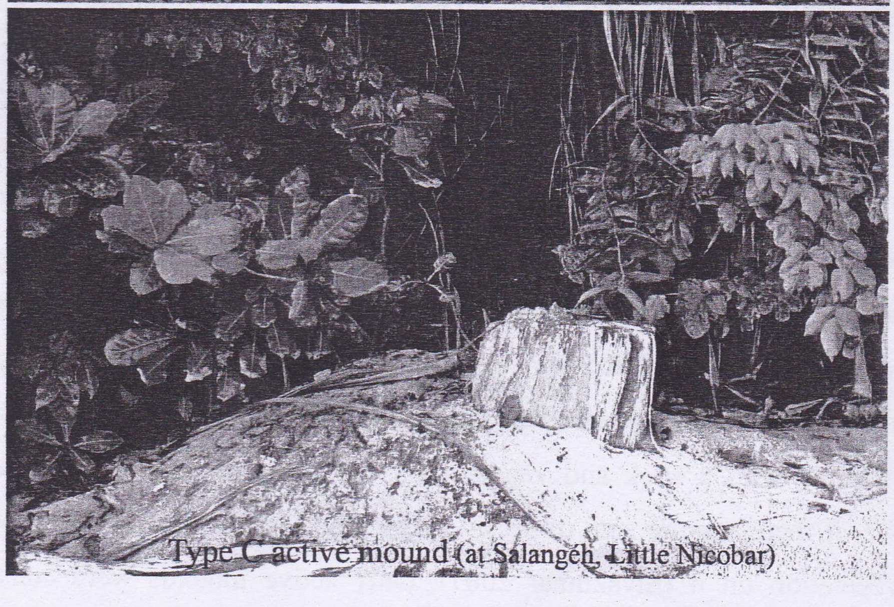
Mounds of megapode were characterised basically into three types: Type A, regular in shape and built on an open spot away from trees; Type B, irregular in shape and built against the buttress or stem of a large living tree; Type C, also irregular in shape but built against, around, under or over a dead rotting tree-stump or log (Sankaran 1995b). Mounds were considered active if the soil was loose and there were signs of recent digging by megapodes, regarded as abandoned if the mound was compact, hard and impenetrable with a stick and vegetation growing on it. Mounds were considered inactive, if there was no sign of recent digging and when the soil was loose without any vegetation on it (Sivakumar 2007). Only active mounds were considered for population estimation.



Type A inactive mound (at Chema Weik, Little Nicobar)



Type B active mound (at Atluch, Bompoka)



Type C active mound (at Salangeh, Little Nicobar)

Distance of mounds from sea-coast, canopy cover (%) and height over the mounds were estimated visually. GPS locations and elevations of mounds were noted. Size (volume) of the mound and average number of birds that use a mound are two pre-requisites for estimating the population of megapodes (Sankaran 1995b, Sivakumar 2000). One pair/mound was set as lower limit and two pairs/ mound was upper limit while considering average number of birds that use a mound (Sivakumar 2010). Mound diameter, height and basal circumference were measured. The mound size, expressed as volume, was calculated using the equation for the volume of a cone: $(1/3)\Pi r^2 h$, where 'r' is the radius and 'h' the height (Sivakumar 2007, 2010).

6.2. Results and discussion

6.2.1. Sight records

Megapodes were sighted from 13 of the 17 islands surveyed namely, Kamorta, Nancowry, Trinket, Katchal, Teressa, Bompoka, Great Nicobar, Little Nicobar, Menchal, Kondul, Cubra, PiloMilo and Treis Islands. No Megapodes could be sighted or heard in Meroe, Chowra, Tillangchong and on Pigeon islet. However, in Meroe two active mounds were located. Lack of sightings from Tillangchong was probably due to execution of very limited surveys during adverse weather conditions. Trax and Battimalv islands could not be visited. There had been no records of megapodes from Car Nicobar in the recent past. Sankaran (1995, 2005) and Sivakumar (2007) did not record Nicobar megapode from Pilo Milo after tsunami and remarked that the species had been extinct from the island. However, two individuals of megapodes were recorded from Pilo Milo during the present study (on 13 May 2011). According to Sivakumar (2007) Cubra islet is too small for the megapode to occur. A pair of megapodes was sighted during this survey on Cubra islet (on 6 May 2009) which occupy an area of about 0.1 km^2. Nevertheless, on a later visit (on 31 May 2011) to Cubra, the species couldn't be recorded.

The first sight records of Nicobar Megapode from Pilo Milo and Cubra during the present study is interesting. According to Dekker (2007), all *Megapodius* species are strong flyers and they can easily cover vast areas of open water, even at the chick stage. He also states that it is therefore no coincidence that species of *Megapodius* are widely distributed and occur on islands in the Pacific, eastern Indonesia, the

Philippines, and the Mariana and Nicobar islands. Locations of detections of Nicobar Megapode during the present study are presented in Appendix 4. Detections were exceptionally high in Bompoka and low in Trinket and Kamorta islands.

6.2.2. Population status and mound attributes

Of the total 73 mounds recorded, Type C mounds were common (46.6%), followed by Type A (27.45%). Low representation of Type B mounds could be due to scarcity of large live trees in the coastal areas after the tsunami (Sivakumar 2007). Status of mounds located included, active (40, 54.8%), inactive (17 mounds, 23.3%) and abandoned (15mounds, 20.5%) and the status of one case was uncertain. Signs of recent digging by Monitor Lizards were evident in a few mounds. Mean distance of the mounds from the coast was 85.5m (SD ±146.3), and maximum mound diameter and height were 4.6m (SD ± 2.1) and 0.7m (SD ±0.3) respectively.

Twenty eight mounds (44.4%) were found within 10m from the beach while 35 mounds (55.6%) were recorded within 10-600m (Fig. 24; Table 18). Occurrence of mounds close to the beach was high especially at sites with narrow flat coastal area between hill and sea as noted by Sivakumar (2007).

Fig. 24. Distance of mounds from shoreline

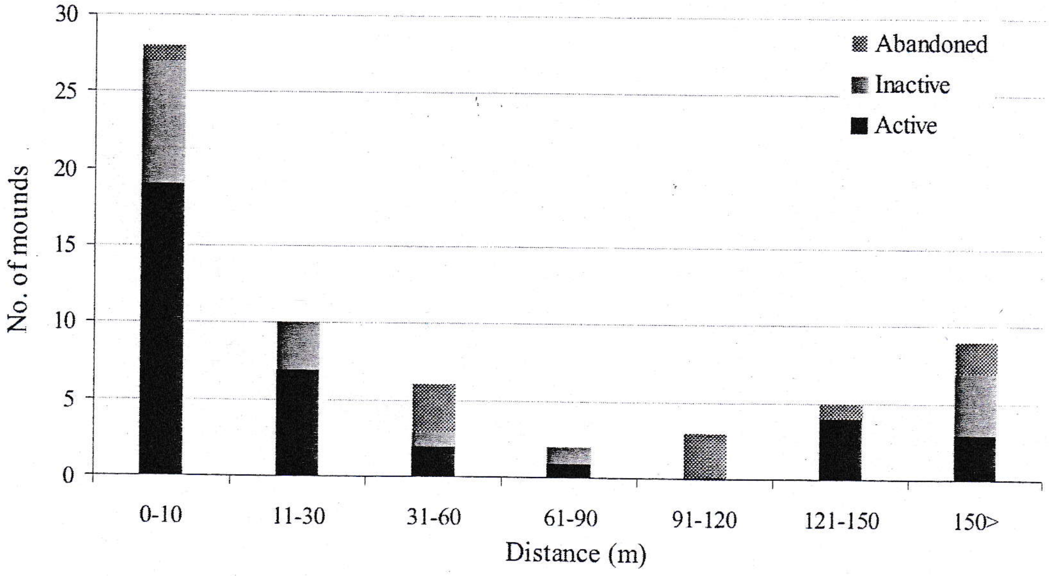


Fig. 25. Distribution of three mound types across various mound size classes

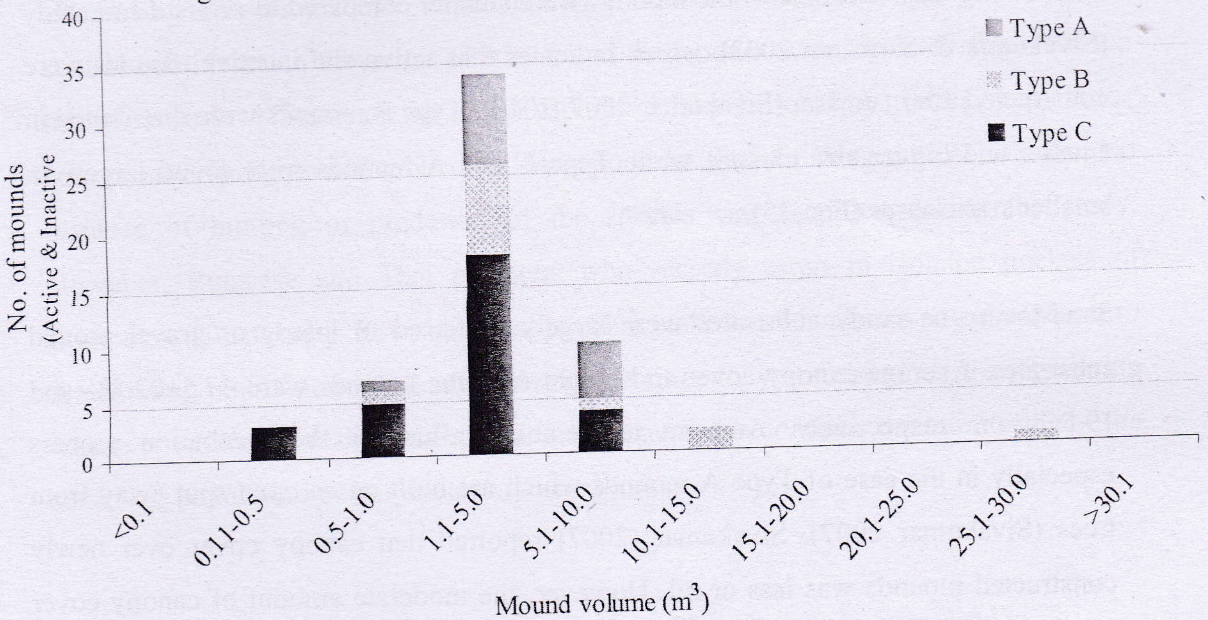
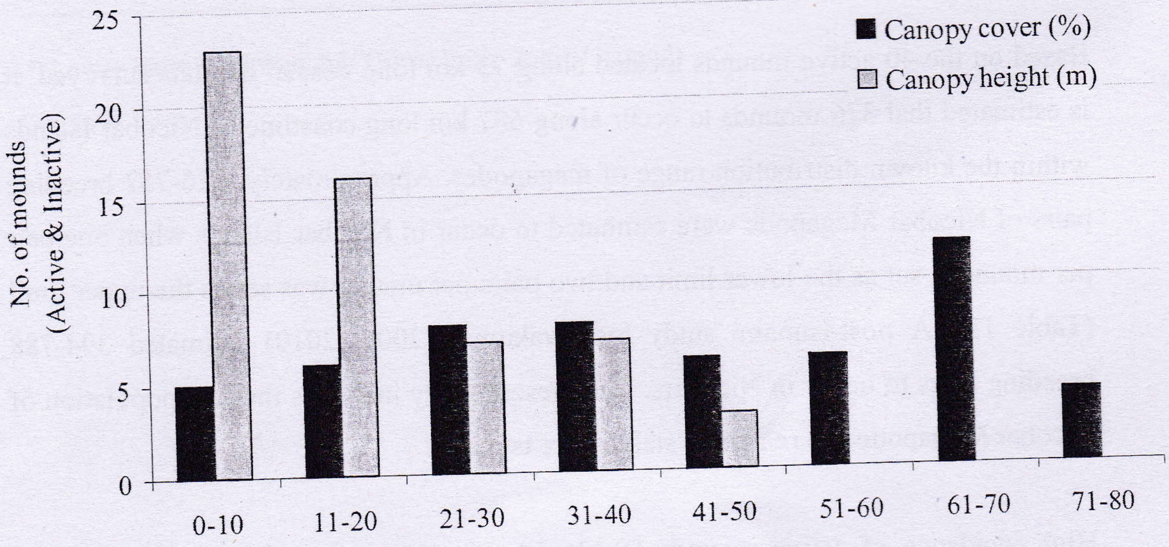


Fig. 26. Canopy cover and height above mounds of Nicobar Megapode.



Mean size (volume) of active and inactive mounds was 3.98±4.18m^3 (range 0.2m^3 to 26.8m^3; Fig. 25). The size of the mounds were smaller compared to pre-tsunami study (Sivakumar & Sankaran 2003), which indicates that active and inactive mounds were constructed after tsunami (Sivakumar 2007, 2010). Type B mounds were distributed in smaller and bigger size classes, while Type C and A mounds were found largely in smaller size classes (Fig. 25).

Sand-loamy or sandy substrates were largely preferred to loamy or gravel mound substrates. Average canopy cover and height over the mounds were 47.5±22.8% and 19.5±12.6m respectively. Ambient temperature influences the incubation process especially in the case of Type A mounds which are built on an open spot away from trees (Sivakumar 2007). Sivakumar (2007) reported that canopy cover over newly constructed mounds was less or nil. However, the moderate amount of canopy cover over the mounds (Fig. 26) found during the present study was due to the regeneration of habitat that is being undergoing for the last 6 years after tsunami has occurred.

This study shows similar patterns in the case of distance of mounds from coast, mound type and size, as observed by Sivakumar (2007), which indicates that no major change in mound characteristics of the Nicobar Megapode has happened in Nicobar Islands.

Based on the 40 active mounds located along 73 km long coastal habitats surveyed, it is estimated that 376 mounds to occur along 687 km long coastline of Nicobar Islands within the known distribution range of megapodes. Approximately, 376-752 breeding pairs of Nicobar Megapode were estimated to occur in Nicobar Islands when one pair per mound is set as the lower limit and two pairs per mound was set as the upper limit (Table 17). A post-tsunami study by Sivakumar (2007, 2010) estimated 394-788 breeding pairs to occur in Nicobars. The present study indicates that the population of Nicobar Megapode has remained stable after tsunami.

High incidence of active mounds (Table 18; Fig. 27) was noticed from Bompoka Island which has only an area of 13.3 km^2. The island is mostly hilly and forested with narrow flat coastal area between hill and sea. According to Sankaran (1995, 2005), Bompoka had a large population of Nicobar Megapode before tsunami. Though Sankaran (2005) reported high run up and ingress of tsunami waves at places in the island, the present study indicates that megapode population in Bompoka had been less affected by tsunami. Even an active mound built on soil substrate was recorded on the central hillside at an elevation of 93msl and megapodes were detected from hill top mixed forest (c. 178msl) on the island. Bompoka Island should be given priority in the conservation programs for Nicobar Megapode in the central group of islands. No instance of hunting or predation of the species was recorded during the study. However, Burmese and Thai poachers who secretly camp in isolated pockets of Bompoka, Tillanchong, Katchal, Great Nicobar and other islands are potential threat to the existing population of Nicobar Megapode since they are notorious for plundering whatever wildlife comes on their way. It is suggested to continue the monitoring of the surviving population of this species.

Table 17. Estimated number of active mounds and breeding pairs compared to previous studies.

Year (Reference)	**Estimated no. of active mounds**	**Estimated no. of breeding pairs (range)***
1994 (Sankaran 1995b)	1161	2,322–4,064
2006 (Sivakumar 2007, 2010)	394	394-788*
2009- 2011 (Present study)	**376**	**376-752***

*(Lower limit: 1pair/mound, Upper limit: 2pairs/ mound)

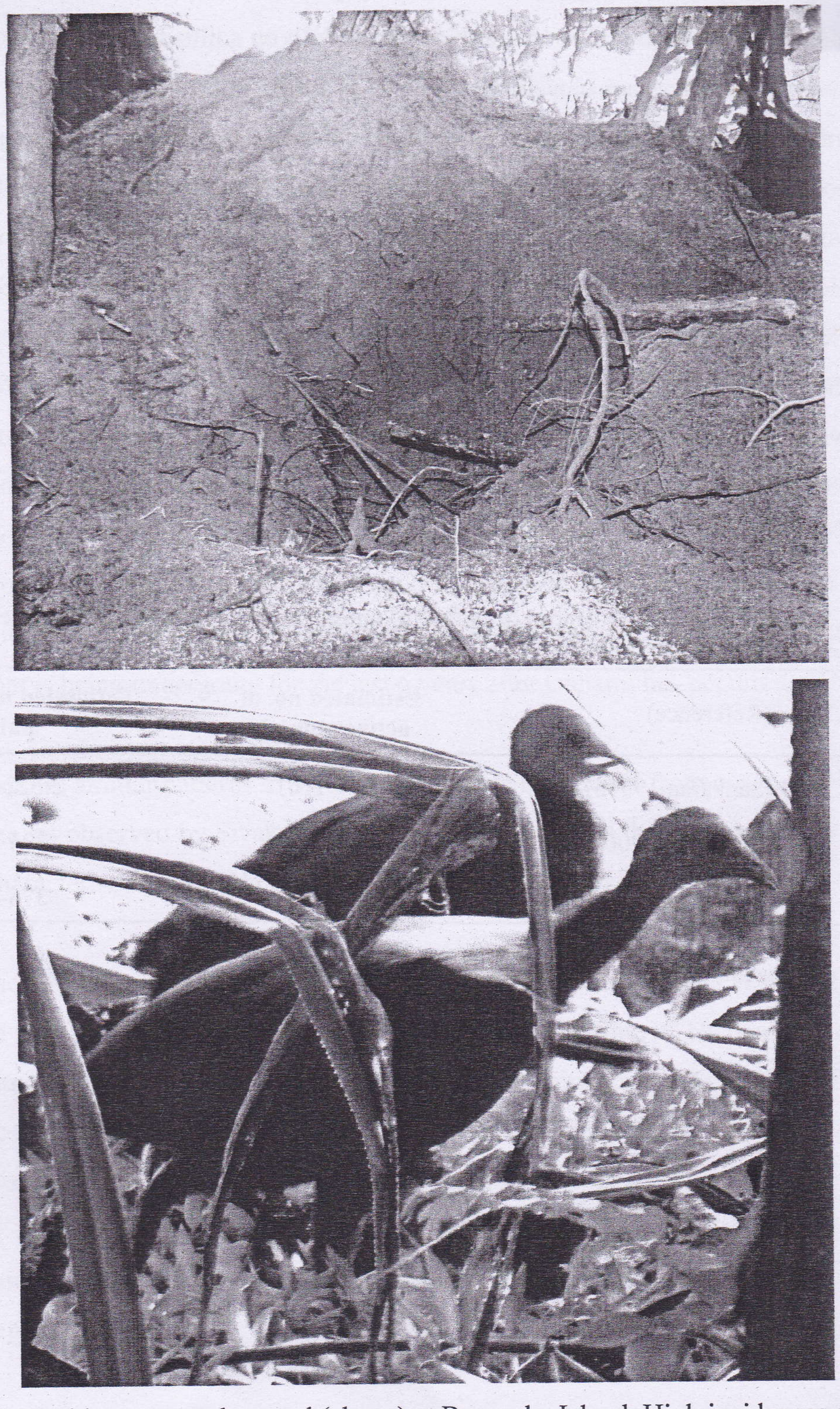


Fig. 27. Freshly excavated mound (above) at Bompoka Island. High incidences of active mounds were found in the island. Nicobar Megapode pair (below) at Atluch, Bompoka.

Table 18. Locations and characteristics of mounds of Nicobar Megapode recorded during October 2009- August 2011 in Nicobar Islands.

Island	Location	Date	Latitude (N)	Longitude (E)	Habitat	Mount type	Status	Substrate	Approx. dist_beach (m)	Canopy cover (%)	Canopy height (m)	Mound diametre (m)	Mound height (m)
Great Nicobar	Chingenh Pasthi	13/11/2009	06° 47′ 59.9″	93° 50′ 39.9″	Littoral forest (secondary)	B	Inactive	Sand-loam	50	65	40	2.85	0.85
	Chingenh Pasthi	13/11/2009	06° 47′ 59.2″	93° 50′ 39.1″	Littoral forest (secondary)	B	Abandoned	Sand-loam	50	70	45	2.55	0.45
	Chingenh Pasthi	14/11/2009	06° 48′ 10.7″	93° 50′ 42.4″	Littoral forest (secondary)	B	Abandoned	Loam	100	—	40	3.1	0.75
	Kopenheat	21/04/2011	06° 57′ 57.8"	93° 44′ 18.4"	Regenerating vegetation	C	Active	Sand	0	30	5	3.5	0.5
	Kasingdon	22/04/2011	06° 57′ 12.1"	93° 45′ 08.1"	Mixed forest (unaffected)	A	Active	Loam	150	—	—	5.1	0.4
	Trinket Bay area	31/05/2011	07° 12′ 09.8"	93° 52′ 36.5"	Regenerating vegetation	C	Active	Sand	2	35	30	2	0.4
Little Nicobar	Reing-Reing	07/11/2009	07° 16′ 19.6″	93° 38′ 13.0″	Mixed hill forest edge	B	Inactive	Loam	0	40	40	4.5	0.65
	Salangéh	26/10/2009	07° 17′ 51.9″	93° 42′ 06.4″	Mixed forest edge (coastal)	C	Inactive	Sand	2	50	12	3.7	0.6
	Lenyih	26/10/2009	07° 17′ 09.6″	93° 40′ 42.8″	Mixed forest (disturbed)	C	Inactive	Sand-loam	80	20	45	4.2	0.8
	Kankohá	26/10/2009	07° 18′ 19.0″	93° 42′ 28.1″	Mixed forest edge (coastal)	C	Inactive	Sand-loam	5	70	10	4.6	0.6
	Chema Weik	28/10/2009	07° 16′ 34.1″	93° 40′ 29.0″	Mixed forest edge	A	Inactive	Sand-loam	25	40	10	4.85	0.65
	Thavai thav	31/10/2009	07° 16′ 19.6″	93° 38′ 13.0″	Littoral forest (secondary)	B	Inactive	Loam	480	40	45	10.5	0.93
	Thavai thav	01/11/2009	07° 16′ 21.3″	93° 38′ 08.0″	Littoral forest (secondary)	B	—	Loam	200	—	—	—	—
	Mohincohin	02/11/2009	—	—	Mixed forest edge (coastal)	C	Inactive	Sand	5	10	8	4	0.85
	Pilo Baha	05/11/2009	—	—	Plantation-forest edge	B	Inactive	Loam	300	60	45	2.47	1.3
	Pilo Baha	06/11/2009	—	—	Plantation-forest edge	C	Inactive	Loam	300	15	20	2.6	0.55
	Pilo Panja	25/05/2011	07° 23′ 40.5"	93° 43′ 34.1"	Regenerating vegetation	B/C	Active	Sand	5	60	7	3.8	0.4
	School Point	25/05/2011	07° 23′ 55.0"	93° 43′ 20.7"	Regenerating vegetation	A	Abandoned	Sand-loam	—	45	12	7	0.45
	Pilo Panja	25/05/2011	07° 23′ 48.9"	93° 43′ 25.3"	Regenerating vegetation	C	Active	Sand	10	70	13	2.8	0.3
Menchal	Menchal	16/05/2011	07° 23′ 43.1"	93° 45′ 54.0"	Coconut groove	C	Active	Sand	3	50	18	4.5	0.[illegible]
Meore	Meroe	23/05/2011	07° 30′ 52.5"	93° 32′ 31.5"	Coconut groove	B	Active	Sand	3	25	30	3	0.4
	Meroe	22/05/2011	07° 30′ 53.8"	93° 32′ 44.9"	Regenerating vegetation	C	Active	Loam	—	60	16	4	0.5
Nancowry	Sapa (Hindrah)	23/02/2010	07° 58′ 04.8″	93° 31′ 39.7″	Pandanus growth (littoral)	B	Inactive	Sand	10	60	15	4	0.5
	Lapet (Hindrah)	23/02/2010	07° 58′ 16.3″	93° 31′ 28.5″	Coconut groove	C	Inactive	Sand	12	30	7	6.5	0.5
	Hindrah	07/01/2011	07° 58′ 16.9"	93° 31 28.6"	Littoral forest	C	Active	Sand (black)	2.5	50	9	5.3	0.95
	Mus	26/02/2010	07° 57′ 03.7″	93° 34′ 49.6″	Pandanus growth (littoral)	C	Inactive	Sand	10	80	5	3	0.3
	Mus	27/02/2010	07° 56′ 46.7″	93° 34′ 45.0″	Regenerating vegetation	C	Inactive	Sand	10	80	5	4	0.3
	Mus	11/04/2011	07° 56′ 48.4"	93° 34′ 45.0"	Regenerating vegetation	A	Inactive	Sand	25	0	7	2.5	0.4
	Mus	11/04/2011	07° 56′ 48.3"	93° 34′ 45.4"	Regenerating vegetation	C	Active	Sand	10	0	0	2.5	0.35
Kamorta	Masala Tapu	15/01/2010	08° 01′ 58.3″	93° 29′ 15.5″	Mixed forest (unaffected)	C	Abandoned	Loam	100	85	—	2.6	0.45
	Masala Tapu	15/01/2010	08° 02′ 06.6″	93° 28′ 04.6″	Mixed forest (unaffected)	C	Abandoned	Loam	100	65	35	2.35	0.2
	Remyok	18/01/2010	08° 06′ 36.2″	93° 32′ 27.9″	Regenerating vegetation	A	Abandoned	Sand	8	40	13	16.15	0.6
	Dering	27/12/2010	08° 06′ 44.7"	93° 29′ 21.4"	Mixed forest (unaffected)	B	Active	Loam (black)	600	70	20	6.7	0.9

	Nyikalang	24/11/2010	08° 11' 52.2"	93° 32' 27.9"	Regenerating vegetation	A	Abandoned	Loam	600	65	14	7.05	0.65
Trinket	Lahom	16/11/2010	08° 02' 45.4"	93° 35' 19.5	Regenerating vegetation	C	Active	Sand	6	30	15	4.3	0.65
Trinket	Trinket	25/11/2010	08° 05' 06.0"	93° 35' 19.5"	Regenerating vegetation	B	Abandoned	Sand-loam	400	55	11	6.8	0.85
Katchal	Jansin	13/01/2011	07° 59' 41.9"	93° 19' 41.8"	Regenerating vegetation	C	Active	Sand-loam	—	70	13	5.5	0.6
Katchal	Jansin	13/01/2011	07° 59' 36.1"	93° 19' 40.1"	Regenerating vegetation	C	Active	Sand-loam	200	70	15	4.7	0.4
Katchal	Jansin	13/01/2011	07° 59' 45.3"	93° 19' 43.2"	Regenerating vegetation	B?	Inactive?	Loam	500	70	12	4.7	0.3
Katchal	Jansin	13/01/2011	07° 59' 43.3"	93° 19' 43.0"	Regenerating vegetation	C	Abandoned	Sand-loam	—	75	13.5	5.5	0.8
Teressa	Safed Balu	15/04/2010	08° 14' 30.8"	93° 09' 12.5"	Regenerating vegetation	A	Abandoned	Sand-loam	40	40	35	8.1	1
Teressa	Kolerue	18/04/2010	08° 12' 35.6"	93° 12' 05.6"	Regenerating vegetation	A	Active	Sand	—	35	20	5.1	0.9
Teressa	Kolerue	18/04/2010	08° 12' 36.8"	93° 12' 05.8"	Regenerating vegetation	C	Abandoned	Sand-loam	150	20	8	6	0.85
Teressa	Kolerue	18/04/2010	08° 12' 37.0"	93° 12' 06.2"	Regenerating vegetation	A	Active	Sand-loam	140	10	8	4	0.75
Teressa	Kolerue	18/04/2010	08° 12' 35.8"	93° 12' 08.9"	Regenerating vegetation	C	Active	Sand	140	5	8	3.55	0.7
Teressa	Reksal	01/05/2010	08° 20' 59.8"	93° 07' 16.7"	Regenerating vegetation	C	Active	Gravel	25	65	10	4.3	0.8
Teressa	Reksal	01/05/2010	08° 20' 54.0"	93° 07' 04.5"	Regenerating vegetation	A	Active	Gravel	2	40	6	3.3	0.6
Teressa	Kolerue	03/03/2011	08° 12' 37.0"	93° 12' 06.2"	Regenerating vegetation	A	Active	Sand-loam	—	30	9	5.4	1.3
Teressa	Kolerue	03/03/2011	08° 12' 43.8"	93° 12' 11.4"	Regenerating vegetation	C	Active	Sand-loam	40	45	9	2	0.4
Teressa	Reksal	09/03/2011	08° 20' 59.8"	93° 07' 16.7"	Regenerating vegetation	A	Active	Sand-loam	25	40	38	4.2	0.75
Teressa	Reksal	09/03/2011	08° 20' 54.0"	93° 07' 04.5"	Regenerating vegetation	B	Inactive?	Sand	4	20	7	3.8	0.6
Bompoka	Atluch	22/04/2010	08° 12' 02.5"	93° 14' 28.3"	Regenerating vegetation	A	Active	Loam	150	78	32	5.3	1.15
Bompoka	Atluch	22/04/2010	08° 15' 05.3"	93° 14' 32.0"	Regenerating vegetation	C	Active	Loam	15	20	15	2.5	0.15
Bompoka	Atluch	22/04/2010	08° 15' 15.6"	93° 14' 26.7"	Plantation (second growth)	C	Active	Sand	9	30	8	4.5	0.65
Bompoka	Atluch	24/04/2010	08° 15' 43.1"	93° 14' 13.7"	Regenerating vegetation	A	Active	Sand-loam	0	30	8	4.2	0.7
Bompoka	Atluch	24/04/2010	08° 15' 38.1"	93° 14' 18.2"	Regenerating vegetation	B	Active	Loam	2	20	28	4.2	0.6
Bompoka	Chukmisuyi	25/04/2010	08° 15' 21.1"	93° 14' 19.9"	Regenerating vegetation	A	Active	Sand	4	40	28	4.2	0.45
Bompoka	Chukmisuyi	25/04/2010	08° 15' 13.2"	93° 13' 18.1"	Regenerating vegetation	A	Active	Sand-loam	40	45	28	5.4	1
Bompoka	Chukmisuyi	25/04/2010	08° 15' 11.6"	93° 13' 18.7"	Regenerating vegetation	A	Abandoned	Loam	60	20	28	3.95	0.7
Bompoka	Chukmisuyi	27/04/2010	08° 15' 01.8"	93° 13' 16.2"	Regenerating vegetation	C	Active	Sand-loam	70	—	13	2.3	0.6
Bompoka	Atluch	18/02/2011	08° 15' 05.3"	93° 14' 32.4"	Regenerating vegetation	A	Active	Sand-loam	10	70	10	4.3	0.5
Bompoka	Atluch	18/02/2011	08° 15' 07.0"	93° 14' 31.6"	Regenerating vegetation	B	Active	Sand-loam	4	30	30	3.1	0.75
Bompoka	Atluch	18/02/2011	08° 15' 15.6"	93° 14' 26.7"	Regenerating vegetation	C	Active	Sand-loam	6	20	8	5.2	0.9
Bompoka	Atluch	19/02/2011	08° 15' 41.0"	93° 13' 45.2"	Regenerating vegetation	B	Active	Sand-loam	18	45	32	5.8	0.95
Bompoka	Atluch	19/02/2011	08° 15' 43.7"	93° 13' 53.1"	Regenerating vegetation	C	Active	Sand-loam	3	55	17	5.5	0.75
Bompoka	Atluch	19/02/2011	08° 15' 45.6"	93° 13' 59.3"	Regenerating vegetation	C	Active	Loam	15	55	40	4.2	0.95
Bompoka	Poahat	19/02/2011	08° 15' 28.1"	93° 13' 25.6"	Regenerating vegetation	C	Active	Sand-loam	5	70	10	4.6	0.7
Bompoka	Poahat	19/02/2011	08° 15' 34.4"	93° 13' 32.8"	Regenerating vegetation	C	Active	Loam	15	70	15	3.2	0.7
Bompoka	Poahat	23/02/2011	08° 15' 13.2"	93° 13' 18.1"	Regenerating vegetation	A	Active	Sand-loam	30	70	22	5.3	1.2
Bompoka	Poahat cave	23/02/2011	08° 15' 10.6"	93° 13' 46.9"	Mixed forest (unaffected)	B	Active	Loam	—	80	38	6	1.5
Bompoka	Poahat cave	23/02/2011	08° 15' 08.2"	93° 13' 56.6"	Mixed forest (unaffected)	B	Abandoned	Loam (red)	—	75	35	5	1
Chowra	Tahup	12/12/2010	08° 26' 36.3"	93° 03' 24.3"	Mixed forest (unaffected)	C	Abandoned	Loam (hill top)	—	75	28	7	0.45
Chowra	Tahup	12/12/2010	08° 26' 36.4	93° 03' 24.7"	Mixed forest (unaffected)	A	Abandoned	Loam (muddy)	—	80	30	6.5	0.6
								Average	85.5	47.5	19.5	4.6	0.7
								SD±	146.1	22.8	12.6	2.1	0.3

* Habitatas with regenerating vegetations are littoral areas affected by tsunami

Chapter 16
Habitat Preference of the Nicobar Megapode *Megapodius nicobariensis* in the Great Nicobar Island, India

K. Sivakumar and R. Sankaran

Abstract Mound-nesting Nicobar megapodes are threatened due to their clumped distribution toward coastal areas of Nicobar group of islands. Despite the obvious importance of habitat to these specialized birds, there have been no detailed studies on habitat preferences in this group. Hence, we have studied the habitat preference of the Nicobar megapode in the Great Nicobar Island based on the nesting and foraging site preferences between 1996 and 1998. Most of the mounds were distributed within 200 m from the high tide mark. Sandy and sandy-loam substrates and the microhabitats of *Pandanus* spp. mixed stands were highly preferred for mound construction. Microhabitats dominated with *Pandanus*, *Macaranga,* and *Dracaena* stands were highly used for breeding as well as foraging in both dry and wet seasons of the year. There was no change in the habitat selection of the Nicobar megapode between seasons ($P > 0.488$). Based on the findings, it is suggested that for the conservation and management of the Nicobar megapode in the Nicobar Islands, all coastal habitats which have sandy and sandy-loam substrates or species of *Pandanus*, *Macaranga,* and *Dracaena* (dominated habitats) will need to be taken into consideration.

Keywords Great Nicobar Island • Habitat preference • Mounds • Nicobar megapode

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16.1 Introduction

Unlike other birds, the megapodes incubate their eggs in incubation mounds where microbial activity generates heat or in burrows in geothermally heated grounds (Jones et al. 1995). As a result of their unique breeding behavior, megapodes have specific habitat requirements. Most megapodes inhabit forests, the sole exception being the mallee fowl *Leipoa ocellata*, which is present in arid and semiarid habitats (Jones et al. 1995). Mound-building megapodes require habitats where mounds have adequate organic decomposition to provide necessary heat for incubation (Dekker 1990). Despite the obvious importance of habitat to these specialized birds, there have been no detailed studies on habitat preferences in this group.

The Nicobar megapode *Megapodius nicobariensis* usually build their mound close to the shore; however, some mounds are also present away from the shore (Hume and Marshall 1878; Sankaran 1995). Various types of mounds are built, and these have been described (Dekker 1992; Sankaran 1995; Sivakumar and Sankaran 2000, 2003, 2005). In the Nicobar Islands, 97% of mounds of the Nicobar megapode were found within 100 m of the beach (Sankaran 1995) where the habitat present is generally classified as the "coastal forest" which is composed of both rain forest as well as deciduous species (Thothathri 1962). This kind of nesting near the beach is also common in some other megapodes (Stuebing and Zazuli 1986). As coastal forests are subject to increasing anthropogenic pressures, understanding habitat requirements of the Nicobar megapode is critical to its habitat management.

16.2 Study Area

The ecology of the Nicobar megapode was studied between December 1995 and May 1998 on Great Nicobar Island (6°76′ and 6°79′N, 93°81′ and 93°84′E). The study period included three dry seasons (period of egg laying) and part of one wet season. Our study area, on the coast, was about 4.5 km long and was bisected by a disused metal road that ended at the lighthouse at Indira Point. The intensive study area was a narrow strip of forest between 40 and 300 m wide that was bounded by the beach to the east and by either wetlands or forests that were inundated during the monsoons to the west (Fig. 16.1). The substrate within this strip of forest was sandy and loamy, and the dominant trees were *Barringtonia asiatica*, *Barringtonia racemosa*, *Terminalia bialata*, *Terminalia catappa*, *Syzygium samarangense*, *Thespesia populnea,* and *Macaranga* spp. The study area also had dense stands of *Pandanus tectorius* and *Pandanus odoratissimus* in patches, and the road was fringed by stands of *Leea angulata*, *Leea grandifolia*, and *Dracaena* spp. There were a few patches where the ground was open and with little vegetation. The substrate of the forest type to the west of this coastal forest was wet and clayey and

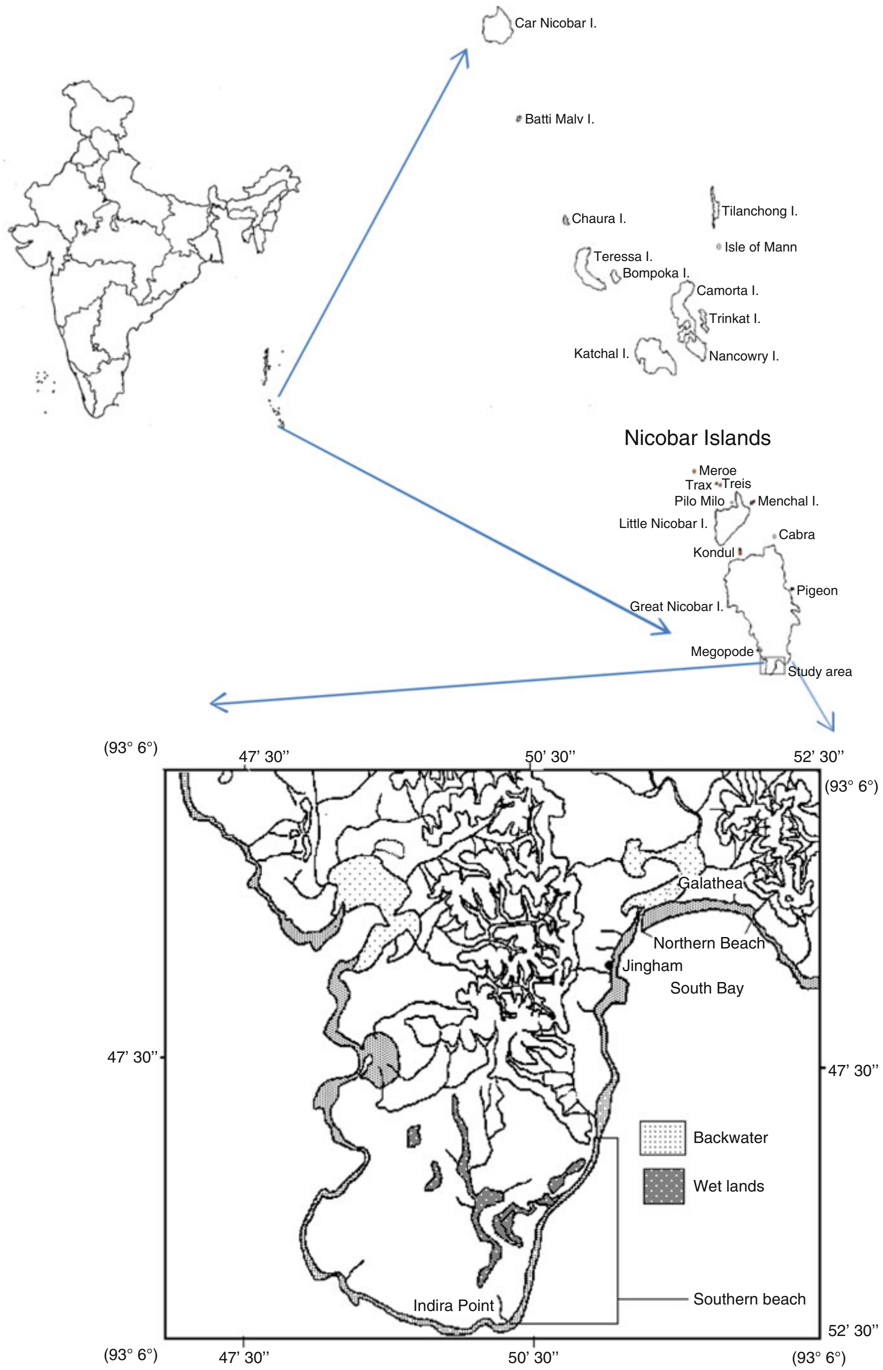

Fig. 16.1 Southern part of the Great Nicobar Island showing study site

covered with *Areca* spp. as well as trees like *Ixora barbata*, *Pongamia pinnata*, *Alstonia kurzii*, *Aisandra butyracea*, *Horsfieldia irya*, *Myristica andamanica*, and *Celtis timorensis*.

16.3 Methods

The study area was systematically surveyed and mapped with the aid of a compass and measuring tapes. The positions of incubation mounds and other landmarks such as the road, huts, and wells were plotted on this map. All the mounds were numbered.

The vegetation of the study area was classified into 14 microhabitats that were dominated by one or more plant species. These microhabitats could be easily identified where measured and plotted to scale on the map. To study the abundance and dominance of flora, ten 20 m × 50 m quadrates were laid. All the trees with a girth at breast height (GBH) of 25 cm or above were recorded. Relative frequency, relative dominance, relative abundance, and important value index (IVI) for each species were calculated. Each substratum category was identified by following Costa and Baker (1981). Habitat preference was arrived at by comparing the available area of the microhabitat with the number of sightings of the birds. Ratio of the sightings per unit area of the respective microhabitat was estimated by using the following formula

$$S_i = C_i/A_i$$

where S_i is ratio of the sightings per unit area of ith microhabitat; C_i is proportion of sightings in ith microhabitat out of the total sightings on total available area; A_i is proportion of total available area of ith microhabitat out of total available area.

All the dead and living tree species present in or around the mound were identified and recorded for studying the tree selection by the Nicobar megapode for mound building. The ratio of the mounds distributed per unit area (M) of the various soil substrates or microhabitats was estimated by using the formula

$$M = P_{\mathrm{m}}/P_{\mathrm{a}}$$

where P_{m} is proportion of mounds distributed in particular substratum or microhabitat, and P_{a} is proportion of area available for that substratum or microhabitat.

For identifying the preference or avoidance of specific microhabitat by the Nicobar megapode, Neu et al. (1974) analysis was used, whereby the observed sighting in each microhabitat type is used in proportion to its availability. When a significant difference in use versus availability is detected by the test, a Bonferroni Z-statistic (Miller 1981) is used to determine the habitat types used more or less frequently than expected.

Table 16.1 Distribution of the mounds in the various substrates available for the Nicobar megapode

Type of substrate	Proportion of the area available	Number of mounds present	Proportion of mounds present	Ratio of proportion of mounds to proportion of area
Sand	0.17	15	0.395	2.32
Sandy loam	0.48	19	0.50	1.04
Loam (moist)	0.35	4	0.105	0.30

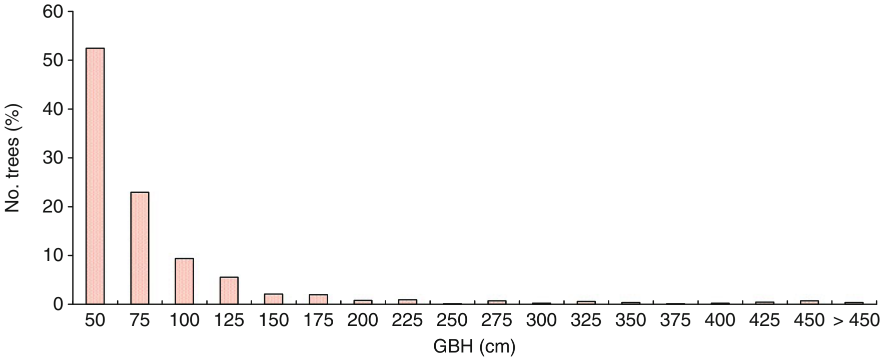

Fig. 16.2 Distribution of trees (GBH >25 cm) on the Nicobar megapode habitat

16.4 Results

16.4.1 Habitat of the Study Area

The earth of the study area was differentiated into three types of soil substrates: sand, sandy loam, and moist loam. Sand substratum was present mainly along the seashore, while the area to the interior, which comprised the majority of the study area, was composed of sandy loam, and the area beyond this was composed either of sandy-loam or moist-loam substrates. The soil to the west of this was clayey. Proportion of these three soil substrates of this study area is presented in Table 16.1.

The majority of the trees in the study area were small in girth. Large trees, with a girth greater than 200 cm, accounted for less than 5% of the trees present (Fig. 16.2). The vegetation in the study area was not homogenous, and the associations seen could be classified into 14 categories. There was some relationship between the distribution of plants and soil substrates. For example, *Pandanus* and *Dracaena* sp. were seen in sand and sandy-loam substrates, while *Macaranga peltata* was restricted to sandy-loam and moist-loam substrates. Moist-loam substratum was also seen in the interior of the forest, where *Areca triandrus* was present.

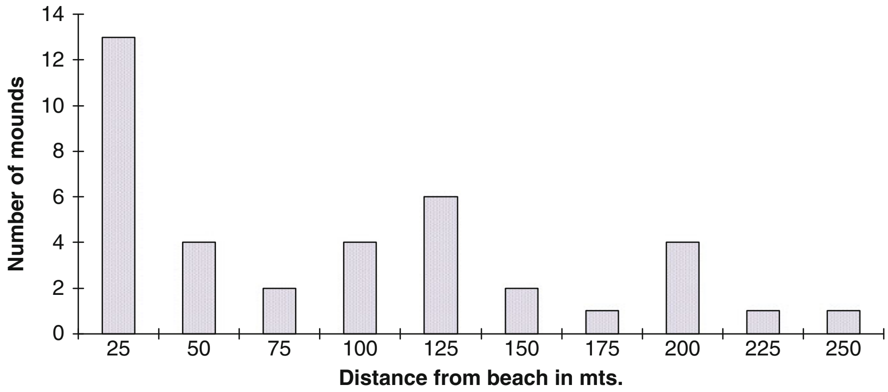

Fig. 16.3 Distribution of mounds of the Nicobar megapode in the study area with respect to distance from the beach

Microhabitats of open mixed forest, dense mixed forest with swamp, and dense mixed forest without swamp were the dominant habitats toward the interior island. Habitats, which had *Pandanus* stands, were distributed toward the coastal area where a large number of mounds were present.

16.4.2 Distribution of Incubation Mounds

Incubation mounds were present throughout the study area. At the start of the study in January 1996, 16 active mounds were located which were under the use of megapode. At the end of the study, the study area had 30 active mounds; two mounds, which were active at the commencement of this study, had been abandoned, and six mounds were not being used, thus making a total of 38 mounds.

The sizes of the incubation mounds varied from 0.15 m^3 to 40.24 m^3 with a mean size of 4.78 m^3 (SE 1.19). Of the 38 mounds that were present in the study area, 36 mounds (94.74%) were found within 200 m of the beach and 23 mounds (60.53%) were found within 100 m of the beach (Fig. 16.3). Only two mounds were present beyond 200 m of the beach, and no mounds were located beyond 250 m of the beach.

16.4.3 Microhabitat Selection for Mound Construction

Of the 38 mounds in the study area, 15 (39.5%) had been constructed on sandy substrate, 19 (50%) in sandy-loam substrate, and the remaining four (10.5%) in loamy area. None of the mounds had been constructed in soils that were inundated during the wet season. However, when the proportion of the mound distribution according to available soil substrates was considered, the most suitable substrate for

Table 16.2 Distribution of mounds in different microhabitats available to the Nicobar megapode

Type of vegetation	Proportion of area available	No. of mounds	Proportion of the mound present	Ratio of proportion of mounds to proportion of area
Areca triandrus	0.057	0	0.000	0.0
Dense *Pandanus* stands	0.097	7	0.184	1.9
Dense *Pandanus* and Acanthaceae	0.011	3	0.079	7.2
Dense *Pandanus* and *Macaranga peltata*	0.015	2	0.053	3.5
Dracaena	0.024	3	0.079	3.2
Dracaena and *Pandanus*	0.020	2	0.053	2.7
Eupatorium adentoforium	0.009	0	0.000	0.0
Macaranga peltata	0.047	2	0.053	1.1
Open forest with *Pandanus*	0.062	8	0.211	3.4
Open mixed forest	0.179	7	0.184	1.0
Clerodendrum paniculatum	0.002	0	0.000	0.0
Dense mixed forest	0.183	4	0.105	0.6
Dense mixed forest with swamp	0.196	0	0.000	0.0
Wetland	0.097	0	0.000	0.0

mound construction was sand (2.32 mounds/unit area) followed by sandy loam (1.04 mounds/unit area, Table 16.1).

Of the 14 types of habitats identified, mounds were present in all habitat types except the area under *A. triandrus*, dense mixed forest with swamp, wetland with grass, *Clerodendrum paniculatum*, and *Eupatorium adenophorum*. The highest number of mounds was present in open forest with *Pandanus* (8 mounds), dense *Pandanus* stands (7), followed by open mixed forest (Table 16.2). However, when the proportion of available habitats was accounted for, dense *Pandanus* with Acanthaceae, dense *Pandanus* with *M. peltata*, *Dracaena* bush, and open forest with *Pandanus* were preferred for the construction of mounds (Table 16.2).

The mean canopy cover above the mound was 58%, and it was less than the mean percentage (81%) of canopy cover of the nonmound area (Student *t* test: $t = -15.94$, $P < 0.01$, df = 81).

16.4.4 Selection of Trees for Mound Construction

Of the eight species of dead trees that were identified at the mound, *S. samarangense* was the most frequently seen, followed by *B. asiatica* and *Hernandia peltata* (Fig. 16.4). A total of 11 species of living trees were present in or around the mounds of the Nicobar megapode. Of these, *Pandanus* was present in 21 mounds and *Syzygium samarangense* present in seven mounds (Fig. 16.4).

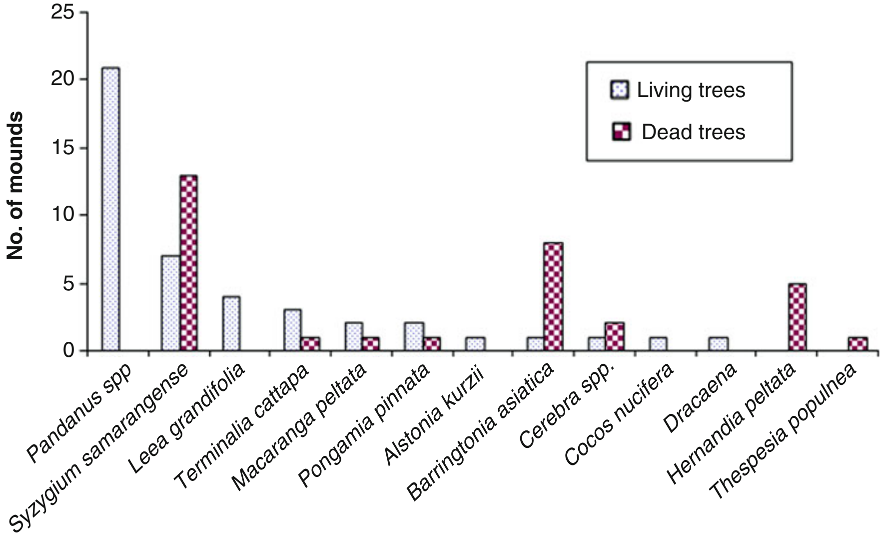

Fig. 16.4 Living and dead trees preferred by the Nicobar megapode for mound construction

Table 16.3 Sandy-loam substratum was highly preferred by the Nicobar megapode irrespective of seasons

Substrate types	Expected utilization level or proportion of area available	Utilization levels in the dry season		Utilization levels in the wet season	
		Upper	Lower	Upper	Lower
Sand	0.17	0.38	0.02	0.02	0.01
Sandy loam	0.48	0.60	0.56	0.85	0.75
Loam (moist)	0.35	0.07	0.05	0.02	0.01

Confidence interval from Bonferroni *Z*-statistic test is given as utilization level

16.4.5 Seasonal Difference in Substrate and Microhabitat Utilization

Of the major soil substrates available to the Nicobar megapode, the majority of sightings in dry season were on sandy loam followed by sandy substrates; however, in wet season, more sightings were in the sandy-loam substrate. When the proportion of available area of the three major substrates was considered, sand substrate was used more during the dry season and loam substrate in wet season. In both seasons, sandy-loam substrates were utilized significantly higher than expected (Table 16.3).

Both in dry and wet seasons, the majority of sightings were recorded in *C. paniculatum* and *Pandanus* habitats (Table 16.4). In general, there was no difference in the habitat preference of the Nicobar megapode between seasons (Student t test: $t = -0.704$, df $= 26$, $P > 0.488$). Microhabitats of *M. peltata*, dense

Table 16.4 *Pandanus, Macaranga,* and *Dracaena* stands are highly preferred by the Nicobar megapode in both dry and wet seasons

Habitats	Expected utilization level or proportion of area available	Utilization levels (dry season)		Utilization levels (wet season)	
		Upper	Lower	Upper	Lower
Areca triandrus	0.06	0.04	0.03	0.02	0.01
Dense *Pandanus* stands	0.10	0.13	0.10	0.16	0.06
Dense *Pandanus* and Acanthaceae	0.01	0.09	0.07	0.10	0.02
Dense *Pandanus* and *Macaranga peltata*	0.02	0.11	0.08	0.14	0.05
Dracaena spp.	0.02	0.03	0.01	0.04	0.01
Dracaena sp. and *Pandanus*	0.02	0.02	0.01	0.09	0.02
Eupatorium adentoforium	0.01	0.02	0.01	0.09	0.02
Macaranga peltata	0.05	0.20	0.16	0.22	0.10
Open forest with *Pandanus* spp.	0.06	0.12	0.09	0.02	0.01
Open mixed forest	0.18	0.16	0.13	0.34	0.19
Clerodendrum paniculatum	0.01	0.07	0.05	0.05	0.01
Dense mixed forest	0.18	0.13	0.11	0.21	0.09
Dense mixed forest with swamp	0.20	0.02	0.01	0.02	0.01
Wetland	0.10	0.02	0.01	0.02	0.01

Confidence interval from Bonferroni *Z*-statistic test is given as utilization level

Pandanus, and dense *Pandanus* with *M. peltata* were highly preferred by megapode in both summer and rain season, while microhabitats of *A. triandrus* and wetland with grass were barely used in both seasons. Microhabitats, which were dominated by or having *Pandanus*, *M. peltata*, and *Dracaena*, were utilized by the megapode more than expected in both seasons (Table 16.4). However, open forest with Pandanus microhabitat was utilized more in the dry season than in the wet season.

16.5 Discussion

16.5.1 The Distribution of Mounds According to Substrate and Microhabitat

Of the three major types of soil substrates present in the study area, the Nicobar megapode preferred to construct mounds in sandy substratum, followed by sandy-loam and the least in moist-loamy substratum, probably because those substrates are easier to dig into and of superior drainage (Sivakumar and Sankaran 2003). Since the coastal habitat of the Nicobar Islands is mainly composed of sand and sandy-loam soil (Thothathri 1962; Saldanha 1989), this would account for the clumped distribution of the Nicobar megapode toward the coastal region (Dekker 1992; Sankaran 1995; Jones et al. 1995).

The microhabitats preferred by the Nicobar megapode also occurred predominantly either on sandy or sandy-loam substrates. Of the 14 microhabitats distinguished, *Pandanus*-dominated microhabitats were used for mound construction.

16.5.2 Seasonal Difference in Substrate and Microhabitat Utilization

As the summer is the peak period of the egg laying, megapodes were concentrated around the incubation mounds, and consequently, most sightings of the Nicobar megapode were on sandy-loam substrates. Areas with greater leaf litter are believed to be richer in soil invertebrates (Goth and Vogel 1995). As relative abundance of food resources were not studied, the influence of this in both substrate and microhabitat selection could not be determined. Choice of substrate in the dry season would be largely governed by location of mounds, whereas in the wet season food could be the main criteria of habitat selection, and choice of substrates would be governed largely by food. It is probable that sandy-loam substrates are richer in food than sandy substrates, indicating as to why this substrate was preferred in the wet season. During the wet season, most of the available moist-loam substrates were inundated with rainwater.

Of the 14 microhabitats, *C. paniculatum*, dense *Pandanus* with Acanthaceae, and dense *Pandanus* with *M. peltata* were used the most. Alien species of *C. paniculatum* was distributed along either side of the road and not away from it with the result that the total available area of this vegetation type was the least. Most of the mounds in the study area were between the seashore and the road. Thus, megapodes from the interior forest had to cross the road to access mounds. As the majority of sightings were from the road, this was the most probable reason for the maximum sighting in *C. paniculatum* in both dry and wet season.

Compared to the dry season, in the wet season the vegetation patches like *C. paniculatum*, dense *Pandanus with* Acanthaceae, open forest with *Pandanus*, and *Dracaena* sp. were utilized less. On the other hand, dense *Pandanus* with *M. peltata*, Dracaena with *Pandanus*, and Eupatorium patches were highly utilized. Uses of mounds were the least during the wet season, thus vegetation around mounds or along the road were utilized less.

In general, there were no microhabitat-specific activities in the Nicobar megapode. Microhabitats of *M. peltata* had high sightings, as the seed of *M. peltata* was a preferred food for the Nicobar megapode (Sivakumar and Sankaran, 2005). Fighting mostly took place in the habitats, which were around the mound, indicating that the mound was the most important factor in location of fights.

16.5.3 Conservation Implications

The clumped distribution of the Nicobar megapode toward the coastal forest, due to its preference for sandy-loam and sandy substrates for breeding especially mound building, is an indicator that the preservation of primary coastal forest is critical to the survival of this species. The major threat to coastal areas in the Nicobar Islands stems from the spread of human habitation and coconut plantations in coastal habitat. There is therefore need to bring adequate areas of coastal forest into the protected area network (Sankaran 1997), thus conserving adequate habitats crucial to the Nicobar megapode. The removal of the dry and dead trees or snags from the coastal habitat should be prohibited since these are necessary for the construction of incubation mounds.

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ANNEXURE 24

Chapter 37

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 435-441, 2010

IMPACT OF TSUNAMI ON CERTAIN RARE AND THREATENED SPECIES OF NICOBAR GROUP OF ISLANDS WITH SPECIAL REFERENCE TO THE NICOBAR MEGAPODE *MEGAPODIUS NICOBARIENSIS*

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INTRODUCTION

The Andaman and Nicobar Islands (latitudes 6°45′ and 13°41′ and longitudes 92°12′ and 93°57′) situated in the Bay of Bengal arch from Arakan Yoma in Mayanmar in the north to Sumatra in Indonesia in the south (Saldanha, 1989; Dagar *et al.*, 1991). The Islands cover an area of 8,249 km^2, with a total coastline of 1962 km; the Andaman group has more than 325 Islands (21 inhabited) covering 6,408 km^2, and the Nicobar group has over 23 Islands (12 inhabited) with an area of 1,841 km^2 (Fig. 1) (Saldanha, 1989). Islands have a hot, humid and uniform tropical climate and vegetation is mostly evergreen forests and mangrove.

The earthquake of magnitude 9.15 with its epicentre at 3.29° N and 95.94° E off the coast of Sumatra with a focal depth of 30 km occurred on 26th December 2004 at 06:28:50 hrs. The tsunami waves reached the coast first, causing a phenomenon called draw down, where the sea level dropped considerably. The draw down was followed by the crest of the wave, which resulted in sea inundating land, also known as the run-up. The waters took several days to recede completely, leaving in its wake a devastation of unimaginable magnitude on the people and wildlife of Nicobar Islands (Sankaran, 2005). It was expected that the highly diversified coastal biodiversity with high endemism might have been adversely affected by the tsunami, which include the coastal living Nicobar megapodes (*Megapodius nicobariensis*). Hence, this study was carried out to assess the impact of tsunami on the certain threatened species in the Nicobar Islands.

MATERIAL AND METHODS

The Nicobar Islands have been surveyed between February and May 2006. As mounds of Nicobar megapode are stationary, inanimate and represent breeding signs, the best way to estimate and monitor the megapode populations is by assessing the number of active mounds (Sankaran, 1995b; Sivakumar and Sankaran, 2003). The coastline of 15 islands where the species was reported earlier has been surveyed for mounds by following standardized survey protocols (Sankaran, 1995b). To estimate the total number of active mounds, the coastline of each island was divided into two segments such as 'Potential Coastal Habitat for Megapode (PCHM)' and 'Non-conducive Coastal Habitat for Megapode (NCHM)' Potential coastal habitat of megapode was identified based on habitat preference of this species (Sivakumar, 2000). Extent of these two coastal habitats was measured using the satellite imageries (2006) and vegetation map.

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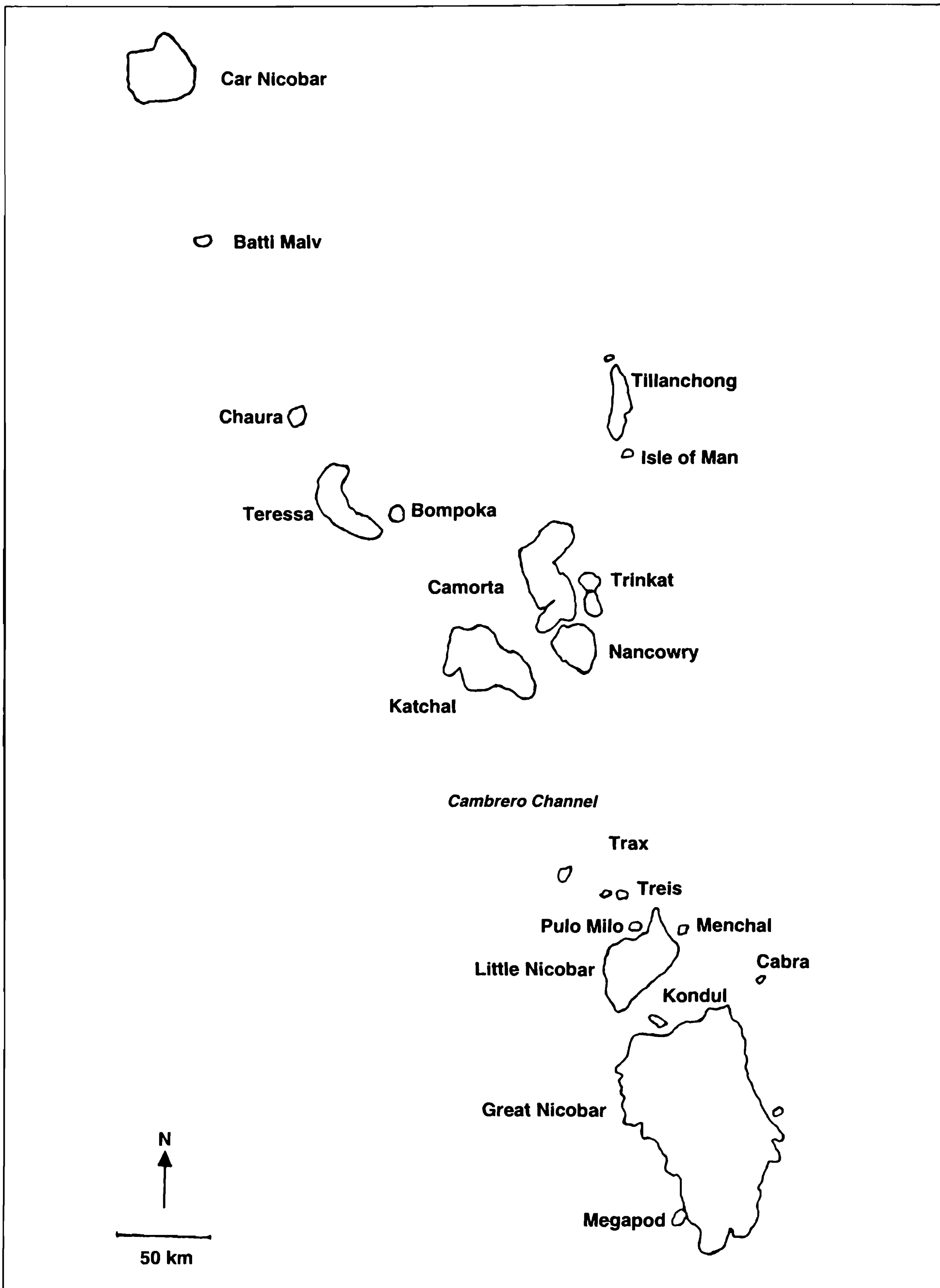

Fig 1. The Nicobar group of islands.

Variable width belt transect was used to count all the mounds and presence of other threatened species within sampled area. Length of transect, and distance between the two transects was set according to the size of the islands but it was uniform for any given islands. Average length of belt transect was 2 km, however, in some cases the length of transect was small due to smaller sizes of islands. Width of the each transect varied depending upon the extent of low lying forest from the shore to near by hills The census was carried out with seven observers walking at 20 m interval abreast parallel to the seashore. Interior forests of Great Nicobar, Little Nicobar, Kamorta, Katchal and Teressa islands were also sampled with fixed width transect i.e. 140 m width and 1 km long. A total of 328 km long coastal habitat was identified as PCHM; of these, 157.5 km coastal forests were sampled in 80 transects. Of the 80 transects, 68 transects were 2 km long, 10 transects were less than 2 km and two transects were more than 2 km. Of the 358.8 km long NCHM, 77.9 km long coastal stretches have been sampled in 39 transects. Boat survey also carried out in the nearest offshore water along the coastline of the all Nicobar islands. Total number of active mounds of the Nicobar megapode *Megapodius nicobariensis*, presence of Coconut Crab *Birgus latro*, Long-tailed Macaque *Macaca fascicularis umbrosa*, Reticulated Python *Python reticulatus* and Malayan Box Turtle *Cuora amboinensis* were also recorded in the each transects.

RESULTS

Present distribution and status of certain threatened fauna of the Nicobar Islands

Giant coconut crab *Birgus latro* : Giant coconut crab usually prefers coastal habitat which have been severely affected due to tsunami. There was no sign of adult giant coconut crab presence in most of these islands; however, evidence of their presence was seen in the Menchal, Tillanchang and Katchal islands, five sites in Menchal, 21 sites from Katchal and one site from Tillanchang Island were recorded.

Malayan box turtle *Cuora amboinensis* : This is the only semi-aquatic land turtle present in this group of islands. A total of 16 dead shells were found on various parts of the coastal habitat of Great Nicobar islands showing that this species has also been badly hit by the tsunami.

Reticulated python *Python reticulatus* : Though this species was reported all over the Great Nicobar Island and young ones were commonly seen in the lowland forests (coastal region) during 1996-98 (Sivakumar, 2000) but, during this survey after spending 42 field days there was no single record of python in this group of islands especially in the lowland forests which have been badly destroyed by the tsunami.

Sea turtles : Though the survey periods was not coincide with the sea turtles peak nesting season, 140 sea turtles crawls were found on the Great Nicobar Island and 54 sea turtles crawls were observed on the Trinket and Tillanchang islands. Several new nesting beaches have been formed all along the west coast of the Great Nicobar Island. Northern part of the Galathea bay which was known for leatherback turtle nesting has severally damaged, however, southern beach has improved for the turtle nesting. Pigs and monitor lizards were observed eating turtle's eggs on most of the beaches.

Coral reef : Good patches of coral reefs were seen around the Nicobar group of islands before tsunami (Baskar and Rao, 1992; Sivakumar, 2000). Of these, most of the coral reefs, especially from the west coast of all islands were damaged by the tsunami. However, patches of coral reefs were seen undisturbed from the North-eastern coasts of most of the islands.

Sea grass beds and Dugong *Dugong dugon* : Of the 15 islands were surveyed by boat for sea-grass beds and dugong, two patches of sea grass beds were seen between Camorta jetty and Champin jetty of Nancowry Island. A dugong mother with a calf was sighted in this patch. Apart from this, it could not locate any other seagrass patches of these islands. It is believed that sea grass are also one of the most affected habitats due to tsunami and hence Dugong.

Nicobar megapode *Megapodius nicobariensis* : After tsunami 2004, the Nicobar megapode continued to be found on all but two islands *viz.* Trax and Megapode in the Nicobars from where it had been reported earlier. The Megapode Island was fully submerged due to rise in sea water level due to tsunami. More than 90 per cent of mound nests were built within 30 m distance from the shore. Of these, around 16 per cent of active mounds were found within 5 m distance from shore.

Of the total 687 km long coastal line of megapode lands, 328 km long coastal forest was identified as the 'Potential Coastal Habitat for Megapode' and remaining 359 km long coastal forests were identified as 'Non-conducive Coastal Habitat for Megapode'. It was estimated that about 800 breeding pairs of the Nicobar megapode occur on the coastal habitat of the Nicobar islands, which is nearly 70 per cent less than what was reported a decade ago (Table 1).

Blue-breasted quail *Coturnix chinensis* : Blue-breasted quail, a sub species endemic to Nicobars, was common on Car Nicobar, Trinket and Camorta Islands. Around 12-15 sightings were recorded during year 1993-04 (Sankaran, 1995a). However, a rapid survey which was carried out in grasslands of Camorta, Trinket, Teressa and Bamboka islands during the month of June 2006. Total of 54 birds were recorded while flushing out these birds in the grasslands by walking by six people. More number of birds recorded in the grasslands of Camorta (29 birds) followed by Teressa, Bomboka and Trinket. Blue-breasted quail were sighted often with Yellow-legged button quail *Turnix tanki*, however, sightings of this button quail was not rare in the Nicobar islands.

Long-tailed Macaque *Macaca fascicularis umbrosa* : A total of 16 troops of Long-tailed Macaque were sighted from the 62 sampling stations. 11 troops from Great Nicobar, two troops from Little Nicobar and three troops from Katchal Island. The group size ranged from seven to 98 individuals with a mean size of 23 individuals. The largest group was sighted in the Katchal (Kapanga). Near Indira Point, a skull of Long-tailed Macaque was found near the sea shore, which may have been killed by tsunami waves.

DISCUSSION

Status and distribution of the Nicobar megapode

After tsunami 2004, the Nicobar megapode continued to be found on all but two islands *viz* Trax and Megapode in the Nicobars from where it had been reported earlier. Compared to previous survey (Sankaran, 1995b), the concentration of mounds towards fringe of sea shore was high and

Table 1. Past and present status of the Nicobar megapode

Island	Estimated no. of active mounds in 1994*	Estimated no. of breeding pairs 1994*	Estimated no. of active mounds in 2006	Estimated no. of breeding pairs 2006
Great Nicobar	515	1416	203	405
Kondul	11	31	1	2
Little Nicobar	311	855	82	165
Menchal	2	6	6	12
Meroe	1	3	2	4
Pilo Milo	0	0	0	0
Trax	3	9	0	0
Treis	4	10	3	6
Nancowry	60	165	7	15
Katchal	69	190	9	1
Camorta	20	55	7	13
Tillanchang	10	28	27	53
Trinket	8	22	26	52
Teressa	119	328	9	18
Bampoka	26	72	13	25
Total	**1159**	**3190**	**394**	**788**

* Source Sankaran, 1995b.

it might be due to tsunami which had significantly reduced the coastal habitat. Around 16% of active mounds were found within 5 m distance from shore which may probably be influenced by high-tide water during full or new moon days. Maintaining mound temperature at a constant rate is important for the successful egg hatching (Sivakumar and Sankaran, 2003), however, influence of sea water on the incubation temperature is expected to adversely affect the hatching success of those mounds which are very close to the shore. Maximum of 800 breeding pairs of the Nicobar megapode occur on the coastal habitat of the Nicobar islands, which is nearly 70% less than what was reported a decade ago. Tsuanmi was believed to be the major cause for this decline.

It is believed that the temperature generated through fermentation of vegetative materials inside the mound is a major source of incubation temperature (Sivakumar and Sankaran, 2003), however, ambient temperature is also thought to contribute to the incubation process. Most of active mounds found on Nicobars were built at the base of available trees on the coastal area. Since most of trees dried due to tsunami waves, green canopy cover over mounds was less or nil. Direct fall of sunlight on the mound through day may not be good for the incubation mound of the Nicobar megapode, as direct sunlight for a longer period may warm up the mound quickly and killing the embryo in an egg. It is a serious concern for the long term survival of this species. However, natural resilience of coastal ecosystem of islands may change this situation provided there is no human intervention.

Status and distribution of certain other threatened fauna of the Nicobar group of islands

Blue-breasted quail was common on Car Nicobar, Trinket and Camorta islands before tsunami (Sankaran, 1995b). Since there was no detailed and systematic survey carried out on this species before and after tsunami it would be difficult to comment on their status with respect to tsunami. However, after tsunami, most of the grasslands in Camorta and Teressa were used for housing and plantations without considering their ecological values, which definitely have endangered this species and its habitat.

Before tsunami, a status survey of the Long tailed macaque, which was also mainly carried out along the coastal areas had recorded 788 groups and the group size ranged from 25 to 56 individuals with a mean size of 36 (Umapathy *et al.*, 2003). During the present survey, only 16 troops and troop size ranged from seven to 98 individuals with a mean size of 23 individuals were recorded during this survey which was carried out after tsunami. However, this data may not be compared with previous survey as the previous survey had few transects interior forests. It is believed that majority of the macaque may have escaped from the killer waves but they have lost their important food resources such as *Pandanus spp.*, *Terminalia spp.* and coconut and coastal habitat due to tsunami.

Giant coconut crab was commonly sighted along the undisturbed coastal areas of the Nicobar islands (Baskar and Rao, 1992; Sivakumar, 2000). They prefer to live inside the fallen log, under the base of the *Barringtonia asiatica* tree or sometimes in a small burrow (Sivakumar, 2000). These crabs normally were seen in more numbers, where barringtonia, pandanus and coconut strands were more (Sivakumar, 2000). After tsunami the habitat of coconut and pandanus were severally damaged or washed away from majority of the coastal areas. However, evidence of their presence in the Menchal, Tillanchang and Katchal islands are giving a hope for resilience of this species in the islands in future.

The other important threatened terrestrial species, which have been adversely affected by the tsunami are Malayan box turtle and Reticulated python These two species were not common even before the tsunami (Baskar and Rao, 1992) and now it become very rare. Juveniles of Reticulated python were commonly seen in the lowland forests of the Nicobar islands (Sivakumar, 2000), however, during this entire survey period, not even single python sighted. Another critically endangered mammal Dugong, which was often sighted from the west and southern coast of Great Nicobar, Katchal Nancowery and Camorta islands (Baskar and Rao, 1992; Das 1996) was also assumed to be severally affected by the tsunami. Presently, during this survey this species was sighted between Nancowry and Camorta islands. This endangered species already under severe threat due to poaching and habitat loss (Baskar and Rao, 1992; Das, 1996). After tsunami, which damaged most of the sea grass beds had left this species at the verge of extinction.

Post tsunami impact

The tsunami waves have washed away most of the planted as well as wild coastal coconut (*Cocos nucifera*) and acreca nut (*Areca catechu*) palms, therefore, plantation of these palms has become important for the future survival of people in this region. It is highly possible that in the absence of appropriate measures, the ongoing plantation activity would encroach upon the majority of the Nicobar megapode and its associated species. After tsunami, most of the low-lying coastal areas submerged and megapodes have built their mounds in evacuated villages. But when the people started returning, they began hunting the megapodes. In years to come, it is expected that tribals will be left with fishing and hunting of wildlife for their survival apart from livelihood support from the Government.

CONSERVATION

The island ecosystem is known for their resilience due to their ability for re-populating habitats and promoting regeneration (Lance, 2000; Thomas *et al.*, 2003). However, the restoration of the original biodiversity is possible only if the natural process such as re-colonization is actively facilitated (Lance, 2000). The aftermath of the tsunami has left the trail of homeless families who need rehabilitation. Finding proper homes and alternate livelihood for them should not undermine ecosystem resilience. Raising plantation crops to generate revenue in the littoral forests should take into account the long term effects of habitat alteration.

The Nicobar megapode and other above mentioned threatened fauna are protected by the various Schedules of the Wildlife (Protection) Act, 1972. Around 70 % of the population of Nicobar megapode had disappeared over the last 12 years. The major reason for the sharp decline is believed to be the tsunami which washed away their habitat along with nests. However, habitat destruction and hunting are the major human induced factors still adversely affect the megapodes, and these forces are likely to continue until a serious conservation programme is implemented.

At present, two National Parks and two Wildlife Sanctuaries cover the megapode and other coastal living fauna. Yet major portions of the potential coastal habitat especially along the west coast are outside protected areas. Inadequate coverage of Protected Areas in the Nicobar group of islands has already threatened several endemic fauna here (Sanakaran, 1997). Therefore, Nancowry group of islands may be declared as the 'Conservation or Community Reserve after obtaining the willingness from the local communities so that the Nicobar megapode and its associates in this region will get a better protection.

Symptoms of avian cholera were noticed in megapodes when the outbreak of this disease killed more than 50% of introduced domestic fowl in the Great Nicobar in 1997 (Sivakumar, 2004). After tsunami, the State Administration had a plan to supply 4,00,000 fowl and 9000 ducks to farmers and tribals which may threaten the native birds including megapode. Introduced dogs and cats are also known for threatening egg laying Nicobar megapodes (Sivakumar, 2000). Therefore, invasive species eradication programme need to be initiated immediately in this region.

After tsunami, hunting on megapodes seems to be on increase in several folds. Though, the Nicobarese attach traditionally cultural values to megapodes, scarcity of animal protein has forced them to hunt megapodes intensively. The two aboriginal tribes of Nicobar islands *viz.* Nicobarese and Shompens are exempt from the Wildlife (Protection) Act, 1972. Considering the changing lifestyle of these tribes, this immunity may be reviewed. In particular, the Nicobarese should be brought under the purview of the Wildlife Protection Act, 1972, while Shombens may be allowed to hunt wild animals.

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ANNEXURE A25

Extracts pertaining to corals

COMPREHENSIVE ENVIRONMENTAL IMPACT ASSESSMENT REPORT

FOR

HOLISTIC DEVELOPMENT OF GREAT NICOBAR ISLAND IN ANDAMAN AND NICOBAR ISLANDS INCLUDING INTEGRATED DEVELOPMENT OF INTERNATIONAL CONTAINER TRANSHIPMENT TERMINAL (ICTT)-14.2 MILLION TEU ALONG WITH GREENFIELD INTERNATIONAL AIRPORT (4000 PEAK HOUR PASSENGERS-PHP), TOWNSHIP & AREA DEVELOPMENT AND 450 MVA GAS AND SOLAR BASED POWER PLANT IN 16610 HA. GREAT NICOBAR ISLANDS, IN NICOBAR DISTRICT

FINAL EIA REPORT

Project Proponent

Andaman and Nicobar Islands Integrated Development Corporation Ltd (ANIIDCO),

(A Government undertaking)

March 2022

अ.नि.द्वी.स.वि.नि.

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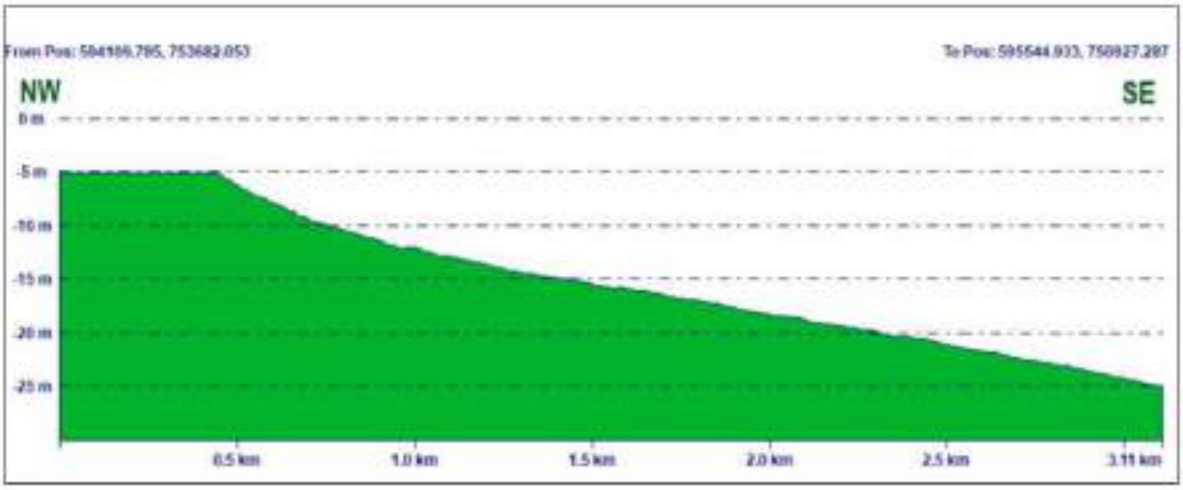
71 species of birds, 26 species of reptiles, 10 species of amphibians, and 113 species of fish have been reported. The region also harbours endemic and endangered species of fauna. To date, 11 species of mammals, 32 species of birds, 7 species of reptiles and 4 species of amphibians have been found to be endemic. Of these, the well-known species are Crab-eating Macaque, Nicobar Tree Shrew, Dugong, Nicobar Megapode, Serpent Eagle, saltwater crocodile, marine turtles and Reticulated Python.

The area harbours coral reefs. These reefs are present around the island with varied thickness and diversity. The corals were severely affected due to 2004 tsunami. In 2008, due to rise in sea water temperature, significant number of corals were bleached all over the world; the corals of Nicobar Island also experienced bleaching. However, the exact quantity of coral bleaching has not been estimated. The corals generally exist along the rocky coastal stretches. The island has plates of dead and live corals. In few areas, new coral recruits were also observed. As a part of the EIA study for this development, Zoological Survey of India (ZSI) has surveyed the area and the final report is attached as an Attachment 1 to this EIA report.

Along the coastal beaches of the Nicobar Island, Leatherback and Olive Ridley turtles are known to nest. The tsunami of 2004 modified the coastal morphology significantly and the turtles stopped visiting the beaches for nesting. However, with the passage of time, some turtles have returned for nesting.

Megapode nesting sites can be seen in various places around the island. Megapodes are mainly solitary birds that do not incubate their eggs with their body heat as other birds do but bury them in mound consisting of decaying vegetation. The megapods before tsunami mainly used to nest near to the shores. However, as the shoreline got modified after the tsunami, there has been a tendency amongst the megapods to nest away from the shores. ZSI has conducted a short-term study on the megapode nesting sites as a part of the EIA. However, a long-term study on megapode has been initiated by ZSI.

Figure 2.6: Depth Profile along the NW-SE Center Line



2.4.2 Side Scan Sonar Survey

With respect to the side scan sonar survey data, the entire survey area, in general, is marked with medium reflectivity which appears to be smooth in nature and can be loose in nature and can be interpreted Clayey SILT/ Sandy SILT, Silty SAND with traces of fine SAND as well as Coral Fragments. The area marked with high reflectivity appears to be rugged in nature and the sediments also appears to be consolidated in nature.

Thirty-Five (35) numbers of sonar contacts were observed in the survey area during side scan sonar survey at the water depth of 9 m to 21 m. No pipeline crossings were observed with in the survey area.

2.4.3 Geotechnical Investigation

As part of investigations, ten (10) boreholes i.e. (06) marine boreholes and (04) land boreholes as presented in **Table-2.4 & Figure-2.7** were undertaken and samples were collected & analysed during previous studies, and the details of the strata encountered landside and marine side are presented in **Table-2.5** and **Table-2.6** respectively.

a straight line. It falls along the extremely important and fragile zone of Northern boundary of Bhitarkanika National Park. This major deepwater port facility at Dhamra, dredged nearly 19 km-long approach channels, aside from land-raising and construction activities on land. The port at Dhamra envisages building of 13 berths, mechanized loading and unloading and an entry channel from North side. The port is one of the largest on the east coast of India with the ability to handle Cape size vessels (180,000 tonnes) and dredged a 19 km long channel through the sea with a draft of 18 m. While obtaining of the environmental clearance, one of the most pressing concerns was on turtles (dredging, lighting, shipping, ballast water discharge, current changes and their impacts, noise pollution, impacts from an expanding local population, ancillary development) as well as other impacts on the ecosystem of the area, on Bhitarkanika National Park and on Gahirmatha Marine Sanctuary. The Dhamra port is fully operational and there is no impact known on sea turtle nesting at Gahirmatha and adjoining areas where sporadic nesting takes place.

Paradip is one of the major ports of India in the east coast commissioned after independence situated in the mouth of Mahanadi and there are sporadic nesting sites along both side estuary and are not known to be impacted by port activities.

The Kakinada Sea Ports Limited (KSPL) is situated near the Hope Island and Coringa Wildlife Sanctuary and sporadic nesting of sea turtles have been occurring in Hope Islands and Sacramento uninterruptedly.

Similarly, the Kolkata Port Trust is a riverine port in the city of Kolkata and is the oldest operating port in India and there is a deep-water dock at Haldia Dock Complex, Haldia. There are number of Cargo ships handled at this port and impact to marine life including sea turtles due to ship movement is not known.

Mitigation Measures with respect to Galathea Bay ecology:

ZSI has also suggested several mitigation measures that needs to be followed to ensure minimum disturbance to the nesting of the leatherback turtles.

(1) Dredging of immediate offshore bottoms as well as shallow estuarine habitats

Reef restoration and coral relocation due to coastal development and/or dredging, are among the most common reasons for transplantation. Dredging activities in the nearshore waters of the developmental projects during the construction phase will apparently destroy the corals and coral beds, but transplantation is a worldwide solution which could be easy executed in Great Nicobar island in alternate suitable offshore habitats. Successful coral reef restoration has previously been accomplished by ZSI in Gulf of Kachchh and the transplanted corals had >90% survival and effectively transformed into a functional coral reef. Towards this, the developers should support with suitable funding.

Similarly, although the offshore congregation of leatherback turtles and other species of turtles are not known to occur in and around Galathea, however as a precautionary measure, installation of a deflector on the drag-head to push the turtles (any species) out of the path of the dredger along with an observer programme to detect any such entrainments is solution to minimize casualties in the offshore waters during dredging for navigational channel for the port. A pilot study is needed for this and towards this, the developers should support with suitable funding. The same practice has been recommended by the IUCN to Dharma Port Corporation Limited.

As per the WII study (Attachment II); the variations in the nests laid by the leatherback between years could be due to variations in the environmental settings or conduciveness of the beaches for nesting as leatherback known to be having the poor nest site fidelity. It may change the nesting site temporarily if the environmental settings of the beach are not favourable for nesting (Kelly et al., 2014). 3. Leatherbacks are known to distribute nests up to 460 km apart within a nesting season in Florida, USA (Kelly et al., 2014). Therefore, the Leatherbacks appears to have adopted a regional rather than a local optimum for nesting, possibly due to their poor nesting beach fidelity and the frequent erosion and degradation of their nesting beaches (Kamel and Mrosovsky, 2004; Kelly et al., 2014). Indian Institute of Science, Dakshin Foundation and ANET have earlier tagged 10 leatherbacks using satellite transmitters from the Little Andaman and monitored for their movements from 2011 to 2014. WII report mentioned that "one of these, turtle that laid eggs at Little Andaman was observed laying eggs in February, 2021 on the beach of the Galathea Bay, Great Nicobar by ZSI Team (pers: C. Sivaperuman, ZSI) that reiterate the weak nesting site fidelity of Leatherback as well as it reveals that the leatherback may distribute nests in different places between years".

Leatherback turtles generally nests on the western flank of the Galathea bay. The nests have also been reported by ZSI on western and eastern beaches of the GNI. The Galathea area where the turtles nest have been kept untouched of the development activity. In addition, ZSI have suggested the following to ensure that there is no disturbance to the turtles during the nesting seasons:

i. stoppage of night construction work during the nesting season of the Leatherbacks,
ii. modification of lighting in the port area,
iii. reduction of underwater noise etc as suggested by ZSI has been adopted for the project. All these measures will be adopted for the project.

Not much of work has been undertaken to understand the movement pattern, nesting fidelity of the leatherbacks. Detailed long-term study, including the satellite tagging, have been suggested. Adequate budgetary provisions have also been kept as a part of the Monitoring (Chapter 6).

(2) Translocation of corals

As per the ZSI report, no coral exists in the bay portion of the Galathea Bay. However, some coral were found on the eastern flank near the peninsular part. These patches of coral are not in the port construction area. However, coral colonies, if affected, due to the construction of the project at the proposed transhipment areas and dredging channels, to be translocated in suitable place where the similar environment as well as topographic features prevails in the Great Nicobar Island.

towards research in support of wildlife species especially towards their conservation by the developers, as part of the Corporate Social Responsibility, species specific EMP could be drafted accordingly by a recognized national agency of repute with experience in Island ecosystem monitoring and submit to the developers. Towards this, the developers should support with suitable funding.

(6) Tracking of wildlife through Radio Telemetry and Satellite Telemetry studies

Radio telemetry and by using advanced molecular tools viz. e-DNA and phylogeny of displaced species viz. Nicobar Megapode, Coconut Crab and Long-Tailed Macaque of Nicobar Islands may be an effective tool, being much on their biology and behaviour is unknown and these studies may be able to guide towards developing suitable strategies for their future survival. Similarly, Satellite telemetry of at least 100 leatherback turtles, e-DNA and phylogeny of leatherback turtles from Great Nicobar Island will reveal many facets on their biology and behaviour by which one can understand other alternate sites for leatherback turtle conservation based on environmental, ecological and economic considerations in a long-term basis. Towards this, the developers should support with suitable funding.

During the construction and operation, there is a possibility that Megapod mounds may reduce. ZSI has initiated a long-term study of the Nicobar megapods. If the study concludes that megapods are getting affected and their nests are getting reduced due to the project activity, translocation of megapods, could be considered.

(7) Disposal of dredged soil

During the construction phase, the dredged soil to be disposed as per the international dredged soil disposal guidelines in which the area should have minimum of 200 m depth and free from coral reefs, sea mount etc. This will be helpful to maintain the water quality in the nearshore region,

(8) Temporary halting of onshore and offshore activities

Construction phase is generally considered as the destructive phase of the project. Therefore, during the construction phase offshore activities to be halted to the possible extent especially during November to February the period in which the Nicobar Megapode, Coconut Crab and Long-Tailed Macaque of Nicobar Islands as well as Leatherback turtles nesting reported. All the activities during the construction phase to be suspended during night hours which will pave a movement of turtles for nesting and other wildlife for their feeding, breeding and roosting.

(9) Reduction of underwater noise pollution

The main sources of underwater noise pollution are shipping, dredging, and seismic surveying. Measures to reduce the noise from shipping vessels include modifying propellers and/or hulls and performing regular maintenance,

Table 4.3: Design Ships and Dredged Levels at Berths

Sr. No.	Vessel Type	Design Vessel Size	Design Vessel Dimensions (m)			Minimum Designed Dredged Level at Berth
			LOA	Beam	Loaded Draft	m with respect to CD
1	Container Vessel	19,650 TEU	398	61.5	16.6	-19.0

4.4.2.3 Criteria for Selection of Dredge Disposal Location

As per the recommendations of ZSI, the dredged material will have to be disposed at the depth of 200m. In GNI area, the continental shelf in the area is very short and gives way to continental slope within a short distance. The purpose of recommendation of ZSI to dispose the dredged material at 200m depth is due to the fact that coral and benthic life is low in such depth as there is limited penetration of sunlight.

As per the plan, the dredged material will be disposed in the SE area of the GNI peninsula at a depth of about 600m. The model result shows that the sediment plum will disperse within a short distance and therefore not going to have any significant impact in an area where the sunlight penetration is practically nil and the marine life is rare. Very few marine flora and fauna is reported at a depth of 600m at a distance of 7500m from the nearest shoreline. Refer figure below:

One more ecological impact that is envisaged during construction related to lighting in the construction area. Light generally affects birds and especially the nocturnal ones. All care should be taken to ensure that excessive lighting does not happen in the area. Using a smaller number or lower intensity lights; repositioning, shielding, redirecting, lowering, or recessing fixtures are some of the available options for reducing illumination in the construction site.

For the airport, a creek which was formed due to tsunami will be reclaimed. The creek was agricultural land and was used for cultivation before tsunami. Tilting of the SW part of the GNI caused ingression of the sea into the land and small mouth opened which caused flooding of these agricultural land. Initially, immediately after the tsunami, there was a total loss of the then existing ecology as trees were uprooted. However, Over the years, the submerged area developed its own ecology and now few saltwater crocodiles have been reported. There have been incidents of crocodile attack on humans and the villagers wanted the removal or culling of the crocodiles. While reclaiming the creek area, the crocodiles will have to be relocated to suitable habitat. Since many crocodile habitats exist in the Island, there should not be problems in relocating the crocodiles. Further, any shifting of crocodiles must be done only with the prior written approval of Chief Wildlife Warden under Section- 11 of Wildlife (Protection) Act, 1972.

The airport will also need to reclaim small part on both ends of the runway. The total reclaimed land will be 194 ha. To ensure that the ecology of the area is only affected to minimum extent, the runway length has been reduced from 4000 m to 3120 m. Now the area which is being designated as reclaimed area will be piled for lighting the runway. This will have only marginal impact on the ecology of the area as there will be practically no change in the tide or current pattern. ZSI, however, have reported few coral patches on the southern end of the runway lighting piles. The coral reefs are further south of the piled area and not in the area where piling is to be undertake, However, during the construction some small patches of coral reefs may get affected. The precise amount of loss will have to be determined just before the construction as the growth and bleaching of corals are common in the Island. However, even if there is any loss of corals during construction, it would not exceed 1-2 ha at the maximum. Even if there is no loss, the project can take some proactive actions and restore some area with coral replantation.

The construction activities lead to inward migration of a huge labour force in the area and thus there would be pressure on trees in the area due to increase in fuel demand. Care will be taken that the labours do not cut small trees or branches as fuel wood, for their requirement in cooking and other purposes. The area being an aviation zone, impact on terrestrial fauna will be negligible.

Mitigation measures for ecology restoration during construction

Various mitigation measures to reduce the ecological impacts will include:

- Reduction of noise levels with proper maintenance of the construction equipment and vehicles.

- Innovative lighting in the construction face. Using a smaller number or lower intensity lights; repositioning, shielding, redirecting, lowering, or recessing fixtures are the options available for light reduction.
- Careful relocation of few crocodiles that inhabit the creek area which will be reclaimed with due consultation from the forest department.
- Care to be taken while piling the runway extensions for airport lighting.
- Coral restoration and replantation measures.

4.2.9 Construction Workers Camp - impacts & mitigation measures:

- The following data is to assess the impact of labour colonies and suggest suitable remedial measures so that the construction of the project could be managed with minimum damage to the environment.

- Total number of construction labours are given

Estimated labour requirement	
Phase I	**Phase II**
1200	1470
Estimated labour + Family + Support requirement	
1680	2058
Water requirement and source (lpcd)	
252000	308700
Quantity of waste generated and fractionation (organic, hazardous, recyclable and biomedical) (Kg/day)	
600	735
Fuel requirement (kg/day)	
405	495

- **Water treatment system for the labour colonies: -**In the initial stages of construction, the treated water will be provided through tankers till the proposed trunk infrastructure is laid down in GNI. Compact waste water treatment plant / Septic tank shall be installed within the labour colonies during the initial phase of construction. However, one the infrastructure is ready, the waster will be supplied through the central waste treatment plant.
- All the waste water generated in the labour colonies will be treated before discharge. In the initial stages the wastes from the toilets will be treated through septic tanks. However, once the central treatment plant is ready, all the waste water will be directed to the treatment plant and will recycled. No water is expected to be discharges. However, some makeup might be required for operation of the plant and the quantity will be used for gardening purposes.

- **Municipal waste management system that is Collection, transportation treatment and disposal system for the labour colonies. (Details of MSW system is given in chapter 2C (2.7.4), Township)**

✓ Separate bins will be installed within the labour colonies for dry and wet waste.

ZSI recommendation on the Galathea Bay site for ICTT

Technical Reason: Based on the thorough scrutiny and examination, Galathea Bay is selected for the ICTT as it was considered as the best site in terms of distance from the international sea route (nearly 40 km away), lesser risk of rock dredging, lesser requirement of reclamation of land to develop onshore storage facilities and lower cost, required availability of natural breakwater, no requirement of hill cutting to use the land, remoteness of habitation and tribal population. Some environmental challenges are investigated for all the proposed sites and Galathea Bay has some ecological and environmental issues like some portion of the designated area is falling under ICRZ Zone 1A; the presence of 117 species of scleractinian corals along with the live coral cover of 17.46%, 8 species of holothurians, saltwater crocodile (Crocodylus porosus Schneider, 1801) in adjoining Galathea River along with mangrove patches, predominant nests of vulnerable leatherback turtle Dermochelys coriacea (Vandelli, 1764), 3 species of marine mammals are sighted, 14 breeding pairs along with 7 active mounds of endemic Nicobar Megapode Megapodius nicobariensis abbotti (Oberholser, 1919), and the Long-Tailed Macaque Macaca fascicularis umbrosus (Miller, 1902). These issues are required to be address with a proper ecological restoration program and recommendations which are illustrated in this report. Prediction of Environmental Impacts, Envisaged Benefit of the Project, Evaluation for Alternate Sites, Environmental Management Plan, Mitigation Strategies in Marine Environment at Proposed Project Sites, and Recommendations are given in details in the report for the proposed 14.2 Million TEU (Twenty Feet Equivalent Unit) ICTT Port, (main project), Airport (4,000 Peak hour passenger, Category 4F), Township and Area Development for 14,960 Ha and Power Plant (405MVA Gas +Diesel) (Additional 45 MVA from solar power will be included in total power generation).

Ecological Reason: Sea turtles are global species and they are known to nest on the sandy beaches in the close proximity to existing and operational coastal facilities globally. Several ports and jetties exist on the eastern and western coast of India (Haldia, Dhamra, Paradeep, Nuagarh, Visakhapatnam, Kakinada, Ennore, Tuticorin, Cochin, Goa, Ratnagiri, Veraval, Diu, and Jafrabad) and despite these coastal facilities, sea turtles continue to nest in close proximity to the establishments. Some examples of existence of major Ports and sea turtle nesting habitats along the east coast of India are illustrated below.

Dhamra port, in Odisha coast is located near the famous mass nesting beaches of Olive Ridley turtles, the Gahirmatha Marine Sanctuary in a straight line. It falls along the extremely important and fragile zone of Northern boundary of Bhitarkanika National Park. While obtaining of the environmental clearance, one of the most pressing concerns was on turtles (dredging, lighting, shipping, ballast water discharge, current changes and their impacts, noise pollution, impacts from an expanding local population, ancillary development) as well as other impacts on the ecosystem of the area, on Bhitarkanika National Park and on Gahirmatha Marine Sanctuary. The Dhamra port is fully operational and there is no impact known on sea turtle nesting at Gahirmatha and adjoining areas where sporadic nesting takes place.

S/N	Evaluation Criteria	Site Evaluation		
		North Site	Central Site	South Site
9	Crocodile Infested Areas	Not affected	Not affected	Affected
	Corals	Not affected	May get affected	May get affected
10	Megapodes	Nests reported	Not affected	Not affected
11	ICRZ	Impacts at the north end of the airport site and around the central part of the runway: Mangroves/ICRZ Zone IV B	Minimal impacts on the southern side of the runway: Partly in ICRZ Zone IV B	CRZ is impacted at the north and south ends of the runway and around the centre of the airport site there are two water bodies: Partly in ICRZ Zone 1 A, I B & IV B
12	Access can be planned by:			
a	Road	Yes	Yes	Yes
b	Speed Boats	No	Yes	Yes
c	Sea Aerodrome	No	No	Yes

Site Selection recommendation: The number of sites on Great Nicobar Island suitable for development of an international airport on Great Nicobar Island are very limited. The island terrain is characterised by hills with only a relatively narrow strip of land on the eastern and southern coasts where urban and tourism development can take place. Various National Parks, environmentally sensitive areas and local tribal areas add further development constraints. The significant constraints imposed by the island terrain and characteristics mean that there is no perfect site available on the island. All sites are compromised to some degree and the most suitable site is the one where these compromises can be managed and the one which provides a high degree of runway usability in line with ICAO recommendations, with aircraft approaches and take-offs available to/from both ends of the single runway. Based on our comparative site assessment and selection analysis, only the South Site should be pursued as this is the only site, we believe can be developed without wholescale terrain modification to allow runway operations in both directions. Having said that, the South Site does present some challenges that still need to be overcome, these include the following:

- The need for some terrain modification to reduce penetration of the aerodrome safeguarded surfaces by natural terrain obstacles to ensure safe aircraft operations, and also to provide an airport platform onto which the airfield and apron areas can be constructed to stringent ICAO longitudinal and transverse profile standards;

10	Environmental Management Cell/ Unit	Environmental Management Cell /Unit of the existing projects department to ensure implementation and monitoring of environmental safeguards.	Responsibilities and roles will be decided before the commencement of work.	During construction phase		-	The cost of the environmental management cell will be included in the project cost
11	Ecology	Flora and Fauna for the whole development and adjacent area will be monitored. Ecological monitoring as suggested by ZSI. For long term understanding of the leatherback turtle, Megapode nesting, ZSI suggest Radio telemetry and by using advanced molecular tools.	Health of the flora and fauna. Loss/ proliferation of Coral and other marine flora and fauna. Leatherback and other turtle species change of nesting behaviour. Satellite tracking of Turtles and Megapodes	Once in a year	Total GNI Development site with special reference to Galathea Bay, Pamaya Bay, Joginder nagar beach.	190	
12	Changes in Coastline/Shore line	Coastal structure like breakwater, Berth, Jetty, etc. might cause sedimentation/ erosion and needs to be monitored	Continuous monitoring of shoreline with the help of high-resolution satellite imageries during construction and operation phase.	Once a year	Total coastline of the development area	100	
13	Public information system	Installation of ten display boards at various locations to inform the public on the air quality met conditions and Tsunami predictions. Similar information will be displayed to the key public officers.	Temperature, Humidity, Air quality index, probable Tsunami	Continuous	Along the Central spine road and Administrative buildings	70	It's a one-time cost
14	Socio-Economics	Regular monitoring of implementation of the proposed rehabilitation and resettlement under LARR act 2013.	All socio-economic parameters with respect to LARR act 2013	Once in 6 months till the R&R process is completed	Project area	20	

6.4.2 Monitoring Schedule during Operation Phase

During operational stage, continuous air emissions from aircrafts, GSE, traffic, powerhouse, wastewater treatment, non-hazardous solid waste and hazardous used oily wastes are expected from airport project and continuous air emissions from gas engine exhausts, wastewater treatment plant, brine water from desalination plant, hazardous used oily wastes are expected. The following attributes which merit regular monitoring based on the environmental setting and nature of project activities are listed below:

6	Marine Water Quality	Marine Water quality monitoring near the outfall point.	Parameters such as pH, Temperature, Conductivity, TSS, TDS, BOD, DO, MPN Coliform Iron and Heavy metals (Hg, Cd, Cr, Pb, Zn, As, Cu)	Quarterly	Marine water quality at 3 locations once in 3 months	5	
		Marine water quality at the work phase and adjacent areas	Physico chemical properties including sediments	Once a month during working period	Atleast 6 points	50	
7	Ecology	Flora and Fauna for the whole development and adjacent area will be monitored. Ecological monitoring as suggested by ZSI. For long term understanding of the leatherback turtle nesting, ZSI suggest Radio telemetry and by using advanced molecular tools. A long-term study to understand the migration pattern of the birds in and around GNI.	Health of the flora and fauna. Loss/ proliferation of Coral and other marine flora and fauna. Leatherback and other turtle species change of nesting behaviour. Satellite tracking of Turtles. Through long-term study the migration routes, locations and duration of the migratory birds will be observed.	Once in a year	Total GNI Development site with special reference to Galathea Bay, Pamaya Bay, Joginder nagar beach.		
8	Emergency preparedness, such as fire fighting	Fire protection and safety measures to take care of fire and explosion hazards, to be assessed and steps taken for their prevention.	Mock drill records, on site emergency plan, evacuation plan.	Once a month	-		
9	Solid waste management	Compliance with the MSW Rules, and the Hazardous & other Wastes (Management and Transboundary Movement Rules).	Comprehensive Waste Management Plan should be in place and available for inspection on-site.	Once in a month	All labour colonies and construction sites	5	Cost is included in the construction cost.

Table-10.1: Environment Management Measures – ICTT Project (Construction phase)

Sr. No	Attribute	Potential Impact	Mitigation Measure	Responsibility	Broad cost in INR Lacs/ Yr	Remarks
1	**Land Environment**	The proposed project facilities berth and harbor area with breakwater will be developed within the offshore. Other infrastructure facilities like Container Storage, Internal Roads, Port & Utility Buildings, parking etc. will be developed on the landside adjacent to the reclaimed land of the port. Overall, for the all phases put together, total 3.27km (2.53 East & 0.74 West) breakwater will be constructed.	The planning will be in accordance with landscape planning concepts to minimise major landscape changes. Land reclamation and change in land use pattern will be limited to the proposed port limits and will be carried out in such a way that to ensure the proper drainage by providing surface drainage systems including storm water network, etc.	Project SPV	500	This is one-time cost and will be included in the Projects cost
		The breakwaters often serve as an anchor for growth of corals, sea grasses, and forms the habitat of benthic animals.				

			western side is to be densified with the same existing species to avoid erosion during high wave incidence and also to ensure that any future development at inland area of west coast have no impact on the turtle nesting site.			
4	**Coral Reefs**	As per the ZSI report, coral do not exist in the Galathea Bay area, however, on the eastern peninsula part (Outside the construction area) some corals were noticed.	Translocation of corals: If the coral colonies in the proposed transhipment areas and dredging channels area is affected then it needs to be translocated in suitable place.	SPV	2000	This is one-time cost for Coral translocation cost for entire project has been included under the Airport operation EMP
		Dredging activities in the nearshore waters of the developmental projects during the construction phase may affect some corals patches				

Table-10.3: Environment Management Measures – Airport Project (Construction phase)

Sr. No	Attribute	Potential Impact	Mitigation Measure	Responsibility	Broad cost in INR Lacs/ Yr	Remarks
1	**Land Environment**	The proposed area is sparsely populated and there are only two villages in the area of proposed airport where form families may be displaced	R&R measure as per RFCTLAR&R (Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement), Act 2013.	SPV		Cost will be provided by UT Administration after SIA as per RFCTLAR&R Act 2013
2	**Reclamation**	Area for runway extending into sea. The options for selecting of a site for an airport are very limited on this island. the present site needs to reclaim land approximately 71 Ha of land in order to establish an operational airport.	Coral restoration, if corals are affected during the reclamation activity.	SPV	3200	This is one-time cost. Approximately 4ha of Coral restoration has been considered. This cost though apportion to the Airport, involves restoration for the entire project including Port, Power plant and Township

Table-10.9: Cost summary table for EMP for all projects - Construction

EMP cost during Construction Phase

All cost in INR Lacs

ICTT				
SN	**Attribute**	**Responsibility**	**Broad cost**	**Remarks**
1	Land Environment/Soil Erosion	Project SPV	500	One Time
2	Changes in Coastline/Shore line	Project SPV	5000	One Time
3	Reclamation	Project SPV	1000	One Time
4	Ecology	SPV	10	Per Year
		Project SPV (ICTT) & UT Administration	400	One Time
		Project SPV (ICTT)	300	One Time
5	Coral Reefs	SPV	2000	One Time
6	Lighting	Project SPV		Part of Project Cost
7	Road construction	Contractor + SPV	10	Per Year
8	Air Emission	Project SPV + Contractor		Included in Monitoring Cost
		Contractor	70	One Time
9	Noise Pollution	Project SPV		Included in Monitoring
10	Waste Water	Project SPV	4	Per Year
11	Solid Waste	Project SPV	100	One Time
12	Social	SPV	30	Per Year
Total Capital Expenditure on EMP for ICTT (Construction Period 8 Years)			**9770**	

India's presence in the Andaman & Nicobar Islands must be strongly demonstrated to counter position their aggressive consolidation in the region. The development of GNI as an economic and defense powerhouse will be the most powerful answer to the above challenge.

Improving connectivity with Indian mainland and other global cities

At present there is very limited connectivity of the GNI with the Indian mainland and other global cities. The only modes for travelling to GNI are through Air and Sea. However, there is very limited infrastructure which is further dependent on weather conditions. To strengthen the presence at GNI, it is important to improve the transport infrastructure of GNI. The proposed Greenfield airport and International Container Transshipment Terminal (ICTT) will provide the required infrastructure not only to improve the connectivity but will also provide the economic benefits.

Promoting sustainable tourism

Like the rest of the Andaman and Nicobar Island group, GNI has long been isolated from the rest of the country. The project aims to tap the tourism potential by creating the required infrastructure.

Tourism development can capitalize on the exceptional tourism assets to attract high-end tourists interested in tropical forests, adventure tourism, beach tourism, water sports as scuba diving, snorkeling etc.

Socio-economic growth of local populace

The financial costs are significantly high with significant environmental issues. The presence of indigenous tribes and concerns for their welfare are key factors for island development. The government is aiming to develop the GNI which will ultimately enhance the socio-economic growth of the local populace and usher in a new era for their all-round development.

Detailed feasibility studies were carried out for each of the interlinked projects. Alternatives were identified and evaluated against specific predetermined criteria, including environmental impact, ecological and biodiversity. Specific studies for endangered species like leatherback turtles, corals megapods etc, were undertaken by reputed organization like Zoological Survey of India (ZSI) and Wildlife Institute of India (WII). The criteria like coastal morphology, density and diversity of the terrestrial and aquatic ecosystem, compliance with ICRZ notifications and impact on the tribes like Shompen and Nicobarese people were also studied in detail. The basic aim for EIA Study and site selection was to ensure that the natural habitat and its attributes are preserved, the deleterious impact of the construction and operation of the project is minimised to an acceptable level and the beneficial impacts are enhanced to the maximum level.

This EIA Study has been structured as per the MoEF&CC notification on EIA, 2006 to cover all the essential required aspects, described in detail under respective sections as given in the above notification.

11.1.4. International Airport

The master planning and design for the airport is done taking into consideration, the most optimum site with respect to minimal environmental impact to rich biodiversity of the island, traffic projections (passenger and cargo), sustainable Planning etc.

In order to work out the optimal size of the airport which will be able to accommodate the anticipated services over next three decades, a comprehensive air traffic forecasts have been made. Figure below shows the projected forecasts.

Table 1: Total Annual Passenger Forecasts (M), Worst, Base and Best cases

Year	Worst Case	Base Case	Best Case
2025	0.07	0.40	0.50
2030	0.12	0.78	0.97
2040	0.35	1.54	2.48
2052	0.81	3.28	5.08

Airport siting studies were carried out and possible sites on the island were assessed for their suitability; the sites were evaluated for their complementing aspects with respect to the proposed population centres, interlinked projects and its impact on environment. Alternatives were identified and evaluated against predetermined criteria, including environmental impact, operational performance, and economic viability. Sub-criteria included coastal morphology, density and diversity of the terrestrial ecosystem, density and diversity of coral, compliance with ICRZ notifications, and impact on the Tribal people. The basic aim of site selection exercise is to ensure that the natural habitat and its attributes are preserved to the maximum and the impact of the construction and operation of the project is at minimum and acceptable level.

It is proposed to locate the airport at Gandhi Nagar and Shastri Nagar (South site) as it was the only site within the project area that is flat enough to facilitate bidirectional take-off and landing. Moreover, the flight path of the aircrafts will be over sea, thus, there will be minimal disturbance to local population and the tribal areas due to over flying of aircrafts at low altitude. Some of the existing families in those villages will be affected by the project. The site includes a large area of revenue land, and minimal forest land will be affected.

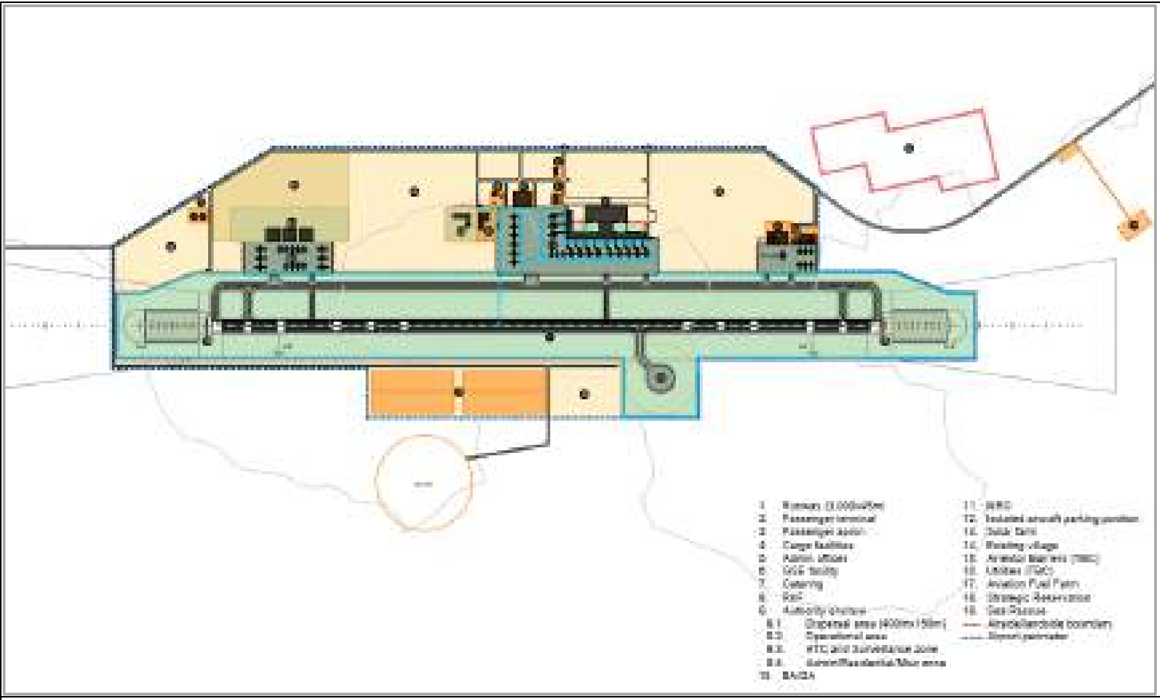


Figure 5: Proposed layout for Greenfield International Airport at GNI

The runway lengths have been kept at 3000 m with provision for further expansion if required. Similarly, other facilities have been safeguarded for future development. A defense enclave has suitably been incorporated in the overall layout with a separate apron for the Defense.

The reclamation of the seashore and the occupation of CRZ has been kept to minimum. Only the peripheral runway safety / support systems are encroaching into the sea / CRZ on reclaimed land at both the North and South ends of runway. The central part of airport also runs over water inlet North Shastri Nagar which will require requisite CRZ / environmental clearance. This inlet area is revenue land which got submerged during Tsunami. The existing corals have been avoided through careful siting of reclamation at South end.

11.1.5. Power plant and Power infrastructure

Power demand of 450 MVA has be projected for all types of industries, non-industrial buildings (residential, commercial & Institutional building), industrial amenities and common utilities (water supply, STP, CETP, street lighting, ICT)..

The power plant is proposed as a combination of Diesel based (about 15%) and Gas based (85%). Initially the plant will run on the diesel, which shall be HSD with low Sulphur and DG sets shall be air cooled with no discharge of water. However, after the system for the safe delivery of the gas are put in place, the gas-based generation will start.

The gas-based power plant will be based on natural gas which has an increasingly role in the global natural gas market. Natural gas is a relatively clean energy source, which produces much less pollution than conventional thermal plants. The gas-based power plant shall have gas turbines in combination to stream turbine for optimized sustainable usages. The Plant shall be air cooled thus mitigating the cooling water discharge and sustaining the environment.

Zoological Survey of India (ZSI) has undertaken a marine ecological study in Eastern, southern and south western part of GNI.

Wildlife Institute of India (WII) has carried out a rapid assessment study to understand the biological or ecological significance of five sites identified for the port. This study was conducted with an aim of assessing the current status of turtle nesting beaches with special focus on leatherback turtles. Study was also aimed to assess the status of megapodes and dugong habitats along these beaches.

GNI consists of Tidal Swamp Forest (Mangrove Forest), Littoral Forest (Beach Forests), Low level Evergreen Forests (Coral Reef Forests), Tropical Evergreen Forests (True Tropical Forests), Southern hill-top evergreen forests and fern breaks. The members of the families Euphorbiaceae, Rubiaceae, Arecaceae, Orchidaceae, Cyperaceae, Poaceae and Annonaceae show high representation in GNI. The distinct flora of the area can be visualized by the fact that the genera *Otenthera* and *Astronia* of Melastomataceae, *Cyrtandromea* of Scrophulariaceae, *Cyrtandra* of Gesneriaceae, *Stemonurus* of Icacinaceae, *Rhopaloblaste* from Arecaceae and *Spathoglottis* of Orchidaceae and many more species are endemic to these areas. A total of 330 species of fauna are recorded from the Campbell Bay National Park area including 28 species of mammals (including 3 marine mammals), 97 species of birds, 23 species of reptiles, 10 species of amphibians, 52 species of butterflies, 24 species of odonates, 20 species of spiders and 76 species of aquatic Hemipterans.

Social Environment

The information on socio-economic aspects of the study area has been compiled from secondary sources, which mainly include census data of 2011. The salient features of the demography and socio-economic profile are as follows:

- Total population is 8,367.
- There are no scheduled castes (SC)
- There are 1,324 persons scheduled tribes (ST)

The percentage of male literates to the total literates of the study area works out to be 63.70%. The percentage of female literates to the total literates, which is an important indicator for social change, is observed to be 36.30% in the study area as per 2011 Census records. Total work participation rate in the project study area is 45.91%. The distribution of workers by occupation indicates that the non-workers are the predominant population. There are 237 number of Shompen and 1087 number of Nicobaries within the Great Nicobar Island.

11.5. Anticipated Environmental Impacts and Mitigation Measures

The proposed integrated development projects will result in certain environmental impacts during construction and operational phases

11.5.1. International Container Transshipment Terminal

During construction phase changes in land use/land cover may change and the topography may change. Due to construction activity and soil compaction/ consolidation, it may cause loss of vegetation, tree cover & soil pollution.

No quarrying is proposed to be carried out in GNI. All the quarry material will be transported from either the main land or from Indonesia depending on the quality of the material and economic feasibility.

During operational phase of ICTT, it is proposed that there will be not be any dusty cargo, dry bulk cargo such as coal, iron ore or hazardous cargo, etc. Hence, direct impact on water due to cargo handling will be insignificant. If no care is taken, the marine water may get polluted as a result of release of contaminants into the marine system. The contaminants include leakage/ spill of oil in port and its surrounding area. As a mitigation measure, no untreated water will be discharged either during the construction or operation phase of the project.

It is proposed that the Port operator will prepare a spill prevention, control, and counter measure plan which will be consistent with the IMO Manual on Oil Pollution Section II – Contingency Planning. All the ship related waste with a potential to cause pollution to the marine environment will be disposed according to the guidelines stipulated by the MARPOL Convention.

As mentioned earlier, the western flank of Galathea Bay has leatherback turtle nesting sites. In order to ensure that turtles are not disturbed during the nesting seasons (between November and February) no offshore construction activity will be undertaken to the extent possible. This is in line with as per ZSI recommendations. Considering that these turtles are sensitive to light, ZSI has recommended low pressure sodium lighting in the port area for minimum disturbance to the turtles. ZSI has also recommended the reduction of underwater noise for minimal disturbance to leatherback Turtles. ZSI has also recommended, long term satellite tacking of leatherback turtles.

Galathea port area does not have any coral reefs. However, few Sporadic coral reefs are reported on the eastern peninsula part from the work area, if impacted, the same may be replanted in a suitable area. Adequate financial provisions have are being kept for the coral replantation work as contingency.

11.5.2. Greenfield International Airport

The activities that take place during construction phases of airport project inlcude levelling of site, construction and erection of main airport structures like terminal building, aprons, runway, construction of blast pads at extreme ends of runway, provision of runway shoulders, for aerodrome reference code. There are impacts on land use, soil, air quality, ecology, demography and socio-economics, access roads and public expectation due to these activities.

Environmental impacts associated with the operation of the project will be minimized by implementing the key design and planning strategies,.

Exhaust emissions from vehicles and equipment deployed during the construction phase also result in marginal increase in the levels of SO_2, NO_2, PM, CO and unburnt hydrocarbons. However, the impacts will be reversible, marginal, and temporary in nature.

It is proposed that a small part of the sea needs to be reclaimed due to the lighting and radar installation of the runway. As per the ZSI report the specific area does not have corals but they may be present in nearby areas. However, if any coral is affected due to the reclaimation, the same will be replanted in a suitable area. Adequate financial provisions have been kept for the coral replantation work.

11.5.3. Power Plant

The probable impacts during construction phase will be on various sectors of environment (such as air, water, soil, socio-economic environment etc.). The present land use of the project site falls under protected or deemed forest category. There will be change in land use after installation of the proposed power project from forest to non-forest category. Also, the proposed project is not likely to have any adverse impact on the surrounding land use during the construction period. Appropriate soil conservation measures associated with improved construction techniques will minimize such impacts. Timely afforestation activities are proposed which will contribute towards soil conservation. The hazardous waste from the construction site is proposed to be collected in the designated area and will not be allowed to come in contact with the soil.

The dust will be the main pollutant affecting the ambient air quality of the area during the construction phase. The impact will be confined within the project boundary and is expected to be negligible outside the plant boundaries.

The present river water may be impacted due to non-point discharges of solids from soil loss and sewage generated from the construction work force stationed at the site. However, the overall impact on water environment during construction will be insignificant. Temporary sanitation facilities (septic tanks) will be set-up for disposal of sewage generated by the work force.

The construction equipment may have high noise levels, which can affect the personnel who will be operating the machines. Use of proper personal protective equipment will mitigate any significant impact of the noise generated by such equipment on the labours working during construction.

The power plant is near to Shompen habitation. In order to ensure that there is no trespassing of labour, in the tribal reserve, adequate number of check points have been proposed.

Apart from localized construction impacts at the plant site, no adverse impact on soil in the surrounding area is anticipated.

The power plant emissions will be monitored through continuous emission monitoring equipment.

11.5.4. Township and Area Development

Township construction will involve cut and fill earthworks which has the potential to change the topography of the land and disrupt the natural drainage of the area.

Due to the increased vehicular movements, there will be an increase in NO_x and CO concentrations at the project site. However, the increase in pollution levels in the ambient air is temporary and will be negligible. It is proposed that most of the construction equipment will be mobile, thus the emissions are likely to be fugitive and

Conservation and Management Plan for Coral Reefs *of* Great Nicobar Island

Submitted by

ZOOLOGICAL SURVEY OF INDIA
Ministry of Environment, Forest and Climate Change

1. INTRODUCTION

Coral reefs are the most primitive living ecosystem of the marine biota, a structure built by colonies of tiny coral animals over millions of years. Due to its enormous productively in oceans environment, corals reefs are often called as 'Rain Forest of the Sea'. The extraordinary beauty, bright palette of colors, and oddly patterned inhabitants, are really a means of delighted arena of this Earth's most important ecosystems. The biodiversity of the reef system supports a vast interdependent food web, from microscopic plants and animals to humans. Corals are the important structural feature of reefs in shallow tropical seas since the 100 million years ago to till date. The highly productivity and biological diversity made the corals most sustainable in this changing environment.

The coral reefs are the natural heritage and stock of biological diversity of the world which supports a great deal of faunal communities. It has been estimated that between1-9 million species live on coral reefs (Ramakrishna et al., 2010). It is a hunting ground, a safe place to hide, a place to breed, to raise young, and to grow old. The productivity of healthy coral reefs not only gives supports for the corals but also to sustain a rich interlinked system of species which has been the main source of food and resources. The reef dwelling species are yielding influential chemicals effective in treatment of disease.

Coral reefs take a great role to form natural breakwaters protecting the fertile coastal lands and human settlements of many islands and continental nations from erosion by storm waves and other climatic or natural problems. But the degradation of coral reef environment has been spreading all over the world ocean gradually due to natural calamities as well as anthropogenic stresses. The possible warming of our climate with associated warming of ocean temperatures, increased sedimentation from development along coastal areas, pollution, and unsustainable fishing methods are only some of the threats to reefs worldwide. As humans change the environment on the surface of the Earth, the conditions underneath the surface of our oceans change accordingly. From the microscopic plants that live within the tissues of the corals to the diversity of invertebrates and fishes that find food and shelter within the colourful caves and crevices, the reef system's millions of species also provide important food resources for sharks, sea turtles and dolphins.

Millions of people throughout the world depend directly on the reefs for their livelihood. Coral reefs cover less than 0.2% of the total area of oceans but act as house of 25% of all marine creatures (Ramakrishna *et al.*, 2010). Coral reefs are dynamic systems, producing lime stones at the rate of 400-2000 tones per hectare per year (Chave *et al.*, 1972). Coral reefs influence the chemical balance of world's oceans (Smith, 1978). Scleractinian corals are strong calcareous aragonite structure formed by gradual deposition of calcium carbonate by the living tissues of corals as the secreted materials with the presence of supportable marine environment. The reef environment supports a pristine environment of marine faunal communities to manage balanced ecosystems. The benthic biotic environment supports a great composition of floral and faunal components. It defined as "all of the bottom terrain from the wave-washed shoreline at flood-tide level to the greatest deeps" (Sverdrup *et* *al.,* 1942). The high water mark on the shoreward side to the boundary marked by the continental self is defined as the littoral zone. The standard distance covered by the littoral zone from the shoreline into the seaward side is 200 m. The littoral zone is further marked from the shoreline up to 50 m as eulittoral and from 50 m to 200 m as sublittoral zone. The eulittoral zone further may divide into intertidal zone and submerged eulittoral benthic zone. Thus the eulittoral benthic zone which lies beyond the low water mark comprises of biota that always remain below water level and are not affected by tidal changes. The cosmopolitan eulittoral fauna, which extends from the higher mark into the sea comprises of interstitial fauna, intertidal fauna (macrofauna), meiobentos, microbenthos and macrobenthos communities. This present proposal deals with the survey, monitoring and conservational aspects of the coral reef ecosystems.

2. GENERAL PRACTICE FOR CORAL CONSERVATION

Coral reefs are natural breakwaters substitute as a first line of defense for coastal communities, protecting the coastline from wave energy and preventing coastal erosion and flooding (Zepeda-Centeno *et al.*, 2019). The high complexity and rugosity in the reef crest may considerably dissolve wave energy that crosses the reef towards the coast (Harmelin-Vivien, 1994; Alcolado *et al.*, 2009; Busutil *et al.*, 2011; Gardner *et al.*, 2005; Zepeda-Centeno *et al.*, 2019). So, a strong, healthy and physically complex coral community can deliver the characteristics needed to increase and maintain coastal protection (Zepeda-Centeno *et al.*, 2019). Coral reefs deliver extensive ecosystem goods and services worth hundreds of billions of dollars globally every year. But this is unfortunate that the coral reef ecosystems of the world are rapidly declining due to climatic and anthropogenic disturbances. As per recent reports of IPCC, up to 90% of coral reefs could be lost by 2050, even if warming is limited to an increase of 1.5°C. Urgent climate action is required along with bold local management to halt declines and support coral reef resilience now and into the future. Coral reef restoration can be used as part of a broader management strategy to combat declines in coral health globally. The restoration methodology is not designed to reduce climate impacts, but rather, it is intended as a complementary tool to support natural recovery following disturbance in high-value areas (ICRI, 2021).

In 2004, the Society for Ecological Restoration International Science & Policy Working Group describes restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed". Further, "restoration attempts to return an ecosystem to its historic trajectory". Restoration projects ideally require no attendance once they are mature. Currently for coral reefs, the term restoration is used to encompass both 'restoration' and 'rehabilitation'; with the latter emphasising "the reparation of ecosystem processes, productivity and services. . ." without meaning a return to pre-existing biotic conditions, and often requiring some attendance. A restored ecosystem "contains sufficient biotic and abiotic resources to continue its development without further assistance or subsidy" (Bostro"m-Einarsson *et al.*, 2020). The overall concept of the coral restoration may include the direct transplantation of coral fragments on the reef, coral gardening where corals are fragmented, grown in nurseries, and planted back on the reef larval propagation where coral larvae are reared until ready to attach to the reef and released, and the use of artificial structures with planted coral with the goal of protecting coastal areas (ICRI, 2021).

The techniques for coral restoration are depending on the basic principle that secures broken corals so they will survive. Asexual reproduction in corals is the prime contributor for this process. In restoring coral reef through asexual propagation and the securement of coral fragments are used to increase solid structures available for coral growth, to increase coral coverage and to alter growing conditions. These objectives can also be referred to structural, biological, and physical conditions. Structural restoration normally includes the building of artificial reefs, sinking of wrecks, or relocation of rocks/dead coral heads. The goal is to surge the quantity of reef construction and environment accessible for the corals and other reef organisms to propagate. Physical restoration is required in areas were the reef has been vanished or exponentially reduced due to disturbances. In areas which have been reduced to rubble or sand, corals will not have solid structure to attach to and will end up being abraded or buried during high waves. Biological restoration generally includes increasing the amount of living corals on the reef in areas were structure is already available. This is normally attained by collecting and rehabilitating naturally broken coral fragments, propagating coral colonies, culturing coral larvae, or transplanting living coral colonies. The overall aim of biological restoration is to regrow corals in areas where populations have been diminished or lost. Physical restoration comprises addressing the conditions in which the corals are developing to improve their health, growth rates, or fecundity. These methods have generally been developed more recently, and some are still in the experimental stages. Methods include mid-water coral nurseries or mineral accretion devices such as Biorock technology. The detailed methodologies for the coral transplantation in global level are cited below.

2.1. Direct transplantation

The earliest and most common method of coral restoration involves the direct transplantation of coral fragments, from a donor to a recipient reef. Overall, direct transplantation studies reported an average survival of 64%, with 20% reporting >90% survival of transplanted corals. Direct transplantation has primarily involved fast-growing corals, with more than three-quarters of case studies using branching coral morphologies (Bostro¨m-Einarsson *et al.*, 2020).

2.2. Coral gardening

Continuous harvesting of coral fragments may have detrimental effects on donor corals and populations. In response to this, a more sustainable model has been developed where coral recruits or small fragments are raised in intermediate nurseries, prior to outplanting on restoration sites. The nursery phase protects corals from damaging conditions during their most vulnerable stages, with the intention of planting them onto damaged reefs once they have reached a size threshold at which their post-transplantation survival is higher. In addition, once fragments have reached a suitable size they can be broken into smaller pieces, and these can be grown in the nursey, multiplying the number of fragments available to outplant. In this review, 48% of case studies involved coral gardening, with a majority of records focusing on the transplantation phase of the concept (transplantation phase 24%, nursery phase 16%, both phases 8%). Corals were raised in either field-based (*in situ*), or land-based (ex situ) nurseries, depending on local conditions. Practitioners advocating the use of a coral nursery phase for reef restoration highlight improved growth and survivorship rates of fragments, compared to direct transplantation. Coral gardening studies exhibited an average 66% survival in the outplanting phase, compared to 64% survival in direct transplantation studies (Bostro¨m-Einarsson *et al.*, 2020).

2.3. Micro-fragmentation

Less than 5% of transplantation studies have been conducted with corals characterised by slow growing life histories. Massive corals have largely been overlooked, mainly due to their slow growth and thicker skeletons, which are less amenable to fragmenting. The micro-fragmentation' technique (developed by Mote Marine Laboratory) that enables massive and encrusting corals to be produced and outplanted using concepts developed for coral gardening (Forsman *et al.*, 2015). A diamond blade saw is used to cut small fragments ($1cm^2$) of massive corals, which are then mounted on tiles. After approximately 12 months, the fragments can either be further sub-divided to generate new micro-fragments or outplanted. Micro-fragments that are secured to reef substrates or dead coral skeletons in an array will readily fuse together to form a larger colony (termed 're-skinning'). The research outcomes show high survival and rapid growth of fragments (Forsman *et al.*, 2015; Bostro¨m-Einarsson *et al.*, 2020).

2.4. Larval enhancement

Larval enhancement methods aim to increase rates of coral fertilisation, larval survival and recruitment. Larval enhancement can be seen grouped into two main types: one where larvae are settled on artificial structures, and one where larvae are settled directly onto the reef. Concrete tetrapods are used for 'seeding'. Approximately 10% of settled larvae survived, and 56% of seeding units harboured. The second larval enhancement technique included collection of coral gametes during spawning and rearing in holding tanks or on the reef, after which larvae are released directly onto the reef in enclosures that retain them over the target substrate during the settlement period (Bostro¨m-Einarsson *et al.*, 2020).

2.5. Artificial reefs

The creation of substratum involves structures that are placed on the seabed deliberately, sometimes to mimic characteristics of a natural reef, or for the purpose of increasing potential habitat for reef fauna, fisheries production, recreational diving opportunities, or the prevention of trawling. The developments of artificial reefs are presently widely used for coral transplantation (Bostro¨m-Einarsson *et al.*, 2020).

2.6. Substratum stabilisation

The direct physical restoration of damaged substratum mostly involves stabilising rubble in an area that has been affected by storms or ship groundings. The rationale for stabilisation is that survival rates for coral recruits are low on loose substratum. The most common method is to install mesh or netting over the rubble to prevent further movement. This is generally a precursor to the transplantation of corals onto the damaged area and/or additional deployment of artificial structures. The survival rate of the coral can be 80% (Bostro¨m-Einarsson *et al.*, 2020).

2.7. Substratum enhancement with electricity

The aim of the technique is to mimic the chemical and physical properties of reef limestone, by encouraging the precipitation of calcium and magnesium on artificial substrata (Goreau, 1996). A direct electrical current is established between electrodes, and calcium carbonate and magnesium hydroxide precipitates at the cathode, while oxygen and chlorine are produced at the anode (Hilbertz, 1976). The purpose of this mineral accretion is to potentially increase the calcification of coral polyps, thereby boosting colony growth and resilience to stressors (Bostro¨m-Einarsson *et al.*, 2020).

3. ZSI's EXPERIENCE IN CORAL CONSERVATION

Zoological Survey of India has the distinction of carrying out prestigious and unique first of its kind Ecological Restoration in coral reef areas in the recent past in the present study site (Gulf of Kachchh) itself with the able support of the Marine National Park Authority of Gujarat Forest Department, while a couple of agencies have tried and given up. ZSI restored a total of about 2000 square meter degraded coral reef area along the Gulf of Kachchh region by employing site specific strategies and multidisciplinary approaches and by involving local community (Satyanarayana and Chandran, 2017).

A total of 232 cement structures with 2320 native coral and branching coral transplant were restored in Pirotan site. In Narara site, 1170 native coral transplants were restored in 214 cement structures and a total of 110 cement structures, 50 iron frames were used to restore 1050 native coral transplants at Mithapur restoration site. Although high survival rates of transplanted native coral species were recorded in all restoration sites after one year of continuous monitoring, Pirotan site recorded maximum (97.24%), than the Narara (96.50%) and Mithapur (96.57%) restoration sites (Fig. 1). As far as concern with the restored branching coral transplants, survival rate of *Acropora* transplants was recorded 85.25% at Mithapur restoration site and 68.75% at the Pirotan site. But the survival rate of *Montipora* transplants was recorded higher in Pirotan restoration site 78.57% than the Mithapur site (59.40%) (Satyanarayana and Chandran, 2017). Pirotan recorded highest survivorship (97.24%) than the other two sites. Coral fragments attached on the artificial cement/iron/pvc structures were found started encrusting on the cement plates by overgrowing on the tied nylon and copper tags from the 2nd month %) (Satyanarayana and Chandran, 2017). Restoration is being done on in Gulf of Kachchh area (Narare Reef, Kalubar Island). About 9000 corals from 49,000 m^2 area (40 times bigger than the MNP-ZSI ICZM transplantation effort carried out from 2012-2018) will be translocated. The aforementioned project work cost around Rs. 4,00,00,000.00 (only for salary and some consumable) whereas other all the support will be made by the sponsoring agency.

4. STATUS OF CORAL REEFS IN GREAT NICOBAR ISLAND

Great Nicobar Island is the largest and southernmost island of the Nicobar group of islands of Andaman and Nicobar Islands. The narrow and shallow coastal water of Great Nicobar Island harbors fringing-type coral reefs. The detailed status of the reef areas of Great Nicobar Island is represented below.

4.1. Distribution of Scleratinian Corals at proposed sites

A total of 245 species of scleractinian corals under 53 genera and 15 families (including 2 genera under *Scleractinia Incertae Sedis*) are recorded from seven sites including the proposed project site of Great Nicobar Island during the present study. No major coral reef exists within the work area of the project. However, scattered coral reefs are available at the peninsular part of the Galathea Bay. A maximum of 117 species is documented from the Galathea Bay followed by 111 species in Sastri Nagar, 107 species from Campbell Bay, 102 species from Laxman Beach, 76 species from Gandhi Nagar, and 25 species from Anderson Bay, and only 15 species from Laxmi Nagar. The occurrence sharing of three groups of corals (Abundantly seen, commonly seen, and rarely seen) are plotted below (Fig. 1). The scleractinian corals of Galathea Bay are scattered with about 117 species of corals ad are reported on the eastern and western peninsular flanks of the bay.

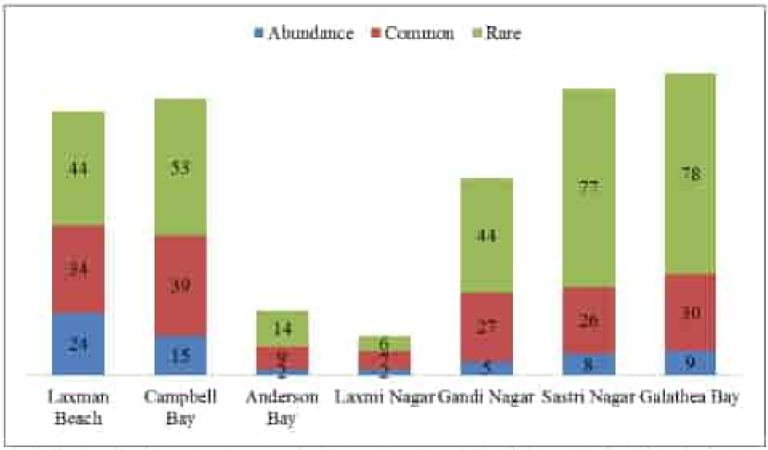


Fig. 1: Species richness of Scleractinian corals from seven selected areas of Great Nicobar Island

4.2. Diversity

The statistical analysis was made to evaluate the ecological status of scleractinian corals from the seven sites of the Great Nicobar Island. The dominance index (D) of the species ranges from 0.01 to 0.07. Five study areas out of the seven represented the dominance of 0.01 while

Anderson Bay represented 0.04 while Laxmi Nagar showcased the lowest numerical value of 0.07 for the dominance index. The Simpson density index suggested the ranges between 0.93 to 0.99. Five study areas such as Laxman Beach, Campbell Bay, Gandhi Nagar, Sastri Nagar, and Galathea Bay harbor a maximum value of 0.99 as Simpson diversity index for each area while a minimum of 0.93 is recorded from Laxmi Nagar. The species diversity index was measured by means of the Shannon index (H) which is ranged from 2.45 at Laxmi Nagar to 4.42 at Galathea Bay. Other ecological indices like Brillouin's, Menhinick's, and Margalef's indices also comprehensively suggested the maximum species diversity from the Galathea Bay region and the minimum from the Laxmi Nagar area (Table 1).

Table 1: Ecological indices of seven study areas of Great Nicobar Island

Indices	Laxman Beach	Campbell Bay	Anderson Bay	Laxmi Nagar	Gandhi Nagar	Sastri Nagar	Galathea Bay
Dominance_D	0.01	0.01	0.04	0.07	0.01	0.01	0.01
Simpson_1-D	0.99	0.99	0.96	0.93	0.99	0.99	0.99
Shannon_H	4.34	4.36	2.91	2.45	4.02	4.40	4.42
Evenness_e^H/S	0.75	0.73	0.73	0.77	0.73	0.74	0.71
Brillouin	4.11	4.11	2.65	2.23	3.76	4.12	4.14
Menhinick	4.65	5.15	2.68	1.89	4.63	5.79	5.91
Margalef	16.35	17.47	5.37	3.38	13.40	18.63	19.43

4.3. Benthic cover

Thorough studies were carried out in the seven study areas of Great Nicobar Island to estimate the benthic cover. A maximum of 39.27% of live coral cover was recorded from the Campbell Bay region followed by 30.81% from Gandhi Nagar, 25.59% from Sastri Nagar, 24.10% from Laxman Beach, 19.92% from Anderson Bar, 17.46 from Galathea Bay, and the minimum of 13.45% from Laxmi Nager. Among the other algae, a maximum of 51.75% was recorded from Galathea Bay while a minimum of 5.52% from Anderson Bay (Table 2).

Table 2: Summary details of Benthic cover of reef ecosystem of Great Nicobar Island

Parameters	Laxman Beach	Campbell Bay	Anderson Bay	Laxmi Nagar	Gandhi Nagar	Sastry Nagar	Galathea Bay	MEAN VALUE
Dead Coral	4.25	9.02	3.40	5.54	3.80	0.40	1.72	4.02
Live coral	24.10	39.27	19.92	13.45	30.81	25.59	17.46	24.37
Other animal	6.45	4.56	7.59	9.48	8.00	3.89	2.48	6.06
Other algae	24.15	6.95	5.52	13.78	19.77	33.87	51.75	22.26
Abiotic	41.05	40.20	63.57	57.75	37.62	36.25	26.59	43.29

The present study indicates a total of 491.7975 ha. reef areas across the seven study areas (Fig. 2) including 116.4173 ha. of reef areas at Galathea Bay which is distributed up to the maximum extent of 1200m (perpendicular) from the coastline on the eastern and western peninsular flanks of the bay while most of the reefs are scattered in distribution within the limit of a mean distance of 500m whereas the reef areas of Sastri Nagar are recorded with the total distributional cover of around 103.8703 ha. along with the mean distributional range from the coast is 250m (perpendicular) along with the maximum of 500m while Laxman Beach represents the minimum of 34.4921 ha. of reef areas within the mean proximity of 150m from the coast while the maximum distributional ranges are within 350m (Fig. 3). It is significant to mention that about 17.46% are live corals are reported among the 116.4173 ha. of reef areas at Galathea Bay.

Fig. 2: Study areas of Great Nicobar Island

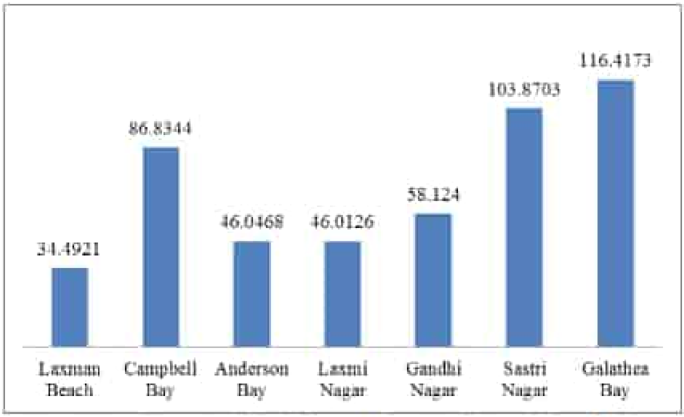


Fig. 3: Reef area cover (in ha.) of seven study areas of Great Nicobar Island

4.4. Similarity index of benthic communities

The grouping among the study sites was carried out based on the benthic covers and life forms of the study areas. The parameters such as percentage cover of dead coral, live coral, other animals, other algae, and abiotic were considered during the preparation of this dendrogram. The maximum similarity was found in the benthic components of Gandhi Nagar and Laxman Beach, followed by Anderson Bay and Laxmi Nagar. The characteristic features of the benthic communities of Galathea Bay are maximally different from all the study areas (Fig. 4).

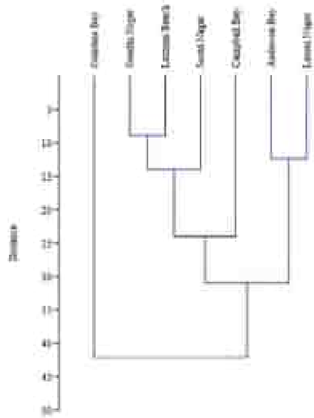


Fig 4: Dendrogram on Euclidean distance to make grouping based on benthic cover at the study sites of Great Nicobar Island

4.5. Similarities and dissimilates based on life forms

The similarities and dissimilates among the study areas were also calculated based on the availability of live coral life forms such as *Acropora* - Branching, Encrusting, Submassive, Digitate, and Tubular; and non-*Acropora* - Branching, Encrusting, Foliose, Massive, Submassive, Mushroom, Heliopora, Millepora, and Tubipora. The maximum similarity was recorded between Anderson Bay and Laxmi Nagar; followed by Sastri Nagar and Galathea Bay. The physical attributes of live coral life forms of Laxman Beach were with the proximity to the cluster of Anderson Bay and Laxmi Nagar whereas Gandhi Nagar and Campbell Bay were seen as the representation of a different subset of the cluster (Fig. 5).

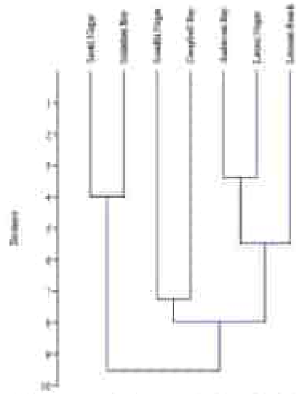


Fig 5: Dendrogram on Euclidean distance to make grouping based on live coral life forms at the study sites of Great Nicobar Island

4.6. Correlation of scleractinian species

Studies on cluster analysis were attributed based on the Raup-Crick index availing absence-presence data of scleractinian species and found that the occurrence in a variety of species availability contributed a major role to denote area-wise cluster formation. The data suggested that the species of communities are narrated a close relationship between Laxmi Nagar and Campbell Bay while the maximum of dissimilarity was found between Laxman Beach and Sastri Nagar (Fig. 6).

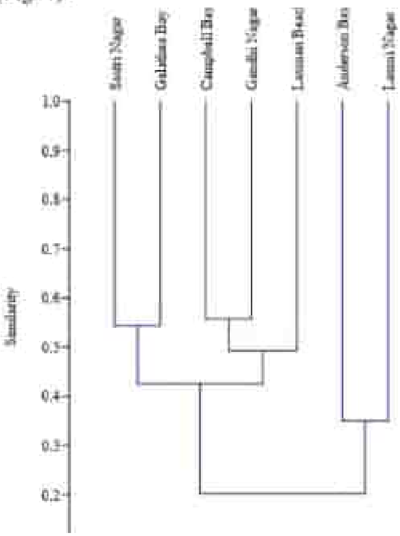


Fig. 6: Bray-Curtis similarity-dissimilarity cluster of scleractinian corals along seven study areas of Great Nicobar Island

5. TRANSLOCATION/RESTORATION SITES OF GREAT NICOBAR ISLAND

As a part of the project on Holistic Development of Great Nicobar Island, it is proposed to translocate and restore the corals falling on the proposed project site.

5.1. Overall observation

As per the above-mentioned analysis, the overall benthic community of Galathea Bay is mostly different from other study areas. All the study areas are situated in close proximity to Great Nicobar Island within a range of nearly 30 km. (aerial distance). The thorough scrutiny of the benthic communities resulted in this differentiation. Another study signified Galathea Bay and Sastri Nagar are sharing maximum similarity in live coral life forms and species occurrence followed by Campbell Bay, Gandhi Nagar, Laxman Beach, and Anderson Bay. The environmental status and physicochemical status of the study areas are conducive with the oligotrophic environment.

5.2. Probable sites and justifications

The details of the probable sites for coral translocation/ restoration are given below (Table 3).

Table 3: Probable sites for coral translocation/ restoration

Site No.	Areas	Present Reef Cover (ha.)	Scleractinian species richness (number of species)	Outcome
Site 1	Laxman Beach	34.4921	102	Increase of reef cover and habitat along with species diversity.
Site 2	Anderson Bay (North-East Bay region)	46.0468	25	Increase of reef cover and habitat along with species diversity.
Site 3	Gandhi Nagar	58.124	76	Increase of reef cover and habitat along with species diversity.
Site 4	Campbell Bay (South-East Bay region)	86.8344	107	Increase of reef cover and habitat along with species diversity.

The species diversity, density, and composition of Galathea Bay are maximally correlated with Sastri Nagar. As Sastri Nagar is situated near the Gakathea Bay (the proposed project site), the developmental works may have some temporary negative impact on the coastal waters which may affect the immediate translocation/ restoration of scleractinian corals. So Sastri Nagar is not selected as the probable site for translocation/ restoration.

6. METHODOLOGIES FOR CORAL TRANSLOCATION/ RESTORATION

6.1. Site Selection

The site selection is completely dependent on the objectives of the work. Here the major objectives of the proposed work depend on the transplantation studies. Hence, site selection will be made as Donor Site and Recipient Site.

Donor Site- The proposed project deals with the transplantation and restoration of corals. Corals will be extracted from Galathea Bay of Great Nicobar Island with the help of coral cutting saw, hammer & chisel, and hydraulic underwater hammer drill etc. Though no dredging will be undertaken near to the eastern and western flanks of the peninsular area of the bay, some corals may get affected due to the dredging in the nearby areas due to the deposition of the dispersed sediments. It has been presumed that that about 4 ha of corals may get affected.

Recipient Site- The coral transplantation will be made at other sites of Great Nicobar Island to restore the coral reefs. Corals will be initially transplanted at Laxman Beach and Joginder Nagar Beach area (Anderson Bay). Transplantation can be made at Gandhi Nagar or Campbell area also if required. These areas will be the recipient sites.

6.2. Benthic cover details of Galathea Bay

- Total benthic cover of Galathea Bay: 116.4173 ha.
- Benthic cover of live coral in Galathea Bay: 20.32 ha.
- Density of coral colonies 51.67 individuals/ 10 m × 10m area
- Density of coral colonies 5167/ ha.
- Depth range 5-25 m.

6.3. Coral colonies for Transplantation

- Coral cover required to be translocated from the proposed site: 4 ha.(Table 4)
- Coral colonies required to be translocated from the proposed site: 20668 (Total Value)
- Colonies will be translocated: 16150 (Approximate)
- Total area required for the coral transplantation: 4 ha. (The coral colonies or fragmented segments will be attached/ fixed with some solid substratum and will be places gradually one by one)

Table 4: Benthic cover and Colonies to be translocated (maximum)

Group	*Translocation required (individual colony/ coralla)*	*Gross major colonies to be transplantation*
Acropora-Branching	310.69	300
Acropora-Digitate	1346.30	1300
Acropora-Tabular	5814.26	5000

Non-Acropora- Branching	621.37	600
Non-Acropora- Encrusting	1242.74	500
Non-Acropora- Foliose	414.25	200
Non-Acropora- Massive	9290.98	7000
Non-Acropora- Submassive	1301.92	1000
Mushroom	118.36	100
Tubipora	207.12	150
TOTAL COVER	20668.00	16150

6.4. Setup and process of translocation/ restoration

The first step for coral translocation is to minimize stress and prevent damage to corals. For successful transplantation of corals species translocation will be made in suitable selected areas that have very similar environmental conditions as the areas they originally came from, especially water flow depth gradient and turbidity. Data on key physicochemical parameters (including salinity, temperature, water current gradients and limits, and turbidity) at both the donor and recipient areas will be collected and also measured using fixed data loggers. The coral colonies will be tagged using colors and codes depicting the depth, location, growth form, and type of species before translocation from the demarcated sites, carried at the same depth while transporting them, and will be placed at the same depth and similar environment at the recipient site. Extraction of the coral colonies will be made from the substratum with help of coral cutting saw, hammer & chisel, and hydraulic underwater hammer drill etc. Coral colonies will be translocated entirely as a whole object, lifted from the sea bottom, and loaded to the carrying trays fixed at the ship/boat bottom at the same depth of excavation carefully with lift bags. The lifted corals will be transferred carefully to hanging and submerged metal cages with soft carpet at the bottom, hanging at required depths at the sides of the carrying vessel, avoiding the exposure and depth difference to the translocated corals. Ambient water quality parameters such as sea surface water temperature and dissolved oxygen will be measured once (with at least three replicates) at the coral donor sites on the day of coral translocation. Corals will be transported to the suitable recipient site as soon as possible on the same day following the removal. The vessel will be progressing at a slow and steady speed when approaching close to the recipient site. After arriving at the coral recipient site, the colonies will be fixed with the boulders gradually to minimize disturbance related to sediment. The coral colonies will be placed at similar depths and orientations similar to the recipient sites as far as possible. Every translocated colony at the recipient site will be tagged with waterproof labels depicting important details pertaining to that particular coral. All the corals will be firmly anchored or attached to the substratum using epoxy without causing lethal damage to the corals. All tags will be nailed in the vicinity of the coral colonies at distances not so close to interfering with the potential growth. This would allow the identification and recording of the rehabilitation progress of corals during post-translocation monitoring (Table 4).

7. CONSERVATION AND MANAGEMENT

The following parameters will be monitored on monthly basis for the period of five years initially to conserve the corals at the translocated site as well as donor site.

7.1. Physicochemical Data Collection

Physicochemical parameters of the water sample indicate the environmental status of the said ecosystem. Data on various parameters will be collected systematically and seasonally to understand ecological cohesion of the coral reef ecosystem of the said project sites (Table 5, Plate 1).

7.1.1. *pH*

The pH indicates the concentration of H^+. In water samples it ranges from 1 to 14. The sample with pH 7.0 indicates the neutral state while pH 1.0 is most acidic and pH14.0 is considered as most alkaline. The pH of reef water can be seen within a stipulated range from (7.5 to 8.4). As salinity is one of the most important physicochemical states for the corals, variation in pH level can be useful for the documentation of threats on corals which may be the effect of pollution and so on. The pH can be measured with a simple pH meter. The data will be collected continuously over three-month intervals.

7.1.2. *Temperature*

Temperature is most important parameter for the coral reefs. The temperature of the air and water can be measured by holding a simple mercury thermometer 0.5 m below the surface or at the depth of study site. It is recommended to record the data while the bulb end is still in the water. A better measurement is to use a maximum/minimum thermometer which measures both the warmest and the coldest that the water has been since the thermometer was last set. Data can be obtained in regular interval to record the temperature gradient of the study site. The data will be collected continuously over three-month intervals.

7.1.3. *Turbidity or Transparency of water*

Light is most required physical agent for the corals reef for the continuation of zooxanthallate life through photosynthesis. Turbidity indicated the cloudy state of water, and is a measure of how far an observer can see under water and how far down the light can go. It is measured with a secchi disc. It is a disc 20 cm in diameter painted black and white and attached to a weighted rope which is marked each metre to show its length. Vertical and horizontal transparency can be measured with the secchi disc. The disc can be attached by a non stretchable rope. Lower the disc into the water until observer can no longer sees. Slowly pull up the disc until you can just see it again from the surface, and write down the distance to the disc as measured by the marks on the rope. If you do not know which mark it is, count them as you pull the disc back up. The data record should me made several times about the same time of a day at different location to get comparative data.

Turbidity meter or nephelometer is a useful tool for the measurement of turbidity. The working principle depends on the passing a beam of light through a water sample and measuring the light scattered by the particulates at the 90° angle to the light beam and directly proportional to the turbidity. Nephelometer Turbidity Units (NTU's) is the reading measures. Turbidity meter – EUTWCII is used for the analysis of turbidity. The data will be collected continuously over three-month intervals.

7.1.4. *Sediment deposition*

The rate of sediment deposition is one of the most important parameter which makes the entire reef vulnerable due to dredging operation and erosion. It can be measured on the basis of collected suspended materials. Sediment traps can be fixed in a stand and should be kept for particular days (not more than 14 days), the jar should be capped and brought to the laboratory for analysis. If there is any small animal in the jar, that should be removed. The sampled sediments will be poured on whatman filter paper and will be filter by Buchner funnel. The filtration process will be made several times to remove salts. Then the sediment sampled will be dried in drying oven at 70°C. Calculation will be made to acquire sedimentation rate as mg of sediment per cm^2 per day. The sediment weight is the total weight minus the filter weight, and the area of the jar opening is πr^2. The data will be collected continuously over three-month intervals.

Sedimentation rate = (Sediment weight/ No. of days at site × πr^2)

7.1.5. *Salinity*

Salinity is a measure of salt is in the water. There are three simple ways to measure salinity. To measure salinity, you will need to collect a sample of water from the surface at the same place where measured the turbidity was made. Put the sample in a clean bottle of a size appropriate to the technique being used, and take it back to the shore for measurement. Hydrometer is a weighted glass tube that floats at a different depth in the water depending on the salinity (or specific gravity). Put the hydrometer in a transparent cylinder or deep jar and fill with sample water until the hydrometer floats. Then put your eye at the level of the water and read the number on the hydrometer scale. Data will be recorded along with temperature. Refractometer is a little like a telescope with a measuring scale in it. Take a small sample of the water and put it under the little cover. Hold the cover down without blocking the light, and read the salinity (or refractive index) by looking through the eye piece. Hand Refractometer-RHS-10 is used for the process. Data will be recorded. Conductivity meter is working by passing electricity through the water. The data will be collected continuously over three-month intervals.

7.1.6. *Nutrient*

For nutrient analysis, water samples will be collected in polypropylene bottles, stored in icebox and transported to the laboratory for immediate analyses. Samples will be filtered using Millipore APFC filter papers (1.2 μm pore size and 47 mm diameter) for analysis of total suspended solids and nutrients. Nitrite, nitrate, inorganic phosphate and silicate were analyzed following the standard methods (Grasshoff *et al.*, 1999). Data quality will be checked by careful standardization, procedural blank measurement and by triplicate samples, finally average readings were taken into account. The precision of nitrate + nitrite (NO_3+NO_2), ammonium, phosphate, and silicate will be ±0.02, 0.02, 0.01, and 0.02 µM, respectively. The data will be collected continuously over three-month intervals.

7.1.7. *Chlorophyll-a and dissolved oxygen*

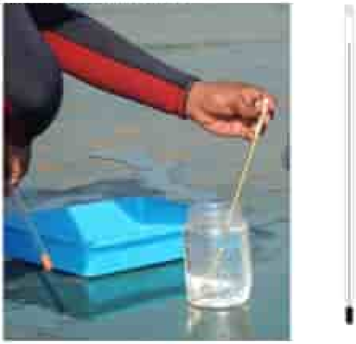
Chlorophyll-*a* pigments will be estimated following Spectrophotometric method (Parsons *et al.*, 1992). For estimation, one litter of seawater will be collected in polypropylene bottles and filtered through Millipore Glass Fibre prefilters (0.7µm pore size, 47 mm diameter) under a pressure less than 100 mm Hg. The pigment will be extracted in 90% acetone and filtrates were kept in refrigerator for 24 hrs. under dark condition. The extract will be centrifuged and the supernatant will be used to determine chlorophyll '*a*' following the spectrophotometric method and optical density will be measured at the wavelength of 630 to 750 for chlorophyll-*a*. Winkler's titration method will be followed for Dissolved Oxygen (Strickland and Parsons, 1972). Seasonal means for DO will be collected based on day and night measurements. The data will be collected continuously over three-month intervals.

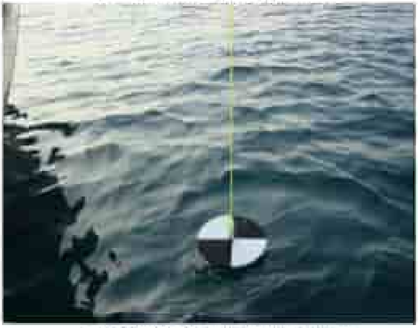
Table 5: Monitoring of the physicochemical parameters of the proposed project sites

Sl. No.	Data	Seasonal Data	Donor Site	Recipient Site
1.	Current speed [m/ s]	•	•	•
2.	Temperature [°C]	•	•	•
3.	Salinity [PSU]	•	•	•
4.	Dissolved oxygen [mg/L]	•	•	•
5.	Turbidity [NTU]	•	•	•
6.	Chlorophyll-a [µg/L]	•	•	•
7.	Inorganic nutrients [µM]	•	•	•
8.	Sedimentation rate [mg/m^2/day]	•	•	•
9.	Organic content of sediments [mg/m^2/day]	•	•	•
10.	C:N ratio of sediments	•	•	•

Plate 1: Physicochemical Parameters documentation


Measurement of pH by pH meter


Measurement of temperature by thermometer


Secchi Disk for water transparency


Turbidity meter – EUTWCH


Sediment trapper


Refractometer-RHS-10 for Salinity

Deployment of water sampler

Water sampler with open ends

Aqua trap non metalic water sampler

Water sampler with messenger

Deployment of water sampler

SYSTRONICS water sample analyzer

7.2. Survey methods for Macro-benthos (Intertidal and Subtidal Fauna)

The fauna occurring in the intertidal zone which is the area between the highest high water mark and the lowest low water mark of the seacoast. The present investigation of GIS requires details of quality and quantity of species composition stressing marine biodiversity area. To achieve this target, the following methodology should be adopted. A general survey of the area is to be made to assess the faunal diversity both qualitatively and also quantitatively to note the dominant group. This data should be recorded separately.

7.2.1. *Methodology*

Intertidal fauna are conveniently collected during low tide period from the exposed coast, the substratum of which may be rocky, muddy, sandy, dead coralline beds, sea grass or algal beds etc.

7.2.2. *Qualitative analysis*

The fauna are hand-picked, scooped out of sandy bottom, chisels out of the rocky or dead coral substratum or washed out of the sea grass or algal beds. The collected specimen should first be kept in the *in situ* seawater and brought to the laboratory.

Samples which are contractile in nature and react instantaneously even for mild stimulus, should be narcotised prior to preservation. In order to narcotise, place the specimen in containers of seawater and allow the specimen to expand or attain its natural form. Add in micro-doses, the narcotiser in the medium so as to respond mildly. Gradually increase the dosage until the specimen ceases to respond to stimuli. At this stage, the narcotised specimen may be transferred to 4 to 10% neutralised sea water formalin for preservation and identification.

The type of narcotiser used differs depending on the faunastic group of the specimen and is as follows:

1. Magnesium Chloride – Coelenterates (Anthozoans & Alcyonarians), Ctenophones
2. Magnesium Sulphate – Asteroides, Ophiuroides, Holothuroides & Molluscs
3. Menthol Crystals – Turbellarians, Nudibranchs (Mollusca), Ascidians
4. Alcohol – Polychaetes, Brachiopods & Protochordates
5. Chloral hydrate – Polychaetes & Molluscs

Narcotised samples may be preserved in 4-10% neutralised sea water formalin solution.

5.6.3. *Quantitative analysis*

Intense quantitative assessment of dominant elements of both ecologically and economically important species may be made as per the Transect Quadrate Method.

5.6.3.1. <u>Transect Quadrat Method (TQM)</u>

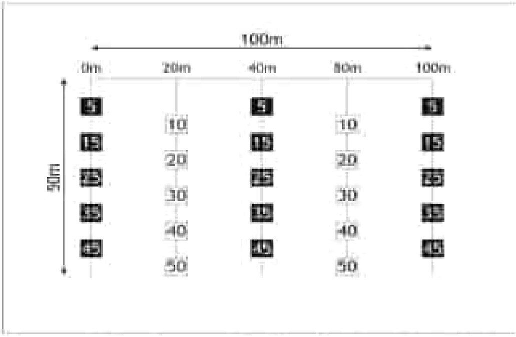
The *in situ* quantitative analysis for intertidal fauna is done by *Transect Quadrat Method,* which is recommended here as an easily adaptable method both with the view of collecting data and for analysis, after perusing through the other methods like Plots and Transact Method of Loya (1978), Random sample method of Bakus (1990) and Line Intercept Transact Method of English *et al.*, (1997). The presently recommended Transect Quadrat Method (TQM) is to cover 100 m along the shore and 50 m into the sea (eulittoral zone) which would cover a sector of eulittoral zone of an area of 5000 sq. m. (Fig. 27). The TQM sector of 100 m wide of a critical habitat may selected either at random, if the ecosystem were to be uniform, or as one sector of 100 m wide of each type of ecosystem, i.e., grass beds, coral reefs, rocky and sandy coast, etc., represented in the critical habitat. This decision of selecting the TQM sector should be based on a preliminary survey of the critical habitat. Mostly the process is preferred during intertidal studies. Where snorkelling and SCUBA diving is possible, this process can be applied. During sub-tidal studies, more man power is required to complete the work.

a. Equipment required

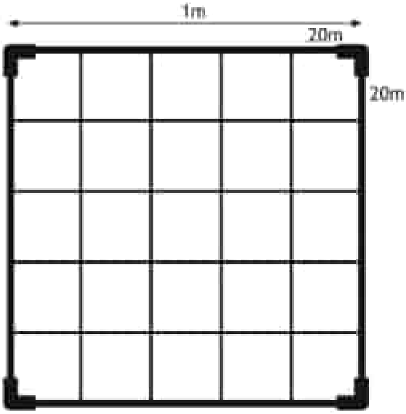
i. Six pieces of nylon ropes each to cover 50m from the high tide mark into the sea and marked at every 5m distance in order to fix Quadrate stations.
ii. A gun metal/ brass/ copper Quadrate structure of 1 sq.m. having a mesh of 20X20 cm to conduct quantitative analysis of fixed stations.
iii. GPS to fix stations.
iv. Snorkelling equipments (Mask, Snorkel, Reef shoe, Fins)
v. Self-Contained Breathing Apparatus (SCUBA) diving equipments (Mask, Snorkel, Diving Cylinders, BCD, Regulator, Reef shoe, Fins, Dive computers, Weight belt with weights)
vi. Plastic slate with pencil

b. Procedure

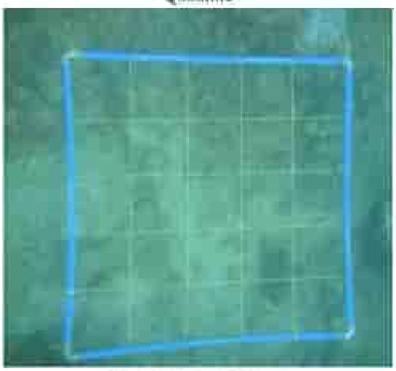
i. Fix a point at the highwater mark with a wooden or metal peg.
ii. Draw the nylon rope, marked at every 5m distance, from this point into the sea for 50m so as to form a transect line perpendicular to the coast
iii. Draw similar transect lines at a distance of every 20m parallel to the first transect line upto 100m. This will give totally 6 transect lines perpendicular to the shore and parallel to each other.
iv. Fix five stations at 10m distance on each transect line beginning at 5/10m on alternate transect lines as shown in the Fig. 3 so as to fix a total number of 30 stations out of 5000 sq. m. area.
v. Each station is to be inventorised for biotic components with a 1 sq.m. Quadrant frame partitioned by 20×20 cm mesh, by placing the Quadrant on the stations. Thus sampling is done in all 30 stations, which covers 6% of the total area of 5000 sq.m.



Diagrammatic representation of survey methodology for Transact Quadrate Method (TQM)
(Area to be surveyed is 100m X 50m = 5000 sq.m.; Total no. of stations to be covered is 6 transacts x 5 stations = 30.3. Sampling area = 6%)



Quadrate



Quadrate at *in situ* condition

5.6.3.2. Quadrat Method

Coral cover is estimated using a 1 m^2 quadrat frame divided into 100 (20×20cm) smaller squares. The observer visually estimates coral cover *in situ* and records the data on an underwater writing slate. The observer uses the grid to estimate total area of each species encountered. A transect line is not required because the frame can be flipped 25 times to measure contiguous non-overlapping areas without reference to the line. In this study, the quadrat was moved successively along the entire 25 m transect line without overlap, encompassing a total area of 25 m^2. The coral coverage by species was estimated in each frame (Jokiel *et al.*, 2005).

5.6.3.3. Photo-Quadrats

Documentation of coral reefs through the process of Photo-quadrat is one of the good monitoring methods of status evaluation. But it is recommended for all kind of data interpretation. It can provide accurate information on reef cover but the analysis of photographs can be time consuming (Rogers *et al.*, 1994).

Photo-Quadrate at *in situ* condition

a. Qualitative Representation:

At every 1 sq. m. area of study, count the number of coral types (er. CM– Coral massive, CF= Coral Folios, CE = Coral Encrusting, etc.) and the associated fauna and sum up the total of each species for all the 30 Quadrates. Calculation given below will represent the percentage of quality composition of 30 sq. m. area as a sample of the total 5000 sq. m.

$$\text{Percentage of live form (benthos) in quality} = \frac{\text{Nos. represented of one species}}{\text{Total numbers of all species}} \times 100$$

b. Quantitative Representation:

At each study square area, measure the area of coral and faunal types represented and calculates it for 30 Quadrates with the help of the quadrat frame of 1 sq. m. and compute the results as follows:

$$\text{\% of live form (benthos) In quantity} = \frac{\text{Total area covered by each type for 30 quadrates}}{\text{Area surveyed (30sq.m.)}} \times 100$$

5.6.3.4. Line Intercept Method

Line Intercept Transects (LIT) are used to collect data on the sessile and non – sessile benthic organisms such as Porifera, Cnidaria, Mollusca, Crustacea, Echinodermata and other coral reef associated organisms. This method is used mainly wherever coral reefs are present and are more than 50 m. away from the shore. Coral reefs and the associated fauna are part of the intertidal community, other than the fauna present in the sandy bottom. These communities are characterized by life form categories, which will provide a clear description of the reef community for GIS mapping of the intertidal coral reefs and other associated fauna mentioned above. The LIT is used to estimate the life form cover of the coral reef and also the reef associated organisms within a specified area by calculating the length of the line that is intercepted by the object (different coral species- Mollusca, Echinodermata and others). This measure of cover is expressed as a percentage, which is considered to be an unbiased estimate of the proportion of the total area covered by that coral reef and associated organisms provided the size of the coral reef is relative to the length of the line and the length of the line is small relative to the area of interest. This method of LIT and Quadrate is used mainly where the coral reefs are present.

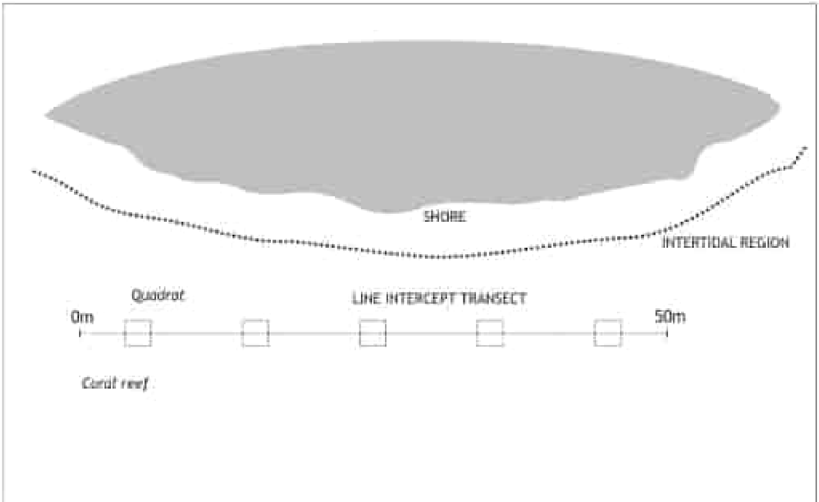


Diagram showing the method of laying LIT and Quadrate on a coral reef at intertidal region

The data collected using LIT is also substantiated by a one square meter quadrate along the line of intercept which will give a clear cut idea of the faunal composition of benthic organisms both qualitatively and quantitatively. Once the transect is laid, the observer moves slowly along the transect recording onto the underwater writing pad about the life forms encountered under the tape. At each point where the benthic lifeform changes, the observer records the transition point in centimeters and the code of the lifeform (Table 6, Plates 2-7). Hence, along the length of a transect (XY) a percent of intercept points (I) are recorded for each of lifeform. The length of each lifeform encountered under the transect (L) is the difference between the transition points recorded for each lifeform. After completion of LIT a quadrat is placed over the line (tape) at every 5/ 10 or 20 m depending on the lifeform present to collect and substantiate the LIT data.

a. Equipment's required

i. GPS (Portable)

ii. Snorkeling equipment's (Mask, Snorkel, Reef shoe, Fins)

iii. Self-Contained Breathing Apparatus (SCUBA) diving equipment (Mask, Snorkel, Diving Cylinders, BCD, Regulator, Reef shoe, Fins, Dive computers, Weight belt with weights)

iv. Underwater writing pad with pencil

v. Plastic measuring tapes (50 m length),

vi. PVS quadrate

vii. Nail and plastic ropes

viii. Underwater camera with housing for digitization

b. Site Selection

i. A general survey of the area to know where the reefs are present.

ii. At least 2 sites should be selected. If distinct windward and leeward zones exist, sites should be selected in each habitat.

iii. The location of sites should be recorded with a GPS.

c. Analysis

Summary of data showing percent cover and number of occurrences of each lifeform may be calculated using the line intercept and quadrat data. After calculating the intercept (length) from the transitions points recorded along the transect the percent cover of a lifeform category is calculated as follows.

$$\text{Percent cover} = \frac{\text{Length of category} \times 100}{\text{Length of transect}}$$

$$\text{Percent cover Lifeform 1} = \frac{L1+L3+L5\ldots.. \times 100}{\text{Length of transect}}$$

$$\text{Percent cover Lifeform 2} = \frac{L2+L4+L6\ldots.. \times 100}{\text{Length of transect}}$$

These analyses will provide quantitative information on the community structure of the sample sites. Successive samples can also be compared from different areas of the coral reef.

Table 6: Lifeform categories and code

CATEGORIES	SUB-CATEGORIES	CODE	NOTES/ REMARKS
Hard Coral			
Dead Coral		DC	Recently dead, white to dirty white.
Dead coral with Algae		DCA	This coral is standing, skeletal structure can still be seen
Acropora	Branching	ACB	At least 2 ° branching, eg. *Acropora palmate, A. formosa*
	Encrusting	ACE	Usually the base plate of immature *Acropora* forms, eg. *A. palifera and A. cuneta*
	Submassive	ACS	Robust with knob or wedge like form eg. *A. palifera*
	Digitate	ACD	No 2 ° branching, typically *includes A. humilis, A. digitifera* and *A. gemmefera*
	Tubular	ACT	Horizontal flattened plates eg. *A. hyacinthus*
Non- Acropora	Branching	CB	At least 2° branching eg. *Seriatopora hystrix.*
	Encrusting	CE	Major portion attached to substratum as a laminar plate eg. *Porites vaughani, Montipora undulata*
	Foliose	CF	Coral attached at one or more points, leaflike, or plate like appearance eg. *Merulina ampliata, Montipora aequituberculata*
	Massive	CM	Solid boulder or mound eg. *Platygyra daedalea*
	Submassive	CS	Tends to form small columns, knobs or wedges eg. *Porites lichen, Psammocora digitata*
	Mushroom	CMR	Solitary, free living corals of *Fungia*
	Heliopora	CHL	Blue coral
	Millepora	CME	Fire Coral
	Tubipora	CTU	Organ-pope coral, *Tubipora musica*
Other Fauna			

Soft Corals		SC	Soft bodied corals
Sponges		SP	
Zooxanthids		ZO	Examples are *Platythoa, Protopalythoa*
Others		OT	Ascidians, anemones, gorgonians, giant clams etc.
Algae	Algal Assemblage	AA	Consists of more than one species
	Coralline Algae	CA	
	Halimeda	HA	
	Macroalgae	MA	Weedy/ fleshy browns, reds etc.
	Turf Algae	TA	Lush filamentous algae, often found inside dameshellfish territories.
Abiotic	Sand	S	
	Rubble	R	Unconsolidated coral fragments
	Silt	SI	
	Water	WA	Fissures deeper than 50 cms
	Rock	RCK	
Other		DDD	Missing Data

Plate 2: Lifeform categories with pictorial representation

DC

DCA

ACB (*Acropora formosa*)

ACE (*Acropora cuneata*)

ACS (*Acropora palifera*)

ACD (*Acropora gemmifera*)

ACT (*Acropora hyacinthus*)

CB (*Seriatopora hystrix*)

CE (*Montipora undata*)

CF (*Merulina ampliata*)

CM (*Platygyra daedalea*)

CS (*Psammocora digitata*)

CMR (*Fungia fungites*)

CHL (*Heliopora coerulaea*)

CME (*Millepora* sp.)

CTU (*Tubipora musica*)

SC (Soft coral)

SP (Sponge - *Clathria mima*)

ZO (Zoxanthids)

OT (Ascidia- *Didemnum molle*)

OT (Sea Anemone- *Heteractis magnifica*)

OT (Gorgonians- *Verrucella corona*)

OT (Giant Clam- *Tridacna gigas*)

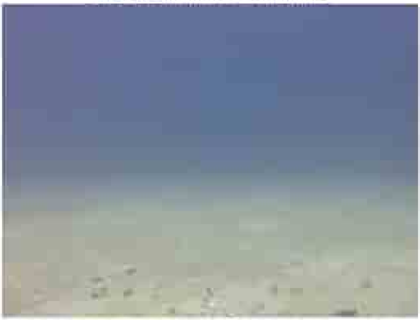
AA (Algal Assemblage)

CA (Crustose coraline algae)

HA (*Halimeda* sp.)

MA (*Acetabularia caranulata*)

TA (Turf algae)



S (Sand)

R (Rubble)

SI (Silt)

WA (Water)

Plate 3: Benthic cover and LIT studies

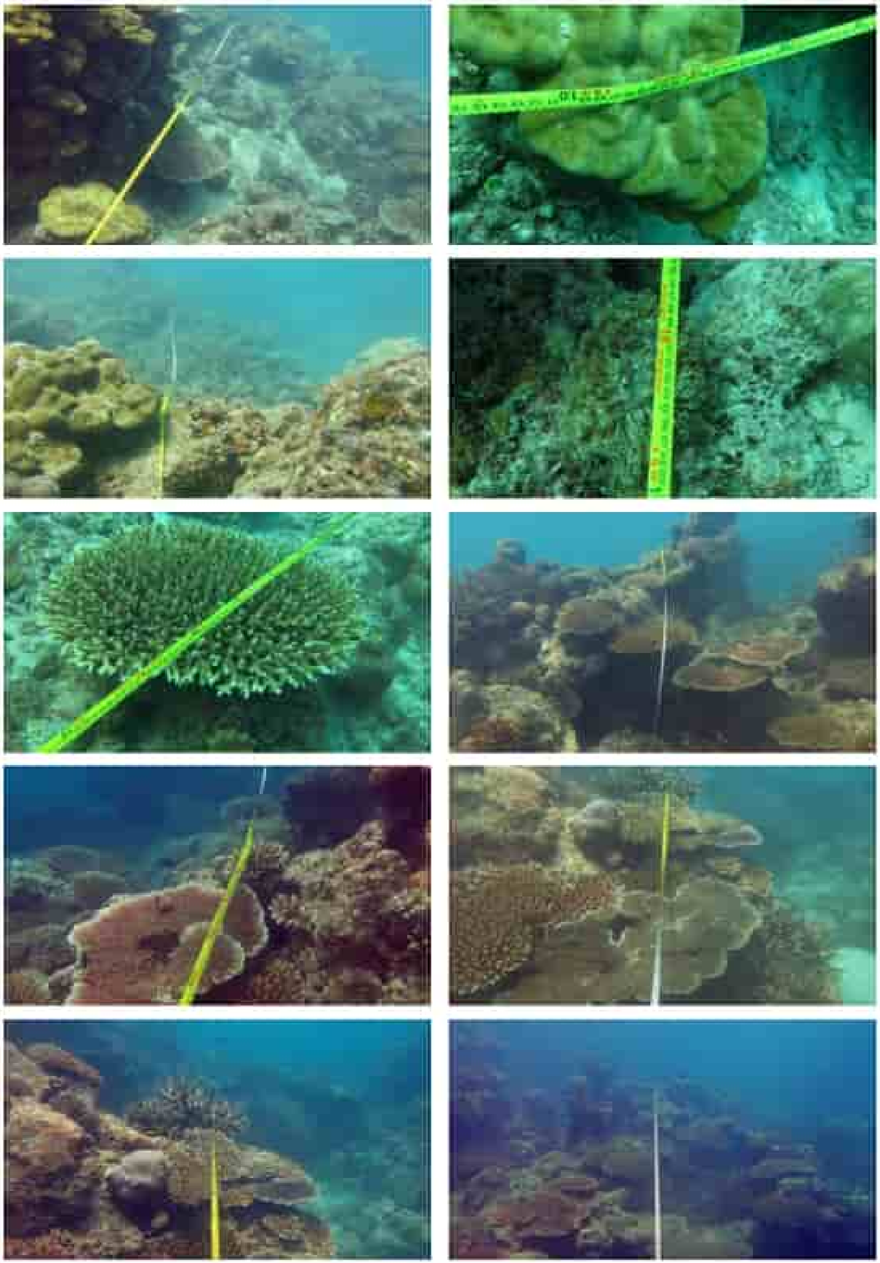


Plate 4: Benthic cover and LIT studies at Laxman Beach, Great Nicobar Island

Plate 5: Benthic cover and LIT studies at Sastri Nagar, Great Nicobar Island

Plate 6: Benthic cover and LIT studies at Galathea, Great Nicobar Island

Plate 7: Scleractinian corals, Great Nicobar Island

Merulina ampliata (Ellis and Solander, 1786)

Acropora clathrata (Brook, 1891)

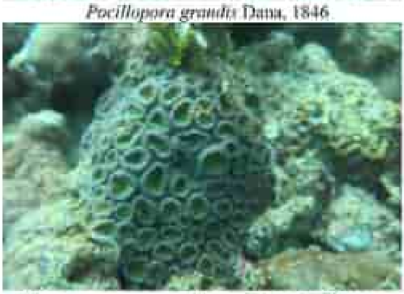
Acropora millepora (Ehrenberg, 1834)

Acropora florida (Dana, 1846)

Echinopora gemmacea Lamarck, 1816

Pocillopora grandis Dana, 1846

Lobactis scutaria (Lamarck, 1801)



Dipsastraea maxima (Veron, Pichon & Wijsman-Best, 1977)

5.6.3.5. Belt Transect

The belt transect method involves surveying a contiguous area along a line transect. It may be considered as a widening of the line transect or a continuous line of quadrats. As with the line transect, information of fauna and flora identified within the belt is recorded. The rapid ecological assessment belt transect method provides information on coral demographics and condition. The coral divers gather data along five evenly spaced segments (each 2.5 × 1 m; 0-2.5 m; 5.0-7.5 m; 10-12.5 m; 15-17.5 m; 20-22.5 m) along each of the same two 25-m transect lines implemented in the LPI survey. This strategy was designed to maximize time for capturing spatial heterogeneity per transect. Within each 2.5 m^2 transect section, all coral colonies whose center falls within 0.5 m on either side of each transect line are identified and 2 planar measurements recorded. For each coral colony identified the extent of mortality is estimated, dedicating special attention to any evidence of disease. Percentage of colony affected as well as lesion severity and levels of coral predation were also recorded (NOAA, 2014).

5.6.3.6. <u>Point Intercept Transect</u>

Pointy Intercept Transect is another way to gather data documentation for the estimation of percent cover, relative abundance and diversity. The intercept method is simpler and quicker to manage data documentation for a large area. In this process observed records only what is located at each specified point along the line on every 20 cm. The number of point scored by a given species divided by the total number of points yields the percent cover.

c. Requirement
   i. SCUBA diving equipments
   ii. Nylone rope and nail
   iii. Measuring tape
   iv. Underwater writing pad with pencil

5.6.3.7. <u>Underwater Video Transect</u>

Underwater video sampling provides highly precise quantitative estimate of coral cover and abundance of common benthic taxa. The video technique in combination with independent sampling, i.e., no need to establish permanent transects, has proven to be a statistically powerful methodology for comparison of univariate and multivariate parameters in repeat surveys of identified sites of moderate – high coral cover (normally >20 %). This method involves the recording of standardized belt transects using a number of replicate transects of pre-determined length and filmed from a standardized height (approx. 40cm). Video footage is subsequently analyzed to extract quantitative coral data using a point sampling method. A digital video camera in an underwater housing is used to record the substrate along two 25m transects placed end to end with a 3 m separation. A red filter in the housing is used over the lens at depths greater than – 4m. The videographer swims approximately 1 m above the transect line with the camera lens pointing directly downward, and additionally records 360° views of the surrounding area at the beginning and end of each transect line. Analysis of the data will be made accordingly Kenyon *et al.* (2005).

Underwater video transect

a. Requirements
   i. SCUBA diving equipments
   ii. Nylone rope and nail
   iii. Measuring tape
   iv. Underwater writing pad with pencil
   v. Underwater video camera with housing

5.6.3.8. Manta Tow Survey

The manta tow technique is used to assess broad changes in the benthic communities of coral reefs where the interest is often an entire reef, or large portion. It enables visual assessment of large areas of reef within a short time and is highly recommended for determining the effects of large scale disturbances such cyclonic storms, coral bleaching and crown-of-thorns starfish. The technique is also useful for selecting sites that are representative of large areas of reef. The manta board is attached to a motor boat with a 17 m length of rope which has buoys placed at distances of 6 m and 12 m from the board. A snorkeller grips the board and is towed for approximately 2 minutes, at the end of which the boat pauses to allow the surveyor to record data. The coverage of bottom features may be recorded on a percentage scale or on a scale of 1–5, where 5 indicates the greatest cover and 0 is used for absence. However, a scale of 1–5 does have the short-coming that observers may be tempted to place a disproportionately large number of values in the middle category, thus creating observer bias. If possible, a scale of 1–6 or 1–4 is more desirable (Done *et al.*, 1982; Kenchington, 1984).

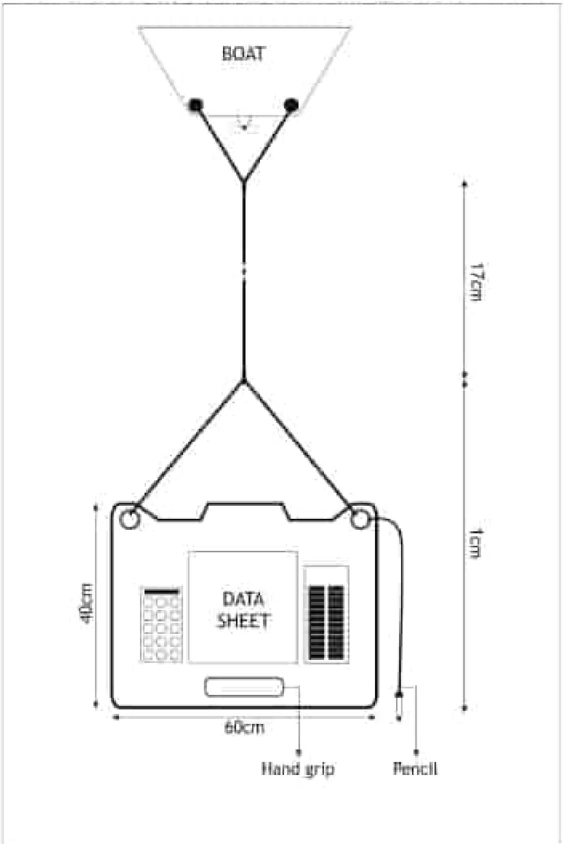
a. Requirements
   i. A small boat with an outboard motor is used for towing observers. The boat should be fitted with a towing bridle.
   ii. A 17 m tow rope connects the manta board to the boat. The rope should be braided and approximately 10mm in diameter. Two buoys are placed on the rope, one at 6 m

from the manta board, and the other at 12 m. These buoys allow the observer to estimate visibility in a standard manner.

iii. The dimensions of the manta board are 600x400x20 mm (length × breadth × thickness). It is recommended that the board be made from marine ply and painted white. Two indented handle grips are positioned towards each corner of the front board. A single handhold is located centrally at the back of the board.

iv. A datasheet is held in position within a recess of the centre of the board. The data sheet should be pre-printed to assist the observer record a set of biological variable and other significant observations.

v. An observer with snorkelling equipment like mask, snorkel, reef shoe and fins.



Manta tow method

5.6.3.9. Video Manta Tow

This method involves towing two SCUBA divers behind a boat at a constant speed (~1.5 knots). One diver manoeuvres the 'benthic towboard' (another name for manta board) equipped with either a downward-facing video camera or a still camera to photograph the benthos at selected intervals. The other diver manoeuvres the 'fish towboard' equipped with a forward-facing video camera to record fish and general reef topography. Towed diver surveys are good to obtain a general description of a large reef area, assess large-scale disturbance. They are best for covering large distances at low levels of taxonomic resolution. Benthic diver attempts to manoeuvre towboard 1 m above bottom. Each minute the benthic diver marks the habitat type on the data sheet. At 5 minute intervals, benthic diver estimates percent cover of major components on data sheet. Macro-invertebrates are recorded when observed in each 5 minute segment on the data sheet. A standard survey lasts 50 minutes (Hill and Wilkinson, 2004).

a. Requirements
   i. 60 m long, 9.5 mm diameter, low-stretch towing rope
   ii. Towing bridle affixed to towboard;
   iii. Towboard with fitted cut-outs or mounts to attach cameras and other instruments
   iv. Housed digital video camera, or housed still camera
   v. 2 strobes and slave sensors (when using housed still camera)
   vi. Depth/temperature recorder
   vii. Waterproof watch with countdown function to signal intervals for visual assessment
   viii. Separate waterproof watch as backup and to monitor dive time
   ix. Depth gauge bottom timer (UWATEC)
   x. GPS unit(s) in towing boat to geo-rectify survey track (Hill and Wilkinson, 2004).

7.3. Pre and Post Translocation Monitoring

The growth rate of the true corals is very slow and sensitive to several ecological factors. Periodical monitoring will be made to record the successful translocation/ restoration. Corals will be monitored for a minimum period of 10 years constantly, irrespective of fair or rough weather conditions. The translocated coral colonies as well as the tagged natural coral colonies at the recipient site will be monitored mostly daily or at least 15 days per month for a period of 1st year. In the 2nd, 3rd, 4th, and 5th years the intensity of monitoring will be reduced gradually depending on the results (Table 7). The data will be collected quarterly during 6th to 10th Year.

Table 7: Time Schedule of the project for coral transplantation/ restoration

Targets	1st Month	2nd Month	3rd Month	4th Month	5th Month	6th Month	7th Month	8th Month	9th Month	10th Month	11th Month	12th Month	13th -120th Month
ESTABLISHMENT	■	■	■	■	■	■	■	■	■	■	■	■	
Recruitment of Staff	■	■											
Procurement of Material	■	■											
Field lab set up	■	■											
PRELIMINARY STUDY													
Sediment traps in selected areas to monitor the sediment movement.	■	■	■	■	■	■	■	■	■	■	■	■	■
Recipient site data collection, selection and gridding	■	■	■	■	■	■	■	■	■	■	■	■	■
Physicochemical Parameters	■	■	■	■	■	■	■	■	■	■	■	■	■
Excavation area data collection, gridding and coral tagging	■	■	■	■	■	■	■	■	■	■	■	■	
Translocation	■	■	■	■	■	■	■	■	■	■	■	■	
SUB-TIDAL													
Photographing and tagging the species to be translocated	■	■	■	■	■	■	■	■	■	■	■	■	
Sub-tidal Coral translocation		■	■	■	■	■	■	■	■	■	■	■	
INTER TIDAL													
Photographing and tagging the species to be translocated	■	■	■	■	■	■	■	■	■	■	■	■	
Inter tidal Coral translocation.	■	■	■	■	■	■	■	■	■	■	■	■	
Post Translocation Monitoring													
Monitoring the Relocated corals (countering the threats until the corals survive well.)	■	■	■	■	■	■	■	■	■	■	■	■	■

8. LONG TERM MONITORING PROGRAMME

Long-term goals aligned with maintaining and supporting reef ecosystem services. These goals are non-exclusive and can complement one another. In planning for coral restoration efforts, clearly articulating the project goal(s) should be the first point of action. Then, objectives can be defined to track and accomplish the goals over shorter time periods like 1-3 years followed by long-term monitoring and adaptive management like 5-10 years. To manage ecosystems effectively, objectives should be SMART (Specific, Measurable, Achievable, Relevant, and Time-bound), informed by reference ecosystems, and consider anticipated environmental change (ICRI, 2021).

	GOALS	RATIONALES – USE RESTORATION TO
SOCIO-ECONOMIC GOALS		
i)	Sustain or recover coastal protection	Sustain or re-establish the regulating ecosystem services provided by reefs to protect coastal communities and infrastructure by attenuating wave energy and mitigating

		disturbances such as erosion and coastal flooding
ii)	Sustain or recover fisheries production	Sustain or re-establish the provisioning services delivered by reefs in providing habitat and nursery areas for commercially important fisheries
iii)	Sustain or enhance local tourism opportunities	Maintain reef aesthetics to support local reef tourism and/or provide opportunities for eco-tourism experiences
iv)	Promote local coral reef stewardship	Support local communities and/or Indigenous traditional owners to engage and reconnect with the local reef environment, improve reef custodianship and promote intrinsic value of reefs (spiritual, traditional, worship)
ECOLOGICAL GOALS		
i)	Re-establish reef ecosystem function and structure	Rehabilitate the function, structure, diversity and health of degraded coral reef ecosystems
ii)	Mitigate population declines and preserve biodiversity	Assist the recovery of endangered coral populations, and preserve innate reef biodiversity from genes to phenotypes to ecosystems
CLIMATE CHANGE ADAPTATION AND SUPPORT GOALS		
i)	Mitigate impacts and promote reef resilience in the face of climate change	Support resistance and recovery processes to reduce risks of impact and ensure that reefs persist through current and projected changing climate conditions
DISTURBANCE-DRIVEN GOALS		
i)	Respond to acute disturbance to accelerate reef recovery	Assist natural recovery process when reefs are affected by acute disturbances such as storms, predator outbreaks, ship groundings, and other structural damages
ii)	Mitigate anticipated coral loss prior to disturbance	Adopt an effective 'no net loss' mitigation policy whereby if a disturbance (e.g. coastal development) cannot be avoided, it should be minimised and offset for example by relocating anticipated losses prior to disturbance

9. BUDGET

The approximate budget for the coral transplantation/restoration will be Rs. 53,57,50,000.00 for a total of 4 ha. which is cited below (Table 8). The amount was estimated considering the remote locality and connectivity of Great Nicobar Island. The cost of the transplantation/restoration will be Rs. 13,39,37,500.00/ha.

Table 8: Approximate budget coral transplantation/restoration

Sl. No.	Head/Activities	Amount (Rs.)
1.	Salaries for 2 Project Scientist, 5 SRF, 12 JRF, 15 Field Assistants, 3 Motor Car Drivers	10,00,00,000.00
2.	Equipment/Infrastructure/ Vehicles/ Set-up materials	30,00,00,000.00
3.	Travel *TA/DA* for Scientists and Scientific Staff	2,50,00,000.00
4.	Vessel/ Boat hiring charges to conduct marine surveys	3,00,00,000.00
5.	Consumables	1,50,00,000.00

6.	Contingencies	1,50,00,000.00
7.	Preparation of Reports and Publications	50,00,000.00
8.	Capacity building and Awareness	1,50,00,000.00
	Subtotal	50,50,00,000.00
9.	Administrative Charges @15% (Excluding Equipment/Infrastructure/ Vehicles/ Set-up materials)	3,07,50,000.00
	TOTAL	53,57,50,000.00

Globally-Coral reef restoration costs estimated from $1,717 up to $2,879,773 USD/ha. (Bayraktarov *et al.*, 2015) which is equal to Rs. 1,31,315.13 to 22,02,43,311.18/ha.

10. GENERAL PRECAUTIONS TO BE TAKEN DURING THE CONSTRUCTION AND OPERATION OF THE PROJECT LIKE

- Proper routing of barges and ships (bringing construction material) avoiding the coral areas.
- Control of runoff of the construction material to ensure that corals don't get affected due to turbidity.
- Precautions to be taken during capital and maintenance dredging.
- Precautions to be taken during the roads on stilt for the wildlife corrodores.
- No discharge of any effluents into the sea during construction and operation.
- Introduction of permit system for scuba and snorkelling to ensure that unauthorised persons do not disturb and stamp on the live corals.
- Potential impacts to shoreline vegetation, wetlands, coral reefs, fisheries, bird life, and other sensitive terrestrial and aquatic and near-shore habitats during port construction and operation should be fully assessed thoroughly.
- Periodical surveys, assessment and modeling of metocean, hydrological, sedimentological as well as coastal geomorphological situations should be examined together with an identification of potential adverse impacts on coastal processes such as erosion and accretion, from the placement of new physical structures.
- Coastal processes monitoring and management plan should be managed in proper way by means of conducting a risk assessment of littoral sediment transport, shoreline morphology and erosion patterns and trends, and coastal inundation profiles.
- The construction and operation phases of the projects with significant sources of air emissions, and potential for significant impacts to ambient air quality, should prevent or minimize impacts by ensuring that the emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines and CPCB Air Quality Guidelines.
- Discharges of process wastewater, sanitary wastewater, wastewater from the construction and operational sites and plants to surface water should not result in contaminant concentrations in excess of local ambient water quality criteria or, in the absence of local criteria, other sources of ambient water quality. CPCB guidelines should be strictly followed.

- Water conservation programs should be implemented commensurate with the magnitude and cost of water use. These programs should promote the continuous reduction in water consumption and achieve savings in the water pumping, treatment and disposal costs. Water conservation measures may include water monitoring/management techniques; process and cooling/heating water recycling, reuse, and other techniques; and sanitary water conservation techniques.
- Waste management should be addressed through a Waste management system that addresses issues linked to waste minimization, generation, transport, disposal, and monitoring.
- Noise prevention and mitigation measures should be applied where predicted or measured noise impacts from a project facility or operations exceed the applicable noise level guideline at the most sensitive point of reception.
- Contamination of land should be avoided by preventing or controlling the release of hazardous materials, hazardous wastes, or oil to the environment. When contamination of land is suspected or confirmed during any project phase, the cause of the uncontrolled release should be identified and corrected to avoid further releases and associated adverse impacts.

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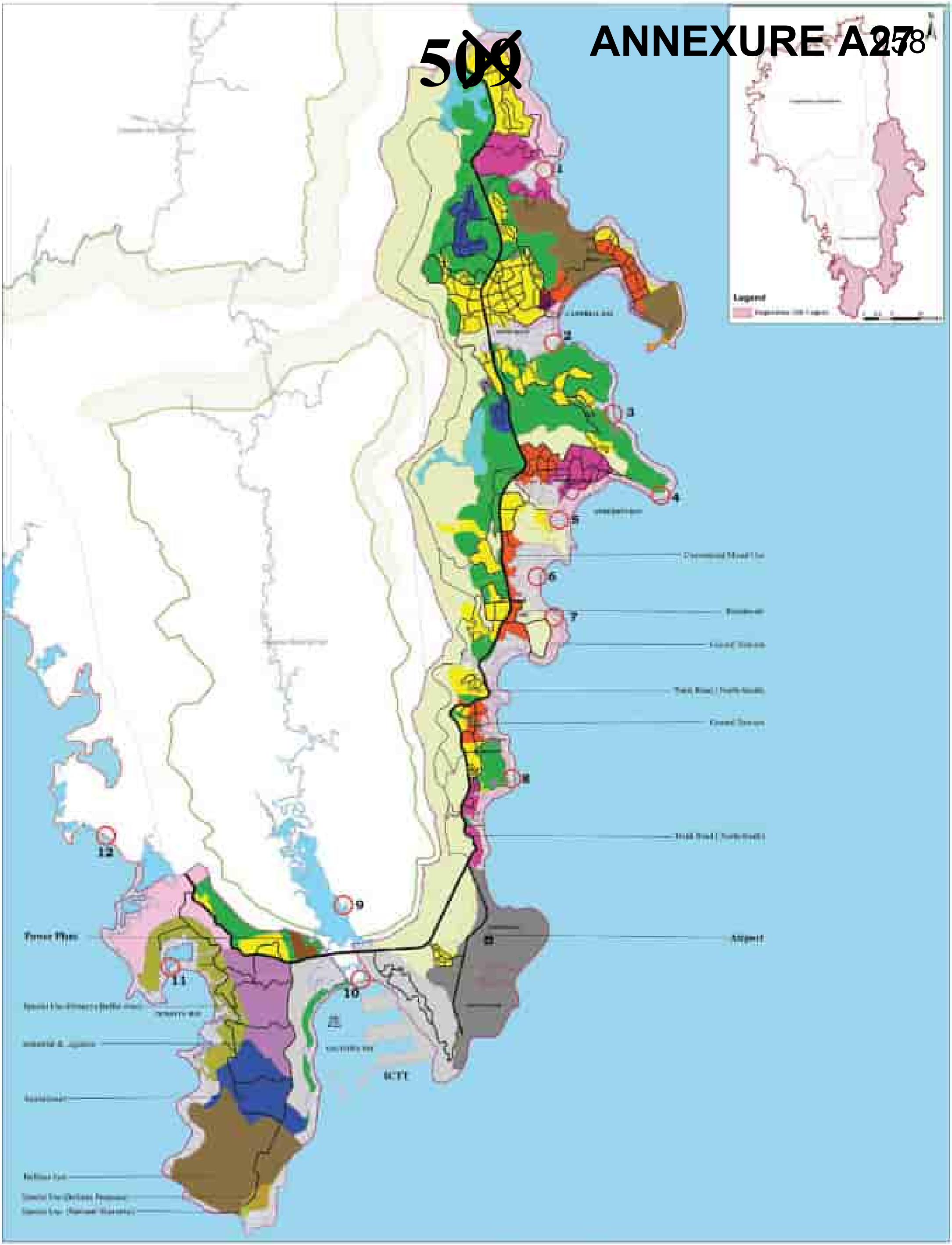


PROJECT:
HOLISTIC DEVELOPMENT OF GREAT NICOBAR ISLAND IN ANDAMAN & NICOBAR ISLANDS

DRAWING TITLE:
LOCATION OF MANGROVES

AECOM

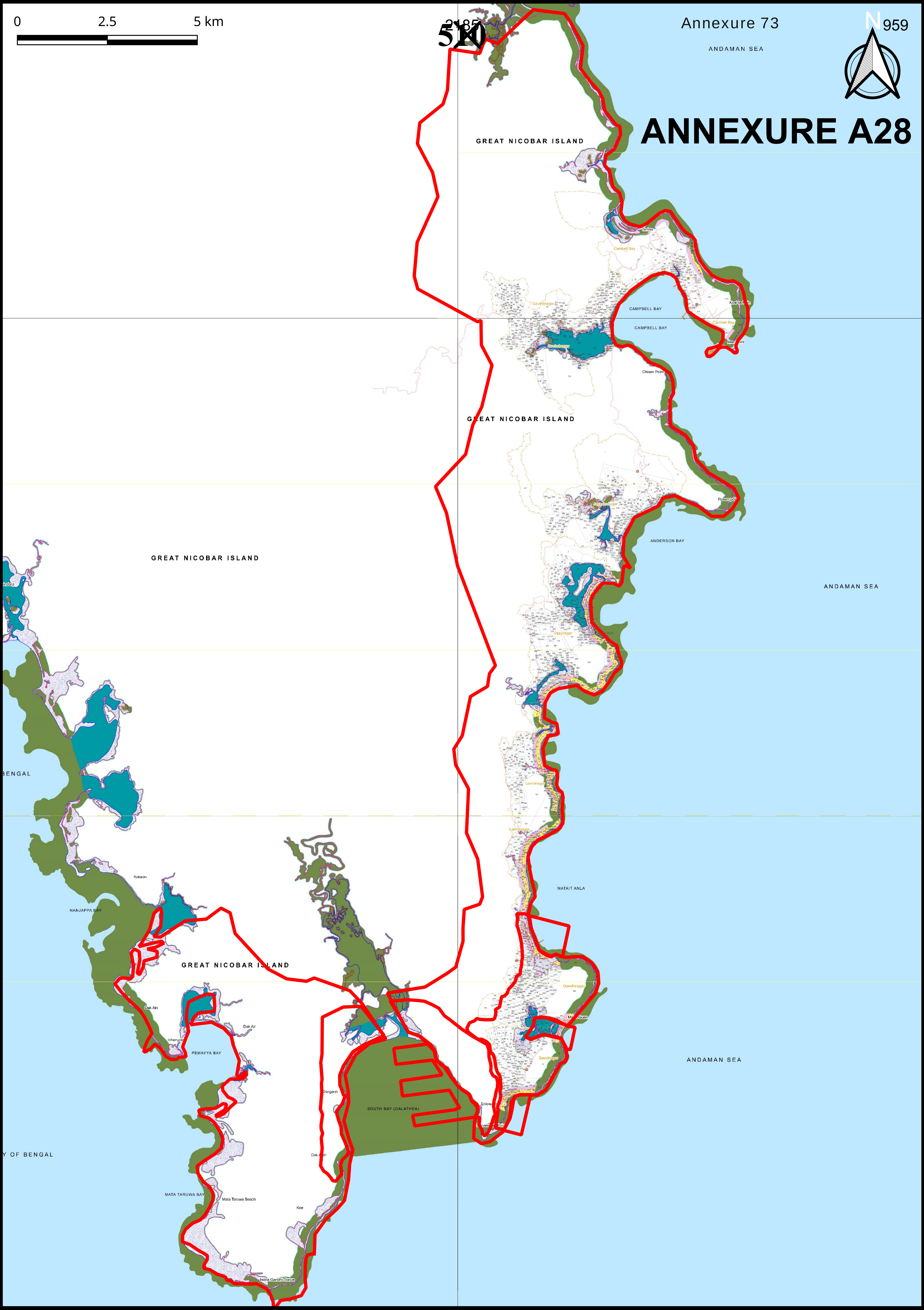
Annexure 73

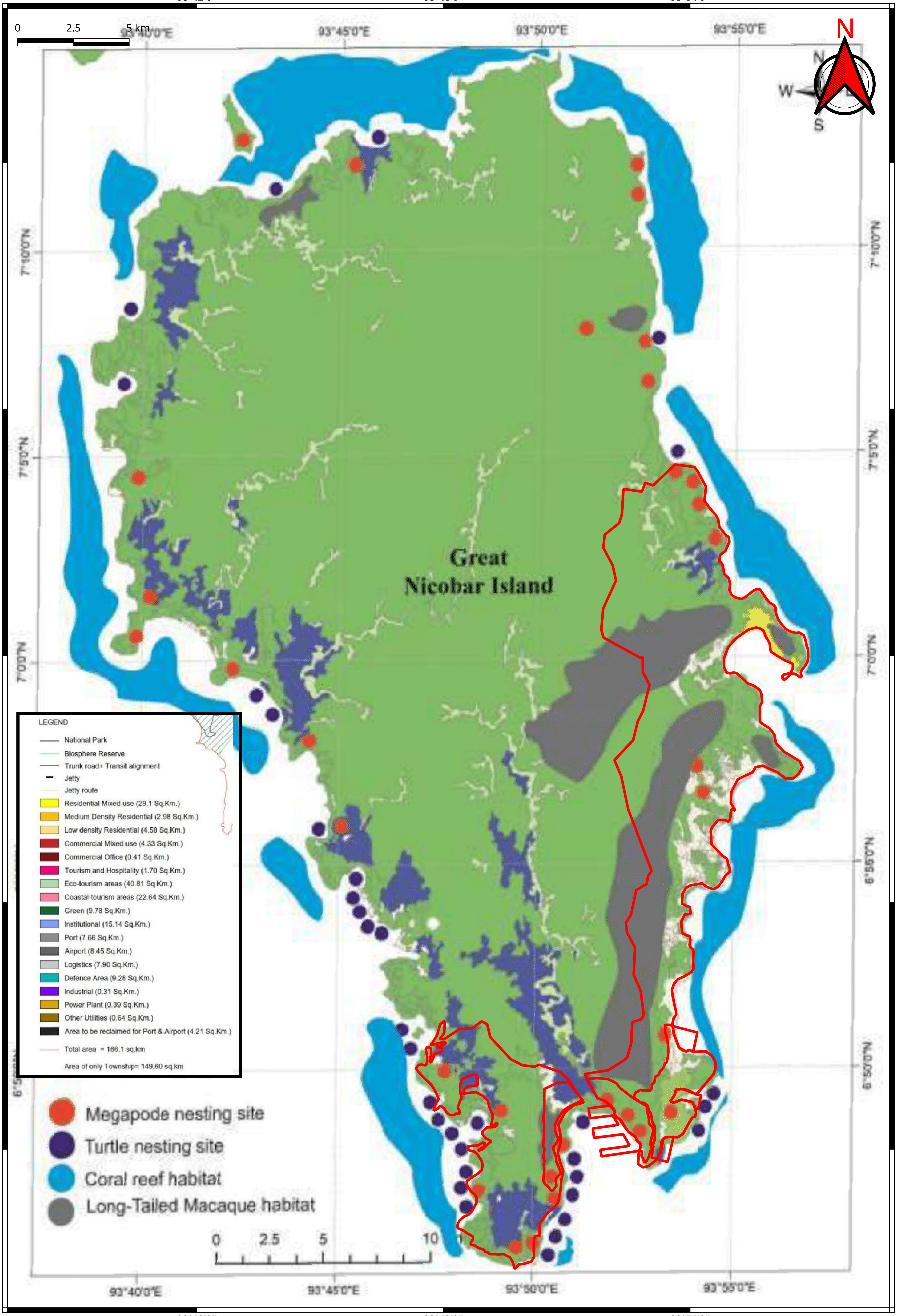
959

2185

510

ANNEXURE A28

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7°12'0"
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7°6'0"
7°5'0"N
7°0'0"
7°0'0"N
6°55'0"N
6°54'0"
6°50'0"N
6°48'0"
Great
Nicobar Island
LEGEND
National Park
Biosphere Reserve
Trunk road+ Transit alignment
Jetty
Jetty route
Residential Mixed use (29.1 Sq.Km.)
Medium Density Residential (2.98 Sq.Km.)
Low density Residential (4.58 Sq.Km.)
Commercial Mixed use (4.33 Sq.Km.)
Commercial Office (0.41 Sq.Km.)
Tourism and Hospitality (1.70 Sq.Km.)
Eco-tourism areas (40.81 Sq.Km.)
Coastal-tourism areas (22.64 Sq.Km.)
Green (9.78 Sq.Km.)
Institutional (15.14 Sq.Km.)
Port (7.66 Sq.Km.)
Airport (8.45 Sq.Km.)
Logistics (7.90 Sq.Km.)
Defence Area (9.28 Sq.Km.)
Industrial (0.31 Sq.Km.)
Power Plant (0.39 Sq.Km.)
Other Utilities (0.64 Sq.Km.)
Area to be reclaimed for Port & Airport (4.21 Sq.Km.)
Total area = 166.1 sq.km
Area of only Township= 149.60 sq.km
Megapode nesting site
Turtle nesting site
Coral reef habitat
Long-Tailed Macaque habitat
0
2.5
5
10
93°40'0"E
93°45'0"E
93°50'0"E
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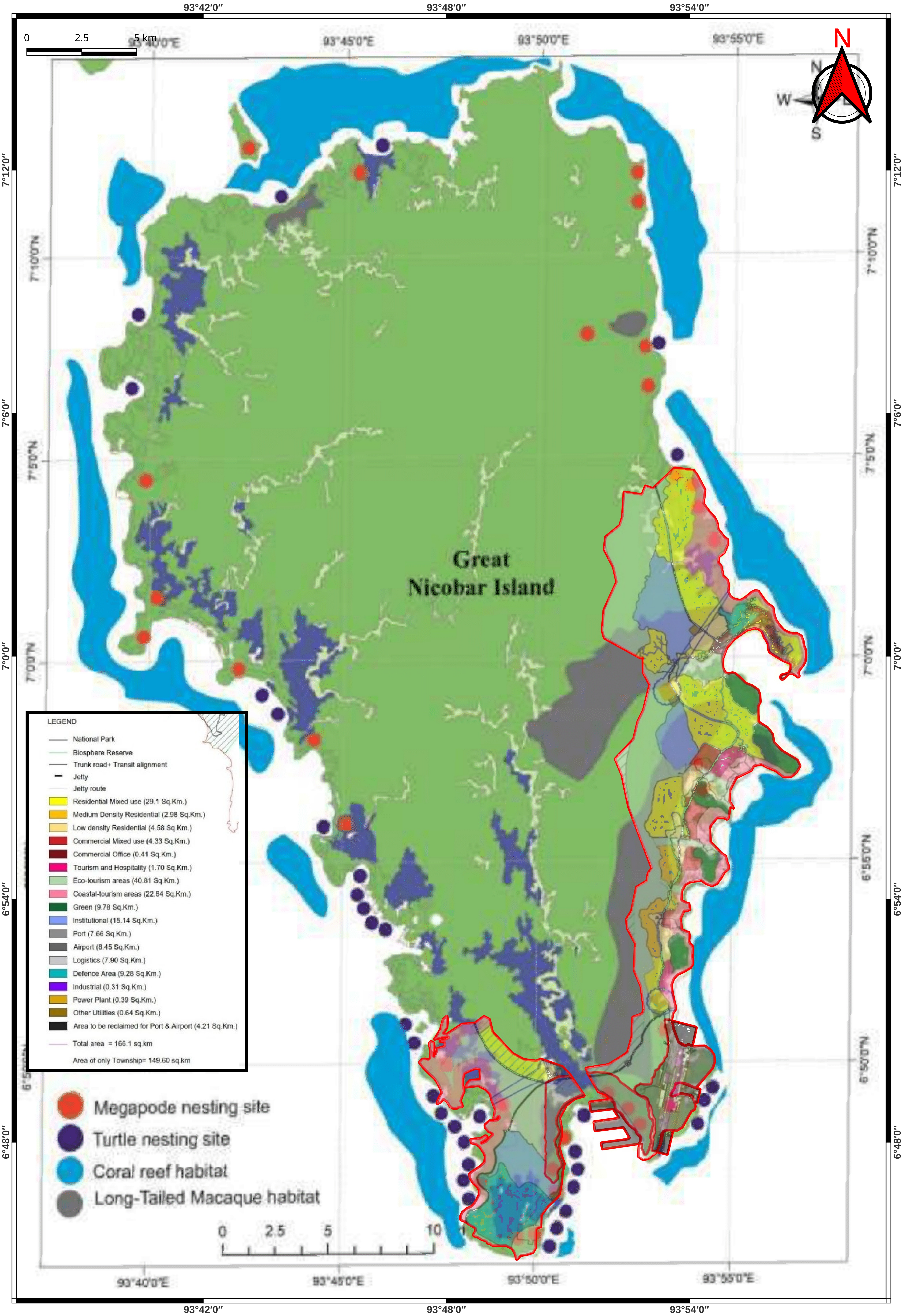
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93°45'0"E
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93°55'0"E
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W
E
S
7°12′0″
7°10'0"N
7°6′0″
7°5'0"N
7°0'0"N
7°0′0″
6°55'0"N
6°54′0″
6°50'0"N
6°48′0″
Great
Nicobar Island
LEGEND
National Park
Biosphere Reserve
Trunk road+ Transit alignment
Jetty
Jetty route
Residential Mixed use (29.1 Sq.Km.)
Medium Density Residential (2.98 Sq.Km.)
Low density Residential (4.58 Sq.Km.)
Commercial Mixed use (4.33 Sq.Km.)
Commercial Office (0.41 Sq.Km.)
Tourism and Hospitality (1.70 Sq.Km.)
Eco-tourism areas (40.81 Sq.Km.)
Coastal-tourism areas (22.64 Sq.Km.)
Green (9.78 Sq.Km.)
Institutional (15.14 Sq.Km.)
Port (7.66 Sq.Km.)
Airport (8.45 Sq.Km.)
Logistics (7.90 Sq.Km.)
Defence Area (9.28 Sq.Km.)
Industrial (0.31 Sq.Km.)
Power Plant (0.39 Sq.Km.)
Other Utilities (0.64 Sq.Km.)
Area to be reclaimed for Port & Airport (4.21 Sq.Km.)
Total area = 166.1 sq.km
Area of only Township= 149.60 sq.km
Megapode nesting site
Turtle nesting site
Coral reef habitat
Long-Tailed Macaque habitat
0
2.5
5
10
93°40'0"E
93°45'0"E
93°50'0"E
93°55'0"E
93°42′0″
93°48′0″
93°54′0″