# INSULAR BIOGEOGRAPHY OF THE NICOBAR ISLANDS FROM A BIRD COMMUNITY PERSPECTIVE

**Thesis**

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**DOCTOR OF PHILOSOPHY**
IN
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By

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# CERTIFICATE

This is to certify that the thesis, entitled “**Insular biogeography of the Nicobar Islands from a bird community perspective**” submitted to the Bharathiar University, in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original work done by **Mr. A. P. Zaibin** during the period of July 2009 – June 2016 of his research in the Department of Zoology at Sálim Ali Centre for Ornithology and Natural History, under my supervision and guidance and the thesis has not formed the basis for the award of any Degree /Diploma /Associateship /Fellowship or other similar title to any candidate of any University.

Signature of the Guide

Head of the Department Director

# DECLARATION

I, **A. P. Zaibin** hereby declare that the thesis, entitled "**Insular biogeography of the Nicobar Islands from a bird community perspective**" submitted to the Bharathiar University, in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original and independent research work done by me during the period of July 2009 – June 2016 under the supervision and guidance of Dr. P. Pramod, Principal Scientist at Sálim Ali Centre for Ornithology and Natural History (SACON) and it has not formed the basis for the award of any Degree /Diploma /Associateship /Fellowship or other similar title to any candidate of any University.

A. P. Zaibin

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# Chapter-I

# GENERAL INTRODUCTION

## 1.1 BACKGROUND

Islands are fascinating locales of immense ecological importance because of distinct geographical water barriers defining distribution of biota with varied abilities of movements, survival and adaptations in space and time. Island groups or archipelagos across the globe differ greatly in geological history, geographical area, isolation, configuration, landscape and biological diversity. Studies in islands have provided profound insights into structuring and workings of ecological community assemblages. Realising this significance of insular systems, numerous studies have been increasingly carried out in many archipelagos on wide-ranging aspects of ecological and biogeographical importance. However, certain island groups have drawn comparatively less attention in ecological research due to various reasons including their general isolation, limited accessibility, hard logistics and administrative restrictions. The Nicobar Island group or archipelago is one of them.

The Nicobar archipelago (1841 km$^2$ in area), which lies in Bay of Bengal comprises of 19 islands, occurs as scattered clusters in three sub-groups separated by deep water channels, and each sub-group has distinct floral, faunal and anthropogenic characteristics (Ripley and Beehler 1989, Sankaran 1997, Das 1999). Most of the earlier ecological studies carried out exclusively in one of the two adjacent archipelagos, the Andamans or the Nicobars, were usually reported as from ‘the Andaman and Nicobar Islands’. This inadvertent consideration of the two archipelagos as more of similar in nature and overall characteristics has resulted in overlooking of biogeographical distinctness of the Nicobars, which warrant a separate treatment in ecological research and analyses.

One of the most important objectives of community ecology is to describe biogeographical patterns and examine underlying processes, and to find general rules (McArthur 1972, Wiens 1989). Community ecology is in the stage of exciting advances, with growing understanding of biological patterns and processes (Simberloff 2004). Since birds are conspicuous, largely diurnal, taxonomically well defined faunal group (Wiens 1989), studying bird community assemblages in insular settings can provide better insights into understanding biogeographical and ecological patterns. Studies on birds of the Nicobar Islands are very limited (Abdulali 1964, 1965, 1967a, 1967b, 1971, 1978 and 1981, Dasgupta 1976, Daniels et al. 1997, Sankaran 1998, Sivakumar and Sankaran 2002) and a thorough inventory of birds inhabiting all islands of the Nicobars is long overdue. Moreover, in the aftermath of 2004 Sumatra-Andaman mega earthquake and consequent tsunami, littoral habitats were devastated, severely affecting associated communities including endemic and threatened species such as Nicobar Megapode *Megapodius nicobariensis*, which preferred to build incubation mounds in the coastal habitats (Sankaran 2005, Sivakumar 2006). Yet, bird community assemblages in different habitats and island groups of this fascinating archipelago have never been investigated in detail.

Since community ecology largely deals with subjects of contingent and complex nature whose domain is very local, there are only few general laws in ecology (Simberloff 2004). Island species-area relationship is one of such laws and most examined fundamental patterns in ecology (Schoener 1976, Lomolino and Weiser 2001). The equilibrium theory of island biogeography (MacArthur and Wilson 1963 and 1967) provided a theoretical framework for the species-area relationships in island systems. The theory proposed that species richness on islands is the result of isolation-dependent immigration and area-dependent extinction (MacArthur and Wilson 1967, Rosenzweig 1995, Whittaker 1998). However, it was demonstrated later that the theory could not provide adequate explanations for the relationship and number of alternative hypothesis were proposed (Neigel 2003). Many investigators examined the constancy of the island species-area relationship and suggested the inclusion of more insular features, besides area and isolation in the explanation of the relationships (Whittaker 1998). Yet, the theory continues to shape current biogeographical thought and biodiversity conservation (Walter 2004). It is important to demonstrate whether archipelagos comply with the same species-area relationships as their constituent islands and also to explain the probable causes for departures from the relationships (Santos et al. 2010). Departures from the relationships are shown by archipelagos with low species-area slope, higher than expected species richness and smaller distance to source of immigration. These aspects are of special importance in the Nicobars since its avifaunal diversity is impoverished (Ripley and Beehler 1989), and adjacent regions are potential sources of multi-directional immigrations (such as Sumatra, Malaya and Andamans which are lying at varying distances in different directions).

A complementary measure to species richness is nestedness (Hu et al. 2011), which is a common biogeographic pattern of community assembly in which small communities or assemblages form proper subsets of large communities (Ulrich and Gotelli 2007). In other words, in a proper nested subset pattern, species poor sites will form a subset of species rich sites (Patterson and Atmar 1986). Nestedness provides important information regarding uniformity of patterns of species richness and composition in a community assemblage (Hu et al. 2011). Nested patterns are characteristics of many types of insular systems, and such patterns have been widely reported for different taxonomic groups including birds in island systems (Davidar et al. 2002, Fleishman et al. 2002, Wright et al. 1998). Nestedness is positive species co-occurrence patterns which is frequently used to understand the community structures of islands within an archipelago (Patterson and Atmar 1986) and has been widely applied to describe patterns of species occurrences and their underlying mechanisms (Ulrich et al. 2009). Diamond (1975) proposed that some pairs of species never coexist in an assemblage due to competitive inter-specific interactions which will result in negative co-occurrence patterns such as ‘checkerboard’ distributions (Collins 2006). Many null models and indices have been proposed to test positive and negative co-occurrence patterns to examine whether communities are random assemblages or governed by deterministic factors such as competitive interactions (Gotelli and Entsminger 2001). Since the Nicobar archipelago occurs as scattered clusters in island groups with distinct biogeographical elements, unique features of habitats and high variations in area among constituent islands (Sankaran 1995 and 1997), it would be a pertinent insular system to examine the co-occurrence patterns and explain the underlying processes.

The species co-occurrence analysis could be used to infer biogeographical affinities (Fleishman et al. 2002), probable source pool(s) (Cutler 1998) and existence of common biogeographical history within the archipelago (Patterson and Brown 1991). The island groups in the Nicobars could be considered as separate biogeographical units considering that different species and subspecies of various taxa have evolved in each group (Abdulali 1978) and there has not been any agreement regarding the biogeographical affinities of biota of these island groups. The island groups with varying proportions of biota in the Nicobars show varying biogeographical affinities to adjacent regions depending on which taxa is considered (e.g. Ripley and Beehler 1989, Das 1999, Hallermann 2009, Harikrishnan et al. 2010). Sumatra or Sundaic region is geographically closer to the Nicobars and it has been suggested that the faunal and floral elements of the Nicobars were derived from Sundaland rather than from much farther Burma or Indo-Chinese region (e.g. Mani 1974, Das 1999). Davis et al. (1995) considered the Nicobar archipelago as a part of the Sundaland biodiversity hotspot. Many species which are commonly distributed in Sundaic region occur in the Nicobars which encompass the western half of Indo-Malayan archipelago (Das 1999, Harikrishnan et al. 2010). On the contrary, Ripley and Beehler (1989), based on a biogeographic analysis of breeding birds of the Andaman and Nicobar archipelagos, argued that bird species colonised the Nicobar archipelago not from adjacent Sumatra, but by island-hopping from south-western Burma, along the Andaman archipelago, crossing permanent water barriers. They proposed that avifauna of the Nicobars is a subset of that of the Andamans and both the archipelagos share a single insular avifauna. Moreover, the depth of water channels that separate the Andaman and Nicobar archipelagos from adjacent biogeographical regions were deep and these island groups were never connected by land-bridge during Pleistocene sea-lowering. Thus, it was concluded that the breeding bird assemblages of the Nicobars show more affinity to Indo-Chinese region than Sundaic or Malayan region. In the context of the two different single-regional colonisation hypotheses concerning the origin of the Nicobar avifauna, either from north lying Burma (Ripley and Beehler 1989) or from south lying adjacent Sumatra (e.g. Mani 1974, Das 1999), this study examines affinities and the directional colonisation of the avifauna of the archipelago based on species co-occurrence patterns.

With this background, the present study investigates community structure, the island species-area relationships, species co-occurrence patterns and biogeographical affinities of birds of the Nicobar archipelago.

## 1.2 OBJECTIVES

Following are the specific objectives of the study:

1) To examine and compare community structure, composition and abundance of birds across different habitats and island groups of the Nicobars.

2) To find island species-area relationships of birds of the Nicobars.

3) To determine nestedness and co-occurrence patterns of distributions of birds of the Nicobars.

4) To examine biogeographical distribution patterns and affinities of birds of the Nicobars.

## 1.3 OUTLINE OF THE THESIS

The thesis is arranged into seven chapters; of which four are technical chapters, each addressing the specific objectives of the present study. Chapter I introduces the present work, providing broad overview and conceptual background of the study. The literature review of all the relevant aspects of study has been done and dealt within respective chapters. The methodology of the studies is also discussed in detail within the concerned chapters. Chapter II provides details of the study area. In the Chapter III, the study investigates patterns of bird community structure and compares community attributes such as species richness, diversity, evenness and abundance distributions across habitats and island groups. Additionally, correlation between species and individuals per sampling unit with few habitat and microclimatic variables are also attempted. The effect of tsunami on endemic species such as Nicobar Megapode is also discussed. In the Chapter IV, the island species-area relationships are examined to find whether the relationship for the entire Nicobars is congruent with individual island groups or islands of different size classes. Chapter V examines the nested subset patterns and co-occurrence distributional patterns and suggest underlying mechanisms. In addition, the species and islands conforming and deviating from the nested patterns were identified. Chapter VI focus on the biogeographical distributional patterns of birds and their affinities with adjacent biogeographical regions in terms of species compositional similarity based on cluster analyses. Chapter VII summarise and conclude briefly the major findings of the study. References and appendices are given at the end.

**Chapter-II**

# STUDY AREA

## 2.1 ANDAMAN AND NICOBAR ISLANDS

The Andaman and Nicobar Islands (6º 5’ 13 º 30’ N and 92 º 20’ 93 56’ E) is a group of true oceanic islands which lies stretched like an arc over a length of 912 km along north-south direction in the Bay of Bengal (Ripley and Beehler 1989). The archipelago comprises of 306 islands and 206 rocky islets, which encompass a total area of 8249 km$^2$ with a coastline of 1962 km. The Andaman and Nicobar Islands have been divided into two major archipelagos namely, the Andaman group (6408 km$^2$) in the north and the Nicobar group (1841 km$^2$) in the south (Saldanha 1989, Rao 1997, Jayaraj and Andrews 2005). Biogeographically, the islands could further be divided into five different archipelagos (Abdulali 1978), which Myers et al. (2000) considered the part of Indo-Burma biodiversity hotspot, and delineated as its western most boundaries. Politically, the Andaman and Nicobar is one of the Union Territories of India.

The islands of the Andaman group are the peaks of extensions of the submerged Arakan Yomas range, which is a southern branch of the eastern Himalayas, while the islands of the Nicobar group are the extensions of the Mentaweri islands to the south and south west of Sumatran Island (Rodolfo 1969, Das 1999).

## 2.2 NICOBAR ISLANDS

The Nicobars consist of 19 islands and some rocky islets which can be divided into three subgroups (Fig. 2.1) as they occur as scattered clusters and each group is separated by deep water channels (Abdulali 1967, Ripley and Beehler 1989, Sankaran 1995 and 1997). Distinct floral, faunal and anthropogenic features among the three island groups further validate this division (Sankaran 1997). The 140 km wide Ten Degree Channel between Little Andaman and Car Nicobar separate the Andamans from the Nicobars. An 88 km wide channel further separates northern Car Nicobar group from central Nancowry group which in turn is set apart from southern Great Nicobar group by a 58 km wide Sombrero Channel (Ripley and Beehler 1989).

The southern or Great Nicobar group comprises of 11 islands of which two are major islands namely Great Nicobar and Little Nicobar (with size of 1045.1 and 159.1 km$^2$ respectively) and remaining nine are either small islands or islets (ranging in size from 0.04 to 4.6 km$^2$).

Megapode Island (0.13 km$^2$) in the group is submerged under coastal waters due to slight tilt in the land after mega earthquake of 2004 and the island is no longer visible. The central or Nancowry group consists of eight medium to small islands (size: 8.2 to 188.2 km$^2$). The northern group consist of only two islands namely Car Nicobar (126.9 km$^2$) and Batti Malv (2.1 km$^2$). Altitude of different islands vary greatly (ranging from 0-600 MSL).

All islands in the Nicobar group are set aside as tribal reserves with restrictions on entry or commutation by non-tribals. According to Sankaran (1995), forest cover extends up to 80% of the total land area of the Nicobar islands, and 60% of it is relatively undisturbed (Sankaran 1995). Of the four Protected Areas in the Nicobars, three uninhabited islands namely Tillanchong, Batti Malv and Megapode Island (now submerged) are wildlife sanctuaries. Great Nicobar Island has been earmarked as a Biosphere Reserve (885 km$^2$), which has two core zones that encompasses Campbell Bay National Park and the Galathea National Park (Sankaran 1995, 1997, Daniels et al. 1997). The Nicobar Islands are considered as a part of Sundaland global hotspots of biodiversity (Mittermeier et al. 2004). In 2013, UNESCO included Great Nicobar Island in its world biosphere reserve network.

Out of the total 19 islands, 11 islands are inhabited largely by indigenous Nicobarese, in addition to some settlers from mainland and aboriginal Shompen tribe who are confined to Great Nicobar. Nicobarese reside in different regions of the inhabited islands while the people from mainland are rather concentrated near administrative headquarters of the island groups and cannot own land in the Nicobars (Sankaran 1997). The inhabited islands in the southern group include Great Nicobar, Little Nicobar and Pilo Milo. The habitations of Kondul Island were shifted to nearby Great Nicobar in the aftermath of tsunami. Nine of the eleven islands in the central and the northern group are inhabited. Far flung or small or coralline islands with unsettling shores such as Menchal, Trak, Treis, Meroe, Tillanchong and Batti Malv are uninhabited but are occasionally visited or camped by Nicobarese (Andrews and Vaughan 2005, *Personal observations*). Although advent of modern culture and development has opened up many opportunities for the Nicobarese, it has altered their metaphysics, psychological landscape, and negatively influenced their traditional respect for environment and concept of sustainable living. Moreover, the increase in number of settlers from mainland and their inadvertent control of economy and trade have adversely affected trade and sustenance of Nicobarese. Widespread availability of air guns has increased prevalence of hunting birds and bats by the Nicobarese who are exempted from the Indian Wildlife (Protection) Act, 1972 (Aul 2007).

### 2.2.1 Habitat types

Forest type of the Nicobar Islands can be broadly classified as tropical evergreen with inland upland forest or grassland (Balakrishnan 1989). Habitat features of different island groups vary widely in occurrence and extend of specific habitat types. 92.87% (1579 $km^2$) of total geographic area of the Nicobars is forested (IIRS 2003). According to IIRS (2003) and Roy et al. (2005) tropical evergreen forest is the largest and evenly occurring habitat in the Nicobars, covering 68.9% of the area (1167.2 $km^2$) and small patches of mixed evergreen forest (5.7%) exists in some places and 65% (1024.5 $km^2$) of the habitats remains undisturbed (Table 2.1 and 2.2). All the islands in the southern group are heavily forested (Sankaran 1997, Table 2.3), except for few small islands where human activities have brought significant modification to landscape. In the Nicobars, 97.5% (1521.3 $km^2$) forested habitats are contiguous, especially in the southern group, while forests of major islands of middle and northern groups such as Kamorta, Katchal and Car Nicobar are fragmented due to pressures from human habitations, agriculture, plantations of coconut and rubber (Roy et al. 2005).

Grasslands widely occur in Nancowry group and cover 9% of the total area (144.8 $km^2$) (IIRS 2003). Upland or hilltop grasslands are distributed in central regions of all the islands in the group, except in Tillanchong and extend to the coastal fringes at some locations. Grasslands cover 60% area of Trinket and Teressa, 30-50% of Kamorta and about 20% Nancowry and Bompoka, and small portion of Chawra and Car Nicobar (Sankaran 1995, 1997). No grassland exists in forested islands such as Katchal, Tillanchong and Batti Malv. Occurrence of grassland is attributed to various factors including human disturbance and clearing of forest in the past (Balakrishnan 1989) or soil characteristics and microclimatic factors (IIRS 2003). Sankaran (1995) argued that the existence of the subspecies of 'Nicobar Blue-breasted Quail *Coturnix chinensis trinkutensis*' in the grasslands indicate natural occurrence of grassland habitats from evolutionary times in these islands allowing colonization and speciation. Grasslands also harbour isolated patches of stunted forest at places similar to Shola forest-grassland matrix of the Western Ghats of the mainland India (Sankaran 2005).

Major wetland habitat types include coral, beach and intertidal mudflats. Coastal wetlands occupy 98.5% (24297 ha) of the total wetland area in the Nicobars where inland wetlands are very less in extent (2%). Mangroves and creeks are sparsely distributed (National Wetland

Atlas 2009). It is important to note that the earthquake and tsunami of 2004 had destroyed almost all littoral and mangrove forests, and coastal wetlands which resulted in inundation and destruction of inland fresh water bodies, marshes, creeks, and coral reefs (Sankaran 2005; *see* Table 2.2).

Table 2.1. Distribution of 10 habitat types in the Nicobar Islands (following Roy et al. 2005). Low-lying habitats which could have severely impacted by tsunami are marked with asterisk.

| **Habitat types** | **Area (km2)** | **% Area** |
|---|---|---|
| Andaman evergreen forest | 1167.21 | 68.94 |
| Grassland | 144.8 | 9.87 |
| Plantations* | 101.56 | 6.00 |
| Mixed evergreen forest | 97.78 | 5.78 |
| Lowland swamp* | 62.57 | 3.70 |
| Mangroves* | 36.83 | 2.18 |
| Littoral forest* | 23.66 | 1.40 |
| Moist deciduous forest | 17.45 | 1.03 |
| Agriculture* | 10.25 | 0.65 |
| Scrub | 8.54 | 0.43 |
| **Nicobar group** | **1670.65** | |

Table 2.2. Estimate of pre-tsunami extend of low lying habitats that could have severely impacted by tsunami (following Roy et al. 2005).

| **Habitat types** | **Area (km2)** | **% Area** |
|---|---|---|
| Plantations | 101.56 | 6.00 |
| Lowland swamp | 62.57 | 3.70 |
| Mangroves | 36.83 | 2.18 |
| Littoral forest | 23.66 | 1.40 |
| Agriculture | 10.25 | 0.65 |
| Total extend of habitats impacted | **234.87** | **13.93** |

### 2.2.2 Vegetation

Balakrishnan (1989) and Sankaran (1995) have remarked on the prominent vegetation formations in different habitat types in the Nicobars. The herbaceous strand formation on the beaches is dominated by *Ipomoea pes-caprae* which is followed by *Scaevola sericea* shrubbery. Stands of *Barringtonia asiatica* dominate along retreating coastlines beyond which littoral forest occur towards the interior, which in turn is dominated by *Henrnandia peltata, Manilkara littoralis, Thespesia populnea, Terminalia* sp., *Hibiscus tiliaceus, Artocarpus* sp. and *Sterculia* sp. Dense stands of *Pandanus* sp. also occur along the coastal belt. Low lying areas, which are perennially inundated during rain, harbour *Atalantia* *alabarica*, *Baccaurea sapida*, *Syzigium* sp., *Myristica* sp., and wild arecanut. Littoral Forests also harbor species such as *Terminalia catappa*, *Barringtonia asiatica*, *Calophyllum inophyllum*, *Casuarina equisetifolia*, *Guettarda speciosa*, *Heritieria littoralis*, *Ochrosia oppositifolia*, *Cycas rumphii*, and *Ixora* sp. (Negi 2002). Stands of tree ferns *Cyathea* sp. are peculiar to forested slopes of Great Nicobar (Daniels et al. 1997).

Hilltop evergreen forest, especially in Great Nicobar Island, is composed of *Canarium manii*, *Cratoxylon formosum*, *Dipterocarpus costatus*, *Hopea andamanica*, *Meusa ferrea* and *Euphorbia* sp. (Negi 2002). The hill forest also have species such as *Acronychia pedunculata, Mussaenda macrophylla, Morus macroura, Calophyllum soulattri, Xanthophyllum vitellinum, Terminalia* sp., *Sideroxylon longipetiolatum, Pisonia excelsa, Mangifera sylvatica* and *Garcinia xanthochymus* (Sankaran 1995). Deciduous trees such *Terminalia procera* and *T. bialata* occur in association with *Pterocymbium tinctorium* along lower altitudes in Great Nicobar (Rao 1996).

A climax formation consisting of annual and perennial grass species is unique to the grassland habitat of the central group (Aul 2007). Major grassland species are *Cajanus scarabaeoides, Carex cruciata, C. cryptostachys, Cassia mimosoides, Chrysopogon aciculatus, Cissus repens, Ischaemum lacei, Trema orientalis, Zizyphus oenopolia, Cissuss spp. Desmodium heteropogon* and *Phragmites karka* (Balakrishnan 1989, IIRS 2003). Grasslands are interspersed with *Pandanus odoratissimus* and *Bentinckia nicobarica* (Aul 2007), and shrubby vegetation in many places.

### 2.2.3 Climate

Climate is determined by Southeast Asian monsoonal regime and is described as warm tropical, humid and oceanic with little seasonal variation due to the proximity of the Nicobar Islands to the equator (Saldanha 1989, Ripley and Beehler 1989, Rao 1996). Both south-west and north-east monsoon brings rainfall to the islands. North-east monsoon occur during October-December and the following period from January-April is driest. South-west monsoon that occur during May-September brings heavy showers. Average annual rainfall is about 3800 mm. Temperature variations is low from a minimum of 20°C to a maximum of about 32°C. However, mean relative humidity (82-85%) is very high. Strong winds accompanied by thunder and storms occur more or less frequently in the island. Cyclonic storms that hit coasts of mainland seldom affect the islands in spite of such winds being originated close to the archipelago. (Ripley and Beehler 1989, Saldanha 1989, Sankaran 1995, Rao 1996).

Table 2.3. Approximate land area and habitat distribution in three island subgroups of the Nicobars (Adopted from Sankaran 1997).

| | | **Habitat area** ($km^2$) | | |
|---|---|---|---|---|
| **Islands** | **Island area** ($km^2$)***** | **Forest** | **Grassland** | **Other habitats** |
| ***Southern group*** | | | | |
| Great Nicobar | 1045.1 | 955 | 0 | 90.1 |
| Megapode # | 0.13 | 0.08 | 0 | 0.05 |
| Cubra | 0.04 | 0 | 0 | 0.04 |
| Kondul | 4.6 | 3.1 | 0 | 1.5 |
| Little Nicobar | 159.1 | 147.1 | 0 | 12 |
| Pilo Milo | 1.3 | 0.3 | 0 | 1 |
| Menchal | 0.7 | 0.2 | 0 | 0.5 |
| Treis | 0.1 | 0.01 | 0 | 0.09 |
| Trak | 0.2 | 0.2 | 0 | 0 |
| Meroe | 1.4 | 0.6 | 0 | 0.8 |
| ***Central group*** | | | | |
| Kamorta | 188.2 | 124.6 | 43.776 | 19.824 |
| Nancowry | 66.9 | 53.1 | 3.8 | 10 |
| Trinket | 36.3 | 20.3 | 5.96 | 10.04 |
| Katchal | 174.4 | 144.4 | 0 | 30 |
| Teressa | 101.4 | 49.7 | 34.629 | 17.071 |
| Tillanchong | 16.82 | 15.82 | 0 | 1 |
| Bompoka | 13.3 | 8 | 3.3 | 2 |
| Chawra | 8.2 | 4.7 | 1.425 | 2.075 |
| ***Northern group*** | | | | |
| Car Nicobar | 126.9 | 69 | 3 | 54.9 |
| Batti Malv | 2.1 | 2 | 0 | 0.1 |
| **Nicobar group** | 1947.19 | 1598.21 | 95.89 | 253.09 |

# Megapode Island is submerged in the sea due to slight tilt in the land after mega earthquake of 2004.
*Sankaran (1997) pointed out discrepancy in published district records regarding the total land area of the whole Nicobar group and sum of areas of all islands (i.e. 1841 $km^2$ and 1947 $km^2$ respectively).

## 2.3. ISLAND GROUPS

The descriptions of islands groups and island characteristics have been sourced and adopted mostly from Sankaran (1995, 1997 and 2005) and appended with personal observations.

### 2.3.1 Southern group

The southern or Great Nicobar group of Islands lies 58 km south of Nancwory group and 172 km north-west of Sumatra. The southern group comprises of 11 islands of which two major islands are Great Nicobar and Little Nicobar. The two islands lie adjacent to each other and are separated by 275m deep St. George channel. The Great channel with a depth of 1600m separate Sumatra from Great Nicobar (Ripley and Beehler 1989).

Great Nicobar Island is the largest (1045.1 km$^2$) and southernmost island of the Nicobars, which makes up more than 50% of the total area of the entire Nicobar group. Great Nicobar is hilly on central and northern half and increasingly flatter towards southern and western portion. Mt. Thuillier (at 670 MSL) situated in the northeast of the island is the highest peak in the Nicobar group and second highest peak in the Andaman and Nicobar Islands. The Great Nicobar group is hillier than the central group (Daniels et al. 1997, Sankaran 2005, Sivakumar 2007). Great Nicobar is the only island with perennial rivers such as Jubilee, Renhong, Amrit Kaur, Dogmar, Alexandria and Galathea, which originate from the peaks, along with more than 25 streams flowing to the sea (Daniels et al. 1997, Sankaran 2005).

Little Nicobar (159.1 km$^2$) is topographically more similar to adjacent Great Nicobar and is predominantly hilly and forested without any major rivers, but many rivulets and streams flows in the island. This inhabited island has a narrow flat littoral region which broadens along western coast. Kondul (4.6 km$^2$) is a small hilly island which lies amidst the St. George channel that separate Great and Little Nicobar. Kondul is predominantly hilly with cliffs and rocks lining the coast, and with very narrow flatland which was inhabited by Nicobarese prior to the tsunami. Pilo Milo (1.3 km$^2$) is formed of three hillocks with flat terrain to the southeast, east and northeast of the island. Its closeness to Little Nicobar makes it convenient for human habituation and is the smallest inhabited island in the Nicobar group. Very few patches of natural vegetation that occur in the island is highly degraded and interspersed with coconut, arecanut and banana groves. Treis (0.5 km$^2$) is a very small island with a hillock which stand as a vertical sheet rock to the east bordering the coastal waters and form an arc around the island. Flat central and low lying region extend towards south, west and northwest. The hillock harbour mixed and secondary forest. Trak (0.2 km$^2$) exist as a smaller sister island formed of a small vertical rocky hillock to east and flat land to the west which is covered by a sparse coconut palms and shrubby vegetation. Coastal waters around Treis and Trak is <30m deep for *c.* 4.5 km, consequently wave currents are very high and quite rough along the coast. Hundreds of Pied Imperial Pigeons *Ducula bicolor* arrive in Treis and Trak in flocks to roost among the vegetation in the forested ridge of the island and many nests in the island. Menchal (1.5 km$^2$) is a small uninhabited island which is mostly hilly with coralline rocks and narrow littoral regions on the western corner. A fresh water spring on the island forms a swampy patch dominated by *Pandanus* trees. Much of the Menchal is planted with coconut, arecanut and banana, while bamboo brakes occur as natural vegetation in the interiors interspersed with mixed forest and undergrowth towards hills. Meroe (1.4 km$^2$) is a small northernmost island of Great Nicobar group and consist of a small hill, coralline rocks or cliffs with sea fronts, wide flat terrains, and a subterraneous sea-linked salt water body at the centre. The natural habitat in this island is sparse. Coralline rocks are peculiar to small islands such as Menchal and Meroe which may have different geological origin in comparison to other islands in the Great Nicobar group. Nicobarese residing in northern Great Nicobar, Little Nicobar and Pilo Milo traditionally hold the ownership of areca, coconut and banana plantations or groves in all of these small uninhabited islands and seasonally visit these islands to reap crops and hunt pigeons (Sankaran 2005, *Personal observations*).

### 2.3.2 Central group

Kamorta (188.2 km$^2$) is the largest island in the central or Nancowry group (Table 2.3). It is seat of administration of the central group of islands. The entire island forms a low hill ridge that stretches in north-south direction interspersed with forest and grassland. The central portion of hill ridge has peaks having heights ranging from 108 to 210 MSL and rest of the island mostly exists at 50 MSL. Few narrow low lying flatlands exist along the coast. At places rolling grasslands abruptly ends at the sea front. The central group of islands is named after Nancowry Island (66.9 km$^2$). Nancowry is formed of hill ridges (highest peak at 118 MSL) and valleys covered with forests and rolling grasslands. Trinket (36.3 km$^2$) lies parallel to east of Kamorta across Beresford channel. Much of the island’s hilly terrain (highest at 29 MSL) is covered in grassland and patches of forest. Hills in south and north of the island is linked to each other by a sand bank. Much of the northern region is flat and has an extended sand bank. Most of the low laying regions of the Trinket had been modified for agriculture and posses no natural vegetation. Katchal (174.4 km$^2$) is the second largest island and consist of low hills (highest peak at 174 m above msl) which is wholly forested. Katchal and Tillanchong are the only islands in the Nancowry group which has no grassland. Much of the littoral regions of the main bays in the west, east and south of the island had been modified for agriculture such as coconut and arecanut plantation. This is the only island in the Nicobars with rubber plantations and large scale planting of rubber in the past in Katchal altered much of the natural habitat of the island. Teressa (101.4 km$^2$) is an elongated island which is hilly and densely forested towards the northern region and more or less largely covered in grasslands towards the southern portion. Highest peak measure at 273 m above MSL, and hills in the northern sections are dominated by Ebony forest. Much of the eastern coast has *c.*300 m littoral zones which are human modified habitats. There are many large and small villages which are predominantly inhabited by Nicobarese. The human pressure on the natural habitat has been significant in the island. Bompoka (13.3 km$^2$) is the second smallest island in the group. Vinayak channel separate Bompoka from adjacent Teressa Island. Bompoka is largely hilly and forested. Grasslands are distributed towards southern portion of the island. The highest forested peak in the central hill region of the island stands at 209 m above MSL, which harbour a limestone cave. A single hamlet with few huts of Nicobarese inhabitants, known as *Poahat*, lies on the eastern coast. Very narrow littoral regions exist at the base of the hills which are planted with coconut. Eastern and northern coast are fringed with sheet rocks. Perennial streams and streamlets flow to the sea from the forested hills along the steep valleys of the northern region. Chawra (8.2 km$^2$) is the smallest island in the group and peculiar in having a 'Table hill' known as '*Tahup'* (at 104 m above MSL) which vertically project out to the sea front along the southern end of the island. '*Tahup'* is difficult to access and covered by mixed evergreen forest at table top of the hill. Caves of coralline origin flank the hill side. The most of remaining regions of the island are evenly flat and lies within few metres above MSL. Vegetation in these regions consists of coconut plantations, plantains, vegetable gardens, and highly degraded small patches of forests. A 20 hectare patch of grassland exists in the centre of island. Chowra is one of the few most densely populated islands in the entire Nicobar group. Fresh water sources are scarce in the island. Tillanchong (16.82 km$^2$) is highly elongated island and very hilly (highest at 323 m above MSL) and entirely forested except for bare cliffs, rounded and edged rocks that descend to the sea along the shore. Two rocky islets namely Paira Rock and Isle of Man, lie off the southern and northern end of the island. Very few beaches and creeks exist on the island. No grassland exists on Tillanchong. Entire Tillanchong Island is earmarked as Wildlife Sanctuary in 1985 and is the only officially Protected Area in the central group (Sankaran 2005; *Personal observations*).

### 2.3.3 Northern group

The northern or Car Nicobar group is represented by only two islands, Car Nicobar (126.9 km$^2$) and Batti Malv (2.1 km$^2$). Car Nicobar is a northern most island of Nicobar and it is separated from the central group by 88 km wide and 250 m deep channel. It is the administrative headquarters of the Nicobar district. The island is flat and dominated by coconut and arecanut plantation, and home gardens. Streams originating from the central region (highest point at 72 m above MSL) flows to two bays namely Sawai in the north and Kimius in the south. Very few patches of grasslands exist in the island. Batti Malv (2.1 km$^2$) is an uninhabited and flat island situated south of Car Nicobar. The island is covered with sparse vegetation and probably of coralline origin. The strong currents around the island's escarpment make it more inaccessible (Sankaran 2005). It is the most populated island in the Nicobar group and thus natural vegetation is sparse and whatever left is highly degraded. Car Nicobar is under heavy pressure from population and habitat modification. Small patches of highly fragmented mixed forest are all left in this island. Dominant habitats include coconut, areca plantations, scrub, home gardens, grasslands and tsunami inundated wetlands.

## 2.4 STUDY LOCATIONS

Present study was carried out in 64 remote locations in 17 of the total 19 islands of the Nicobar archipelago namely Great Nicobar, Cubra, Kondul, Little Nicobar, Menchal, Pilo Milo, Treis, Meroe, Katchal, Nancowry, Trinket, Kamorta, Bompoka, Teressa, Chowra, Tillanchong and Car Nicobar (Figure 2.1; Table 2.4). The 64 study sites are spread over islands located in the three subgroups. The two small islands namely Batti Malv and Trak could not be visited due to strong currents around the islands' escarpments.

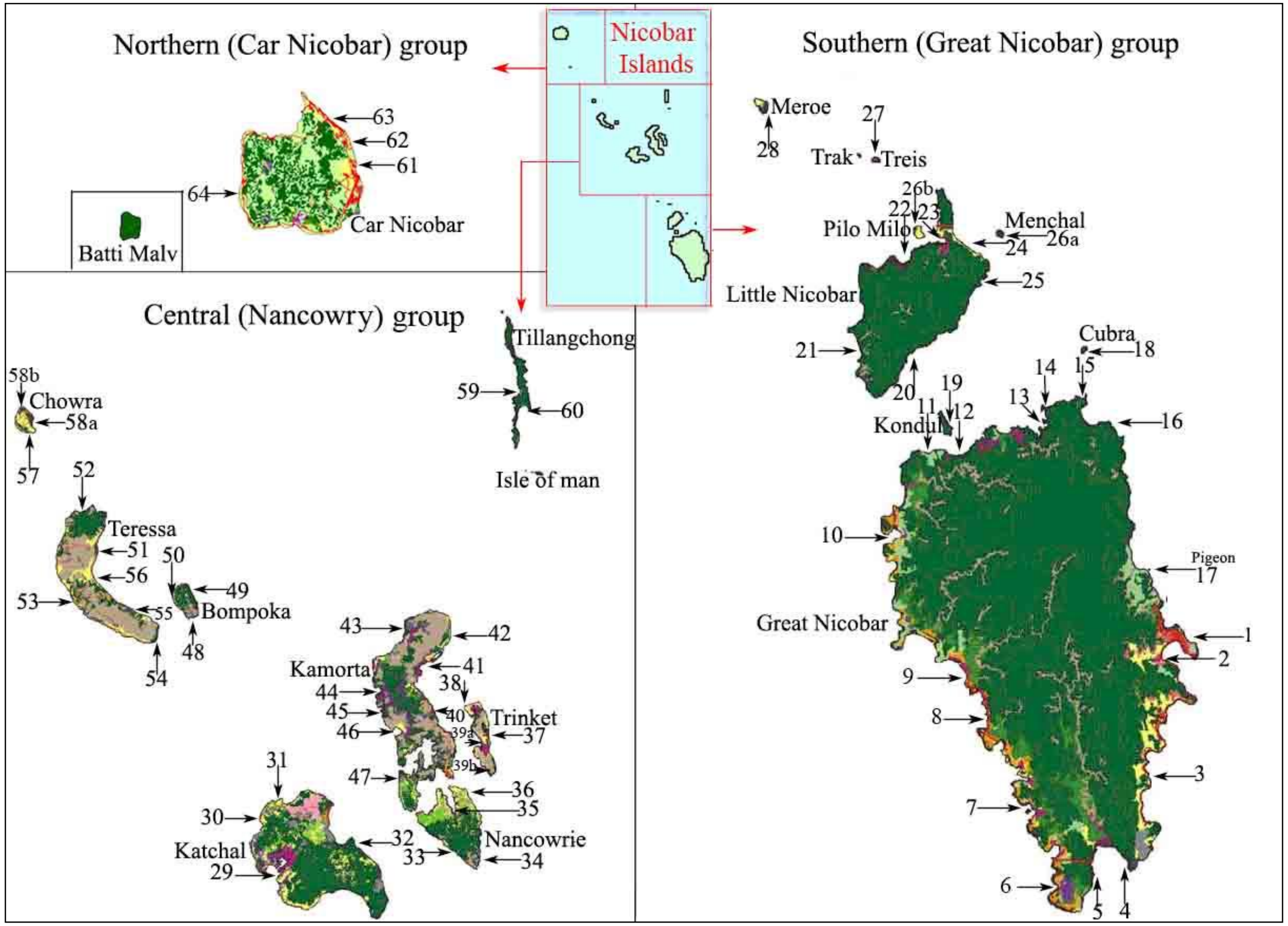

Fig. 2.1. Locations surveyed to study bird communities in 17 islands of the Nicobars (arrow marks are followed by location codes; *see* Table 2.4 for names of locations; map adopted from Roy et. al. 2005).

Table 2.4. Details of survey location codes marked on the map in Fig. 2.1.

| Island | Code | Location |
|---|---|---|
| Great Nicobar | 1 | Campbell Bay (PWD beach) |
|  | 2 | Mugger nullah |
|  | 3 | 30 & 32 kms |
|  | 4 | 38 kms |
|  | 5 | Chingenh Pasthi |
|  | 6 | Pilo Baha |
|  | 7 | Pilo Bakka |
|  | 8 | Kasingdon |
|  | 9 | Kopenheat |
|  | 10 | Ayoam Bay |
|  | 11 | Utham Bay |
|  | 12 | Hafra Bay |
|  | 13 | Ganges Harbour |
|  | 14 | Pithai |
|  | 15 | Happeyy (near Murray Point) |
|  | 16 | Trinket Bay |
|  | 17 | Pigeon |
| Cubra | 18 | Cubra |
| Kondul | 19 | Kondul |
| Little Nicobar | 20 | Lanye (Pulo Ulan) |
|  | 21 | Thavai thav |
|  | 22 | Komath |
|  | 23 | Makachua |
|  | 24 | Pilo Panja |
|  | 25 | Reing-Reing |
| Menchal | 26a | Menchal |
| Pilo Milo | 26b | Pilo Milo |
| Treis | 27 | Treis |
| Meroe | 28 | Meroe |
| Katchal | 29 | West Bay |
|  | 30 | Jansin |
|  | 31 | Jhula |
|  | 32 | Upper Katchal & Ol-hi-poh |
| Nancowry | 33 | Hindrah & Hoi Manyen |
|  | 34 | Mus |
|  | 35 | Chinlak |
|  | 36 | Olthyak & Thapong |
| Trinket | 37 | Hukkuh |
|  | 38 | Safed Balu |
|  | 39a | Ok Chauka |
|  | 39b | Thavai Oank |
| Kamorta | 40 | Mehon |
|  | 41 | Kakana |
|  | 42 | Nyikalang |
|  | 43 | Mohreak |
|  | 44 | Ol hinpun |
|  | 45 | Remyok |
|  | 46 | Dering |
|  | 47 | Masla tapu |
| Bompoka | 48 | Light House |
|  | 49 | Atluch |
|  | 50 | Poahat |
| Teressa | 51 | Bengali |
|  | 52 | Reksal |
|  | 53 | Hinam |
|  | 54 | Kolerue & Tamoh |
|  | 55 | Chukmachi |
|  | 56 | Kalasi |
| Chowra | 57 | Tahup |
|  | 58a | Rahion |
|  | 58b | Hinniya |
| Tillanchong | 59 | West coast |
|  | 60 | East coast |
| Car Nicobar | 61 | Malacca |
|  | 62 | Lapathi |
|  | 63 | Kinmai |
|  | 64 | Aurong |

**Chapter-III**

# BIRD COMMUNITY STRUCTURE IN THE NICOBAR ISLANDS

## 3.1 INTRODUCTION

### 3.1.1 Studies on birds of the Nicobar Islands

Studies on bird assemblages of the Nicobar Islands are sparse and baseline information on distributional pattern of many bird species including endemics in the region is minimal or lacking. Earliest ornithological explorations and specimen collection trips to these islands occurred from the latter half of the 19th century. Hume's (e.g. 1873, 1874 and 1876) collection expedition in 1873 to the Nicobar Islands and also to the Andaman Islands, accompanied by number of collectors yielded many new species (Kloss 1903). Richmond (1902) commented on 520 bird specimens of nearly 100 species (including nine newly described) collected mostly from Great and Little Nicobar Islands by W. L. Abbott.

After independence, Abdulali (1964, 1965, 1967a, 1967b, 1971, 1978 and 1981) carried out major expeditions in the Nicobars. Abdulali attempted to make representative collections from different islands in the Nicobars, since there were no island-wise record of type localities of the specimen collected during historic expeditions in the later 19th century and were simply listed as 'Andamans' or 'Nicobars' or 'the Andaman *and* Nicobar Islands' (Abdulali 1978). Abudlali (1978) alluded to the possibility of evolution of different subspecies of bird species in many of the Andaman and Nicobar Islands which are located far from the mainland and distributed over almost 500 miles. He obtained a specimen of new species of owl from Great Nicobar Island and described new subspecies of bird species from the three island groups. Davison and Hume could collect many more specimens of some species in the Nicobars than Abdulali (1967) in spite of similar effort and time in some of his collection trips, which he attributes to rapid reduction in several species over the last century or so. Abdulali's frequent surveys in the Nicobars yielded insights into systematics, distribution and ecology of bird species and subspecies in different islands groups.

Subsequently, Das (1971), Dasgupta (1976), Saha and Dasgupta (1980), Daniels et al. (1997), and Sivakumar and Sankaran (2002) reported new records of the birds of the Nicobars. Tikader (1984) collated descriptions of the birds of the Andaman and Nicobar Islands based on the collections of Zoological Survey of India. Sankaran and Vijayan (1993) reviewed current settings of the avifauna of the Andaman and Nicobar Islands. Chandra and Kumar (1994) reported their observation on birds of Great Nicobar Island. Sankaran (1998) listed species and subspecies of birds endemic to the Nicobar Islands based on his field surveys, collating information on earlier records from literature. Pande et al. (2007) conducted few days of rapid reconnaissance bird surveys in three islands, namely Car Nicobar, Kamorta and Great Nicobar. Vijayan (2009) provided an overview of studies of avifauna of the Andaman and Nicobar Islands and its conservation. Rajan and Pramod (2013) reviewed introduced birds of the Andaman and Nicobar Islands.

Rasmussen (1998) described a new species of Scops Owl from Great Nicobar Island. Rasmussen (2000) reviewed the status of Nicobar Sparrowhawk *Accipiter butleri* on Great Nicobar Island. Recently, Rajeshkumar et al. (2012) described seemingly a new species of *Rallina* crake from the island.

Detailed studies on population, nesting, breeding and behaviour of the critically endangered and endemic Nicobar Megapode *Megapodius nicobariensis* had been carried out spanning more than a decade (Dekker 1992, Sankaran 1995, Sivakumar and Sankaran 2003, 2005, Sivakumar 2000, 2003 and 2007). Sankaran (2005) and Sivakumar (2006) conducted post-tsunami surveys, especially to assess the impact of the catastrophe on the critical population of Nicobar Megapode.

Mukherjee and Dasgupta (1975) commented on taxonomic status of Nicobar Emerald Dove *Chalcophaps augusta*. Ripley and Beehler (1989) examined geographical affinities of birds of both the Andamans and the Nicobars. Unnithan (1996) compared variations in Olive-backed Sunbirds *Nectarinia jugularis* of the Andamans with that of three island groups of the Nicobars. Sankaran (1997) discussed the high endemicity of species and subspecies of birds and proposed the need of developing a protected area network in the Nicobar Islands. Sankaran (1995 and 1998) studied the nest collection and decline of Edible-Nest Swiftlet *Collocalia fuciphaga* in the Nicobar Islands. Daniels et al. (1997) examined patterns of distribution of birds and Sivakumar (2003) observed breeding biology of seven bird species on the island. Pande and Sant (2009) observed curious nesting habits of Olive-backed Sunbird in Great Nicobar Island. Manchi and Sankaran (2009) observed predators of swiftlets and their nest in the Andaman and Nicobar Islands. Oommen and Shanker (2009) analysed interactions and mixed foraging associations between Racket-tailed Drongos and Sparrowhawks on Great Nicobar Island.

Literature review of ornithological studies of the Nicobar Islands indicates historic specimen collection expeditions, sporadic reports of additional new species records, reviews on the status of distribution of endemic birds, rapid bird surveys of more accessible islands, discovery and / or description of new species, comprehensive studies on status, ecology, distribution and breeding biology of critically endangered Nicobar Megapode, taxonomic status and variation of few bird species, and an analyses of geographical affinity of bird species composition of the island group with adjacent source pools.

Remoteness, inaccessibility, administrative restrictions as tribal region, hard logistics and above all, an untameable sea could be few reasons that limited flocking of ecological investigators and enthusiasts alike to these fantastic islands. Furthermore, more accessible and much larger Andaman group of islands have always been clumped with much distinct and comparatively smaller Nicobar group of islands due to political or administrative reasons and invariably considered together as ‘the Andaman and Nicobar Islands’. Thus, the Nicobar archipelago deserves to be treated as a distinct group and necessitate separate consideration in ecological investigations.

Limited ornithological explorations in the Nicobar islands (e.g. Hume 1876, Butler 1899, Abdulali 1965, 1967a, 1967b, 1971, 1978, 1981, Dasgupta 1976, Daniels et al. 1997, Sankaran 1998, Sivakumar and Sankaran 2002) call for further studies in the region especially in the wake of mega-earthquake and tsunami of December 2004 and subsequent large scale destruction and inundation of coastal habitats. Almost all bird species present in the Nicobar Islands were distributed in suitable habitats throughout the islands. Ultimately, the loss of coastal habitat would have resulted in declines in the populations of many bird species. Sykes (2005) pointed out the need of surveys to assess the impact of the tsunami on endemic bird species of the Nicobar Islands. One of the worst affected species due to the loss of coastal habitat has been the Nicobar Megapode *Megapodius nicobariensis*, an endemic bird species to the Nicobar Islands, which occurred in higher concentrations in littoral forests.

In the Nicobars, occurrence, abundance and distributions of numerous species remain unstudied. Bird community assemblage of different islands of this fascinating island group were never been investigated in detail before. I carried out a study in the Nicobar Islands to examine and compare community structure, composition and abundance of birds across different habitats and island groups.

## 3.2 METHODS

Surveys in the Nicobars involved camping along the coast and exploring the coastal and interior habitats in 64 different remote locations mostly away from hamlets (Chapter II; Fig. 2.1 and Table 2.4). Camps were shifted consecutively to subsequent locations after every 2-5 days employing a *dungi* boat.

### 3.2.1 Bird sampling

The bird surveys in 17 islands of the Nicobars (Fig. 2.1; Table 2.4) were carried out during April 2009 to September 2011. The 10 different habitat types described (Table 2.1 and Table 2.2) were grouped into four major broad categories of habitats for sampling during the study (Fig 3.1): 1) *forest*: Andaman evergreen, mixed evergreen and moist deciduous hill forest unaffected by tsunami, 2) *littoral habitat*: low lying habitats that were severely affected by tsunami which were previously covered by littoral forest, lowland swamps, mangroves, creeks and marshes located between coast and hillock, 3) *grassland-scrub habitat*: grass-covered landscape interspersed with forest patches and scrubland in the central and northern groups of islands, and 4) *grove*: human modified landscape with groves, home gardens, agriculture and plantations.

Fixed radius point count sampling of birds was done as it provides highly reliable and cost-effective estimates of species richness and abundance, especially in uneven terrains (Ralph et al. 1995, Bibby et al. 1992). Point counts were done at every 100m distance in thickly vegetated areas and 150m distance in grasslands along a transect walked randomly in the different habitats. Each point count was of five minutes duration. All the birds detected (seen/heard) within 50m radius of the points were noted. The counts were avoided during stormy or rainy days. Most of the counts were carried out during morning hours between 05:45 and 10:30 hrs. Count stations were scanned while entering and leaving the station to record any undetected birds during the five minutes count. Since the objectives of the present study were to inventory bird species (presence/absence) including rare species, determine species richness, relative abundance and habitat associations of birds, only independent point counts in different habitats of 17 islands were carried out in the Nicobars (e.g. Nur et al. 1999). Total of 1244 independent point counts were done in different habitats of the three island groups (Table 3.1). The surveys in each of the 17 island attempted to cover maximum area and habitats within the constraints of logistics. Persistent efforts were taken to explore

Fig. 3.1. Four major habitats distinguished in the Nicobars: *forest* (a and b), *littoral habitat (*c and d), *grassland-scrub habitat* (e and f) and *grove* (g and h). Southern group is covered uniformly by evergreen and mixed forest (a and b); central group is unique in having grassland-forest mosaic (e and f); littoral habitats are severely affected by tsunami (c and d); groves or plantations comprise of rubber, plantain (g and h), coconut, areca nut and other cash crops.

the avifauna throughout and outside sampling to maximise the detections and record bird species to prepare island-wise bird list. Additional exploratory surveys starting from camping sites to island interiors were conducted to make the most of the field days and to record rare and vagrant species. Attempts were made during twilight and night hours to detect and document the bird groups with nocturnal habits such as owls in areas adjacent to the camps. Birds were identified in the field itself, except for few species which were photographed to ascertain their identity later using literature. Field guide by Kazmierczak and Perlo (2000) was used for the field identification of bird species recorded from the region.

### 3.2.2 Habitat attributes

For each point counts, GPS locations, elevation and site attributes were recorded along with visual estimation of approximate maximum canopy cover and height. During second year of the study, approximate distance to four nearest neighbour trees located in four directions from the spot of point sampling (to estimate tree density) and microhabitat attributes such as temperature and humidity were recorded for each point count station as additional habitat variables.

### 3.2.3 Effect of tsunami on Nicobar Megapode

Since Nicobar Megapode was one of the most severely affected species by tsunami, surveys were carried out between January 2009 and August 2011 in 15 islands with an objective of assessing post-tsunami status of Nicobar Megapode. Eight islands in the southern group and seven in the central group 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 pressure. Sivakumar (2007) catogorised 687 km coastal line of islands as (a) potential habitat (328 km) and (b) Non-conducive habitat (359 km) for megapodes. A total of 73 km coastline habitats in 44 sites of 15 islands with previously known distribution of megapodes were surveyed during this study. Direct sighting of the species, calls and the presence of its mounds were recorded. Surveys were done mostly from 0600 hrs to 1130hrs.

Mounds of megapode were characterised into three types: built independently of any tree (Type A), built around the buttress of a growing tree (Type B) and built around base of tree stump or a fallen log (Type C; Sankaran 1995, Sivakumar 2000). Mounds were considered active if the soil was loose and there were signs of recent digging by megapodes, and regarded as abandoned if the mound were 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). Distance of mounds from sea-coast, canopy cover (%) and height over the mounds were estimated visually. GPS locations and elevations of mounds were noted. 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: $(1/3)\prod r^{2}h$, where ‘r’ is the radius and ‘h’ the height.

### 3.2.4 Data analyses

Relative abundance of a species decides its significance in an assemblage (Magurran 2004). Many models have been proposed to describe species-abundance relationships of which major ones are geometric, log series, truncated log normal and broken stick models (Henderson and Seaby 2001). As species diversity is studied in relation to the four major abundance models, the abundance data was fitted to any of these models prior to estimating indices of diversity in order to understand overall community patterns (Renner 2003, Magurran 2004). Software Species Diversity and Richness (version 2.65; Henderson and Seaby 2001) was used to find best-fit curve for species-abundance data among four major models of species-abundance distributions. The software computes the expected number of species in each abundance level from the observed abundance and tests for the significant difference between them. A significant difference discards the abundance model in consideration (Henderson and Seaby 2001).

Rank abundance curves were plotted for habitats and island groups to display species abundance distributions and to visualise differences in evenness among assemblages. Assemblages with high dominance will show steep plots (as in geometric or log series distribution) while assemblages with higher evenness will show shallow slopes (as in log-normal distributions) (Magurran 2004).

Software EstimateS (version 9.1.0) was used to estimate total species richness from the observed richness, and to plot species accumulation curves, employing non-parametric estimators namely Chao 2 and Jacknife 2 (Colwell 2013).

The software Species Diversity and Richness was also used to calculate different diversity indices and test for significant differences in measured diversity between island groups and habitats. The widely used diversity indices such as Simpsons and Fisher's alpha were calculated for each habitats and island groups. According to Magurran (2004), Simpson index is one of the most important and robust measures of diversity which reflects the variance of species abundance distributions. Fisher's alpha is a robust and parametric measure of diversity which has been widely applied to log-series abundance distribution patterns and is unaffected by sample size (Magurran 2004). Equitability or evenness index measures the similarities of abundance distributions of different species (Magurran 2004). Equitability J index provide comparison of Shannon-Wiener index with the distribution of individuals in the observed species which would have the maximum diversity (Henderson and Seaby 2001).

Kruskal Wallis test was used to find significant difference in total number of species and individuals per point counts among the four habitats and three island groups. Mann-Whitney U test was used to detect significant difference of total number of species and individuals per point counts between any of the two habitats and island groups.

To find the bird-habitat relationships, Pearson correlation analyses were done between total number of species and individuals per point counts against habitat and microclimatic variables namely, approximate maximum canopy cover, canopy height, tree density, temperature and humidity. The tree density was calculated by equation, $A/d^2$, where 'A' is the basal area unit, i.e. 1 $m^2$ and 'd' is the average distance (m) to the four nearest neighbour trees in each point count. Temperature and humidity were measured using a hygro-thermometre.

All species observed, i.e. including the species opportunistically recorded outside the point count sampling (N= 112), was used to find total number of species exclusive and shared among island groups and habitats, and also to calculate the number of species in each avian taxonomic order and family.

A checklist of birds sighted during the present study along with historic records and published records from the region (Abdulali 1964, 1965, 1967a, 1967b, 1971, 1978 and 1981, Dasgupta 1976, Daniels et al. 1997, Sankaran 1998, Sivakumar and Sankaran 2002) that has been reviewed in Kazmierczak and Perlo (2000), and Rasmussen and Anderton (2005) is presented in Appendix 6. Breeding or wintering status follows Kazmierczak (2000) and classification of birds follows BirdLife International (2012).

## 3.3 RESULTS

A total of 112 species of birds were recorded during the study period (Appendix 3). Out of the total species recorded, there were 59 native residents, 43 migrants and two introduced species. Eight species were of uncertain status which includes isolated record(s) of species new to the Nicobars.

### 3.3.1 Taxonomic composition of birds of the Nicobars

Analyses of taxonomic composition (Fig. 3.2; Table 3.1) showed that avifauna of the Nicobars comprised of 39 families in 14 orders. Passeriformes was the most species-rich order of birds (37 species; 33% of all orders), followed by Charadriiformes (19 species; 17%), Ciconiiformes (12 species; 10.7%), Falconiformes (11 species; 9.8%), Columbiformes (7 species; 6.3%) and Coraciiformes (6 species; 5.4%). Psittaciformes and Galliformes were represented by only two species, while Anseriformes and Pelecaniformes comprised of single species. Ardeidae was the most abundant family (12 species; 10.7%), followed by Accipitridae (10 species; 8.9%), Scolopacidae (9 species; 8%) and Columbidae (7 species; 6.3%). Nine families comprised of two species each while 16 families comprised of a single species (Table 3.1).

### 3.3.2 Bird community structure

Number and composition of bird species varied prominently across island groups. Of the total species 112 recorded, the central group was most species-rich (95 species) followed by the southern group (81 species; Fig. 3.3). Car Nicobar Island (the northern group) was poor in species richness (29 species). Twenty six species were commonly found across all the three island groups. Sixty five species were shared between southern and central group, while almost all the species found in northern group occurred in other two groups. Number of species exclusively found in central group (28 species) was higher than that of the southern group (16 species; Fig. 3.3).

Of the total 112 species recorded, 91 species were encountered during the point count sampling. A total of 10,338 individuals were recorded from 1244 point counts conducted in 64 different locations of the 17 islands of the Nicobars (Table 3.2; Appendix 1).

From a total of 528 point counts, littoral habitat was found to harbour the largest number of species (82) and individuals (4888). From 539 point counts, forest showed a similar number of individuals in comparison to littoral habitat (4369 individuals) but with a less species

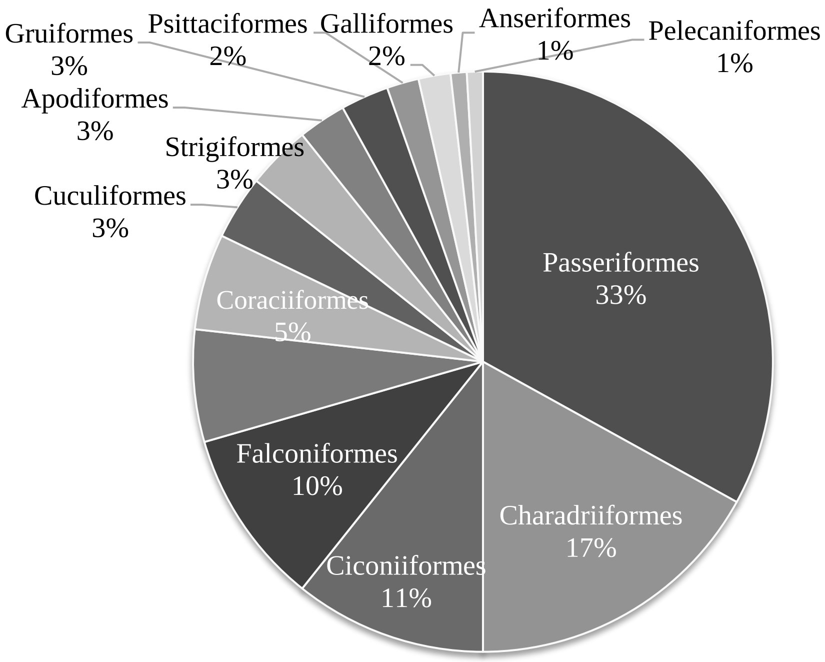

Fig 3.2. The proportion of bird species in different taxonomic orders in the Nicobars (N= 112).

number (50). Grassland-scrub habitat (559 individuals of 30 species from 110 counts) and grove (522 individuals of 31 species from 67 counts) were less diverse. Littoral habitat harboured the highest number of species exclusive to the habitat (34 species; Fig.3.4), and most of them were water-dependent species. Number of habitat specialist in forest and grassland-scrub habitat was few (5 and 3 respectively). In all, 18 species that were commonly found in all the habitats (Fig. 3.4) were wide-ranging generalist species.

The most abundant 15 bird species of each habitat is presented in Figures 3.5-3.8. Green Imperial-pigeon *Ducula aenea* was exceptionally abundant and widespread in forest followed by Nicobar Bulbul (a central group endemic). Olive-backed Sunbird *Nectarinia jugularis*, Asian Glossy Starling *Aplonis panayensis* and Oriental White-eye *Zosterops palpebrosus* constituted the most abundant species in the tsunami-affected littoral habitat (Fig. 3.6). All these three species were found feeding on nectar or fruits of the regenerating plants in the littoral habitat and were likely aided in pollination and dispersal. The three species were abundant or fairly common in other habitats also. Introduced Red-whiskered Bulbul *Pycnonotus jocosus whistleri* was found to be more abundant in littoral habitat than the Nicobars Bulbul *Hypsipetes nicobariensis* which was one of very abundant species in the forest. Asian Glossy Starling *Aplonis panayensis*, Long-tailed Parakeet *Psittacula longicauda*

Table 3.1. Number and proportion of species representing different bird families in the Nicobars.

| SI No. | Family | No. of Species | % |
|---|---|---|---|
| 1 | Ardeidae | 12 | 10.7 |
| 2 | Accipitridae | 10 | 8.9 |
| 3 | Scolopacidae | 9 | 8.0 |
| 4 | Columbidae | 7 | 6.3 |
| 5 | Charadriidae | 6 | 5.4 |
| 6 | Alcedinidae | 5 | 4.5 |
| 7 | Cuculidae | 4 | 3.6 |
| 8 | Motacillidae | 4 | 3.6 |
| 9 | Muscicapidae | 4 | 3.6 |
| 10 | Strigidae | 4 | 3.6 |
| 11 | Sturnidae | 4 | 3.6 |
| 12 | Apodidae | 3 | 2.7 |
| 13 | Dicruridae | 3 | 2.7 |
| 14 | Sylviidae | 3 | 2.7 |
| 15 | Psittacidae | 2 | 1.8 |
| 16 | Campephagidae | 2 | 1.8 |
| 17 | Hirundinidae | 2 | 1.8 |
| 18 | Laniidae | 2 | 1.8 |
| 19 | Laridae | 2 | 1.8 |
| 20 | Monarchidae | 2 | 1.8 |
| 21 | Nectariniidae | 2 | 1.8 |
| 22 | Pycnonotidae | 2 | 1.8 |
| 23 | Rallidae | 2 | 1.8 |
| 24 | Anatidae | 1 | 0.9 |
| 25 | Corvidae | 1 | 0.9 |
| 26 | Dromadidae | 1 | 0.9 |
| 27 | Emberizidae | 1 | 0.9 |
| 28 | Estrildidae | 1 | 0.9 |
| 29 | Falconidae | 1 | 0.9 |
| 30 | Glareolidae | 1 | 0.9 |
| 31 | Megapodiidae | 1 | 0.9 |
| 32 | Meropidae | 1 | 0.9 |
| 33 | Oriolidae | 1 | 0.9 |
| 34 | Phaethontidae | 1 | 0.9 |
| 35 | Phasianidae | 1 | 0.9 |
| 36 | Pittidae | 1 | 0.9 |
| 37 | Turdidae | 1 | 0.9 |
| 38 | Turnicidae | 1 | 0.9 |
| 39 | Zosteropidae | 1 | 0.9 |
|  | **Total =** | **112** |  |

and Hill Myna *Gracula religiosa* were the three hole-nesters that benefitted from innumerable dead standing trees along the coast which they used for perching and nesting. Though Hill Myna was fairly common in Great Nicobar, it was very rare in the central group. Abundant species found in the littoral habitat consisted largely of frugivores, a few insectivores and nectarivores.

Daniels et al. (1997), in a study in Great Nicobar Island, also found Long-tailed Parakeet, Asian Glossy Starling, Green Imperial-pigeon, Olive-backed Sunbird as the most widespread species along with Hill Myna, Andaman Cuckoo-dove *Macropygia rufipennis*, Racket-tailed Drongo *Dicrurus paradiseus* and Pompadour Green-pigeon *Treron pompadora*.

Mean total number of species and individuals per point counts was highest in forest and littoral habitat and least in grassland-scrub habitat (Table 3.2). Mean total number of species and individuals per point counts was highly varied among point counts (Table 3.2), in much

Table 3.2. Total number of point counts, and species and individuals encountered per count in the island groups and major habitats in the Nicobars.

| | **Point counts** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Total counts** | **Species in counts** | **Total individuals** | **Species per count** | | | | **Individuals per count** | | | |
| | | | | Mean | SD | Max | Min | Mean | SD | Max | Min |
| ***Island groups*** | | | | | | | | | | | |
| Northern group | 39 | 26 | 633 | 5.21 | 1.58 | 10 | 2 | 16.2 | 11.7 | 62 | 3 |
| Central group | 852 | 78 | 7450 | 4.43 | 2.08 | 12 | 0 | 5.4 | 5.4 | 49 | 0 |
| Southern group | 353 | 51 | 2255 | 3.17 | 1.94 | 13 | 0 | 6.4 | 6.4 | 38 | 0 |
| ***Habitats*** | | | | | | | | | | | |
| Forest | 539 | 50 | 4369 | 4.55 | 1.97 | 13 | 0 | 8.1 | 4.4 | 34 | 0 |
| Littoral habitat | 528 | 82 | 4888 | 4.05 | 2.22 | 11 | 0 | 9.3 | 7.7 | 62 | 0 |
| Grassland-scrub | 110 | 30 | 559 | 2.38 | 1.54 | 8 | 0 | 5.1 | 5.2 | 32 | 0 |
| Grove | 67 | 31 | 522 | 3.69 | 1.66 | 8 | 1 | 7.8 | 5.6 | 38 | 1 |

Table 3.3. Total number of point counts, and species observed during the systematic counts and during the entire study period.

| Island groups | Islands | Island area (km$^2$) | No. of point counts | No. of species in counts | Total species |
|---|---|---|---|---|---|
| Southern | Great Nicobar | 1045.1 | 125 | 37 | 72 |
| | Cubra | 0.04 | 7 | 6 | 6 |
| | Kondul | 4.6 | 24 | 17 | 26 |
| | Little Nicobar | 159.1 | 95 | 38 | 51 |
| | Pilo Milo | 1.3 | 25 | 20 | 25 |
| | Menchal | 0.7 | 33 | 18 | 22 |
| | Treis | 0.4 | 26 | 21 | 25 |
| | Meroe | 1.4 | 18 | 11 | 21 |
| Central | Kamorta | 188.2 | 181 | 54 | 70 |
| | Nancowry | 66.9 | 96 | 39 | 55 |
| | Trinket | 36.3 | 117 | 45 | 61 |
| | Katchal | 174.4 | 155 | 42 | 64 |
| | Teressa | 101.4 | 141 | 36 | 45 |
| | Bompoka | 13.3 | 92 | 27 | 36 |
| | Chowra | 8.2 | 31 | 25 | 33 |
| | Tillanchong | 16.82 | 39 | 13 | 23 |
| Northern | Car Nicobar | 126.9 | 39 | 26 | 29 |

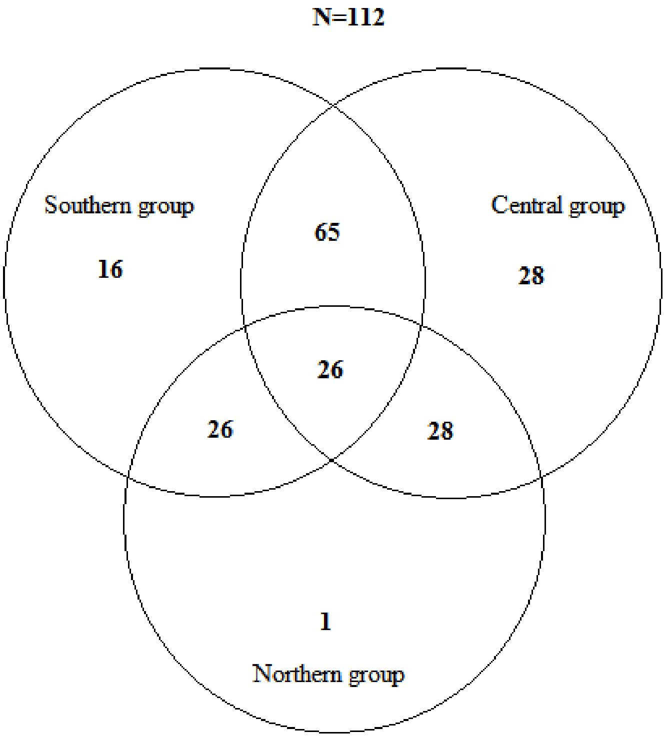

Fig. 3.3. Venn diagram of number of species recorded during the study from the Nicobar Islands showing exclusive and shared species among island groups.

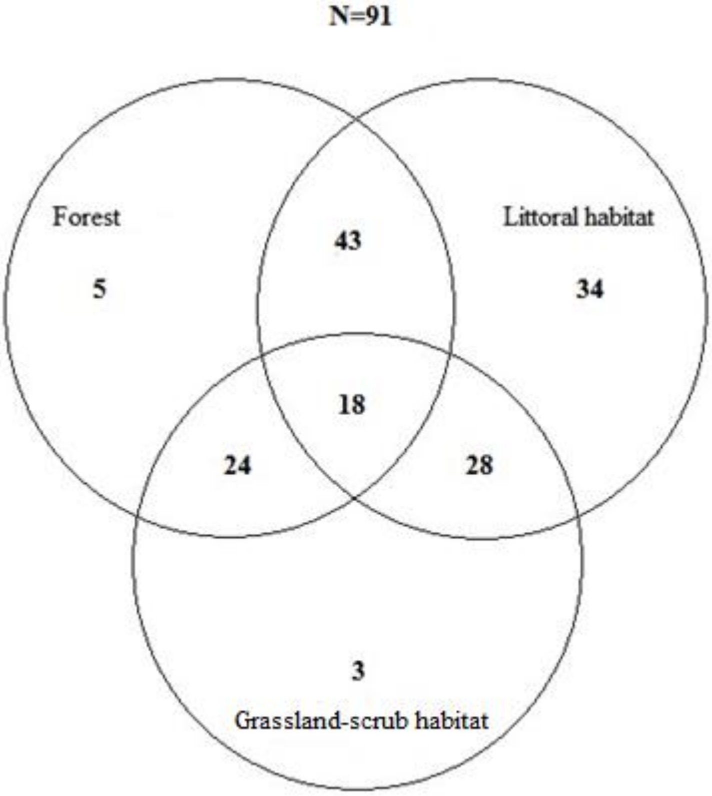

Fig. 3.4. Venn diagram of number of species recorded in the systematic study during point counts that were common and exclusive to the three habitats in the Nicobar Islands.

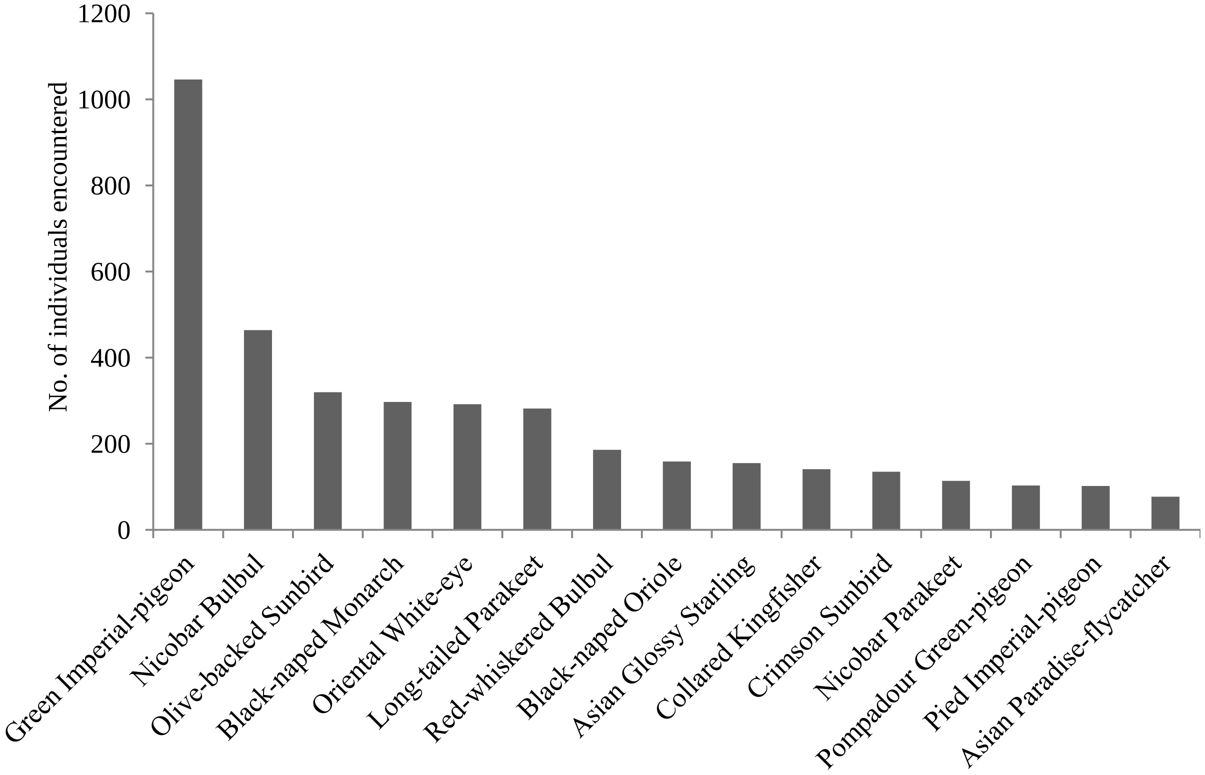

Fig. 3.5. Highly abundant bird species in forest (top 15).

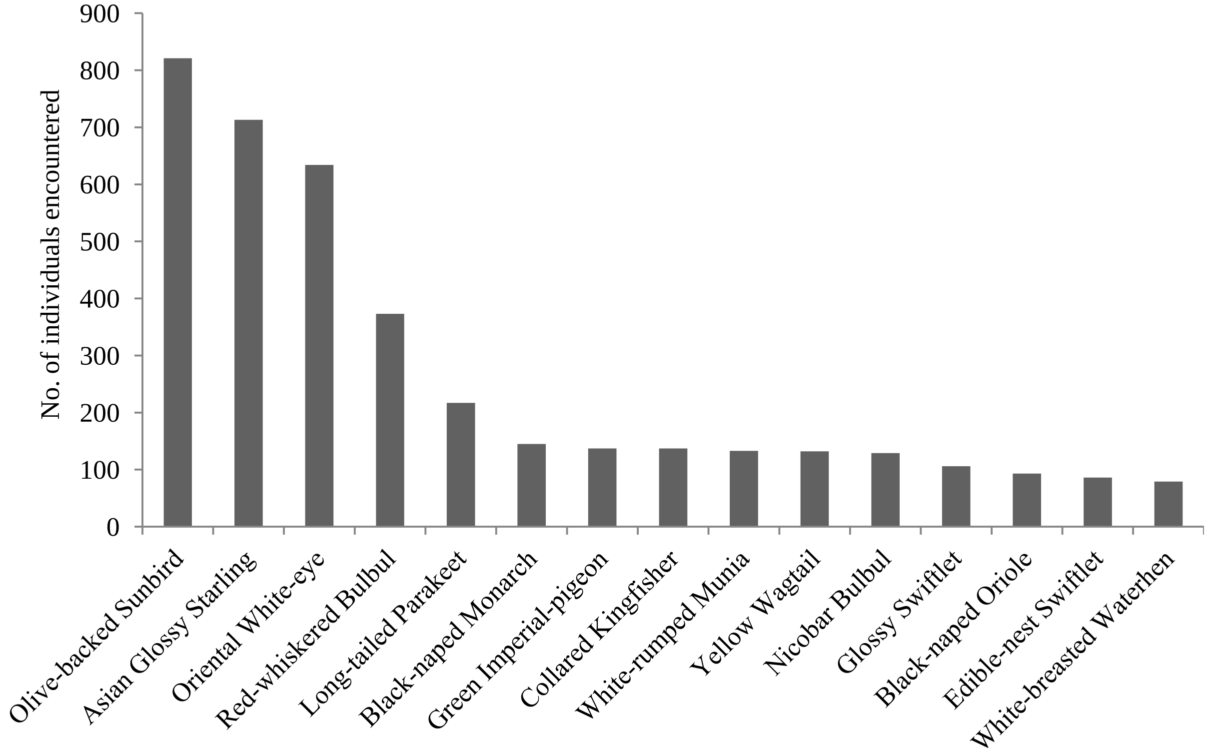

Fig. 3.6. Highly abundant bird species in littoral habitat (top 15).

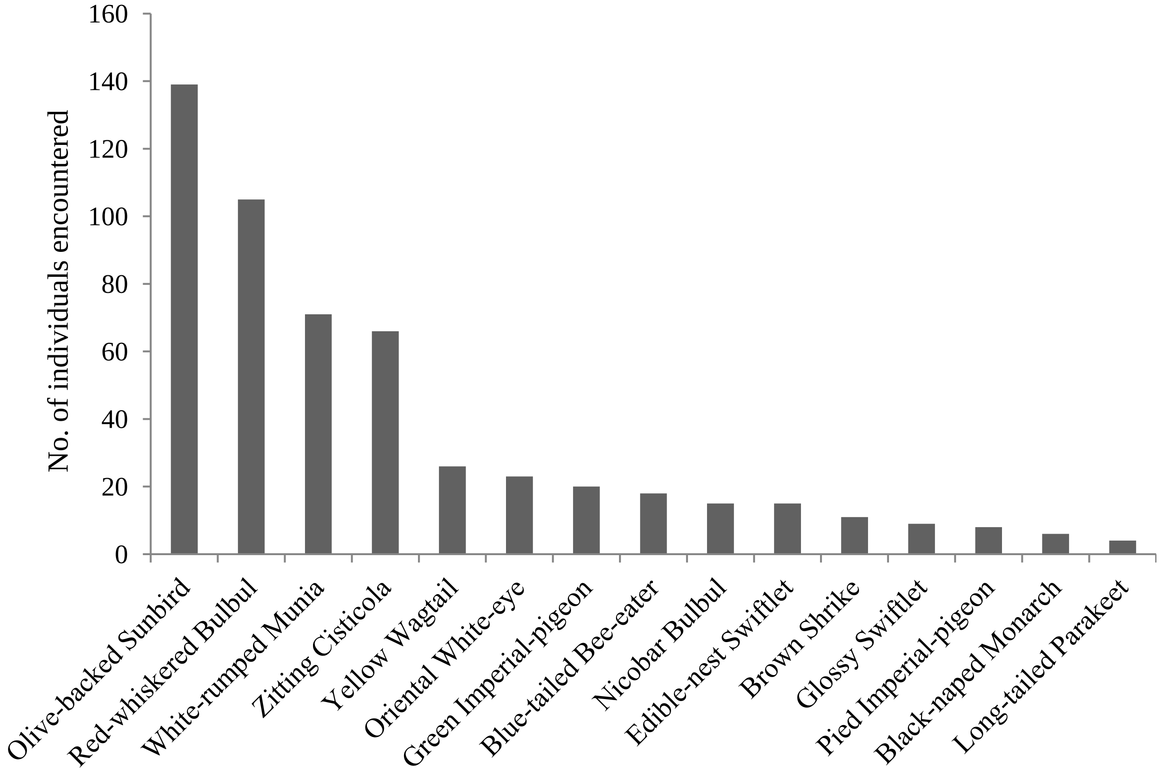

Fig. 3.7 Highly abundant bird species in grassland-scrub habitat (top 15).

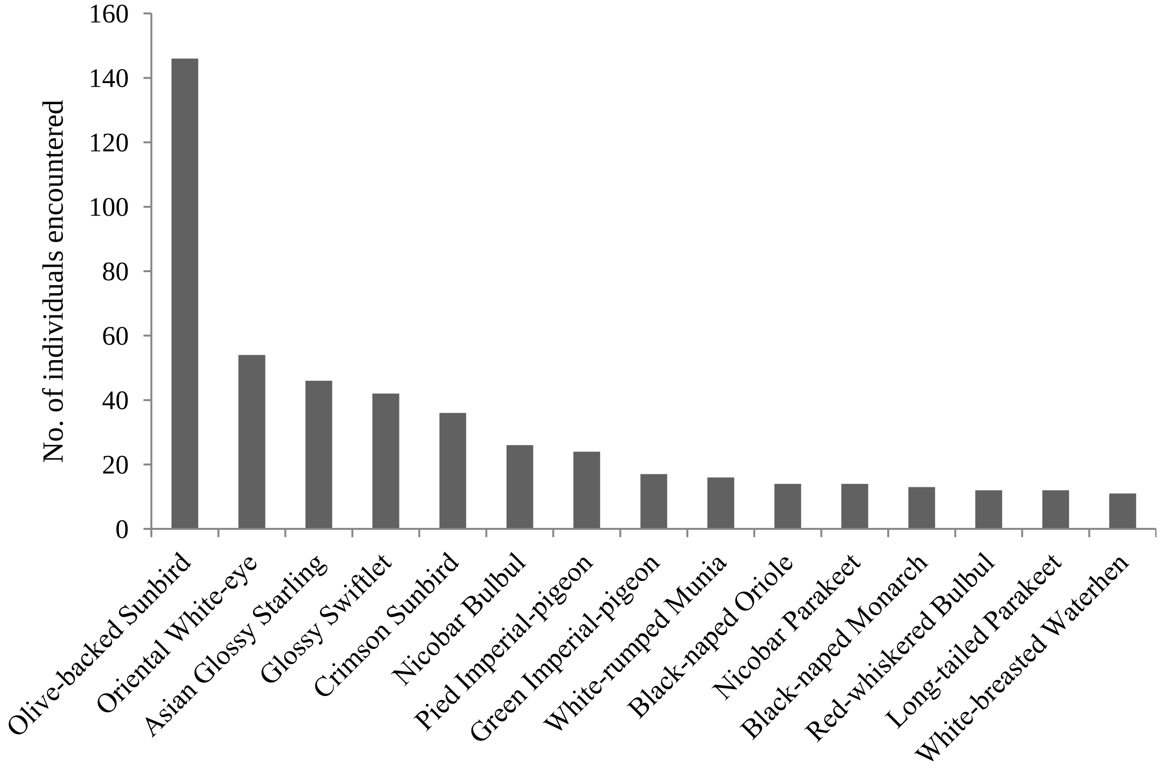

Fig. 3.8. Highly abundant bird species in grove (top 15).

populated and disturbed Car Nicobar (which represent the northern group) probably because of small number of point counts carried out and due to high incidence of generalist found in congregations in certain counts.

The total number of species per point count is significantly different among the four habitats (Kruskal Wallis test; $\chi^2 = 113.03$; $p = 0.0001$; df = 3) and the three island groups (Kruskal Wallis test; $\chi^2 = 108.40$; $p = 0.0001$; df = 2). Mann-Whitney U test also found a significant difference between the total number of species per point counts between all the habitat classes and island groups, except between littoral habitat and grassland-scrub habitat (Mann-Whitney U test; $p = 0.891$).

The total number of species per point count was significantly different among the forest habitats (Kruskal Wallis test; $\chi^2 = 54.88$; $p = 0.0001$; df = 2) and among the littoral habitats (Kruskal Wallis test; $\chi^2 = 108.22$; $p = 0.0001$; df = 2) across the three island groups. This indicates that species richness were not uniform in the similar habitats of different island groups. However, species richness per point count of the forests of the northern and the central group was not significantly different (Mann-Whitney U test; $p = 0.827$).

The total number of individuals per point count was significantly different among the four habitats (Kruskal Wallis test; $\chi^2 = 60.0$; $p = 0.0001$; df = 3) and the three island groups (Kruskal Wallis test; $\chi^2 = 119.31$; $p = 0.0001$; df = 2). Mann-Whitney U test found a significant difference between the total number of individuals per point counts between all the habitat classes and island groups, except between forest and littoral habitat (Mann-Whitney U test; $p = 0.755$), between littoral habitat and grove ($p = 0.251$) and between forest and grove ($p = 0.166$).

The total number of individuals per point count was significantly different among the forest habitats ($\chi^2 = 101.0$; $p = 0.0001$; df = 2) across the three islands groups. Similarly, it was different among the littoral habitats ($\chi^2 = 69.48$; $p = 0.0001$; df = 2) of the island groups. This indicates that species were not equally abundant in the similar habitats of different island groups.

#### 3.3.2.1 Species-abundance distributions

Out of the four major species-abundance models, the species-abundance data (for the entire Nicobars, each island group and habitat) of the present study followed both log-series and truncated log-normal distribution models. Only results for the latter model are presented (Fig. 3.9 and Table 3.4) which show that there is no significant difference in observed and expected number of species at each abundance class. For the entire Nicobars, 30.8% of birds were rare with less than four individuals per species and 17.5% of birds were having 4-10 individuals. Twenty one species (23%) were abundant having >100 individuals per species. The analyses rejected both geometric and broken stick models for the abundance data for the entire Nicobar, island groups and habitats.

#### 3.3.2.2 Species accumulation curves

The species accumulation curve for the entire Nicobars seems to have approached an asymptote with a total of 1244 point counts (Fig. 3.10). The species accumulation curves for different island groups are shown separately in Fig. 3.11- Fig. 3.13. Bird species diversity estimates based on non-parametric estimators calculated with point count sampling data are shown in Table 3.5.

The curves for observed species are slightly below the estimated species richness indicating that increasing effort could yield more species. However, this was very obvious from the fact that the total number of species found during point counts was lower (91 species) than the total number of species recorded throughout the study period (112 species) which include the species encountered outside the sampling. Thus, having almost ‘known’ the overall species richness in the Nicobars, this could be used to examine how reliably the non-parametric estimators predict the species richness. The estimation of second order Jackknife was found to be reliable, which predicted total species richness of the Nicobars to be 115 (Table 3.5). Second order Chao predicted 104 species.

The estimated species richness using point count data by the second order Jackknife for the central group was 103 (overall total species recorded for the group was 95 species). The Jackknife predicted 36 species for the northern group (overall species observed was 29 species) (Table 3.5). Both the estimators underestimated the number of species in the southern group (i.e. predicted species richness using point count sampling data was well below the overall species found throughout the study including opportunistic detections which was 81 species). The central group had the more number of singletons (i.e. rare species with a single detection) and doubletons (i.e. rare species with only two detections) than other groups. Grassland-scrub habitat had higher number of singletons while forest and littoral habitat had higher number of doubletons (Table 3.5).

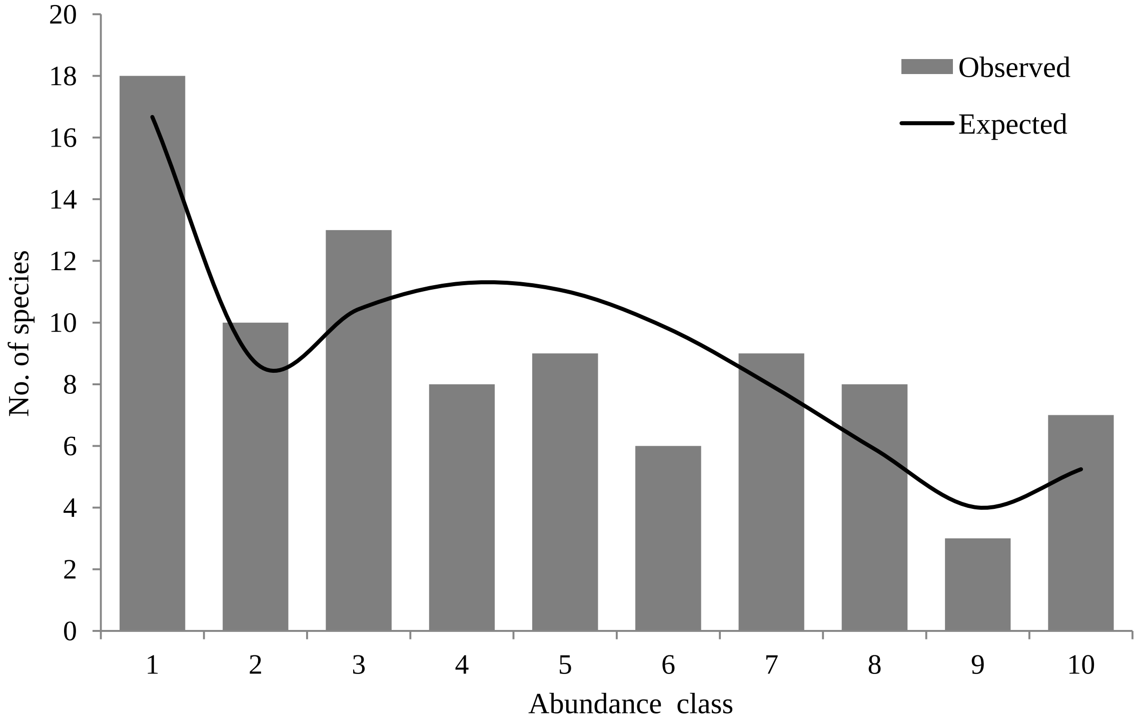

Fig. 3.9. Bird species-abundance distribution patterns in the Nicobars. The data fitted to truncated lognormal model shows no significant difference in observed and expected number of species at each abundance class ($\chi^2 = 5.454$; $p = 0.79$; df = 9).

Table 3.4. Summary of data fitted to truncated lognormal model showing observed, expected and missing species number of species along with Chi squared test of differences.

| | **Species** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Observed** | **Expected** | **Missing** | $\chi^2$ | ***p*** | **df** | **Lamda statistics*** |
| Nicobars | 91 | 100.0 | 9.0 | 5.454 | 0.79 | 9 | 98.4 |
| ***Island groups*** | | | | | | | |
| Northern group | 26 | 27.9 | 1.9 | 4.932 | 0.42 | 5 | 37.0 |
| Central group | 78 | 88.1 | 10.1 | 2.821 | 0.95 | 8 | 85.5 |
| Southern group | 51 | 54.2 | 3.2 | 5.447 | 0.61 | 7 | 67.6 |
| ***Habitats*** | | | | | | | |
| Forest | 50 | 56.0 | 6.0 | 9.988 | 0.27 | 8 | 53.0 |
| Littoral habitat | 82 | 87.8 | 6.0 | 6.956 | 0.54 | 8 | 102.5 |
| Grassland-scrub | 30 | 41.8 | 11.8 | 1.856 | 0.76 | 4 | 42.6 |
| Grove | 31 | 33.8 | 2.8 | 4.857 | 0.43 | 5 | 46.8 |

*Lambda the diversity statistics= the estimated species number divided by the standard deviation.

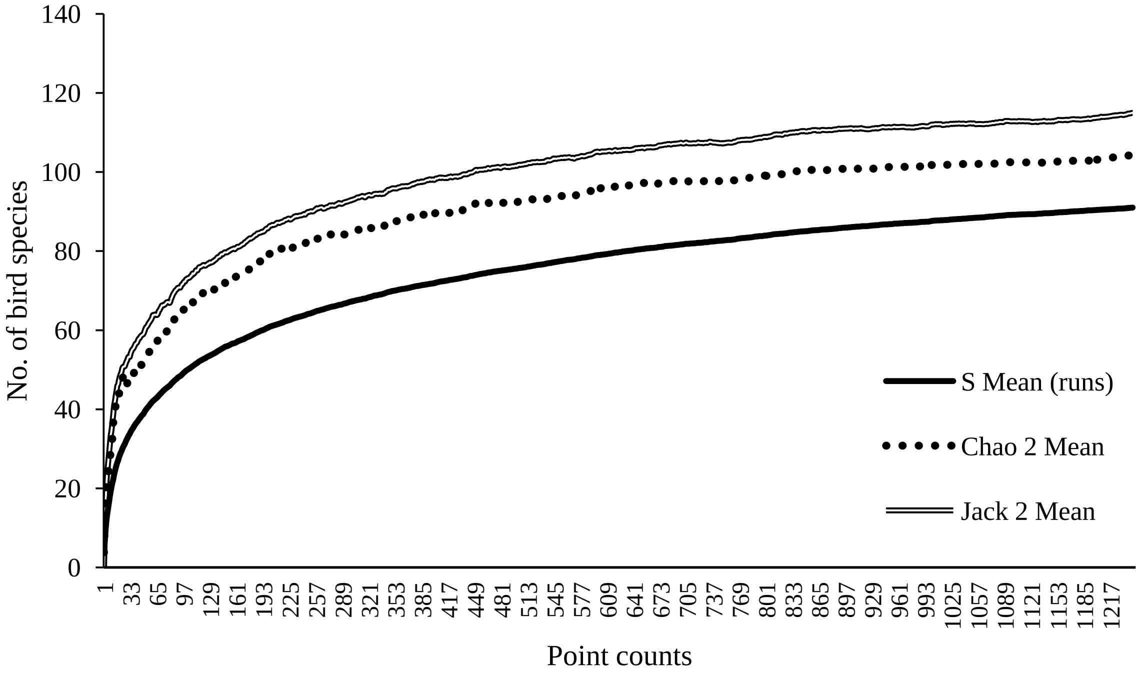

Fig. 3.10. Species accumulation curve of all point counts in the Nicobars.

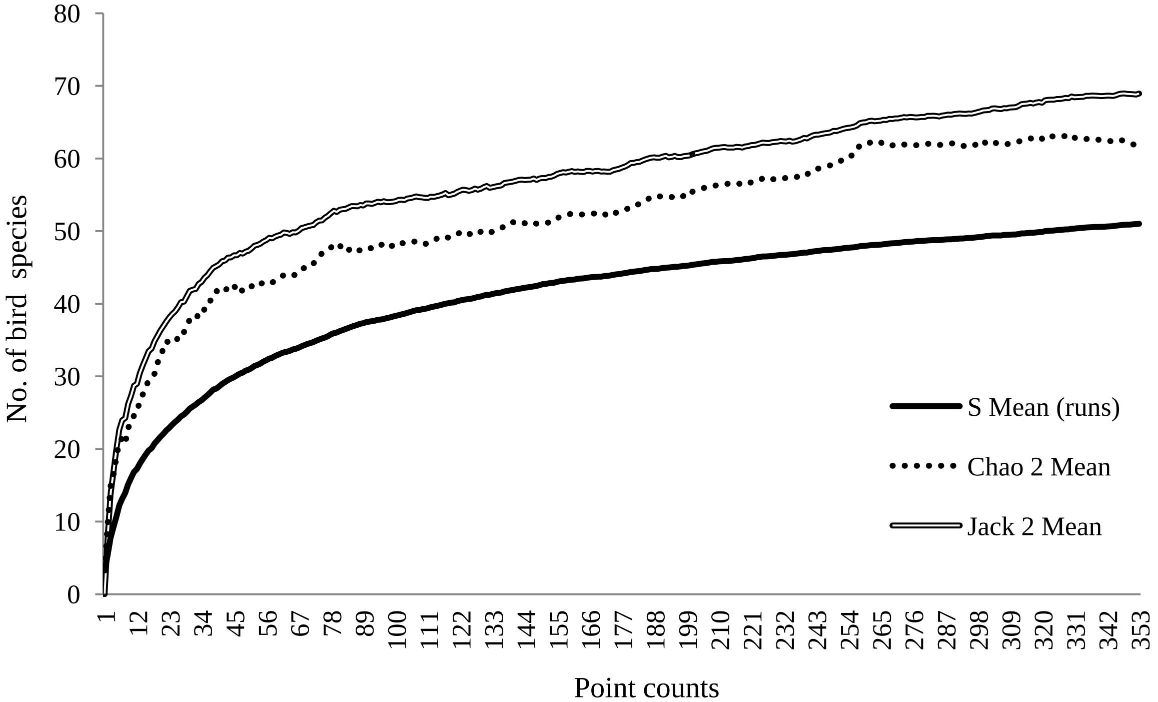

Fig. 3.11. Species accumulation curve of point counts in the southern group.

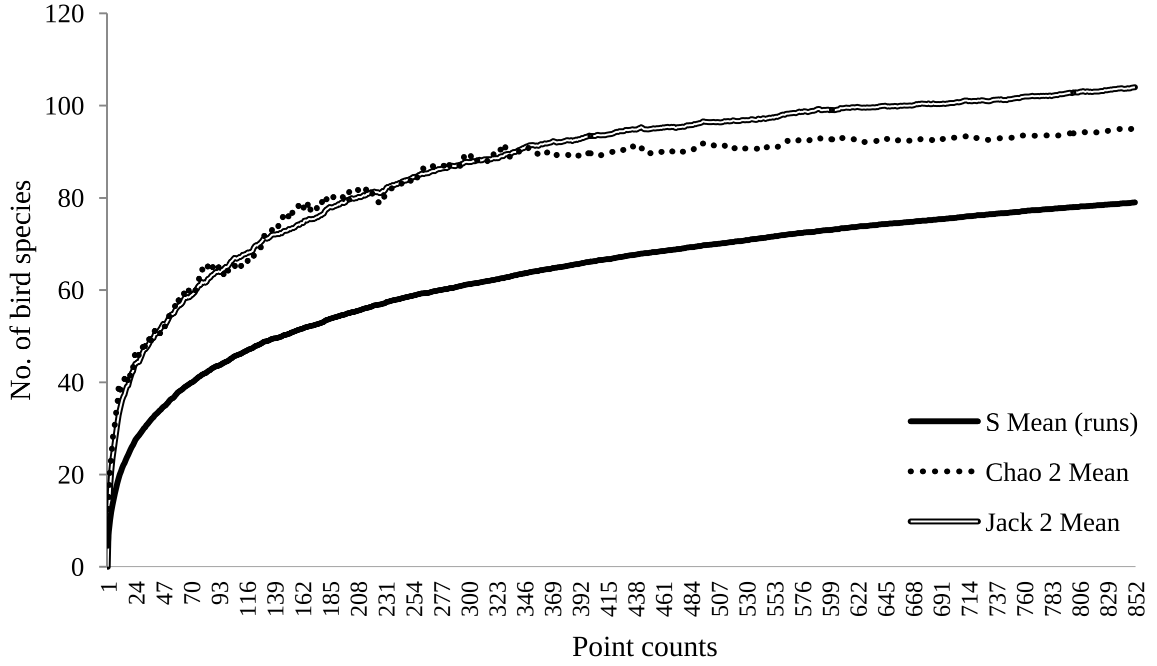

Fig. 3.12. Species accumulation curve of point counts in the central group.

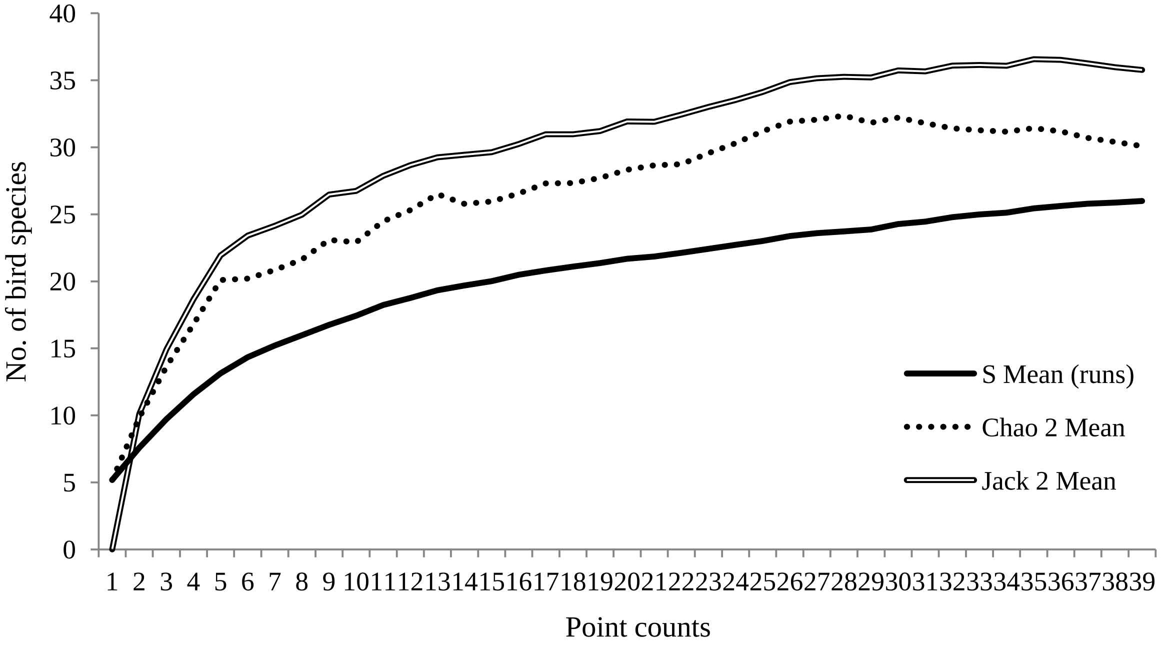

Fig. 3.13. Species accumulation curve of point counts in the northern group (Car Nicobar Island).

Table 3.5. Bird species diversity estimates based on non-parametric estimators calculated with point count sampling data.

| | **$S_{obs}$** | **Singletons** | **Doubletons** | **Chao-2** | **Jackknife-2** |
|---|---|---|---|---|---|
| Nicobars | 91 | 9 | 9 | 104.32 ± 8.84 | 114.98 |
| ***Island groups*** | | | | | |
| Northern | 39 | 4 | 4 | 30.09 ± 4.24 | 35.77 |
| Central | 78 | 9 | 9 | 95.04 ± 10.25 | 103.97 |
| Southern | 51 | 6 | 2 | 61.97 ± 8.86 | 68.94 |
| ***Habitats*** | | | | | |
| Forest | 50 | 7 | 8 | 62.08 ±9.71 | 66.97 |
| Littoral habitat | 82 | 8 | 8 | 97.97 ±9.97 | 107.95 |
| Grassland-scrub | 30 | 10 | 3 | 41.99 ± 9.64 | 46.84 |
| Grove | 31 | 7 | 3 | 38.88 ± 7.38 | 42.82 |

$S_{obs}$ indicates the species observed.

### 3.3.2.3 Species diversity

All diversity indices (Simpson, Fisher's alpha) showed higher diversity for the central group than the southern and the northern group. Similarly, all indices yielded significantly higher diversity values for littoral habitat than forest. Grove was the least diverse of all the habitats (Table 3.6).

The randomisation test (Henderson and Seaby 2001) between diversity measures showed that most of the habitat pairs and all island group pairs were significantly different in diversity attributes, except between grassland-scrub habitat and grove (Table 3.7). Fisher's alpha index was also not significantly different between forest and grove.

### 3.3.2.4 Evenness

Equitability or evenness was significantly different across all island groups and habitats, except between grassland-scrub habitat and grove (Table 3.6 and 3.7). The rank-abundance curve of island groups depicts that the central group is more even than southern and northern group (Fig. 3.14). The rank-abundance curve of the habitats shows that littoral habitat is more even than forest (Figures 3.14 and 3.15). Grassland-scrub habitat and grove were highly uneven. A shallow slope for the littoral habitat indicates comparatively even distribution of individuals among species. In both grassland-scrub habitat and grove, a steep slope indicates that few abundant species dominate the bird community (Fig. 3.15).

### 3.3.2.5 Similarities in species composition

The cluster analysis among different habitats depicted that grassland-scrub habitat and grove were more similar in species composition than forest (Fig. 3.16). It also indicated that littoral habitat was very distinct in species composition.

### 3.3.2.6 Bird-habitat relationships

The results of correlation analyses of the total number of species and individuals per point counts with habitat and microclimatic variables are shown in Table 3.8. The number of species per count in forest, littoral habitat and grove was significantly correlated only with a single microhabitat attribute, i.e. temperature, and there were no relationships with maximum canopy cover, canopy height and tree density. However, in littoral habitat, species per count was also correlated significantly with humidity.

The number of individuals per count in forest was related with elevation; in littoral habitat it was significantly correlated with canopy cover, tree density and humidity; in grove it was significantly related only with tree density. In grassland-scrub habitat, both species and individuals per count were not related with any of the variables measured.

### 3.3.2.7 Endemic birds of the Nicobar Islands

Six bird species are endemic to the Nicobar Islands, and four restricted-range species are shared with the Andaman Islands. Three of the endemic species are globally threatened (Nicobar Sparrowhawk *Accipiter butleri*, Nicobar Megapode *Megapodius nicobariensis* and Nicobar Bulbul *Hypsipetes nicobariensis*), two endemics are near-threatened (Sykes 2005; South Nicobar Serpent-eagle *Spilornis klossi* and Nicobar Parakeet *Psittacula caniceps* which are confined to the southern group) and one is a data deficient species (Nicobar Scops-owl *Otus alius*; Rasmussen 1998). Relative abundance of five species exclusively endemic to the Nicobars in different habitats is shown in Fig. 3.14 and Appendix 1. Nicobar Scops-owl was not recorded during the study. Nicobar Bulbul constituted the most abundant endemic threatened species in forest and littoral habitat.

It seems that loss of coastal habitats have not significantly influenced the currently existing population of endemic bird species except the Nicobar Megapode. Most of the endemics, except Nicobar Megapode, are currently found in the suitable habitats that are distributed

Table 3.6. The bird community characteristics depicted by various indices in the island groups and major habitats in the Nicobars.

| | No. of species | Individuals | Simpsons D | Equitability J | Fisher's alpha |
|---|---|---|---|---|---|
| Nicobars | 91 | 10338 | 14.855 | 0.6995 | 13.740 |
| ***Island groups*** | | | | | |
| Northern | 26 | 633 | 7.088 | 0.7342 | 5.460 |
| Central | 78 | 7450 | 12.495 | 0.6823 | 12.150 |
| Southern | 51 | 2255 | 9.076 | 0.7055 | 9.277 |
| ***Habitats*** | | | | | |
| Forest | 50 | 4369 | 10.367 | 0.7206 | 7.918 |
| Littoral habitat | 82 | 4888 | 12.287 | 0.7020 | 14.000 |
| Grassland-scrub | 30 | 559 | 7.439 | 0.7051 | 6.781 |
| Grove | 31 | 522 | 8.553 | 0.7650 | 7.218 |

Table 3.7. Results of tests for detecting significant difference between diversity indices calculated for different island groups and habitats using the software Species Diversity and Richness.

| | Simpsons D | Equitability J | Fisher's alpha |
|---|---|---|---|
| ***Between island groups*** | | | |
| Central & Northern | C > N ($p<0.05$) | C > N ($p<0.05$) | C > N ($p<0.05$) |
| Central & Southern | C > S ($p<0.05$) | C > S ($p<0.05$) | C > S ($p<0.05$) |
| Southern & Northern | S > N ($p<0.05$) | S > N ($p<0.05$) | S > N ($p<0.05$) |
| ***Between habitats*** | | | |
| Littoral habitats & Forest | L > F ($p<0.05$) | L > F ($p<0.05$) | L > F ($p<0.05$) |
| Forest & Grassland-scrub | F > G ($p<0.05$) | F > G ($p<0.05$) | F > G ($p<0.05$) |
| Forest & Grove | F > O ($p<0.05$) | F > O ($p<0.05$) | F = O **($p\geq0.05$)** |
| Littoral habitat & Grassland-scrub | L > G ($p<0.05$) | L > G ($p<0.05$) | L > G ($p<0.05$) |
| Littoral habitat & Grove | L > O ($p<0.05$) | L > O ($p<0.05$) | L > O ($p<0.05$) |
| Grassland-scrub & Grove | G = O **($p\geq0.05$)** | **O > G** ($p<0.05$) | **G = O ($p\geq0.05$)** |

C = Central, S = Southern, and N = Northern groups; F = Forest, L = Littoral habitat, G = Grassland-scrub, O= Grove.

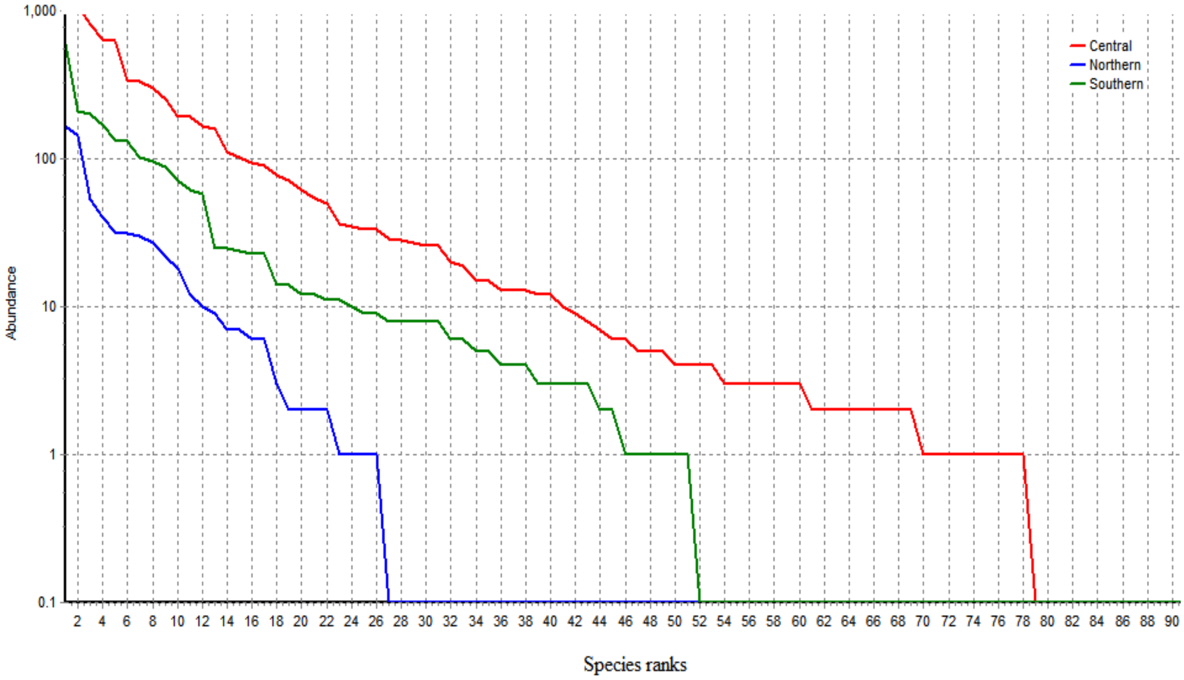

Fig. 3.14. Logarithmic species rank abundance curves of the three island groups of the Nicobars.

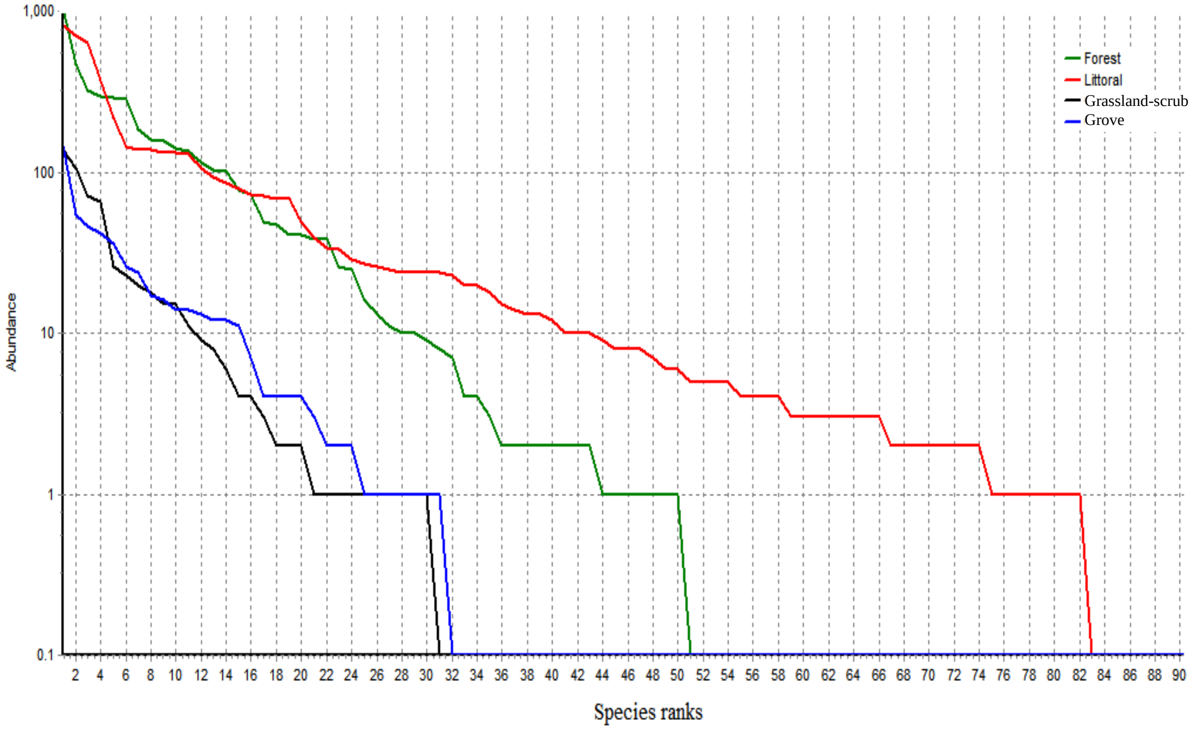

Fig. 3.15. Logarithmic species rank abundance curves of the four habitats in the Nicobars.

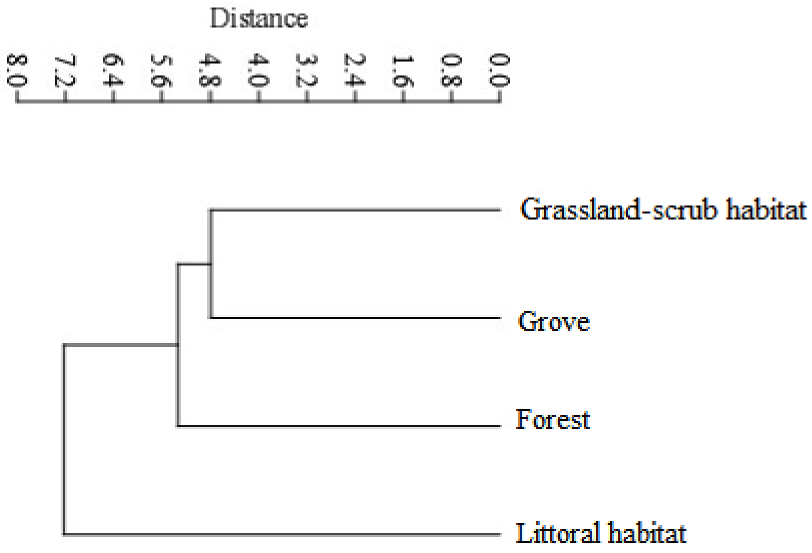

Fig. 3.16 Similarities in bird species composition among habitats depicted using Euclidean index (Cophenetic correlation: 0.959).

throughout the island, which have not been affected by tsunami. These endemics do not seem to have any specific preference to coastal littoral forests.

Since baseline information on few endemics are scarce, details of current distribution, abundance status (total number of detections from 1244 point counts) and observations on habitat and ecology of five endemics are given below.

**1) South Nicobar Serpent-eagle** *Spilornis klossi*

**Local name:** *Sieng*' (southern group), *Kalang ukayak* (central group). **Current distribution:** The population in the central group is sometimes considered as a separate species *Spilornis minimus* (Rasmussen and Anderton 2005). *Spilornis klossi* was recorded from four sites on Great Nicobar (Chinghen Pasthi, Pilo Bakka, Kopenheat and Ayaom Bay), four sites on Little Nicobar (Lanye near Pulo Ulan, Thavai thav, Reing-Reing and Komath), Menchal, Pilo Milo and on Treis Island. Though a *Spilornis* species (probably *S. minimus*) was recorded from Kamorta, Nancowry and Katchal, its specific identity couldn't be confirmed. **Altitudinal range:** 0 - >100m above msl. **IUCN category:** Near Threatened. **Current population status:** uncommon (8 sightings from the central group). **Habitat and ecology:** The species was recorded from mixed, evergreen forests, grassland-scrub and tsunami-affected littoral habitat; occur in coastal and inland areas. A single individual of the species found carrying nesting material on 05 May 2011 on Treis Island.

Table 3.8. Pearson correlation of total number of species and individuals per point counts with habitat and microclimatic variables.

| | **Canopy height** | **Canopy cover** | **Tree density** | **Elevation** | **Temperature** | **Humidity** |
|---|---|---|---|---|---|---|
| ***Forest*** (No. of counts= 269) | | | | | | |
| Species/ count | -0.03 | -0.033 | 0.071 | -0.049 | **-.170**** | 0.054 |
| Individuals/count | 0.042 | -0.055 | 0.05 | **-.147*** | -0.109 | 0.079 |
| ***Littoral*** (No. of counts=180) | | | | | | |
| Species/ count | 0.083 | 0.018 | 0.052 | -0.046 | **-.247**** | **.308**** |
| Individuals/count | 0.119 | **-.287**** | **.152*** | -0.003 | 0.044 | **.243**** |
| ***Grassland –scrub*** (No. of counts=10) | | | | | | |
| Species/ count | 0.184 | 0.264 | 0.229 | -0.276 | 0.264 | -0.208 |
| Individuals/count | 0.569 | 0.436 | -0.022 | -0.561 | -0.157 | 0.201 |
| ***Grove*** (No. of counts=41) | | | | | | |
| Species/ count | -0.03 | 0.02 | 0.26 | -0.18 | **-.364*** | 0.27 |
| Individuals/count | 0.06 | -0.30 | **.601**** | -0.13 | -0.18 | 0.11 |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

### 2) Nicobar Sparrowhawk *Accipiter butleri*

**Local name:** *Misheha* (generally for all Sparrowhawks in the central group). **Current distribution:** Only two sightings from Nancowry Island. The species was not sighted in any of the other islands in the Nicobars during the surveys. An immature bird was found in mixed forest surrounded by grassland near Thapong (N 08º 00' 25.4", E93º 33' 45.2") on 01 Mar 2010. Another individual was sighted in mixed evergreen hill forest near Hindrah (N 07º 58' 16.6", E 93º 31' 37.4") on 05 Jan 2011 about 300m off the coast. **Altitudinal range:** between 60 and 73m above msl (Thapong); 52msl (Hindra). **IUCN category:** Vulnerable. **Current population status:** Rare (only two sightings). **Habitat and ecology:** It seems that the species prefers midstorey. When approached closely, the species was less wary than other Sparrowhawks. Similar behaviour was noted in the other individual too. No calls were heard. Average canopy cover and height at the sites were 67.5% and 22.5m respectively. The species might not have affected by tsunami, since it occurred in mixed hill forests off the coast.

### 3) Nicobar Parakeet *Psittacula caniceps*

**Local name:** *Kariaka-thakaru* or *Kariaka-kafong*. **Current distribution:** Recorded from Great Nicobar, Kondul, Little Nicobar and Menchal. **Altitudinal range:** 6 - 186m above msl. **IUCN category:** Near Threatened. **Current population status:** Common (134 detections). **Habitat and ecology:** The species inhabited mixed and evergreen forest, bamboo clumps. On Menchal Island, it was found in arecanut and coconut groves, and among *Pandanus* clumps. Nicobar Parakeet and the Long-tailed Parakeet were found on the same islands; however, there seems to be ecological segregation. The Nicobar Parakeet was mainly found in interior forests while the Long-tailed Parakeet was a forest edge species. A large congregation of the species was encountered on 16 May 2011 on Menchal Island; the species was seen in a forested landscape dominated by *Rhophalablestis agestata* trees and was feeding on unripe fruits or inflorescence of this species. Nicobar Parakeet was also seen feeding on ripe fruits of *Pandanus*. It was almost absent from the tsunami-affected littoral habitats. The parakeet was largely confined to high canopy (interior) forest in all islands in its distributional range. However, fairly common occurrence of Nicobar Parakeet in coastal and inland coconut plantations of Menchal was interesting. Long-tailed Parakeet, which co-exists with Nicobar Parakeet in all other islands, was either absent or uncommon in Menchal.

# Five endemic bird species of Nicobar Islands

South Nicobar Serpent-eagle ↑
(at Pilo Bakka, Great Nicobar)

Nicobar Sparrowhawk ↑
(near Hindra, Nancowry)

Nicobar Parakeet ♀ ↑
(at Menchal)

Nicobar Parakeet ♂ ↑
(at Menchal)

Nicobar Bulbul ↑
(at Bengali, Teressa)

Nicobar Megapode ↑
(at Atluch, Bompoka)

**4) Nicobar Bulbul** *Hypsipetes nicobariensis*

**Local name:** *Haanch.* **Current distribution:** Sighted from all islands in the central group except Chowra, a coralline island of 8.2 km$^2$. Although not far from Teressa, where this species was common, its apparent absence in Chowra was interesting. **Altitudinal range:** 0-221m above msl. **IUCN category:** Vulnerable. The present study provided supporting evidence for down-listing of the species to Near Threatened by BirdLife International (2011). **Current population status:** Abundant (634 detections). **Habitat and ecology:** It was a generalist found in all habitat types from coast to interior (Mixed forest, grassland edges, scrubland, deciduous and cleared forest, *Pandanus* vegetation, arecanut, coconut, rubber plantations and in tsunami-affected regenerating habitats). Noisy flocks of >40 birds were seen on the upper canopies of fruiting trees in Kamorta and Tillanchong. The nesting and breeding biology of the species has not been described yet. Immature and fledgling birds being fed by adults were observed during late February to mid-April. Immature birds, which were very dull and brownish coloured, have not been described or illustrated yet in literature. Nicobar Bulbul co-existed with the introduced Red-whiskered Bulbul *Pycnonotus jocosus whistleri* (locally called *Pinchalok*). The effect of the Red-whiskered Bulbul on the life history of Nicobar Bulbul was not clear. Nicobar Bulbul was comparatively more common in forested habitats than in edges and secondary habitats, where Red-whiskered Bulbul was common. The overall abundance of both the species was almost equal. Though the introduced Red-whiskered Bulbul has been perceived as a threat to the endemic Nicobar Bulbul, the present study could not find any aggression between the species. However, a detail comparative study on biology of both the species is required to examine competitive interaction between the species. The occurrence of Nicobar Bulbul in the secondary vegetation of tsunami-affected littoral habitat is an indication of the species' resilience and ability to recover. Observations suggested that the bird is common throughout its range and has not been affected by the tsunami.

**5) Nicobar Megapode** *Megapodius nicobariensis*

**Local name:** *Pikaiyi* (southern group), *Kungva* (Kamorta and Trinket), *Kijav* (Teressa and Bompoka). **Current distribution:** Kamorta, Nancowry, Trinket, Katchal, Teressa, Bompoka, Great Nicobar, Little Nicobar, Menchal, Kondul, Cubra, PiloMilo and Treis Islands. Megapodes could not be found on Meroe, Chowra, Tillanchong Islands and on the Pigeon islet. **Altitudinal range:** 0 - 178m above msl. **IUCN category:** Vulnerable. **Current population status:** Less common (54 detections from central group; 23 detections in the southern group). **Habitat and ecology:** Recorded from mixed and evergreen forest, coastal tsunami-affected littoral habitats and in coconut groves.

### 3.3.3 Effects of tsunami on Nicobar Megapode

The locations of mounds and sightings of Nicobar Megapode in the Nicobar Islands are given in Appendix 4 and 5 respectively. 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. 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 lizard 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.

Almost 64% of mounds were found within 50m from the coast. 20 mounds were recorded within 50-600m and 20 mounds from the coast. Occurrence of mounds at the fringe of sea-coast was high especially at sites where there was considerable reduction in littoral habitats between coast and hillock subsequent to tsunami. Mounds which are close to shore are prone to high tidal waves during full moon days and could adversely affect hatching success (Sivakumar 2007).

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

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 was one of the factors that contribute to the incubation process especially in the case of Type A mounds (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 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.

### 3.3.4 Checklist of birds of the Nicobar Islands

Surveys in the Nicobar Islands yielded a total of 112 bird species, of which 91 species were recorded during point counts, while additional 21 species were recorded outside the regular counts. Checklist of birds of the Nicobar Islands prepared comprises of 143 species of 44 families when historical, new, isolated and doubtful records were compiled (Appendix 6).

#### 3.3.4.1 New records of species from the Nicobar Islands

New bird species recorded for Nicobar during the present study were Grey-faced Buzzard *Butastur indicus* (Zaibin et al. 2014; Appendix 7), Oriental Honey Buzzard *Pernis ptilorhynchus*, Pied Cuckoo *Clamator jacobinus*, White-tailed Tropicbird *Phaethon lepturus*, Great Egret *Casmerodius albus* and Mugimaki Flycatcher *Ficedula mugimaki*. The species that were previously considered as doubtful records in literature such as Osprey *Pandion baliaetus*, Peregrine Falcon *Falco peregrines* and Crow-billed Drongo *Dicrurus annectus* were also sighted during the study confirming their occurrence. Andaman Drongo *Dicrurus andamanensis* and Large Hawk-cuckoo *Hierococcyx sparverioides* were recorded from central group of islands which had only been previously reported from Great Nicobar Islands (Daniels et al. 1997, Sivakumar and Sankaran 2002). House Crow *Corvus splendens* and Forest Wagtail *Dendronanthus indicus* were sighted during the present study. Though Sankaran (1995) noted these two species in Nicobar, Kazmierczak and Perlo (2000) and Rasmussen and Anderton (2005) didn’t mention them.

## 3.4 DISCUSSION

A total of 112 species were recorded including six new records for the Nicobars and confirmed the occurrence of some notable species during the present study. The estimation of species richness by second order Jackknife estimator, based on sampling of different habitats and island groups, was found to be reliable which predicted total species richness of the Nicobars to be 115. This is close to the total number of birds found in the study including opportunistic observations.

An analysis of taxonomic representation indicated the ‘impoverished’ nature (Mani 1974, Ripley and Beehler 1989) of the Nicobar avifauna. Most of the species were less represented in most taxonomic orders and families. Unlike continental regions, where higher percentage of total avifauna belongs to the order Passeriformes, it was significantly less represented in the Nicobars (33%). Similarly, Ripley and Beehler (1989) found that breeding birds of the Andaman and Nicobar archipelagos were taxonomically less represented, which they attributed to oceanic nature of the archipelagos. Consequently, the best represented taxa in the present analysis consist of water associated species such as waders and kingfishers, and also Sparrowhawks and pigeons which are known to be strong dispersers (e.g. Ripley and Beehler 1989).

### 3.4.1. Bird community structure

The results of the study suggested that the bird communities across different habitats and island groups varied significantly in terms of species richness, abundance and composition.

Significantly higher species richness was observed in the central-northern group disproportionately for its area (which forms only 27.6% of the total area of the Nicobars) than the southern group (which encompass *c*. 62 % of the total area). The reasons for this disparity between species richness and island area were probably due to occurrence of unique landscape such as grassland-forest mosaic in the central-northern group and differences in biogeographical history among island groups, which are discussed in subsequent chapters (Chapters IV-VI).

### 3.4.1.2 Bird species-abundance patterns

The species-abundance models are useful tools which use all the information in the data in recognising community organisation (Magurran 2004). There has been intense debate regarding which model best identify and describe the abundance patterns (e.g. Hill and Hamer 1998).

The species-abundance data of birds of the entire Nicobars, all habitats and island groups followed both truncated log-normal and log-series distribution models. Log-normal distributions have been widely reported in tropics which have been attributed to diverse saturated communities in equilibrium (Wiens 1989, Magurran 2004). On the other hand, log-series patterns of distributions are predicted to occur in less diverse unsaturated communities where species randomly arrive and occupy the communities (May 1975, Magurran 2004). Tokeshi (1999) proposed truncated log-normal distributions which best describe underlying species abundance patterns and take into account high representation of rare species which is characteristics of many assemblages.

The species richness and abundance patterns were not uniform in similar habitats across island groups. This heterogeneity in assemblages across geographical locations might be one of the reasons for not able distinguish between the two models. However, many studies have shown to similarly follow both the log-series and truncated log normal and its difficult to decide which model best describe the data (Magurran 2004). Since both of the models similarly fit to all habitats and island groups, general biological explanation for the underlying processes determining the overall species-abundance patterns could be same throughout the Nicobars.

In general, it could be suggested that the bird communities of the Nicobar Islands are poorly structured and unsaturated which follow a log-series distribution considering an impoverished avifauna due to high insularity, high incidence of rare and uncommon species, non-nestedness of species distributions, less incidence of competitive segregations (*see* Chapter V), and heterogeneity of species diversity and evenness within similar habitats across island groups. Moreover, the rank abundance curves also indicated less evenness in species-abundance distributions of the communities.

### 3.4.1.3 Differences in diversity between habitats

The forest habitat category considered in this study was natural habitats while the littoral habitats were highly devastated and disturbed with secondary regenerating vegetation, in the aftermath of tsunami. Thus, a comparison between these two major habitat types could be considered as between natural forest and young secondary vegetation.

All diversity indices showed that diversity in littoral habitat with young secondary vegetation is higher than in natural hill forest. A very significant difference between forest and littoral habitat in bird species richness, abundance and composition in spite of these two habitats being highly connected was obvious. The littoral habitat was severely impacted by the tsunami which resulted in: (1) physical uprooting of littoral forest trees and mangroves, (2) scorching of littoral vegetation due to salt stress from sea water inundation, and (3) sea water inundation of inland freshwater bodies, destruction of marshes and creeks (Sankaran 2005). The littoral habitats was characterised by sandy or sand-loamy substrates which were dominated by pioneer vegetations. Thus, it was clear that dissimilarity of point count stations across habitats in their major vegetation and landscape attributes, accounted for the very significant differences in their avian richness, abundance and composition.

### 3.4.2 Bird-habitat relationships

The species richness in forest, littoral habitats and grove was negatively influenced by the temperature. The temperature has been reported to influence species distributions directly through physiological effects on species (Repasky 1991). The temperature is also known to influence the species composition indirectly by determining characteristics and distributions of vegetation and resource availability for species (Root 1988). It is remarkable that the species richness was not correlated with features of vegetation such as maximum canopy cover, canopy height and tree density. However, in littoral habitat species per count was also correlated significantly with humidity.

The abundance of species significantly reduced with increasing elevation in forest. The negative relationship of elevation on abundance could only be noted in forest because all other habitats were occurred on lower elevations.

The species abundance in disturbed habitats such as littoral and grove was positively influenced by tree density, while in the former habitat; canopy cover had a significant negative effect. Littoral habitat was peculiar in having wetlands and secondary regenerating vegetation, which exclusively harboured many water-dependent species including flocking waders. This might be the reason for negative correlation of species abundance with canopy cover. In grassland-scrub habitat, both species and individuals per count were not related with any of the variables measured. Thus, the influence of habitat and microhabitat features on species abundance varied across habitats. Nevertheless, it was clear that physical environment or microhabitat, vegetation structure and composition influenced the avian community organisation in the Nicobars (e.g. Root 1988, Repasky 1991).

### 3.4.3 Effects of tsunami on Nicobar Megapode

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 the Nicobar Islands. Sampling the incubation mounds is considered as a suitable way to assess the population of megapodes since mounds are stationary. Size (volume) of the mound and average number of birds that use a mound are two parameters that are pre-requisites for estimating the population of megapodes (Sankaran 1995, Sivakumar 2000).

A total of 376 mounds were estimated to occur along 687 km long coastline of the Nicobar Islands with known distribution of megapodes based on the 40 active mounds located along 73 km long coastal habitats. Approximately, 752 breeding pairs of Nicobar Megapode were estimated to occur in the Nicobar Islands when two pairs per mound were set as upper limit.

A post-tsunami study by Sivakumar (2007) estimated 788 breeding pairs to occur in the Nicobars. The present study indicates that the population of Nicobar Megapode has been recovering from the decline caused by the tsunami and has reached stable levels without further decline.

Chapter-IV

# ISLAND SPECIES-AREA RELATIONSHIPS IN THE NICOBAR ARCHIPELAGO

## 4.1 INTRODUCTION

A central concern in island biogeography is to explain the overall patterns of species richness across islands and archipelagos, and to identify the mechanisms causing those patterns (Bunnefeld and Phillimore 2012). Species-area relationship is one of the ecology's few genuine laws and most examined fundamental patterns (Schoener 1976, Lomolino and Weiser 2001). Though the positive relationship between number of species and area has been one of the earliest ecological patterns known to biogeographers, the ubiquity of this pattern was investigated and tested only after the proposal of the theory of island biogeography by MacArthur and Wilson (1967). They put this relationship into a theoretical and mathematical framework by proposing species-area curve. The theory predicts that the species richness on an island represents balance between colonisation of new species and extinction of the species already present. According to MacArthur and Wilson (1967) the rate of colonisation decreases with increase in distance from source of immigration and the rate of extinction increases with decrease in island area. The constancy of these relationships on different archipelagos and taxa have been examined by numerous investigators which consequently resulted in inclusion of more insular characteristics such as inter-island distances, elevation, habitat diversity, latitude, geological age and history, besides area and isolation in the explanation of the relationships (Whittaker 1998).

There are different types of species-area relationships based on the scale and nestedness of areas analysed (Rosenzweig 1995). The relationships investigated within a group of islands or an archipelago is described as archipelagic or island species-area relationship (Santos et al. 2010). The island species-area relationships are often expressed in power function form, $S = cA^z$, in a linear semi-log form, $S= c + z \log A$, or in a linear log-log form, $\mathrm{Log}\ S= \log c + z \log A$, where S = number of species, A = area, c = intercept of the y-axis, $z$ = exponential constant that represents slope of the relationship between species richness and area (Rosenzweig 1995). In linear models, the slope of the regression line, $z$, represents the rate at which species accumulate with increments in area (Connor and McCoy 1979). The exponent $z$ is unitless and useful for comparison of species-area relationships among different archipelagos (Neigel 2003, Dengler 2009). Differences in the $z$-values could signify the underlying processes such as immigration, extinction and speciation, and their relative significance in determining species richness in an island system (Rosenzweig 1995, Borges and Hortal 2009).

Although a number of hypotheses have been proposed to explain the species-area relationship on islands, there have been little consensus on its causes (Whittaker 1998). The geographical determinants of the species richness on isolated islands are suggested to be island area, distance to the nearest source pool, latitude, habitat diversity (or its indirect measure, maximum altitude), and geological age and history of the island (Rosenzweig 1995, Whittaker 1998, Borges and Hortal 2009). The hypotheses proposed to explain species richness of birds on islands include (Whittaker 1998): 1) The *random placement hypothesis*: large islands sample more individuals at random and will contain more species, 2) The *habitat diversity hypothesis*: large islands contain more habitats and hence more species, 3) The *equilibrium hypothesis*: species richness on an island is in a dynamic equilibrium between immigration and extinction, 4) The *disturbance hypothesis*: small islands are prone to greater disturbance which make islands less suitable for certain species or portion of the species pool, and 5) The *small island habitat hypothesis*: small islands because of their size possess habitats which are absent in larger islands and sample surplus species.

Rosenzweig (1995) assumed that archipelagos follow the same species-area relationship as their constituent islands. Santos et al. (2010) were the first to test this assumption and found that almost all archipelagos follow the same relationships as their constituent islands, and recommended that entire archipelagos can be considered as distinct entities in large-scale biogeographical and macroecological studies. Exceptions to this pattern were shown by archipelagos with low species-area slope, higher than expected species richness and smaller distance to source of immigration. Separate analyses of species-area relationships for each island groups or categories in an archipelago could test this assumption of coherence (e.g. Bunnefeld and Phillimore 2012).

The species-area relationships were evaluated for the entire Nicobar archipelago, island groups and islands of different size classes. Then, it was examined whether the species area relationship for the entire Nicobar archipelago was followed by its constituent islands, island groups and island size categories to understand the degree of departure from the overall relationship.

## 4.2 METHODS

Birds recorded from point count sampling and opportunistic encounters outside the systematic counts were used to make presence-absence data matrix of resident species for 17 islands of the Nicobar archipelago (*see* Chapter V; Table 5.1). For a few species of birds, which were observed in most of the islands of their distribution during my surveys, but failed to record them in certain other island/s where it has been known to exist, available published records were used for incorporating those species in the matrix. Few resident species such as Grey Heron *Ardea cinerea*, Purple Swamphen *Porphyrio porphyrio*, Slaty-breasted Rail *Gallirallus striatus* and Striated Swallow *Hirundo striola* which were recorded by previous investigators (mostly doubtful records), but could not be recorded during the present survey were not included in the data matrix. Only exception to this is Nicobar Scops Owl *Otus alius*, a data deficient and extremely rare endemic, which is added to the resident bird list.

Of the total 112 species recorded from the Nicobars, there were 59 resident birds (excluding introduced species, doubtful and / or isolated new records) and 43 winter visitors, two introduced species and eight vagrants. Out of the 59 resident birds, only 38 species were selected for all the analysis after excluding water-dependent bird species which are strong fliers and more mobile than other resident land birds. This selection was done as it is crucial to take into account of species' differential dispersal abilities when analysing patterns of community assembly (Zalewski and Ulrich 2006). However, analyses incorporating the water-dependent birds, i.e. all residents, were also done to understand the effect of their exclusion. The number of point counts carried out was proportional to the extent of habitat type in the islands (except for few very large islands). The present survey covered all the islands in the Nicobar archipelago except two inaccessible islands: Trak (in the southern group) and Batti Malv (in the northern group).

### 4.2.1 Data Analyses

Multiple regression analyses have been widely used to distinguish the relative contribution of the competing hypotheses in explaining the species-area relationships (Rosenzweig 1995). Prior to computing regression analyses, Pearson correlation coefficients were used to understand the degree of correlations among following predictor variables of each island in the prediction of species richness of birds: 1) island area, 2) distance to the largest island in the group, 3) distance to the nearest island, 4) distance to the Andaman archipelago,

Table 4.1. Characteristics of 17 islands of the Nicobar archipelago.

| **Island groups** | **Island code** | **Islands** | **Observed residents** | **Total residents** | **Selected residents** | **No. of endemics** | **Island area** (km$^2$) | **Dist. to the largest island** (km) | **Dist. to the nearest island** (km) | **Dist. to Sumatra** (km) | **Dist. to Little Andaman** (km) | **Dist. to Sumatra or Andamans** (km) | **Max. Elevation** (m) | **Mid-latitude** | **Length of coastline** (km) | **Corrected Perimeter Area Ratio** | **Total no. of habitats** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Southern | GN | Great Nicobar | 46 | 47 | 29 | 5 | 1045.1 | 0.00 | 1.77 | 172.00 | 389.41 | 172.00 | 670 | 7.006270 | 213.0 | 1.85802 | 4 |
| | CU | Cubra | 6 | 6 | 5 | 1 | 0.04 | 4.73 | 4.73 | 214.32 | 385.34 | 214.32 | 64 | 7.288448 | 1.3 | 1.69200 | 1 |
| | KN | Kondul | 26 | 29 | 20 | 2 | 4.6 | 1.77 | 1.77 | 216.51 | 385.96 | 216.51 | 151 | 7.217884 | 7.5 | 0.98612 | 4 |
| | LN | Little Nicobar | 38 | 39 | 26 | 3 | 159.1 | 7.39 | 0.72 | 224.57 | 363.73 | 224.57 | 402 | 7.339531 | 78.0 | 1.74385 | 4 |
| | PM | Pilo Milo | 23 | 27 | 18 | 2 | 1.3 | 21.76 | 0.72 | 234.43 | 366.68 | 234.43 | 66 | 7.402721 | 3.0 | 0.74199 | 3 |
| | MN | Menchal | 21 | 22 | 19 | 3 | 0.7 | 18.31 | 2.30 | 228.86 | 370.45 | 228.86 | 78 | 7.397808 | 3.3 | 1.11228 | 4 |
| | TE | Treis | 22 | 23 | 13 | 2 | 0.4 | 31.02 | 1.31 | 243.62 | 358.16 | 243.62 | 39 | 7.473629 | 2.7 | 1.20388 | 4 |
| | MR | Meroe | 19 | 21 | 15 | 1 | 1.4 | 38.88 | 10.11 | 254.48 | 349.25 | 254.48 | 32 | 7.517690 | 5.3 | 1.25125 | 4 |
| Central | KM | Kamorta | 45 | 50 | 32 | 3 | 188.2 | 0.00 | 0.32 | 300.28 | 275.20 | 275.20 | 210 | 8.113492 | 112.5 | 2.31255 | 5 |
| | NN | Nancowry | 43 | 44 | 31 | 3 | 66.9 | 0.32 | 0.32 | 289.43 | 296.97 | 289.43 | 138 | 7.979184 | 44.3 | 1.52735 | 5 |
| | TR | Trinket | 37 | 45 | 28 | 2 | 36.3 | 2.55 | 2.55 | 298.57 | 288.57 | 288.57 | 29 | 8.079686 | 30.0 | 1.40416 | 5 |
| | KT | Katchal | 38 | 41 | 30 | 3 | 174.4 | 7.71 | 7.71 | 291.63 | 290.87 | 290.87 | 228 | 7.947475 | 78.0 | 1.66560 | 4 |
| | TS | Teressa | 33 | 39 | 26 | 4 | 101.4 | 28.26 | 3.43 | 337.54 | 247.86 | 247.86 | 273 | 8.276040 | 53.3 | 1.49125 | 5 |
| | BP | Bompoka | 27 | 28 | 22 | 3 | 13.3 | 23.56 | 3.43 | 337.03 | 261.00 | 261.00 | 209 | 8.242453 | 12.8 | 0.98590 | 5 |
| | CH | Chowra | 21 | 22 | 14 | 2 | 8.2 | 52.89 | 11.42 | 368.53 | 233.31 | 233.31 | 104 | 8.453855 | 9.6 | 0.94343 | 4 |
| | TI | Tillanchong | 22 | 30 | 20 | 1 | 16.8 | 23.39 | 53.33 | 333.80 | 245.45 | 245.45 | 323 | 8.499212 | 42.0 | 2.88792 | 4 |
| Northern | CN | Car Nicobar | 23 | 36 | 24 | 2 | 126.9 | 125.12 | 31.94 | 446.30 | 141.95 | 141.95 | 76 | 9.174852 | 54.4 | 1.36181 | 4 |

5) distance to Sumatra, 6) latitude (of central region of each island as representative of the island), 7) maximum elevation, 8) island shape index, and 9) number of habitat types. Area and perimeter of each island were acquired from Sankaran (1997). Shortest straight-line distances to the nearest shores of the adjacent island, largest island, the Andaman archipelago and Sumatra were measured using Google Map. In order to measure the effect of island shape on species richness, a shape index was calculated: Corrected Perimeter Area Ratio (CPA) = (0.282*P)/Sq root of A, where P= perimeter and A= area (Fattorini 2008). This index is based on Perimeter Area Ratio (PARA) – a simple ratio of patch perimeter to area. Habitat types encountered on each islands during surveys were identified and classified as: 1) evergreen forest, 2) mixed forest, 3) littoral habitat, 4) grove (human modified habitats and / or disturbed forest) and 5) grassland-scrub habitat (Table 4.1).

The species-area relationships expressed in the semi-log model form $S= c + z \log A$, best accounted for the variation in data and reduced the probability of violation of statistical assumptions, and thus used in the present study. Because of considerably small number of islands in the Nicobar archipelago (n= 19; of which only 17 islands were considered in the analyses) and high variations in values of variables (e.g. area range = 0.04 – 1045 $km^2$; distance to largest island in the group = 0 – 125.1 $km^2$), all independent variables were $\log_{10}$ transformed to improve normality and reduce heteroscedasticity. However, species-area curves using log-log models were also calculated in order to compare *z*-values of the Nicobars with that of other islands and archipelagos elsewhere (Table 4.10).

The linear relationships between species richness and island area were tested among island groups, small, and medium-large islands. The relationships of all other independent variables on species richness were also separately analysed using simple bivariate regression analyses. Stepwise multiple regression analyses were performed to determine relative contributions of each of the independent variable on the dependent variable - species richness (Table 4.8 and 4.9). The limited number of islands in the island groups was a major impediment in further finer analyses. Northern group of islands was represented by only two islands, Car Nicobar and Batti Malv, of which only former was surveyed and included in the analysis. Analyses were conducted by incorporating Car Nicobar to the central group and also by excluding it. Regression analyses done for southern group and central-northern group (i.e. combined with Car Nicobar Island) can also be considered as a subset analyses for islands with and without grassland habitats.

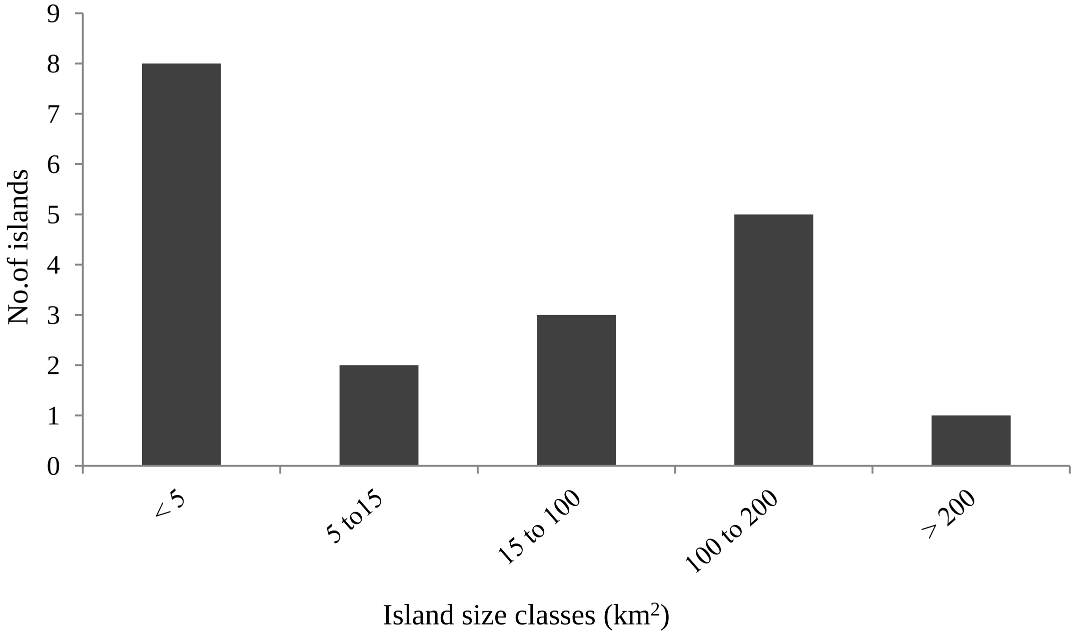

Fig. 4.1. Size class distribution of islands in the Nicobar archipelago.

Among the 19 islands (excluding very sparsely or un-vegetated rocky outcrops), almost half of the islands are very small (Fig. 4.1; Table 4.1), and most are medium sized. Only single exceptionally large island, Great Nicobar, exceeds 1000 $km^2$ in size which accounts for 53.7% of the total land area of the Nicobar archipelago. Maximum elevation of islands was significantly correlated with island area ($r$= 0.663, $p$<0.01). Most of the islands were granitic in origin. Small islands such as Menchal, Meroe and Chowra were coralline islands. Islands with large area and higher elevation were found to be more forested or vegetated than the smaller islands.

## 4.3 RESULTS

The characteristics of 17 islands of the Nicobars are shown in Table 4.1. Results of Pearson correlations between predictor independent variables and species richness of birds are given in Tables 4.2-4.7. Tables 4.8 and 4.9 summarises the results of the regression analyses and Figures 4.2-4.7 shows the regression plots for the relationships. For the entire Nicobar archipelago, the number of species showed a strong positive relationship with island area (Fig. 4.2; $R^2$ = 0.810, $z$ = 5.660±0.708, $p$ <0.0001), and a significant negative relationship with distance to the largest island in the group (Fig. 4.3; $R^2$ = 0.240, $z$ = -5.065 ± 2.330, $p$

<0.046). The relationship between number of species (S) and island area (A) can be expressed by the equation: S = 15.401+ 5.660 Log A (Table 4.9).

Stepwise multiple regression analyses showed that the best fit model has three predictors namely island area, isolation measure and number of habitats (Table 4.9). Area contributed to 81% of the variance of the number of species across islands. The contribution of the isolation measure in predicting number of species was considerably less (5.2%). Additionally, the multiple regression entered number of habitats into the model at third step of the analysis ($t = 2.623$, $p<0.021$) contributing only 4.8%. These three variables together explained 91% variation. Though the habitat variable was significantly correlated with area ($r= 0.642$, $p<0.005$), the multiple regression retained it in the model. Apart from the above predictors, comparison by the Pearson correlation coefficient indicated that, for the entire Nicobar archipelago, the measures of isolation such as distance from the nearest island, Andamans, Sumatra, Andamans/ Sumatra, latitude and CPA were not correlated with species richness (Table 4.2), except with elevation ($r= 0.509$, $p<0.018$). However, elevation was significantly correlated with area, increasing multicollinearity, and stepwise regression procedure excluded it. Alternate analyses by inclusion of resident water-dependent birds also yielded qualitatively similar results (area and distance to the largest island as the predictors), except that habitat didn’t enter into the model (Table 4.8).

Regressions were performed separately for the island groups, and for the small and medium-large islands since these subsets varied considerably in area, island configuration, isolation and habitat diversity. Analyses showed that the measured effects of area and distance varied significantly based on which group or subset of islands or island size categories were considered (Table 4.9, Fig 4.4- 4.7).

Stepwise regression analysis for the southern group showed that island area was the only predictor of species richness (Table 4.9) and its positive relationship was very strong ($R^2 = 0.897$, $z = 4.952 \pm 0.683$, $p < 0.0001$). The distance to largest island had no significant dependence in the southern island group ($r= -0.428$, $p<0.29$).

Similarly, analysis of small islands ($<10$ km$^2$) showed a lack of relationship of the isolation measures with species richness. Great Nicobar (the largest island comprising of 53.7% of total land area of the Nicobars) and Little Nicobar (medium sized island), might have contributed largely to the strong relationship of area in the group.

Table 4.2. Pearson correlation coefficient matrix of island characteristics and species richness for 17 islands in the Nicobars.

| # | Area | D_Largest | D_Nearest | D_Andamans | D_Sumatra | D_Anda/Suma | Elevation | Latitude | CPA | Habitats |
|---|---|---|---|---|---|---|---|---|---|---|
| Species (selected residents) | __.900***__ | __-.489*__ | -0.335 | -0.242 | 0.168 | 0.188 | __.509*__ | 0.236 | 0.365 | __.733**__ |
| Species (all residents) | __.915***__ | __-.498*__ | -0.347 | -0.238 | 0.142 | 0.132 | 0.479 | 0.220 | 0.404 | __.712**__ |
| Area | | -0.301 | -0.084 | -0.396 | 0.252 | -0.072 | __.663**__ | 0.334 | 0.425 | __.642**__ |
| D_Largest | | | __.662**__ | -0.447 | 0.476 | -0.295 | -0.298 | 0.410 | -0.338 | -0.143 |
| D_Nearest | | | | -.537* | __.486*__ | -0.325 | -0.080 | __.509*__ | 0.134 | -0.192 |
| D_Andamans | | | | | __-.937***'__ | 0.249 | -0.026 | __-.965***__ | -0.127 | -0.350 |
| D_Sumatra | | | | | | 0.058 | -0.099 | __.984***__ | 0.032 | 0.415 |
| D_Anda/Suma | | | | | | | -0.128 | -0.008 | 0.055 | 0.352 |
| Elevation | | | | | | | | -0.018 | 0.478 | 0.219 |
| Latitude | | | | | | | | | 0.155 | 0.412 |
| Log_CPA | | | | | | | | | | 0.070 |

Table 4.3. Pearson correlation coefficient matrix of island characteristics and species richness for the southern group of islands (n=8).

| # | Area | D_Largest | D_Nearest | D_Andamans | D_Sumatra | D_Anda/Suma | Elevation | Latitude | CPA | Habitats |
|---|---|---|---|---|---|---|---|---|---|---|
| Species (selected residents) | __.947***__ | -0.428 | -0.498 | 0.154 | -0.507 | -0.507 | __.814*__ | -0.517 | 0.161 | 0.705 |
| Species (all residents) | __.970**__ | -0.456 | -0.537 | 0.155 | -0.549 | -0.549 | __.817*__ | -0.556 | 0.214 | 0.672 |
| Area | | -0.540 | -0.397 | 0.207 | -0.617 | -0.617 | .881** | -0.621 | 0.397 | 0.576 |
| D_Largest | | | 0.135 | __-.899**__ | __.895**__ | __.895**__ | __-.792*__ | __.960***__ | -0.442 | 0.085 |
| D_Nearest | | | | -0.118 | 0.164 | 0.164 | -0.457 | 0.178 | 0.219 | -0.238 |
| D_Andamans | | | | | __-.834*__ | __-.834*__ | 0.573 | __-.875**__ | 0.257 | -0.352 |
| D_Sumatra | | | | | | __1.000***__ | __-.817*__ | __.980***__ | -0.524 | 0.064 |
| D_Anda/Suma | | | | | | | __-.817*__ | __.980***__ | -0.524 | 0.064 |
| Elevation | | | | | | | | __-.828*__ | 0.521 | 0.247 |
| Latitude | | | | | | | | | -0.453 | 0.039 |
| Log_CPA | | | | | | | | | | -0.138 |

* *p* <0.05;   ** *p*<0.01;  *** *p*<0.001;  # All independent variables are on **log scale,** except habitats

Table 4.4. Pearson correlation coefficient matrix of island characteristics and species richness for the central-northern groups of islands (n=9).

| | Area | D_Largest | D_Nearest | D_Andamans | D_Sumatra | D_Anda/Suma | Elevation | Latitude | CPA | Habitats |
|---|---|---|---|---|---|---|---|---|---|---|
| Species (selected residents) | **.822**** | **-.746*** | **-.683*** | 0.394 | -0.608 | 0.384 | -0.012 | -0.527 | 0.392 | 0.521 |
| Species (all residents) | **.807**** | **-.738*** | **-.668*** | 0.338 | -0.556 | 0.331 | -0.156 | -0.450 | 0.455 | 0.520 |
| Area | | -0.321 | -0.345 | -0.059 | -0.174 | -0.063 | 0.090 | -0.110 | 0.390 | 0.141 |
| D_Largest | | | **.852**** | **-.728*** | **.839**** | **-.711*** | 0.072 | **.765*** | -0.322 | -0.602 |
| D_Nearest | | | | -0.600 | 0.651 | -0.586 | 0.041 | .681* | 0.005 | **-.813**** |
| D_Andamans | | | | | **-.961**** | **.999***** | 0.181 | **-.975**** | 0.167 | 0.500 |
| D_Sumatra | | | | | | **-.957**** | -0.146 | **.965***** | -0.329 | -0.496 |
| D_Anda/Suma | | | | | | | 0.183 | **-.972***** | 0.169 | 0.494 |
| Elevation | | | | | | | | -0.145 | 0.411 | -0.088 |
| Latitude | | | | | | | | | -0.103 | -0.530 |
| Log_CPA | | | | | | | | | | -0.085 |

Table 4.5. Pearson correlation coefficient matrix of island characteristics and species richness for the central group of islands (n=8).

| # | Area | D_Largest | D_Nearest | D_Andamans | D_Sumatra | D_Anda/Suma | Elevation | Latitude | CPA | Habitats |
|---|---|---|---|---|---|---|---|---|---|---|
| Species (selected residents) | **.888**** | **-.816*** | **-.720*** | **.865**** | **-.924***** | **.868**** | -0.039 | **-.875**** | 0.387 | 0.535 |
| Species (all residents) | **.862**** | **-.821*** | **-.714*** | **.782*** | **-.871**** | **.789*** | -0.181 | **-.771*** | 0.453 | 0.545 |
| Area | | -0.563 | -0.545 | 0.613 | -.733* | 0.627 | 0.204 | -.719* | 0.449 | 0.295 |
| D_Largest | | | **.817*** | **-.837**** | **.858**** | **-.804*** | 0.277 | **.754*** | -0.305 | -0.509 |
| D_Nearest | | | | -0.615 | 0.578 | -0.586 | 0.204 | 0.673 | 0.061 | -.776* |
| D_Andamans | | | | | **-.964***** | **.996***** | -0.322 | **-.950**** | 0.153 | 0.390 |
| D_Sumatra | | | | | | **-.963***** | 0.196 | **.899**** | -0.396 | -0.327 |
| D_Anda/Suma | | | | | | | -0.330 | **-.949***** | 0.162 | 0.377 |
| Elevation | | | | | | | | 0.249 | 0.396 | -0.245 |
| Latitude | | | | | | | | | -0.002 | -0.400 |
| Log_CPA | | | | | | | | | | -0.145 |

* $p$ <0.05;   ** $p$<0.01;  *** $p$<0.001;  # All independent variables are on **log scale,** except habitats.

Table 4.6. Pearson correlation coefficient matrix of island characteristics and species richness for medium-large islands (> 35 km$^2$; n=8).

| # | Area | D_Largest | D_Nearest | D_Andamans | D_Sumatra | D_Anda/Suma | Elevation | Latitude | CPA | Habitats |
|---|---|---|---|---|---|---|---|---|---|---|
| Species (selected residents) | 0.115 | __-.854**__ | -0.664 | 0.501 | -0.344 | 0.645 | 0.138 | -0.343 | 0.632 | 0.387 |
| Species (all residents) | 0.242 | __-.841**__ | -0.668 | 0.536 | -0.485 | 0.398 | 0.096 | -0.442 | 0.693 | 0.428 |
| Area |  | -0.111 | -0.004 | 0.345 | -0.627 | -0.507 | __.811*__ | -0.565 | 0.569 | -0.599 |
| D_Largest |  |  | __.831*__ | __-.708*__ | 0.603 | -0.519 | -0.152 | 0.592 | -0.498 | -0.392 |
| D_Nearest |  |  |  | -0.667 | 0.501 | -0.538 | -0.281 | 0.533 | -0.603 | -0.493 |
| D_Andamans |  |  |  |  | __-.919***__ | 0.421 | 0.527 | __-.953***__ | 0.487 | 0.000 |
| D_Sumatra |  |  |  |  |  | -0.043 | -0.648 | __.991***__ | -0.493 | 0.265 |
| D_Anda/Suma |  |  |  |  |  |  | -0.185 | -0.130 | 0.176 | 0.629 |
| Elevation |  |  |  |  |  |  |  | -0.659 | 0.581 | -0.409 |
| Latitude |  |  |  |  |  |  |  |  | -0.482 | 0.239 |
| Log_CPA |  |  |  |  |  |  |  |  |  | 0.005 |

Table 4.7. Pearson correlation coefficient matrix of island characteristics and species richness for small islands (< 10 km$^2$; n=7).

| # | Area | D_Largest | D_Nearest | D_Andamans | D_Sumatra | D_Anda/Suma | Elevation | Latitude | CPA | Habitats |
|---|---|---|---|---|---|---|---|---|---|---|
| Species (selected residents) | __.794*__ | 0.063 | -0.314 | -0.211 | 0.244 | 0.404 | 0.538 | 0.209 | __-.740*__ | __.817*__ |
| Species (all residents) | __.817*__ | 0.132 | -0.395 | -0.233 | 0.274 | 0.413 | 0.405 | 0.220 | __-.837**__ | __.826*__ |
| Area |  | 0.251 | 0.139 | -0.677 | 0.694 | 0.466 | 0.615 | 0.654 | __-.720*__ | __.830*__ |
| D_Largest |  |  | 0.297 | -0.576 | 0.638 | __.733*__ | -0.350 | 0.615 | -0.233 | 0.397 |
| D_Nearest |  |  |  | -0.530 | 0.522 | 0.174 | -0.044 | 0.519 | 0.411 | 0.029 |
| D_Andamans |  |  |  |  | __-.994***__ | -0.479 | -0.449 | __-.997***__ | 0.320 | -0.484 |
| D_Sumatra |  |  |  |  |  | 0.570 | 0.391 | __.995***__ | -0.334 | 0.537 |
| D_Anda/Suma |  |  |  |  |  |  | -0.096 | 0.523 | -0.224 | 0.663 |
| Elevation |  |  |  |  |  |  |  | 0.423 | -0.390 | 0.329 |
| Latitude |  |  |  |  |  |  |  |  | -0.304 | 0.488 |
| Log_CPA |  |  |  |  |  |  |  |  |  | -0.519 |

* $p < 0.05$;   ** $p < 0.01$;  *** $p < 0.001$;  # All independent variables are on **log scale,** except Habitats

Table 4.8. Regression models showing $R^2$, intercept, slope, $F$ and $t$ statistics for all 59 residents in the entire Nicobars, island groups, and islands of two size classes.

| | **Variables** | ***n*** | **$R^2$** | **$R^2$ change** | ***F*-test** | ***p*-value** | **Intercept** | **Slope** | ***t*-test** | ***p*-value** |
|---|---|---|---|---|---|---|---|---|---|---|
| * | Species / log area | 17 | 0.836 | | 76.658 | 0.000 | 21.920 | 9.059 ± 1.035 | 8.755 | 0.000 |
| * | Species / log dist. largest island | 17 | 0.248 | | 4.940 | 0.042 | 40.065 | -8.112 ± 3.650 | -2.223 | 0.042 |
| * | Species / habitat | 17 | 0.507 | | 15.415 | 0.001 | -2.669 | 8.614 ± 2.194 | 3.926 | 0.001 |
| *** | Species /log area/ dist. largest island/ habitats | 17 | 0.836 | 0.836 | 76.658 | 0.000 | | 6.801 ± 1.037 | 6.557 | 0.000 |
| | | | 0.891 | 0.054 | 57.015 | 0.000 | 17.030 | -4.195 ± 1.321 | -3.175 | 0.007 |
| | | | 0.923 | 0.032 | 51.700 | 0.000 | | 2.832 ± 1.221 | 2.320 | 0.037 |
| | ***Southern group*** | | | | | | | | | |
| * | Species / log area | 8 | 0.941 | | 94.843 | 0.000 | 22.374 | 8.349 ± 0.857 | 9.739 | 0.000 |
| | ***Central-northern groups*** | | | | | | | | | |
| * | Species / log area | 9 | 0.651 | | 13.042 | 0.009 | 12.939 | 14.308 ± 3.962 | 3.611 | 0.009 |
| * | Species/ log dist. largest island | 9 | 0.545 | | 8.388 | 0.023 | 44.918 | -7.860 ± 2.714 | -2.896 | 0.023 |
| * | Species / log dist. nearest island | 9 | 0.446 | | 5.625 | 0.049 | 42.131 | -7.800 ± 3.289 | -2.372 | 0.049 |
| *** | Species / log area / log dist. largest island | 9 | 0.651 | 0.651 | 13.042 | 0.009 | 23.674 | 11.265 ± 2.333 | 4.828 | 0.003 |
| | | | 0.907 | 0.256 | 29.213 | 0.001 | | -5.689 ± 1.401 | -4.062 | 0.007 |
| | ***Central group*** | | | | | | | | | |
| * | Species/ log dist. Sumatra | 8 | 0.759 | | 18.898 | 0.005 | 587.566 | -219.803 ± 50.562 | -4.347 | 0.005 |
| * | Species / log area | 8 | 0.743 | | 17.348 | 0.006 | 11.038 | 15.997 ± 3.841 | 4.165 | 0.006 |
| | ***Medium-large islands*** *(>35 km$^2$)* | | | | | | | | | |
| * | Species / log dist. largest island | 8 | 0.708 | | 14.514 | 0.009 | 45.651 | -4.641 ± 1.218 | -3.810 | 0.009 |
| | ***Small islands*** *(<10 km$^2$)* | | | | | | | | | |
| * | Species / habitats | 7 | 0.652 | | 9.356 | 0.028 | 3.333 | 5.278 ± 1.725 | 3.059 | 0.028 |

* indicates simple regression; ***indicates multiple regression

Table 4.9. Regression models showing $R^2$, intercept, slope, $F$ and $t$ statistics for all 38 residents in the entire Nicobars, island groups, and islands of two size classes.

| | **Variables** | ***n*** | $\mathbf{R^2}$ | $\mathbf{R^2}$ **change** | ***F*-test** | ***p*-value** | **Intercept** | **Slope** | ***t*-test** | ***p*-value** |
|---|---|---|---|---|---|---|---|---|---|---|
| * | Species / log area | 17 | 0.810 | | 63.889 | 0.000 | 15.401 | 5.660 ± 0.708 | 7.993 | 0.000 |
| * | Species / log dist. largest island | 17 | 0.240 | | 4.726 | 0.046 | 26.734 | -5.065 ± 2.330 | -2.174 | 0.046 |
| * | Species / habitat | 17 | 0.537 | | 17.403 | 0.001 | -0.969 | 5.630 ± 1.350 | 4.172 | 0.001 |
| *** | Species / area / log dist. largest island /habitats | 17 | 0.810 | 0.810 | 63.889 | 0.000 | 10.912 | 4.021 ± 0.711 | 5.658 | 0.000 |
| | | | 0.862 | 0.052 | 43.833 | 0.000 | | -2.649 ± 0.905 | -2.927 | 0.012 |
| | | | 0.910 | 0.048 | 43.789 | 0.000 | | 2.194 ± 0.836 | 2.623 | 0.021 |
| | ***Southern group*** | | | | | | | | | |
| * | Species / log area | 8 | 0.897 | | 52.530 | 0.000 | 15.529 | 4.952 ± 0.683 | 7.248 | 0.000 |
| | ***Central-northern groups*** | | | | | | | | | |
| * | Species / log area | 9 | 0.675 | | 14.544 | 0.007 | 9.211 | 9.434 ± 2.474 | 3.814 | 0.007 |
| * | Species/ log dist. largest island | 9 | 0.557 | | 8.798 | 0.021 | 30.258 | -5.143 ± 1.734 | -2.966 | 0.021 |
| *** | Species / log area / log dist. largest island | 9 | 0.675 | 0.675 | 14.544 | 0.007 | 16.206 | 7.451 ± 1.266 | 5.887 | 0.001 |
| | | | 0.935 | 0.260 | 42.878 | 0.000 | | -3.707 ± 0.760 | -4.880 | 0.003 |
| | ***Central group*** | | | | | | | | | |
| * | Species/ log dist. Sumatra | 8 | 0.853 | | 34.785 | 0.001 | 256.900 | -96.092 ± 24.128 | -3.983 | 0.011 |
| * | Species / log area | 8 | 0.788 | | 22.342 | 0.003 | 7.845 | 10.648 ± 2.253 | 4.727 | 0.003 |
| *** | Species / log dist. Sumatra / log area | 8 | 0.853 | 0.853 | 34.785 | 0.001 | 256.900 | -96.092 ± 24.128 | -3.983 | 0.011 |
| | | | 0.949 | 0.096 | 46.770 | 0.001 | | 5.469 ± 1.775 | 3.082 | 0.027 |
| | ***Medium-large islands*** *(>35 km$^2$)* | | | | | | | | | |
| * | Species / log dist. largest island | 8 | 0.684 | | 16.153 | 0.007 | 30.061 | -2.778 ± 0.691 | -4.019 | 0.007 |
| | ***Small islands*** *(<10 km$^2$)* | | | | | | | | | |
| * | Species / habitats | 7 | 0.585 | | 7.039 | 0.045 | 3.111 | 3.426 ± 1.291 | 2.653 | 0.045 |

* indicates simple regression; ***indicates multiple regressions

Table 4.10. Results of log-log regressions showing intercept c and slope *z* of species-area curves for the whole Nicobar archipelago, island groups and island size classes.

| **Data categories** | ***n*** | $R^2$ | ***F*-test** | ***p*-value** | **Intercept** | **Slope** | ***t*-test** | ***p*-value** |
|---|---|---|---|---|---|---|---|---|
| ***Selected 38 residents*** | | | | | | | | |
| Nicobars | 17 | 0.760 | 47.559 | 0.000 | 1.139 | 0.147 ± 0.021 | 6.896 | 0.000 |
| Southern group | 8 | 0.713 | 14.879 | 0.008 | 1.140 | 0.139 ± 0.036 | 3.857 | 0.008 |
| Central-northern groups | 9 | 0.670 | 14.222 | 0.007 | 1.078 | 0.183 ± 0.049 | 3.771 | 0.007 |
| Central group | 8 | 0.753 | 18.254 | 0.005 | 1.056 | 0.203 ± 0.048 | 4.272 | 0.005 |
| Medium-large islands (>35 km$^2$) | 8 | 0.014 | 0.083 | 0.783 | 1.424 | 0.012 ± 0.117 | 0.287 | 0.783 |
| Small islands (<10 km$^2$) | 7 | 0.617 | 8.053 | 0.036 | 1.142 | 0.214±.075 | 2.838 | 0.036 |
| ***All 59 residents*** | | | | | | | | |
| Nicobars | 17 | 0.771 | 50.530 | 0.000 | 1.284 | 0.162 ± 0.023 | 7.108 | 0.000 |
| Southern group | 8 | 0.724 | 15.727 | 0.007 | 1.287 | 0.160 ± 0.040 | 3.966 | 0.007 |
| Central-northern groups | 9 | 0.686 | 15.293 | 0.006 | 1.242 | 0.186 ± 0.048 | 3.911 | 0.006 |
| Central group | 8 | 0.756 | 18.593 | 0.005 | 1.221 | 0.205 ± 0.047 | 4.312 | 0.005 |
| Medium-large islands (>35 km$^2$) | 8 | 0.053 | 0.337 | 0.583 | 1.571 | 0.026±.0.045 | 0.580 | 0.583 |
| Small islands (<10 km$^2$) | 7 | 0.667 | 10.032 | 0.025 | 1.296 | 0.250 ± 0.079 | 3.167 | 0.025 |

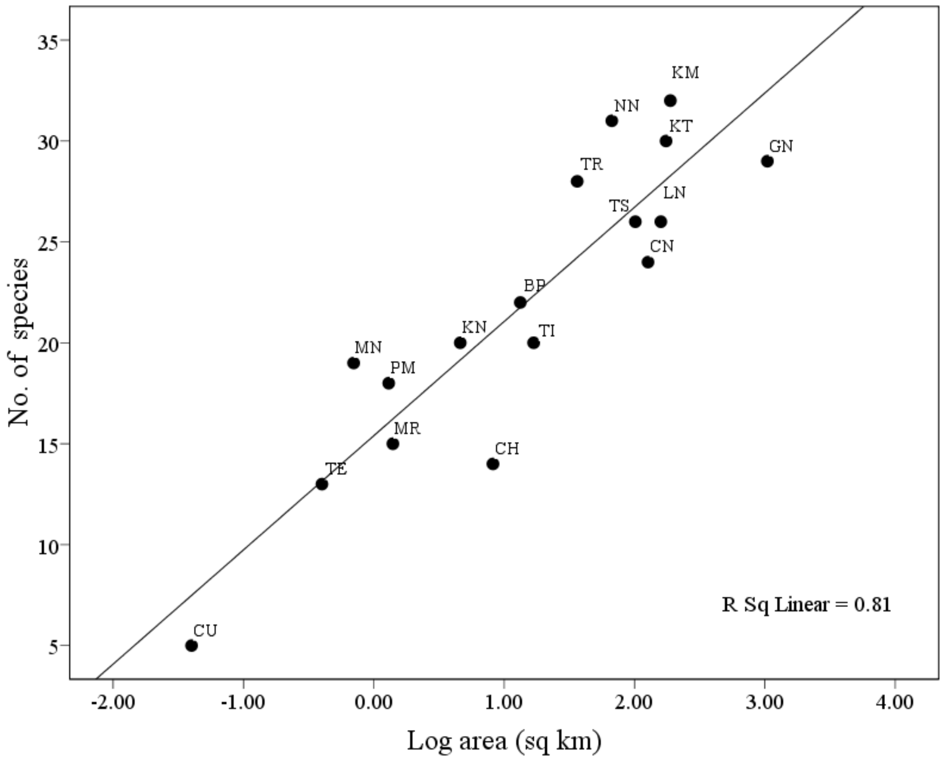

Fig 4.2. Relationship between number of species and island area for the entire Nicobar archipelago. S = 15.401+ 5.66 Log A.

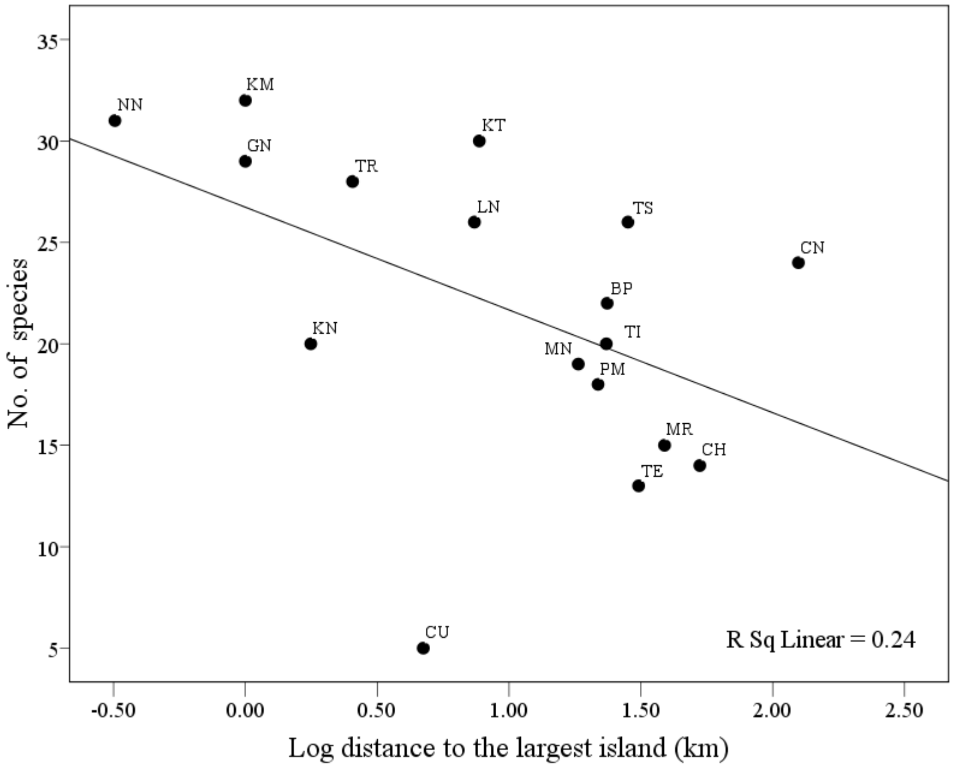

Fig. 4.3. Relationship between number of species and distance to largest island for the entire Nicobar archipelago.

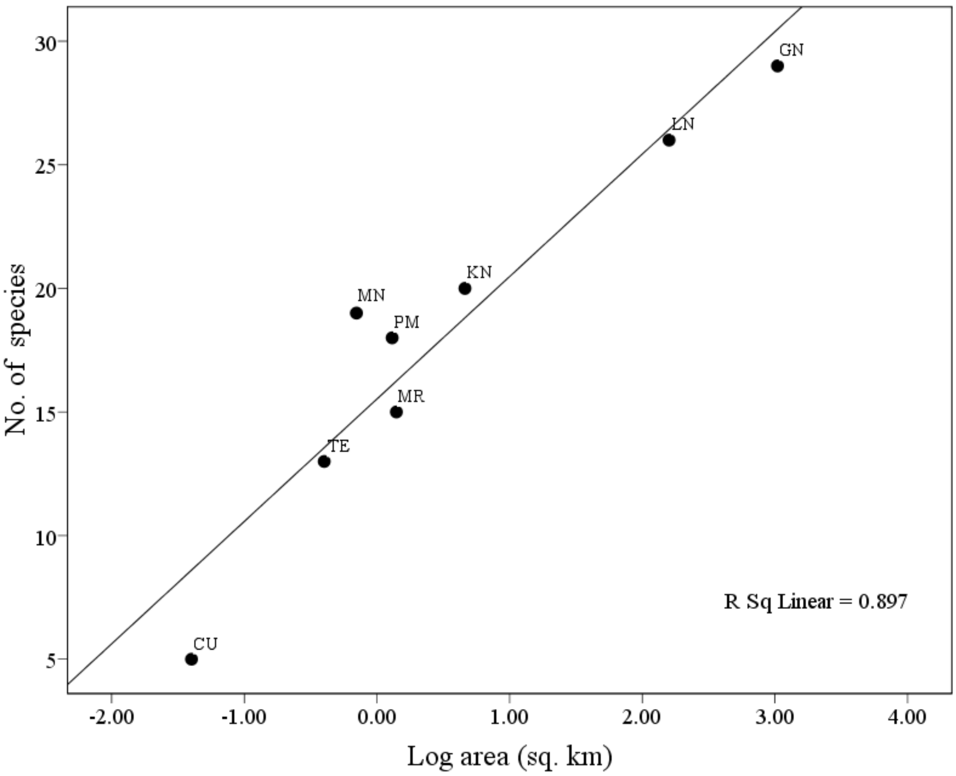

Fig 4.4. Relationship between number of species and area for the southern group of islands. S = 15.529+4.952 Log A.

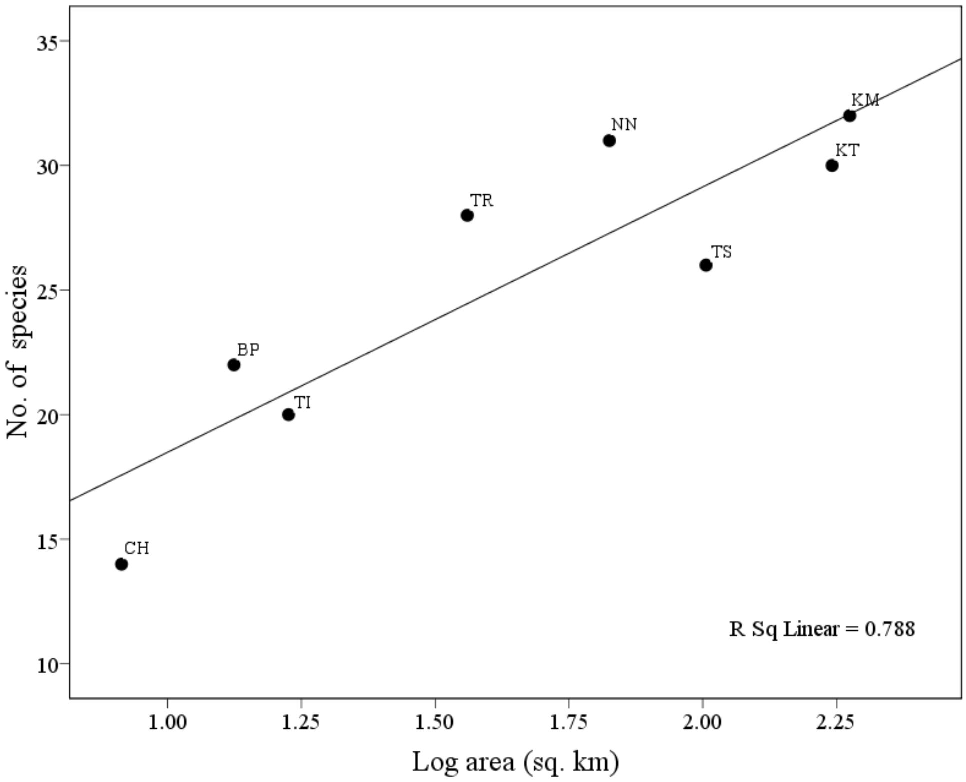

Fig 4.5. Relationship between number of species and area for the central group of islands. S = 7.845 + 10.65 Log A.

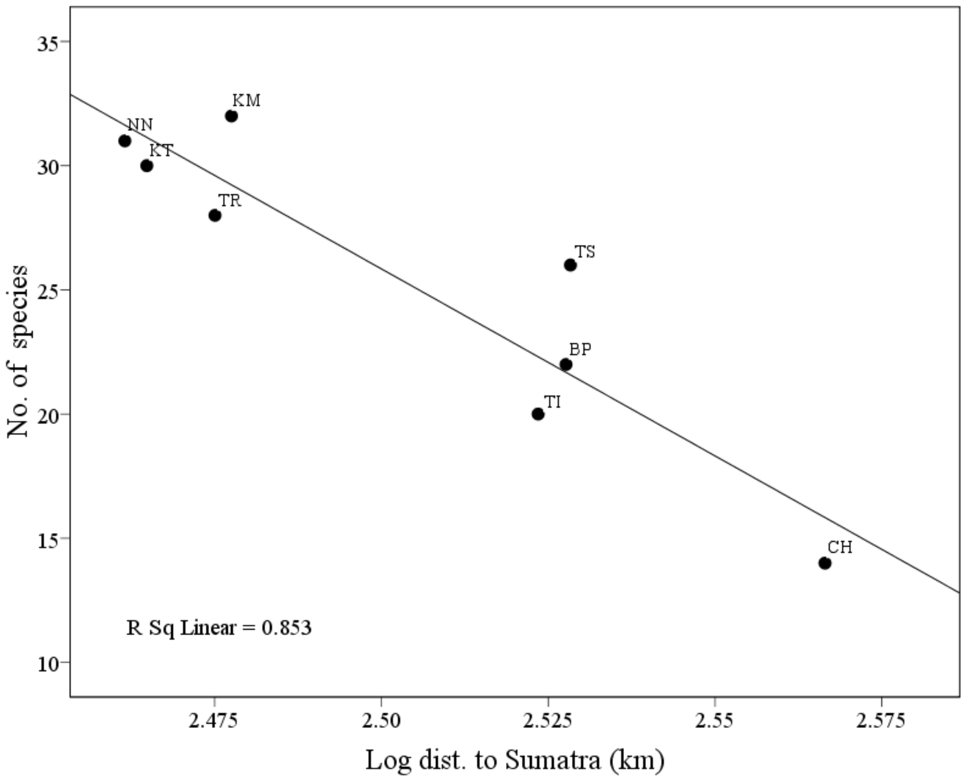

Fig. 4.6. Relationship between number of species and distance to Sumatra for the central group of islands.

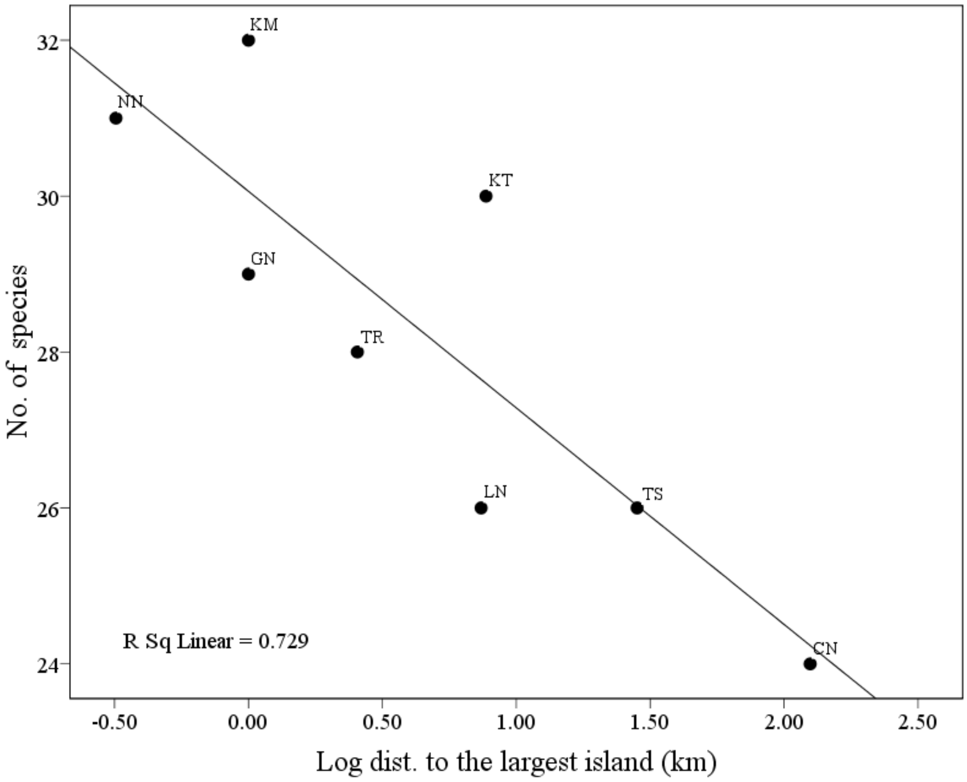

Fig. 4.7. Relationship between number of species and distance to the largest island for medium-large islands.

All the other islands in the southern group are small in size (< 5 $km^2$), whose dependence on area was also found to be very strong ($R^2$ = 0.846, $z$ = 7.318 ± 1.559, $p$ <0.009) when analysed separately. Area, CPA and number of habitats, in that order, were the significant variables for small islands (< 5 $km^2$) in the southern group. Multiple regressions selected only area as the predictor variable.

Small islands of the entire Nicobar archipelago (<10$km^2$) showed a positive linear relationship of species richness with number of habitats ($R^2$ = 0.585, $z$ = 3.426 ± 1.291, $p$ <0.045), area ($R^2$ = 0.534, $z$ = 4.903 ± 2.046, $p$ <0.062), and negative relationship with increasing complexity of shape of the islands as indicated by CPA ($R^2$ = 0.583, $z$ = -34.557 ± 13.070, $p$ <0.046). Multiple regressions retained only habitat as the predictor for small islands (<10$km^2$) (Table 4.9).

Stepwise regression extracted area and distance to largest island (contributions to $R^2$: 0.675 and 0.260 respectively) as predictors of species richness for the central-northern group. Moreover, Pearson correlation showed a negative relationship with distance to nearest island ($r$= -0.683, $p$<0.043) in the group. All the islands in this subset (except Katchal and Tillanchong) are peculiar in harbouring grassland habitats (mostly interspersed with evergreen stunted forest reminiscent of 'shola' habitats in Western Ghats).

Similarly, when islands of central group was considered alone (excluding Car Nicobar Island, which is a medium-sized island forming northern island group along with much smaller Batti Malv Island), significant correlation existed between species richness and all the measures of isolation including distance to largest ($r$= -0.816, $p$<0.014), nearest ($r$= -0.720, $p$<0.044), Andamans ($r$= 0.865, $p$<0.006), Sumatra ($r$= -0.924, $p$<0.001), Sumatra/ Andamans ($r$= 0.868, $p$<0.005), along with the area ($r$= 0.888, $p$<0.003) and latitude ($r$= -0.875, $p$<0.004). However, all the isolation measures of distances were significantly correlated with each other, and with area. Stepwise multiple regression included distance to Sumatra, a measure of isolation from the nearest largest source pool, as the strong predictor ($R^2$ = 0.853 $z$ = -150.563 ± 25.525, $p$ <0.001). The dependence of measures of isolation (distance from the largest island, nearest island, Sumatra) on species richness was prominently shown only in the analysis of the central-northern group as well as the central group alone.

When set of medium-large islands (ranging in size between 36.3-1045.1 $km^{2)}$ was analysed, distance to largest island was the only variable correlated with species richness, and consequently the only predictor (Table 4.9; $R^2 = 0.684$, $z = - 2.778 \pm 0.691$, $p < 0.007$). Thus the striking effect of measures of isolation was largely contributed by medium-large islands in these subsets.

Regression plot for species-area relationship showed prominent clusters of small (<17km$^2$), medium (>30-160 km$^2$) and large islands (>188 km$^2$) (Fig. 4.2). Similarly, for plot of relationships between the distance to largest island and species richness, small islands clumped together, while medium sized islands were showing a more linear structure of negative correlation (Fig. 4.3).

Lack of relationship of distance for small islands was evident from the scatter plot (Fig. 4.3). For instance, Chowra (area: 8.2 km$^2$; dist. from Kamorta: 52.8 km) and Meroe (area: 0.7 km$^2$; dist. from Great Nicobar: 38.88 km) differ in degree of isolation and island sizes, but had similar species richness, illustrating the lack of relationship of distance to largest island in the southern group and less significance of area in the central group.

The results of log-log regressions separately carried out for comparative purpose are shown in Table 4.10. For all resident data set of the whole Nicobar archipelago, the value of the exponent $z$ was 0.16. The value of $z$ varied considerably for different subsets of islands analysed. For example, the slopes of the species area regressions were significantly higher for the central ($z$= 0.20) and the central-northern group ($z$= 0.18) than the southern group ($z$= 0.16). Strikingly, small islands were found to have the highest $z$-value ($z$= 0.25). The data with selected resident subset (excluding the water-dependent birds) also exhibited qualitatively similar patterns (Table 4.10).

## 4.4 DISCUSSION

Due to high variations in values of predictor variables (e.g. area range = 0.04–1045 km$^2$; distance to largest island range = 0–125.1 km$^2$; Table 4.1), and low variations of species richness among islands (range = 5-32 species), semi-log models were recognised as the best-fit to the data than log-log or power function models. The island species-area relationship using the semi-log model for the Nicobar archipelago can be expressed by the equation: $S = 15.401 + 5.66 \text{ Log } A$ (for selected residents); $S = 21.920 + 9.059 \text{ Log } A$ (for all residents). The relationship using log-log model can be expressed by the equation: $\text{Log } S = 1.139 + 0.147 \text{ Log } A$ (for selected residents); $\text{Log } S = 1.284 + 0.162 \text{ Log } A$ (for all residents) (Tables 4.8-4.10).

The regression analyses for the entire Nicobar archipelago provided significant results which could explain 90% percent of the variation and indicated that area, measures of isolation and habitat diversity, in that order, play a role in determining species richness.

Although area proved to be a very powerful predictor of overall bird species richness in the Nicobar archipelago, the relationship was not consistent among island groups and islands of different size categories. Medium sized islands in the central group such as Kamorta, Katchal, Nancowry, Trinket and Teressa were having strikingly higher number of species disproportionately for their area than Greater Nicobar (the largest island comprising of 53.7% of total land area of the Nicobars) and Little Nicobar in the southern group, and Car Nicobar in the northern group. For the central group, distance to Sumatra, i.e. isolation from the nearest largest source pool, was the major predictor. The negative relationships of species richness on isolation measures (distance from the largest island, nearest island, Sumatra) was prominent only in the central and central-northern group in comparison to the southern group, and was largely contributed by medium-large islands in the central group. Similarly, small islands in the central group showed within group dissimilarity in species richness, strongly influenced by the degree in distance from largest island or nearest island. Medium-large islands (ranging in size between 36.3-1045.1 km$^2$) didn’t show a significant species-area relationship.

Southern group exhibited very strong relationship with island area and was strikingly lacking in the effect of isolation. This indicated that the strong relationship of area for the entire Nicobar archipelago could largely be explained by the robust relationship of area with species richness in the southern group. For small islands in the southern group, besides area, species richness was also influenced by the number of habitats, shape of the islands (CPA) and maximum elevation as indicated by the regression analyses. This was probably due to inter-island variations in habitat characteristics and unique features of small islands such as CPA influencing the species richness. A strong correlation of species richness of small islands with number of habitats and CPA unlike the medium-large islands was probably due to ‘small island effects’ (Barrett et al. 2003).

Since the southern group was strongly influenced by area alone, it could be suggested that area-dependent extinction processes better explain the species richness in the group. Lack of effect of isolation in the southern group was probably due to frequent species colonisation triggered by the rescue effect (Brown and Kodric-Brown 1977). On the other hand, the significant effects of measures of isolation along with area in the central and central-northern group indicate differential immigration and / or area-dependent extinction as mechanisms determining the species richness.

The islands in the entire Nicobar archipelago occur more scattered and isolated in the island groups. There are considerable variations in island configuration or inter-island distances within the Nicobar archipelago. Most of the islands in the central group are medium-sized and occur relatively more scattered than in the southern group where one exceptionally large (Great Nicobar) and another medium-sized island (Little Nicobar) occur along with small satellite islands. The variations within the archipelago in landscape characteristics also existed between island groups. The central group is unique in having grasslands interspersed with forest while southern group is uniformly forested. These factors also led to the non-uniform, restricted or discontinuous distributional patterns of species in the Nicobars. The clear-cut variations in characteristics such as area, island configuration, isolation and habitat diversity across the island groups consequently resulted in differential effects of area and isolation on species richness. Thus, it could be concluded that this exceptional lack of coherence in determining species richness within the Nicobar archipelago was possibly due to the differences between the island groups in any or combinations of features such as area, heterogeneous landscape, inter-island isolation, isolation from source pools, and geological and climatic history (e.g. Santos et al. 2010; also *see* Chapters V and VI). On the other hand, Davidar et al. (2002) found that the area and habitat diversity were the only two determinants of species richness on the adjacent the Andaman archipelago and the effects of these two variables were consistent within the island groups and for small islands in the Andamans. Unlike in the Nicobars, the close proximity of large islands and archipelagos in the Andamans resulted in the absence of isolation effect in determining species richness which in turn led to uniform patterns of distribution of species in the Andamans (Davidar et al. 2002).

In the present study, the value of the $z$ for the total species richness (S=59) of the Nicobar archipelago is 0.16. The $z$ value varied considerably across island groups and island size classes. It was significantly higher for the central ($z$= 0.20) and the central-northern group ($z$= 0.18) than the southern group ($z$= 0.16). The small islands were found to have the highest $z$ value of 0.25. Interestingly, the medium- large island size class (i.e. all islands >35 km$^2$) didn't adhere to the species-area relationship (Table 4.10).

In numerous studies, it has been found that the slopes of log-log regression lines, *z*, tend to fall within the range of 0.20 to 0.40 (MacArthur and Wilson 1967, Connor and McCoy 1979, Rosenzweig 1995). However, this varies across island types and taxonomic groups. Oceanic islands tend to have higher *z* value than the continental shelf islands, while plants tend to have a higher *z* value than the vertebrates (Triantis et al. 2012). MacArthur and Wilson (1967) predicted that the value of *z* increases with increasing isolation due to significant effect of extinction within the oceanic island groups. On the contrary, Schoener (1976) and Connor and McCoy (1979) found that the value of *z* decreases with increasing isolation.

In the Nicobar archipelago, influence of distance seems to suggest differential colonisation of islands in the central or central-northern group while the effect of area seems to suggest the selective extinction processes in the southern group. Lower values of *z* for different subsets of bird species in the Nicobars is clearly a prominent departure from the results of numerous studies conducted elsewhere.

The departure of the overall species richness of the Nicobar archipelago from the island species-area relationships of its constituent islands was probably due to occurrence of islands in three scattered clusters or groups with varying characteristics such as isolation, heterogeneity of landscape, multiple sources of immigration of new species (which include Sumatra, Malaya, Andamans in the present study), varying geological history, number and age of islands (e.g. Santos et al. 2010). Such departure will also take place in archipelagos where the proximity to the source allows inter-island variation in colonisation rates and / or the dispersal of particular species group, which in turn will produce non-nestedness and anomalous patterns of distributions of widespread species in different clusters of islands (*see* also Chapters V and VI). According to Santos et al. (2010), almost all archipelagos across the world as a rule follow the same island species-area relationship as their constituent islands, with only few exceptions. The present study suggests that the Nicobar archipelago is one of those exceptions.

## Chapter-V

# NESTEDNESS AND CO-OCCURRENCE PATTERNS OF BIRD ASSEMBLAGES IN THE NICOBAR ARCHIPELAGO

## 5.1 INTRODUCTION

A key question in community ecology of insular systems such as islands is whether species assemblages are composed randomly or non-randomly determined by the factors such as competitive interactions between species; extend of island area, degree of geographical isolation, latitude and habitat diversity. Diamond’s (1975) analyses of the distribution of birds of Bismark archipelago found that community assemblages were competitively structured and interspecific competitive interactions determined non-random species assemblages. Ever since Diamond (1975) proposed community assembly rules such as checkerboard distribution (i.e. pairs of species never co-occur together in the same island or site), different null models have been employed to test his assumptions (Ulrich and Gotelli 2007). When Connor and Simberloff (1979) pioneered null model analyses to test such patterns, intense debate and controversy over the null models started which lasted over decades (Gotelli and Entsminger 2001). Null models have been recognised as necessary and useful tools in the study of community ecology (Gotelli and Graves 1996, Gotelli 2001). A null model is based on randomization of ecological data where certain components of the data are held constant while others are allowed to vary, and is designed to make a pattern that would be expected in the absence of a particular ecological mechanism (Gotelli and Graves 1996). Two of the most commonly used null models are nestedness and species co-occurrence (Patterson and Atmar 1986, Gotelli 2000).

Nested subset structure is a common biogeographic pattern of community assembly in which small communities or assemblages form proper subsets of large communities (Ulrich and Gotelli 2007). In other words, in a proper nested subset pattern, species poor sites will form a subset of species rich sites (Patterson and Atmar 1986). Nested patterns have been widely reported for different taxonomic groups including in island birds (Davidar et al. 2002, Fleishman et al. 2002, Wright et al. 1998).

Assessing degree and scale of nestedness among assemblages could reveal mechanisms affecting species composition and community assembly (Patterson and Brown 1991). The mechanisms that cause nestedness have been attributed to area effects related to selective extinction, distance effects related to differential colonisation, nested habitats, speciation, hierarchical niche relationships, passive sampling and scale of observations (Patterson 1987, Wright et al.1998, Worthen et al. 1998, Patterson and Atmar 2000, Lomolino 1996).

Though significant nestedness has been reported for different taxa and insular systems, certain species and island assemblages do not conform to the nested patterns. The species that deviate from this nested pattern and occur where they are not expected are called idiosyncratic species, while islands with many idiosyncratic species are called idiosyncratic islands (Atmar and Patterson 1993, Azeria 2004). An important goal of nestedness analysis is to identify the idiosyncratic species and islands and infer causes of idiosyncrasy, which has practical applications in conservation biology such as planning strategies for species conservation and allocation of sites for conservation programmes (Ulrich et al. 2009, Azeria 2004).

Nestedness is a species co-occurrence pattern that mainly suggests positive species associations, while co-occurrence patterns such as ‘checkerboard’ distributions (‘some pairs of species never coexist, either by themselves or as part of a larger combination’ Diamond 1975) suggest negative species associations (Azeria 2004, Meyer and Kalko 2008). Diamond’s (1975) assembly rule analysis recognised the checkerboard and other distributions and reasoned that the presence of such patterns of distributions in any community is an indication for prevalence of deterministic factors such as competitive interactions structuring an assemblage. Due to statistical advances in null model analysis that occurred since Connor and Simberloff’s (1979) seminal paper, many metrics or indices and null models have been proposed to quantify and test nestedness and co-occurrence, and to investigate whether community assemblages are shaped by competitive interactions (Gotelli and Entsminger 2001) or other deterministic factors.

The features of the Nicobar archipelago such as the occurrence of islands in distinct scattered clusters as island groups demarcated by deep water channels, the differences in landscape characteristics between island groups (i.e. forest-grassland mosaic in the central-northern group and uniformly forested southern group), the high variations in area among constituent islands, and differences in species richness between island groups make the Nicobars an apt insular system to explore the patterns of community assemblage and suggest the potential causal role of underlying processes such as extinction and colonisation.

## 5.2 METHODS

A presence-absence matrix of island-wise distribution of resident land birds was prepared for the Nicobar archipelago. Only those species observed during the present study (except for the rare endemic Nicobar Scops Owl) were included in the matrix. Nevertheless, those species recorded in most of the islands, but missed to record in certain islands where the species have been reported earlier were incorporated into the matrix from the published literature (Abdulali 1964, 1965, 1967a, 1967b, 1978 and 1981, Sankaran 1997 and 1998). All nestedness and co-occurrence analyses were based on the presence-absence data, which is the basic unit of analysis in community ecology and biogeography (Mc Coy and Heck 1987).

To minimise bias due to inclusion of the species groups with different life history or habitat use strategies, the nestedness analyses were conducted for the whole species assemblage of the Nicobars, and for different subsets of island groups and subsets of selected and all resident species based on differences in mobility. The selected resident subset consists of non-water dependent resident birds while all resident subset included water-dependent species which are strong dispersers. Such subsets were considered because dispersal ability or differences in mobility of species could significantly influence nestedness and co-occurrence patterns (Zalewski and Ulrich 2006, Meyer and Kalko 2008).

### 5.2.1 Quantification of nestedness

A variety of different methods have been proposed to quantify nestedness. The detections of nestedness in presence-absence matrices are affected by both the type of metric used to quantify nestedness and reference null models used to test it (Ulrich and Gotelli 2007). There has been much debate over the most suitable methods and appeal for critical reassessment of many previous studies that have used biased metrics and unconstrained null models (Ulrich et al. 2009). The order in which a matrix is packed can substantially affect nestedness results (Strona et al. 2014). Comprehensive reviews of nestedness analyses recommend Brualdi and Sanderson discrepancy index (BR) as the best metric and fixed-fixed algorithm (FF) which maintains fixed row and fixed column totals as the best performing null model, which provides a conservative test of nestedness when used together (Ulrich and Gotelli 2007, Ulrich et al. 2009). Recently, an unbiased model called as ‘curveball algorithm’ has been introduced to randomise ecological binary matrices with fixed rows and fixed columns totals (Strona et al. 2014). For nestedness analyses, the online application- Nestedness for Dummies (NeD) was used which allowed selecting different metrics and combining them with different null models (Strona et al. 2014). Though different metrics and null models were considered for exploratory nestedness analyses and for comparing with relevant earlier studies, only FF (fixed rows and fixed columns) null model with BR metric (Brualdi and Sanderson discrepancy index) was used in detecting nestedness, which has been particularly recommended for island datasets (Gotelli 2000). The FF algorithm in the null matrices preserve observed differences in species richness between islands (column totals), and observed differences in the frequency of occurrence among species (row totals) (Gotelli 2000). Idiosyncrasy analyses of species and islands were done using program-NODF (Almeida-Neto and Ulrich 2011).

Matrix temperature metric (*T*) proposed by Atmar and Patterson (1993) was also calculated using the programme- Nestedness Temperature Calculator for the whole assemblage matrix of birds of the Nicobar archipelago and the island groups, as the programme was used to quantify nestedness of birds and butterflies of the Andaman archipelago (Davidar et al. 2002) which is located adjacent to the Nicobars. Though *T* metric has been criticised for its bias (Ulrich et al. 2009), it was nevertheless calculated to allow a comparison between the two adjacent archipelagos. The programme packs the matrix to maximum fill and compute observed matrix temperature to test against a (simulated) system generated mean matrix temperatures of matrices (in the present study 1000 matrices) randomly generated by Monte Carlo simulations (Atmar and Patterson 1995).

### 5.2.2 Causes of nestedness

The order in which islands and species are packed can be compared with potential independent variables that could affect nestedness such as area, isolation and number of habitats to examine their role in generating nestedness (Patternson and Atmar 2000). Presence-absence matrices of the different subsets of species were sorted with the species in rows with decreasing richness and the islands in columns with decreasing area, isolation measures, habitat diversity and latitude to understand which independent variables generated the strongest nested pattern (Fleishman and MacNally 2002). Thus, to assess the role of area, isolation measures, habitat diversity, elevation and latitude in determining nestedness, Spearman rank correlations were performed between the island ranks in the maximally packed matrix and the ranked independent variables. This method could suggest the possible role of extinction and colonisation events in creating the nested patterns (Patterson and Atmar 2000).

### 5.2.3 Co-occurrence patterns

Stone and Robert's (1990) checkerboard score (*C*-score) index measure the extent to which species are segregated across sites and is based on average number of “checkerboard units” between all possible pairs of species in the matrix. The number of ‘checkerboard units’ (*CU*) for any two species is calculated as $CU = (r_i\text{-}S)/(r_j\text{-}S)$, where $r_i$ and $r_j$ are the row totals (number of occurrences) for species *i* and *j*, respectively, and *S* refers to the number of co-occurrences. The *C*-score when compared with other indices is relatively insensitive to noise in the data and demonstrated to be less prone to Type I and II errors. The *C*-score should be significantly larger in a competitively structured community than expected by chance (Gotelli and Entsminger 2001, Meyer and Kalko 2008). The *C*-score was used along with fixed rows and fixed columns (FF) null model in the co-occurrence analyses. EcoSim software (version 7.0) was used to calculate observed C-*score* metric and FF null model to test it with the simulated score (Gotelli and Entsminger 2001). As the detections of co-occurrence patterns are affected by both the choice of null models and randomisation algorithm, sequential swap algorithm was used to generate null matrices with 5000 iterations which EcoSim set as the default. Standardised effect size (SES), i.e. observed C-*score*–mean simulated C-*score*)/standard deviation of simulated score, was also calculated. SES indicates the number of standard deviations that the observed index is above or below the mean score of simulated matrices. SES for C-*score* of non-random matrices generally is $> 2$ or $< -2$ which is statistically significant with a probability of $< 0.05$ (Gotelli and Entsminger 2001).

Non-random co-occurrence patterns are less likely to be detected at assemblage level due to lack of competition for resources among large number of species without any ecological interactions (Meyer and Kalko 2008). So, in addition to performing co-occurrence analyses on whole species assemblages of the Nicobars and island groups, analyses were also done for resident bird families with two or more representative species. Though taxonomic groups such as families are not always correspondingly similar to guild, many studies have used taxonomy to categorise biota into guilds (Collins et al. 2011).

## 5.3 RESULTS

### 5.3.1 Nestedness patterns

No significant nestedness was detected for the whole bird species assemblages in the Nicobar archipelago (Table 5.4). The whole bird species/island binary matrix (Table 5.1) was not significantly nested than expected by chance, either for the whole resident species or selected resident species subset (Table 5.4). However, bird assemblages of island groups within the archipelago exhibited significant nestedness. The central group comprising of eight islands were found to be significantly nested when matrix with all the resident birds of the group (Table 5.3) was analysed (BR = 24.0, $p < 0.05$). The southern group (BR = 9.0, $p < 0.01$) was very significantly nested (Table 5.4) when selected residents in the matrix (Table 5.2) of the group was analysed separately. The nestedness of the southern group was stronger than that of the central group.

The analyses using Nestedness Temperature Calculator showed a significant nestedness for the whole assemblage of the Nicobars as well as for all the island groups (Table 5.5). Observed matrix temperatures ($T$) were found to be significantly different from the simulated mean matrix temperatures of the whole assemblage and the island group subsets. Since $T$ metric has been demonstrated to be a biased metric (Ulrich et al. 2009), it was used only to compare general aspects of nestedness of the Nicobars in the present study with that of the Andamans by Davidar et al. (2002).

### 5.3.2 Causes of nestedness

Nestedness of bird assemblages in the central group was significantly correlated with island area, all measures of isolations, latitude and number of habitats (Table 5.6). The distance to the largest island was found to be the principal determinant of the nested pattern in the central group ($r_s = 0.905$, $p < 0.002$). The only determinants of nestedness in the southern group was island area ($r_s = 0.905$, $p < 0.002$) and number of habitats ($r_s = 0.881$, $p < 0.004$). Strikingly, the measures of isolations had no effect in determining the nested subset patterns of bird assemblages of the southern group (Table 5.6).

### 5.3.4 Idiosyncratic species and islands

For the whole bird assemblage of the Nicobars, the species that showed highest idiosyncrasies in distributions were White-headed Starling *Sturnus erythropygius,* Black-crowned Night-heron *Nycticorax nycticorax,* Stork-billed Kingfisher *Pelargopsis capensis,* South Nicobar Serpent-eagle *Spilornis klossi,* Nicobar Parakeet *Psittacula caniceps,* Crimson Sunbird *Aethopyga siparaja,* Black-backed Kingfisher *Ceyx erithaca,* Watercock *Gallicrex cinerea,* Greater Racket-tailed Drongo *Dicrurus paradiseus,* Nicobar Sparrowhawk *Accipiter butleri,* Nicobar Scops Owl *Otus alius,* Lesser Whistling-duck *Dendrocygna javanica* and

Table 5.1. Maximally packed presence-absence matrix of all 59 resident birds in 17 islands of the Nicobar archipelago. Idiosyncratic scores are given and species having relatively higher idiosyncrasy in occurrences are highlighted in bold. Refer to Table 4.1 for island codes.

| ***Species*** | **KM** | **GN** | **TR** | **NN** | **KT** | **LN** | **TS** | **CN** | **TI** | **KN** | **BP** | **PM** | **TE** | **MN** | **CH** | **MR** | **CU** | **No. of islands** | **Idiosyncrasy** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Eudynamys scolopaceus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 17 | 0.000 |
| *Nectarinia jugularis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 17 | 0.000 |
| *Haliaeetus leucogaster* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 17 | 0.000 |
| *Aplonis panayensis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 16 | 0.000 |
| *Hypothymis azurea* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 16 | 0.000 |
| *Chalcophaps indica* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 16 | 0.000 |
| *Ducula aenea [nicobarica]* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 16 | 0.000 |
| *Psittacula longicauda* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 16 | 0.063 |
| *Oriolus chinensis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 15 | 0.067 |
| *Megapodius nicobariensis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 15 | 0.133 |
| *Caloenas nicobarica* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 15 | 0.067 |
| *Ducula bicolor* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 15 | 0.133 |
| *Egretta sacra* | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 15 | 0.067 |
| *Todiramphus chloris* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 14 | 0.143 |
| *Collocalia fuciphaga* | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 14 | 0.143 |
| *Amaurornis phoenicurus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 14 | 0.071 |
| *Macropygia rufipennis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 13 | 0.154 |
| *Collocalia esculenta* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 13 | 0.077 |
| *Butorides striata* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 13 | 0.000 |
| *Treron pompadora* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 13 | 0.077 |
| *Sterna sumatrana* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 12 | 0.167 |
| *Zosterops palpebrosus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 12 | 0.167 |
| *Ardeola grayii* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 11 | 0.273 |
| *Terpsiphone paradisi* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 10 | 0.200 |
| *Columba palumboides* | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 10 | 0.200 |
| *Zoothera citrina* | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 10 | 0.200 |
| *Ixobrychus sinensis* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 10 | 0.300 |
| *Bubulcus ibis* | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0.125 |
| *Ixobrychus cinnamomeus* | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 8 | 0.375 |
| *Lonchura striata* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0.125 |
| *Ninox scutulata* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0.125 |

*Continued....*

| ***Species*** | **KM** | **GN** | **TR** | **NN** | **KT** | **LN** | **TS** | **CN** | **TI** | **KN** | **BP** | **PM** | **TE** | **MN** | **CH** | **MR** | **CU** | **No. of islands** | **Idiosyncrasy** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ninox affinis* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0.143 |
| *Gracula religiosa* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0.143 |
| ***Aethopyga siparaja*** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 7 | **0.714** |
| *Spilornis sp* | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 7 | 0.286 |
| ***Dicrurus paradiseus*** | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 7 | **0.571** |
| *Gorsachius melanolophus* | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0.143 |
| *Hypsipetes nicobariensis* | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0.286 |
| *Ardea purpurea* | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 0.286 |
| *Cisticola juncidis* | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 7 | 0.286 |
| *Halcyon pileata* | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 6 | 0.333 |
| *Alcedo atthis* | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 6 | 0.333 |
| *Mesophoyx intermedia* | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0.167 |
| ***Accipiter butleri*** | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | **0.500** |
| *Egretta garzetta* | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0.333 |
| *Coturnix chinensis* | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0.400 |
| ***Pelargopsis capensis*** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 5 | **0.800** |
| ***Gallicrex cinerea*** | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | **0.600** |
| *Turnix tanki* | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0.400 |
| *Accipiter virgatus* | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0.000 |
| ***Spilornis klossi*** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 4 | **0.750** |
| ***Psittacula caniceps*** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | **0.750** |
| *Lalage nigra* | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0.250 |
| ***Ceyx erithaca*** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **0.667** |
| ***Nycticorax nycticorax*** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | **1.000** |
| ***Otus alius*** | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | **0.500** |
| ***Sturnus erythropygius*** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | **1.000** |
| ***Dendrocygna javanica*** | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | **0.500** |
| ***Otus sunia*** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | **0.500** |
| Total no. of species | 50 | 47 | 45 | 44 | 41 | 39 | 39 | 36 | 30 | 29 | 28 | 27 | 23 | 22 | 22 | 21 | 6 | | |

Table 5.2. Maximally packed nested presence-absence matrix of all resident birds in eight islands of the southern group of islands. Idiosyncratic scores are given and species having higher idiosyncrasy in occurrences are highlighted. Refer to Table 4.1 for island codes.

| **Species** | **GN** | **LN** | **KN** | **PM** | **TE** | **MN** | **MR** | **CU** | **No. of islands** | **Idiosyncrasy** |
|---|---|---|---|---|---|---|---|---|---|---|
| *Eudynamys scolopaceus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Haliaeetus leucogaster* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Nectarinia jugularis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Megapodius nicobariensis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Ducula bicolor* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Aplonis panayensis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Hypothymis azurea* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Aethopyga siparaja* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Chalcophaps indica* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Ducula aenea [nicobarica]* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Psittacula longicauda* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 7 | 0.143 |
| *Egretta sacra* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Macropygia rufipennis* | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 6 | 0.167 |
| *Oriolus chinensis* | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 6 | 0.167 |
| *Collocalia fuciphaga* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 6 | 0.167 |
| *Caloenas nicobarica* | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 6 | 0.167 |
| *Todiramphus chloris* | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 5 | 0.200 |
| *Collocalia esculenta* | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 5 | 0.200 |
| *Dicrurus paradiseus* | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 5 | 0.200 |
| *Butorides striata* | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 5 | 0.000 |
| *Treron pompadora* | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 5 | 0.200 |
| *Pelargopsis capensis* | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 5 | 0.200 |
| *Amaurornis phoenicurus* | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 5 | 0.200 |
| *Sterna sumatrana* | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 4 | 0.250 |
| *Spilornis klossi* | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 4 | 0.250 |
| *Psittacula caniceps* | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4 | 0.250 |
| *Ardeola grayii* | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 4 | 0.250 |
| *Ardea purpurea* | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 0.000 |
| ***Ixobrychus sinensis*** | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 4 | **0.500** |
| *Terpsiphone paradisi* | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0.333 |
| *Columba palumboides* | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0.333 |
| *Gracula religiosa* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0.000 |
| *Ixobrychus cinnamomeus* | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 0.333 |
| *Ceyx erithaca* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0.000 |
| *Zosterops palpebrosus* | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0.333 |
| *Ninox scutulata* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0.000 |
| *Ninox affinis* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.000 |
| *Bubulcus ibis* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.000 |
| ***Spilornis sp*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | **1.000** |
| *Mesophoyx intermedia* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.000 |
| *Gorsachius melanolophus* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.000 |
| *Zoothera citrina* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.000 |
| ***Gallicrex cinerea*** | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | **1.000** |
| *Halcyon pileata* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.000 |
| ***Nycticorax nycticorax*** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | **1.000** |
| *Accipiter virgatus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.000 |
| *Alcedo atthis* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.000 |
| *Otus alius* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.000 |
| *Lonchura striata* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.000 |
| *Egretta garzetta* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.000 |
| Total no. of species | 47 | 39 | 29 | 27 | 23 | 22 | 21 | 6 | | |

Table 5.3. Maximally packed nested presence-absence matrix of all resident birds in nine islands of the central-northern group of islands. Idiosyncratic scores are given and species having higher idiosyncrasy in occurrence are highlighted. Refer to Table 4.1 for island codes.

| ***Species*** | **KM** | **TR** | **NN** | **KT** | **TS** | **CN** | **TI** | **BP** | **CH** | **No. of islands** | **Idiosyncracy** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aplonis panayensis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Eudynamys scolopaceus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Hypothymis azurea* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Oriolus chinensis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Todiramphus chloris* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Chalcophaps indica* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Ducula aenea [nicobarica]* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Psittacula longicauda* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Caloenas nicobarica* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Nectarinia jugularis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Zosterops palpebrosus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Haliaeetus leucogaster* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Amaurornis phoenicurus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 0.000 |
| *Sterna sumatrana* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 7 | 0.125 |
| *Collocalia fuciphaga* | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 0.125 |
| *Collocalia esculenta* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Butorides striata* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Zoothera citrina* | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 0.125 |
| *Treron pompadora* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | 0.000 |
| *Egretta sacra* | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 0.125 |
| *Macropygia rufipennis* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 6 | 0.143 |
| *Terpsiphone paradisi* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 6 | 0.143 |
| *Columba palumboides* | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 6 | 0.143 |
| *Hypsipetes nicobariensis* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 6 | 0.143 |
| *Megapodius nicobariensis* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 6 | 0.143 |
| *Ducula bicolor* | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 6 | 0.143 |
| *Ardeola grayii* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 6 | 0.143 |
| *Lonchura striata* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 6 | 0.143 |

*Continued.....*

| ***Species*** | **KM** | **TR** | **NN** | **KT** | **TS** | **CN** | **TI** | **BP** | **CH** | **No. of islands** | **Idiosyncracy** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cisticola juncidis* | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 6 | 0.286 |
| *Bubulcus ibis* | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 5 | 0.167 |
| *Accipiter butleri* | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 5 | 0.167 |
| *Ixobrychus sinensis* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 5 | 0.000 |
| *Ninox affinis* | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 4 | 0.200 |
| *Coturnix chinensis* | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 4 | 0.200 |
| *Halcyon pileata* | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 4 | 0.200 |
| *Ixobrychus cinnamomeus* | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 4 | 0.400 |
| *Alcedo atthis* | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 4 | 0.400 |
| *Spilornis sp* | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 0.000 |
| *Gorsachius melanolophus* | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 4 | 0.200 |
| *Ninox scutulata* | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 4 | 0.200 |
| *Egretta garzetta* | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 4 | 0.200 |
| *Turnix tanki* | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 4 | 0.200 |
| *Gracula religiosa* | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0.000 |
| *Mesophoyx intermedia* | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 0.250 |
| *Lalage nigra* | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0.000 |
| *Accipiter virgatus* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.000 |
| *Ardea purpurea* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.000 |
| *Gallicrex cinerea* | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0.333 |
| ***Dicrurus paradiseus*** | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | **1.000** |
| ***Sturnus erythropygius*** | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | **1.000** |
| *Dendrocygna javanica* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.000 |
| ***Otus sunia*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | **0.500** |
| ***Nycticorax nycticorax*** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1.000** |
| ***Otus alius*** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | **1.000** |
| Total no. of species | 50 | 45 | 44 | 41 | 39 | 36 | 30 | 28 | 22 | | |

Table 5.4. Results of nestedness analyses conducted with program NeD on the species by island matrix for different subsets of bird assemblages of 17 islands of the Nicobar archipelago. The analyses was done using 'curviball algorithm' null model (fixed rows- fixed columns; FF) together with BR metric.

| | **Nestedness measures** | | | |
|---|---|---|---|---|
| | **BR index** | ***z*-score** | **Relative nestedness** | ***p*** |
| **All residents** | | | | |
| *Nicobar archipelago* | 96.0 | 0.363 | 0.014 | >0.05 |
| *Central-northern group* | 36.0 | -0.995 | -0.055 | >0.05 |
| *Central group #* | 24.0 | -1.814 | -0.136 | **<0.05** |
| *Southern group* | 26.0 | -0.615 | -0.043 | >0.05 |
| **Selected residents** | | | | |
| *Nicobar archipelago* | 56.0 | 0.249 | 0.013 | >0.05 |
| *Central-northern group* | 22.0 | 0.88 | 0.063 | >0.05 |
| *Central group* | 14.0 | -0.086 | -0.009 | >0.05 |
| *Southern group #* | 9.0 | -2.391 | -0.253 | **<0.01** |

# indicates significant nestedness

Table 5.5. A comparison of nestedness measures of 47 selected birds of the Andamans (Davidar et al. 2002) with 38 selected bird of the Nicobars in the present study (for whole assemblages and island group subsets) based on the analyses using Nestedness Temperature Calculator (Atmar and Patterson 1995). The significance of differences between matrix temperatures (observed) and system temperatures (simulated) are given.

| **Archipelago/ groups** | **Matrix fill %** | **Observed T$^o$** | **Simulated ST$^o$** | ***p*** |
|---|---|---|---|---|
| Davidar et al. (2002) | | | | |
| Andaman archipelago | 53.6 | 6.43 | 73.53 | <0.01 |
| North Andamans | 41.7 | 11.46 | 63.87 | <0.01 |
| Middle Andamans | 60.9 | 3.88 | 60.87 | <0.01 |
| South Andamans | 53.3 | 5.37 | 62.23 | <0.01 |
| Present study | | | | |
| Nicobar archipelago | 56.4 | 17.5 | 64.95 | <0.01 |
| Central-north group | 62.3 | 18.33 | 51.05 | <0.01 |
| Central group | 62.9 | 12.41 | 49.01 | <0.01 |
| Southern group | 56.0 | 6.56 | 52.14 | <0.01 |

Table 5.6. Results of Spearman's rank order correlations of island rank order in the maximally packed matrix with rank order of island area, measures of isolation, latitude and habitat diversity. The variable with highest correlation coefficient and significant *p*-value (in bold) considered as the principal determinant of the nested pattern for each subset.

| | **Nestedness measures** | | | | **Rank correlation** | | |
|---|---|---|---|---|---|---|---|
| | **BR index** | ***z*-score** | **Relative nestedness** | ***p*** | ***n*** | **$r_s$** | ***p*** |
| ***Central group #*** | | | | | | | |
| Area | 24.0 | -1.487 | -0.123 | p>0.05 | 8 | .786* | 0.021 |
| D_Largest | 24.0 | -1.712 | -0.123 | p<0.05 | 8 | **.905**** | **0.002** |
| D_Nearest | 24.0 | -1.832 | -0.132 | p<0.05 | 8 | .810* | 0.015 |
| D_Andamans | 24.0 | -1.718 | -0.133 | p<0.05 | 8 | .714* | 0.047 |
| D_Sumatra | 24.0 | -1.782 | -0.124 | p<0.05 | 8 | -.714* | 0.047 |
| D_Anda/Suma | 24.0 | -1.899 | -0.135 | p<0.05 | 8 | -.714* | 0.047 |
| Latitude | 24.0 | -1.569 | -0.119 | p>0.05 | 8 | 0.643 | 0.086 |
| Habitats | 24.0 | -1.765 | -0.135 | p<0.05 | 8 | .738* | 0.037 |
| ***Southern group @*** | | | | | | | |
| Area | 9.0 | -1.899 | -0.246 | <0.05 | 8 | **.905**** | **0.002** |
| D_Largest | 9.0 | -1.716 | -0.213 | <0.05 | 8 | 0.571 | 0.139 |
| D_Nearest | 9.0 | -1.692 | -0.224 | <0.05 | 8 | 0.429 | 0.289 |
| D_Andamans | 9.0 | -1.894 | -0.232 | <0.05 | 8 | -0.452 | 0.260 |
| D_Sumatra | 9.0 | -1.816 | -0.231 | <0.05 | 8 | 0.452 | 0.260 |
| D_Anda/Suma | 9.0 | -2.209 | -0.249 | <0.05 | 8 | 0.452 | 0.260 |
| Latitude | 9.0 | -2.124 | -0.256 | <0.05 | 8 | 0.571 | 0.139 |
| Habitats | 9.0 | -2.018 | -0.231 | <0.05 | 8 | .881** | 0.004 |

# indicates significant nestedness in the central group (for all resident matrix) and in the southern group (for selected resident matrix).

Table 5.7. Results of the idiosyncrasy analyses of species and islands done using program-NODF. Islands with highest idiosyncrasy scores are highlighted in bold and indicated by asterisk, and islands with high nestedness are underlined for each subset.

| Island code | Islands | No. of species | | Idiosyncrasy | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Nicobars | | Southern group | | Central-northern group | | Central group | |
| | | *a#* | *b#* | *a* | *b* | *a* | *b* | *a* | *b* | *a* | *b* |
| GN | Great Nicobar | 47 | 29 | 0.106 | 0.138 | 0.043 | 0.034 | - | - | - | - |
| LN | Little Nicobar | 39 | 26 | 0.128 | 0.077 | 0.051 | 0.000 | - | - | - | - |
| KN | Kondul | 29 | 20 | **0.310*** | **0.250*** | **0.172** | 0.150 | - | - | - | - |
| PM | Pilo Milo | 27 | 18 | **0.222*** | 0.167 | 0.074 | 0.000 | - | - | - | - |
| TE | Treis | 23 | 13 | **0.217*** | 0.154 | **0.261*** | 0.077 | - | - | - | - |
| MN | Menchal | 22 | 19 | **0.273*** | **0.263*** | **0.182*** | 0.105 | - | - | - | - |
| MR | Meroe | 21 | 15 | **0.190*** | 0.133 | **0.190*** | 0.067 | - | - | - | - |
| CU | Cubra | 6 | 5 | **0.500**** | **0.600**** | 0.167 | **0.200*** | - | - | - | - |
| KM | Kamorta | 50 | 32 | 0.060 | 0.063 | - | - | 0.040 | 0.031 | 0.000 | 0.000 |
| TR | Trinket | 45 | 28 | 0.156 | 0.143 | - | - | 0.111 | 0.107 | 0.089 | 0.107 |
| NN | Nancowry | 44 | 31 | 0.114 | 0.065 | - | - | 0.068 | 0.000 | 0.068 | 0.000 |
| KT | Katchal | 41 | 30 | 0.122 | 0.100 | - | - | 0.146 | 0.100 | 0.122 | 0.100 |
| TS | Teressa | 39 | 26 | **0.179*** | **0.231*** | - | - | 0.103 | 0.115 | 0.103 | 0.115 |
| TI | Tillanchong | 30 | 20 | 0.067 | 0.050 | - | - | 0.100 | 0.050 | 0.100 | 0.050 |
| BP | Bompoka | 28 | 22 | 0.143 | 0.136 | - | - | 0.071 | 0.045 | 0.071 | 0.045 |
| CH | Chowra | 22 | 14 | **0.227*** | **0.214*** | - | - | **0.182*** | 0.143 | **0.227*** | **0.214*** |
| CN | Car Nicobar | 36 | 24 | **0.222*** | **0.208*** | - | - | **0.222*** | **0.208*** | - | - |

***#a*** refers to all resident species (59 *sp.*) subset; ***b*** refers to selected non-water dependent resident species (38 *sp.*) subset.

Oriental Scops-owl *Otus sunia* (Table 5.1). All these species are island group endemics/ species with disjunct distribution/ species with rare or isolated distributions.

Since no significant nestedness was found for the whole assemblage of the Nicobars, it was more meaningful to identify idiosyncratic species within the island groups where the significant nestedness was detected. In the central or central-northern group, White-headed Starling *Sturnus erythropygius* (which has a very restricted and discontinuous distributions in just two islands- Katchal and Car Nicobar Islands), Greater Racket-tailed Drongo *Dicrurus paradiseus* (found in most of the islands of southern group, but restricted to Katchal and Car Nicobar in the central-northern group), Nicobar Scops Owl *Otus alius* (the rarest of all endemics with a single record from Great Nicobar in the southern group and a photographic record from Teressa in the central group), Lesser Whistling-duck *Dendrocygna javanica* (recorded only from Trinket Island), Black-crowned Night-heron *Nycticorax nycticorax* (rarely recorded probably due to its crepuscular or nocturnal habits) and Oriental Scops-owl *Otus sunia* (isolated records from Kamorta and Katchal Islands) were the species showing idiosyncrasies in occurrence (Table 5.3). The idiosyncratic species of the southern group were Watercock *Gallicrex cinerea*, (Crested?) Serpent-eagle *Spilornis sp.*, Black-crowned Night-heron *Nycticorax Nycticorax* and Yellow Bittern *Ixobrychus sinensis*. Except the Serpent-eagle, all species were water-dependent with sporadic occurrence (Table 5.2).

Asian Koel *Eudynamys scolopaceus*, Olive-backed Sunbird *Nectarinia jugularis*, White-bellied Sea Eagle *Haliaeetus leucogaster* were ubiquitous species, occurring on all 17 islands surveyed. Glossy Starling *Aplonis panayensis*, Black-naped Monarch *Hypothymis azurea*, Emerald Dove *Chalcophaps indica*, Green Imperial Pigeon *Ducula aenea [nicobarica]* and Long-tailed Parakeet *Psittacula longicauda* occurred on 16 sixteen islands. Black-naped Oriole *Oriolus chinensis*, Nicobar Megapode *Megapodius nicobariensis*, Nicobar Pigeon *Caloenas nicobarica*, Pied Imperial Pigeon *Ducula bicolor* and Pacific Reef Egret *Egretta sacra* occurred on 15 islands (Table 5.1). All these species consequently showed high nestedness in distribution.

Cubra Island showed highest idiosyncrasy when the entire Nicobar was considered, followed by other small islands such as Kondul, Menchal, Chowra, Pilo Milo, Treis and Meroe. Car Nicobar and Teressa also showed idiosyncrasies at lower degrees. The pattern was more or less the same when subsets of islands groups and resident species were separately analysed (Table 5.7).

### 5.3.5 Co-occurrence patterns

The species co-occurrence analyses at whole assemblage level of the Nicobars showed significant segregation of species (Table 5.8). The southern group possessed a rather poorly structured community than in the central or central-southern group where it was slightly more structured. The patterns were qualitatively very similar for both selected species and all resident species subsets. Analyses of co-occurrence at family level indicated that most of species within the families were randomly assembled. Table 5.8 shows the significantly segregated groups of species of bird families with highest C–*score* values. The only bird families that showed significant co-occurrence patterns were Strigidae of the central-northern group and Alcedinidae of the entire Nicobars.

## 5.4 DISCUSSION

### 5.4.1 Nestedness patterns

Unlike many studies in islands and other insular systems where nestedness has been widely reported across a range of taxa (e.g. Davidar et al. 2002, Azeria 2004, Meyer and Kalko 2008), the whole resident bird assemblage in the Nicobar archipelago did not show a significant nested pattern. A common and recent biogeographical or evolutionary history among sites, similar contemporary environments and hierarchical organization of niche relationships of species have been suggested as the essential conditions for the nested subset pattern to occur (Patterson and Brown 1991). The absence of nested subset pattern for the whole Nicobar archipelago suggests that the constituent islands and islands groups violate any or all of these conditions for nestedness to occur. This strongly indicates that at least two of the island groups within the Nicobar archipelago probably have its own unique biogeographical history, peculiar environments and / or non-hierarchical niche relationships of species. On the other hand, a significant nestedness within the central group (for all residents) and the southern group (for selected residents) indicate that the constituent islands in the respective island groups conform to the perquisites for occurrence of the nested patterns.

When subsets of central and northern group (Car Nicobar Island) were considered together, the bird assemblages didn’t show a nested pattern suggesting that the two island groups differed in species composition and underlying processes that determine nestedness. The lack of nestedness in all resident subset of the southern group, that included more mobile water-dependent species, was probably due to sporadic dispersal of these species among islands in the group. The central group showed significant nestedness only for all resident subset suggesting the less sporadic movements of water-associated species in the group.

A comparison of the present study with that of Davidar et al. (2002) indicates that the bird assemblages of the Andaman archipelago is strikingly more nested than the whole assemblages of the Nicobar archipelago (Table 5.5). Overall nestedness within island groups was also higher in the Andamans than in the Nicobars. North Andamans was the least nested group in the Andaman archipelago which showed higher idiosyncrasy in species and island distributions, while central-northern group was the least nested in the Nicobar archipelago with higher anomalies in distributions (Tables 5.4 and 5.5). The overall pattern of nestedness of the entire Andamans was more similar to pattern of nestedness within the southern group of the Nicobars than with the entire Nicobars.

### 5.4.2 Causes of nestedness

A nested subset pattern suggests a hierarchical community organisation which can be caused by different mechanisms such as area effects related to selective extinction, distance effects related to differential colonisation, nested habitats, speciation, hierarchical niche relationships, passive sampling and scale of observations (Patterson 1987, Wright et al.1998, Worthen et al. 1998, Lomolino 1996).

The significant correlation of nestedness of bird assemblages in the central group with area, measures of isolations, latitude and habitat distributions (Table 5.6) point towards interplay of the different underlying mechanisms influencing the community assembly, among which the differential colonisation (as indicated by strong correlation of nestedness with the distance to the nearest island; Table 5.6) played the most prominent role. Intra-island distances in the central group were substantial because islands within the group occurred more scattered than in the southern group.

In the southern group, the selective extinction and habitat nestedness, as indicated by the significant correlation of nestedness with the island area and number of habitats, apparently were the only mechanisms that determined community assembly. The range of variations in the island area between smallest and largest island in the southern group was very high (0.04 $km^2$ – 1045.1 $km^2$). Rare or less common forest birds such as *Otus alius, Alcedo atthis, Accipiter virgatus, Ninox scutulata, Ninox affinis* and *Zoothera citrina* were found only on the large islands in the southern group. Similarly, for the whole Andamans as well as within its each island group, area was the most significant factor that influenced nestedness in forest bird distributions (Davidar et al. 2002). Thus the patterns of nestedness and underlying mechanisms that determine nestedness of the Andamans were similar to the southern group of the Nicobars than to the other island groups or entire Nicobars. Since the differences in mobility or dispersal ability of species could significantly influence nestedness (Zalewski and Ulrich 2006), the lack of effect of isolation on nestedness of selected residents of the southern group was possibly due to high mobility and frequent dispersal of bird species between islands (Fleishman et al. 2002). On the other hand, the species inhabiting the central group were probably less vagile and selective colonisers with respect to the distance between islands.

The prominent effect of isolation in the central group and effect of island area and number of habitats in the southern group as the variables determining species richness and similarity in species composition within island groups has also been clearly shown by regression (Chapter IV) and cluster analyses (Chapter VI). This reinforce the conclusion that the underlying mechanisms, that determined species richness, species composition, nestedness and co-occurrence, were consistently different for the two islands groups, i.e. southern group is dominated by area effects related to selective extinction, while the central group is dominated by the distance effects related to differential colonisation.

The differences of each island group in island configuration (islands in the southern group are mostly less scattered than the islands in the central-northern group), landscape characteristics (i.e. forest-grassland mosaic in the central-northern group and uniformly forested southern group), and distribution of area (exceptionally large and very small islands in the southern group) are all indications of different underlying processes governing species assemblages of the two island groups. Nevertheless, the present analyses should be considered as only suggestive as it was difficult to resolve to what degree the underlying mechanisms such as selective extinction, differential colonisation, habitat nestedness and other processes influence the nested patterns in the island groups (e.g. Collins 2006).

Davidar et al. (2002) found a distinct latitudinal trend in nestedness of birds in the Andamans based on analysis using *T* metric, where Middle and South Andaman groups were more nested than North Andamans. Apparently a similar trend was also found in the Nicobars where the southern group was more nested than the central or central-northern groups (Tables 5.4 and 5.5). However, there has been appeal for critical reassessment of many previous studies that have used biased metrics such *T* metric (Ulrich et al. 2009). Thus, the nestedness analyses of birds of the Andamans may reveal different patterns of nestedness or non-nestedness when other comparatively reliable metric such as BR or conservative null models such as FF which has been applied in this study. Yet, valid interpretations on nestedness and its causes could be drawn from the variations in *T* metric values from Davidar et al. (2002) for comparison between the archipelagos (Table 5.5).

### 5.4.3 Idiosyncratic distributions

The lack of nested subset pattern for the whole assemblage might have also be due to speciation of endemics exclusive to the island groups, and disjunct, restricted or sporadic distributions of some species in the Nicobars. This was indicated by the following idiosyncratic species identified when whole assemblage of the Nicobars was considered: South Nicobar Serpent-eagle *Spilornis klossi* (central group endemic), Nicobar Parakeet *Psittacula caniceps* (southern group endemic), Nicobar Sparrowhawk *Accipiter butleri* (central-northern group endemic), Nicobar Scops Owl *Otus alius* (the rarest of all endemics with just a type specimen collected from Great Nicobar in the southern group and a photographic record from Teressa in the central group), White-headed Starling *Sturnus erythropygius* (which has a very restricted and discontinuous distributions in just two islands- Katchal and Car Nicobar), Greater Racket-tailed Drongo *Dicrurus paradiseus* (found in most of the islands of southern group, but restricted to Katchal and Car Nicobar in the central-northern group), Crimson Sunbird *Aethopyga siparaja* (confined to the southern group), Oriental Scops-owl *Otus sunia* (isolated records from Kamorta and Katchal Islands), Black-crowned Night-heron *Nycticorax nycticorax* (rarely recorded probably due to its crepuscular or nocturnal habits), Lesser Whistling-duck *Dendrocygna javanica* (recorded only from Trinket Island), Stork-billed Kingfisher *Pelargopsis capensis*, Black-backed Kingfisher *Ceyx erithaca*, Watercock *Gallicrex cinere* (species with sporadic distributions) (Table 5.1). The idiosyncratic species of the southern group were mostly resident water birds with sporadic distributions. The idiosyncrasy of species depended on whether analyses were done for whole assemblage or separately for island groups. The endemics and species restricted to particular island group that showed non-nested distributions in whole assemblage of the Nicobars, in turn exhibited a nested patterns of distributions within islands groups as they were widely distributed within the respective group (Tables 5.2 and 5.3). Identifying the causes of idiosyncrasy of these species may need detailed study of their ecology, natural history and even experimental manipulations (e.g. Collins et al. 2011). Majority of idiosyncratic islands were small in size (<10 km$^2$). The inter-island variations in landscape characteristics and inherently unique features of small islands such as large border area (Barrett et al. 2003) could be the causes of their non-nestedness.

### 5.4.4 Conservation implications

Nestedness analysis is an important tool in prioritising conservation reserves and it has been widely applied to identify sites for species conservation (Azeria 2004). Reviving the SLOSS (single-large-or-several-small) reserves debate, Patterson and Atmar (1986) and Patterson (1987) argued that significant nested patterns in a region could suggest that a single large reserve will be sufficient for species conservation since it will harbour more species than a group of small sites of same total area (Simberloff and Martin 1991). According to Cook and Quinn (1995), when frequent colonisation is a major factor in increasing nestedness, then preservation of multiple small sites may be necessary. In this context, it could be suggested that reserves in large islands in the Nicobars will be effective in the southern group (due to area effects related to selective extinction), while reserves in different islands will be required for species conservation in the central or central-northern group (due to distance effects related to differential colonisation). However, this would be a very simplistic view of prioritising and designing conservation reserves and there has been strong criticism against the use of summary statistics of nestedness to qualify an entire community and provide recommendations for reserve designs (Simberloff and Martin 1991). Moreover, nestedness of assemblages varies spatially across different taxonomic groups and a single group such as birds cannot be taken as a surrogate to characterise the whole community (Fleishman et al. 2002). Incidentally, Great Nicobar, an exceptionally large island in the southern group, encompass much of the protected areas in the Nicobars (*c*.30%), where two national parks, Galathea and Campbell Bay, constitute to form Great Nicobar Biosphere Reserve. Tillanchong Island and Batti Malv Island Wildlife Sanctuaries are the only declared protected areas in the central-northern group. Sankaran (1997) has dealt in detail on the lacunas in protected area network in the Nicobar archipelago. He has appealed to take urgent steps to establish protected areas, especially in the islands of Kamorta, Katchal and Nancowry in the central group as well as in Little Nicobar in the southern group. This study suggests that the small islands such as Menchal (which had high incidence of endemics like Nicobar Parakeet) in the southern group, Chowra (unique in having mixed forest on table top of a coralline hill) and Bompoka (which had high incidence of endemic Nicobar Megapode), and undisturbed forested northern region of the medium-sized Teressa Island in the central group need to be added to this list. Though, nestedness has only limited use as a conservation tool due to its scale and context-dependent nature, the present study could identify nested patterns in bird assemblages within island groups in the Nicobars and suggest underlying mechanisms causing nested subset patterns (e.g. Frick et al. 2009).

### 5.4.5 Co-occurrence patterns

A community with many species combinations showing negative species associations such as ‘checkerboard distributions’ is considered highly structured due to prevalence of interspecific competitions (Diamond 1975). The influence of competition or other factors in determining community structure was dependent on at what level the analyses were carried out (Table 5.4). The species co-occurrence analyses at whole assemblage level of the Nicobars showed significant segregation of species which was probably due to restricted distribution of some endemics and other species within island groups, rather than due to effects of interspecific competitions. The southern group possessed a rather poorly structured community than the central or central-southern group.

However, co-occurrence analyses among species of similar guilds or species in the same taxa such as family are more meaningful than at assemblage level since the competition for resources occur among species which potentially have more ecological interactions (Meyer and Kalko 2008). Many studies have considered taxonomy to group species into guilds (Collins et al. 2011). Co-occurrence analyses at family level indicated that most of species within different families were randomly assembled. The average Standardised Effect Size (SES) value for C-*score* > 2 or < -2 indicates statistically significant non-random co-occurrence (Gotelli and Entsminger 2001). According to a review by Gotelli and McCabe (2002), SES value for the *C*-score reported for birds is 3.65.  Except for species of Strigidae of the central-northern group and Alcedinidae of the entire Nicobars, all species groups in the other families didn’t show significant non-random segregated patterns (SES values were mostly below > 1 or < -1). Thus, overall patterns suggest that negative competitive interactions are less common and bird community assemblages are less structured in the Nicobars. In the Nicobars, most families or genera of resident birds were represented by less than two or few species. The impoverishment of avifauna in general and less representation of species within guilds or families *per se* could be major causes for the random co-occurrence patterns.

## Chapter-VI

# BIOGEOGRAPHIC DISTRIBUTION PATTERNS AND AFFINITIES OF BIRDS OF THE NICOBAR ARCHIPELAGO

## 6.1 INDRODUCTION

The biogeographical history of the Nicobar archipelago is contentious (e.g. Mani 1974, Ripley and Beehler 1989) which is largely due to lack of empirical analysis to deduce the affinities of the island biota (Ripley and Beehler 1989). The Nicobar archipelago is part of Sundaland biodiversity hotspot (Davis et al. 1995) and Sundaic biogeogrpahic sub-region of Southeast Asia (Woodruff 2010), which is geographically complex and very much affected by changes in climate, sea level and geology during both Pliocene and Pleistocene (Outlaw and Voelker 2008). This has lead to complex patterns of biological diversity and thus the biogeography of this region remains poorly understood (Meijaard 2009). It is crucial to understand the geographical and geological history of the Nicobar archipelago in particular, and Southeast Asia in general to examine its biogeography.

### 6.1.1 Geographical and geological settings

The Nicobar archipelago is considered to be of volcanic origin and is an extension of the Mentawai island chain to the west of Sumatra (Das 1999) which was formed approximately 60 million years ago as a result of upward thrusting of oceanic plates during Indian subcontinent's collision with mainland Asia (Whitten et al. 2001). Though, the Sundaland region continued to be geologically active throughout Pliocene, its geological settings was not different since the late Miocene (*c.* 10 Ma). However, the geographical configuration and extent of many islands in the regions were affected by tectonic activities (6-3 Ma), and island groups were connected through volcanic emergence along plate margins, resulting in smaller islands being stepping-stone landmasses among larger ones (Outlaw and Voelker 2008). The present geography of Southeast Asian region is unusually small and fragmented and reflects only *c.* 2% of the last million years. About 90% of the times, region's landmasses were few times larger than present with lowered sea levels, cooler climates, and with vast expanse of forest and savanna covering the emerged plains of Sunda shelf (Woodruff 2010).

The long-term patterns of connection and isolation of islands in the Pleistocene (Heany 1991) owing to global sea-level lowering in defining the species composition of island biota is of considerable importance in biogeography. The rise of sea levels at *c.* 3 Ma increased the distance between islands and island groups (Moss and Wilson 1998). The presence of permanent water barriers or land connection with neighbouring land masses during Pleistocene defines an island as either true oceanic or land-bridge. Permanent water barriers have isolated the Andaman and Nicobar archipelagos from the adjacent regions (Ripley and Beehler 1989), hence islands of the Nicobars can be considered truly oceanic.

These complex settings of the region allow the testing of several biogeographical hypotheses regarding species distribution patterns (Outlaw and Voelker 2008). The biogeographic accounts of Southeast Asia have focussed on two aspects in the region- occurrence of land bridges between the islands and changes in habitats due to climatic factors (Hope et al. 2004, Meijaard 2009). Many biogeographers consider Pleistocene Last Glacial Maximum and accompanying sea-level changes as major factors in the explanation of biogeogrpahic patterns and species divergence. It has been suggested that most species immigrated across Sundaland during glacial period, until 10,000 years ago, when higher sea-levels again separated the island biota (Meijaard 2009). Stressmann (1939; cross referred from Meijaard 2009), hypothesised alternate dry and wet periods during Pleistocene to explain the distribution of forest and grassland fauna in Southeast Asia. Moreover, a dry savanna corridor hypothesis during glacial maxima has been proposed to explain disparity in biogeographical patterns between western and eastern Sundaland (Yang 2012).

The patterns of species occurrence on constituent islands and island groups in an archipelago and their affinities with adjacent biogeographical regions as source pools are traditionally and widely used to understand the roles of distinct water (geographical) barriers in separating populations of islands from the adjacent mainland regions.

### 6.1.2 Biogeographical settings

The biogeographical affinities of the Nicobar archipelago had been attributed to geographically closer Sumatra or Sundaic region than to much farther Burma or Indo-Chinese region to which the Andaman archipelago is closer (e.g. Mani 1974, Das 1999). Based on floristic affinities, Davis et al. (1995) considered the Nicobar archipelago as a part of the Sundaland biodiversity hotspot, which encompass the western half of Indo-Malayan archipelago (Fig. 6.1). Many floral and faunal groups which are commonly occurring in Sundaic region and the Nicobars, do not have distribution in the Andamans (Das 1999, Harikrishnan et al. 2010). Ripley and Beehler (1989) contested this assumption based on their analysis of similarity of the breeding avifauna of the Andaman and Nicobar archipelagos with the adjacent regions. They argued that bird species colonised the Nicobar archipelago not

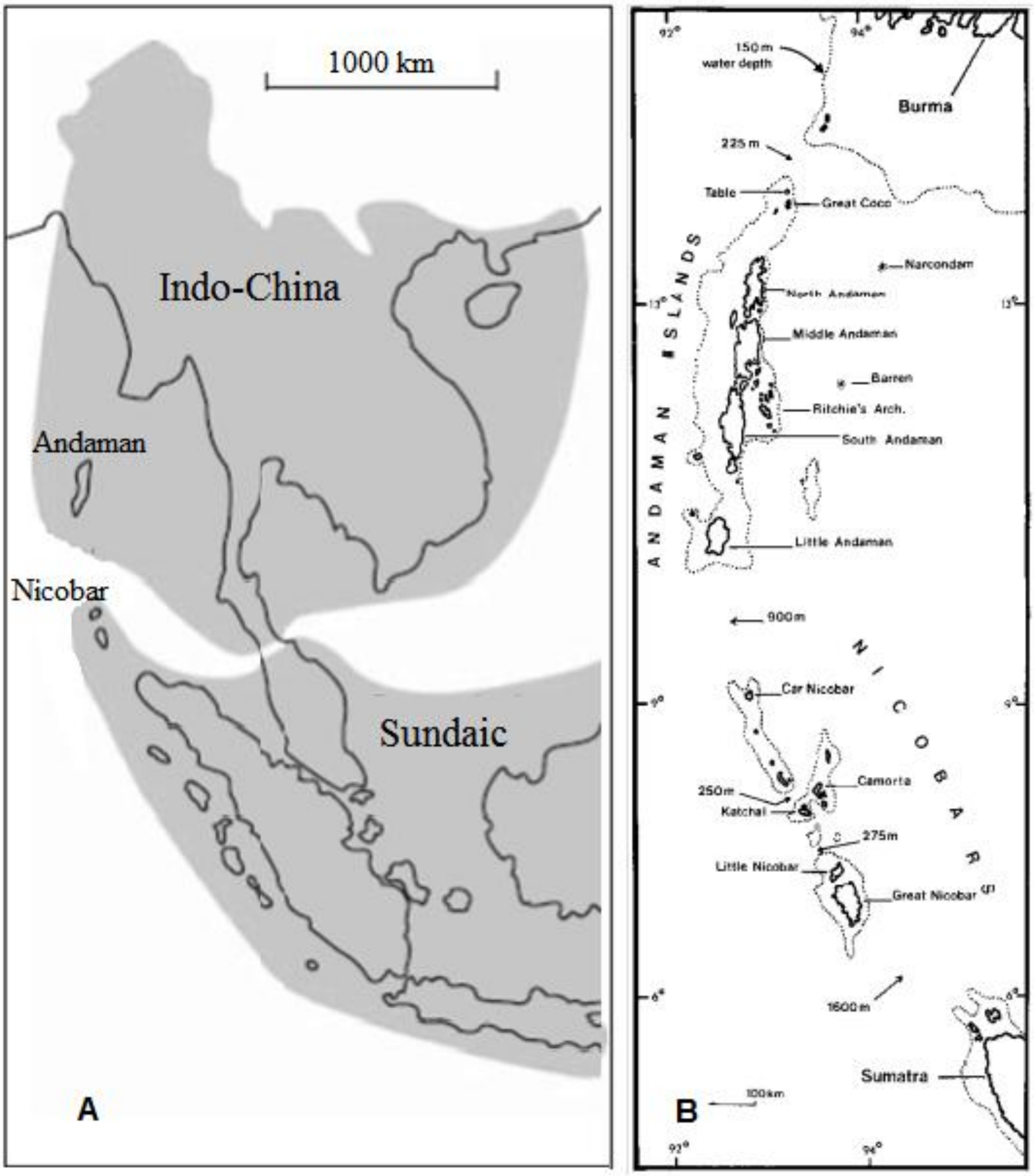

Fig. 6.1. **A**. Map of Southeast Asia depicting biogeographic subregions adjacent to the Andaman and Nicobar Islands (Map adopted from Woodruff 2010) where the Andamans is the part of Indo-China and the Nicobars is the part of Sundaic biogeographic subregions. **B**. Map of the Andaman and Nicobar Islands with adjacent biogeographic regions of potential source pools, and showing the shelf area that would be exposed by a sea level lowering at bathymetric contours of 150 m (Map from Ripley and Beehler 1989).

from adjacent Sumatra, but by island-hopping from south-western Burma, along the Andaman archipelago, crossing permanent water barriers. According to Ripley and Beehler (1989), the depth of channel were deep enough to separate the Andaman and Nicobar archipelagos from any adjacent source pools and these regions were never connected by a Pleistocene land-bridge. Ripley and Beehler (1989) charted a map of the region in which they considered shelf area that would be exposed by a maximum Pleistocene sea lowering at bathymetric contour of 150 m (Fig.6.1.B). According to it, the Nicobar archipelago has been permanently isolated by 900m deep Ten Degree Channel from the Andaman in the north and by 1600m deep Great Channel in the south from Sumatra. Water barriers existed between the island groups too. A 270m deep Sombrero Channel separated the southern group from the central group. All islands in the southern group were joined to form a single land mass. A 250 m deep channel separated Car Nicobar-Teressa-Bompoka land mass from all other interconnected islands in the central group. Thus, many present day geographically closer islands were interconnected and formed much larger land masses. The island groups were much closer and at least few intervening islands existed between them in the currently submerged shelf region (Fig.6.1.B) which could have potentially acted as stepping stones for different taxa during periods of colonisations.

The conclusion of Ripley and Beehler (1989) has few inadequacies: 1) analyses of quantitative differences in shared number of breeding species that occur in adjacent regions of potential source pools doesn't necessarily reflect the single-directional colonisation of entire avifauna of the archipelago, 2) it didn't explain the very disjunct, or exclusive, or endemic distribution of certain taxa including birds in the three island groups, and thus overlooked patterns of distributions of birds within the Nicobar archipelago, 3) it didn't differentiate between highly mobile water-dependent resident species known for their wide-ranging movements and land birds that are comparatively less mobile, and 4) it overlooked the very distinct variations in features of habitats and geography between the southern and central-northern groups, and among islands in the group.

The nested analysis could be used as an insightful method to infer complex biogeographical patterns within the archipelago (Fleishman et al. 2002). Patterson and Brown (1991) suggested that a common biogeographical history, similar contemporary environments and hierarchical organization of niche relationships as the necessary conditions for nested subset pattern to occur. Thus, the nested analysis of bird distributions within archipelago could explore and suggest the probable source pool(s) (Cutler 1998) and prevalence of common biogeographical history among island groups (Patterson and Brown 1991). From the perspective of the Nicobar archipelago, I analysed island-wise and island group wise occurrence of both 38 selected and all 59 resident birds to detect nestedness within the island groups and in the entire archipelago. The results were examined to infer underlying mechanisms of the observed patterns and to discuss their implications on biogeography of the Nicobar archipelago (Chapter V).

For the single-directional colonisation to accept as an explanation for present composition and distribution of birds species in the Nicobar archipelago, similar deterministic factors influencing species richness and composition of the island groups and significant nestedness for entire archipelago and islands within the three groups were expected. Additionally, the cluster analyses, using shared species of the Nicobars with the adjacent regions of potential source pools, were expected to depict that the Nicobars and / or Andamans are closely clustered with a particularly single adjacent region in terms of compositional similarity of birds.

## 6.2 METHODS

To find similarities among islands and island groups based on their bird species composition and to infer avifaunal affinities of the Nicobar archipelago with adjacent biogeographical regions of potential source pools, clustering analyses were done using unweighted pair-group method (UPGMA) and three indices: Sorenson's similarity index (sensitive to similarity among clusters), Euclidean dissimilarity index (sensitive to dissimilarity among clusters), and Simpson's similarity index (insensitive to differences in species numbers) (Patterson and Brown 1991, Peterson et al. 2000, Azeria 2004). UPGMA is an average linkage clustering method (Peterson et al. 2000). Cophenetic correlation coefficient values were used as criteria in determining the goodness of fit of the different cluster analyses (Sokal and Rohlf 1962) and as a method of verifying similarity or dissimilarity (accuracy of clusters). This coefficient is the Pearson correlation between similarities of similarity matrix and cophenetic matrix made from dendrogram (i.e. correlation between the original distances and the predicted distances that result from the particular hierarchical cluster configuration). A value closer to 1 indicates the greater accuracy of the clustering the data and a value above 0.75 is necessary for the clustering to be considered meaningful (www.ncss.com). All hierarchical cluster analyses were done using the software PAST (v.3.0). The results of nested analyses (Chapter V) were also considered to infer biogeographical patterns. Island-wise presence-absence matrix of residents of 17 islands sampled was used in the cluster analyses. Except for Nicobar Scops Owl *Otus alius*, only those species recorded during the study were included in preparing the matrix of resident birds (Appendix 2) to find similarities among islands and island groups. However, the species recorded in certain islands during the study, but missed to record from other islands were incorporated into the island-wise matrix from the previous published records (Abdulali 1964, 1965, 1967a, 1967b and 1978, Sankaran 1997 and 1998). To explain affinities of birds of the Nicobars and the Andamans with adjacent regions of potential source pools, matrix of distribution of birds (Appendix 2) based on Ripley and Beehler (1989) was used. Cluster analyses were separately done using different subsets of data: for all 59 residents species recorded during the study, selected 38 non-water dependent land birds. The analyses were also done for shared species of the island groups, entire Nicobars, and the Andaman and Nicobars with the adjacent regions.

## 6.3 RESULTS

### 6.3.1 Similarity of islands and island groups

Cluster analysis showed different patterns based on the type of indices (Sorenson, Euclidean and Simpson) used and subset of species (all residents and selected non-water dependent resident land birds) considered for the analyses (Figs. 2-6).

For selected residents, clustering using Sorenson's similarity index with highest cophenetic correlation (0.908), identified five clusters at 0.77 similarity level (marked by dotted line and numbered in the dendrogram; Fig. 6.2). The first division of the dendrogram (Cluster 1; Fig. 6.2) identified Cubra Island as having bird species composition distinctive from all other islands. Cubra is the smallest island in the entire Nicobar archipelago with an area of *c.*0.04 km$^2$ and lies at a distance of 4.73 km from the nearest largest island, i.e. Great Nicobar in the southern group. The island is a rocky outcrop with stunted trees and shrubs and comprise of the six widely distributed bird species namely, *Eudynamys scolopaceus*, *Nectarinia jugularis*, *Haliaeetus leucogaster*, *Ducula aenea [nicobarica]*, *Psittacula longicauda* and *Megapodius nicobariensis*. Cubra also showed high idiosyncrasy in species composition, especially when entire archipelago was considered (Chapter V, Table 5.7). The next division (Cluster 2) separated offshore small islands (Chowra in the central group, and Meroe and Treis in the southern group) from all remaining islands which were further grouped into three clear geographic regions, namely northern (Cluster 3), central (Cluster 4) and southern (Cluster 5) island groups. Dendrogram showed the three clusters in accordance with their separation by deep water channels (Fig. 6.2): Car Nicobar, which lies in the Ten Degree Channel, is separated from the nearest island of the central group by the wide open sea (76.6 km); the central group of islands are separated from the nearest island of the southern group by Sombrero Channel (39.5 km). This clustering of geographically closer islands conforming to their degree of separation by intervening water channels was also noted within each island groups. In the central group, adjacent islands clustered together mostly in accordance with

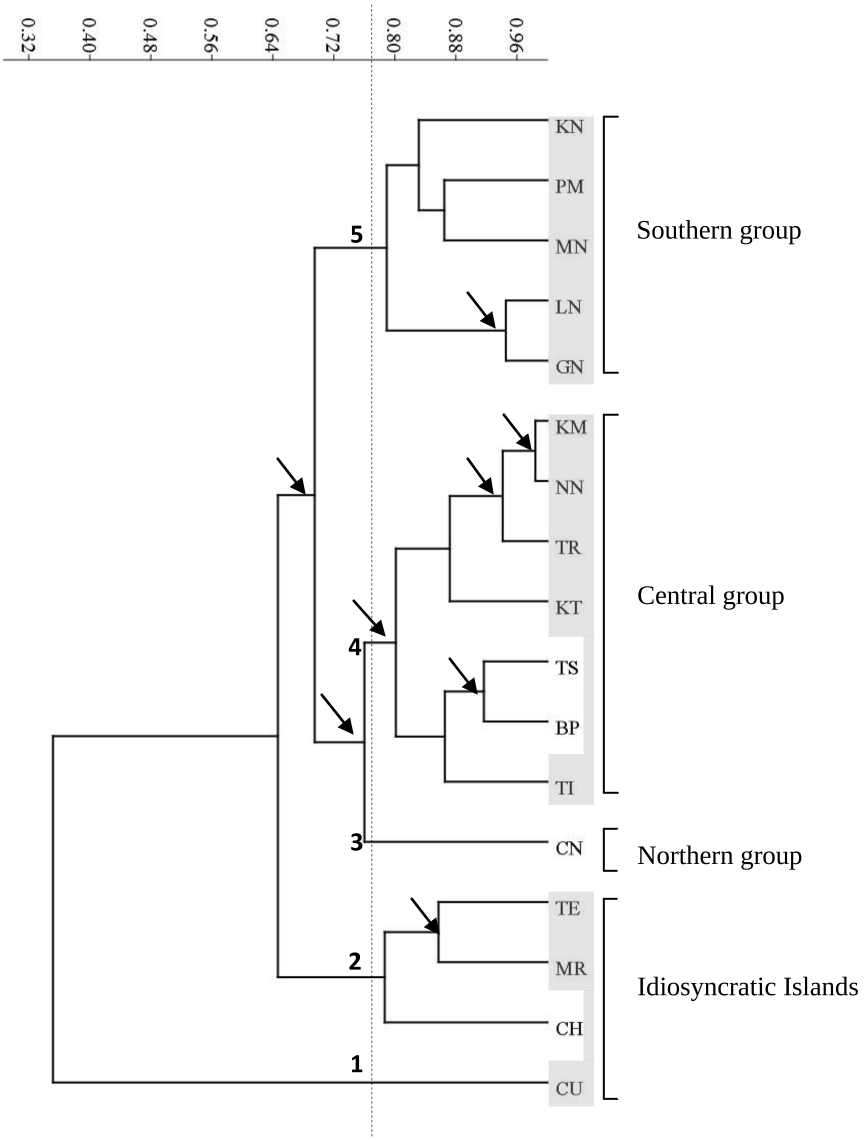

Fig. 6.2. Dendrogram depicting the Sorenson's similarity in composition of the selected 38 species among 17 islands of the Nicobar archipelago. Cophenetic correlation coefficient is 0.908. Higher similarity indicates a greater number of shared species. *See* Table 4.1 for island codes. Arrows indicate geographically closer islands or island groups that clustered according to the degree of separation by intervening water channels. Shaded area indicates Pleistocene interconnections among islands.

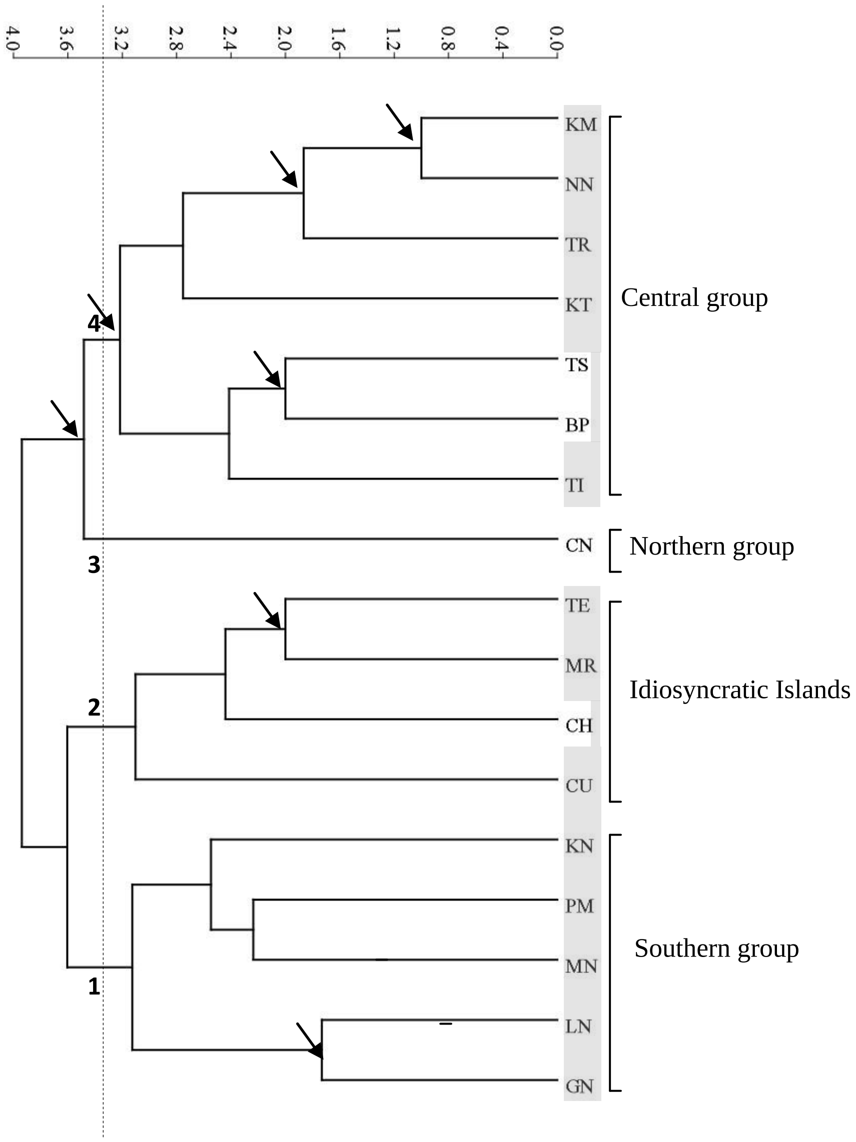

Fig. 6.3. Dendrogram depicting the Euclidean dissimilarity in composition of the selected 38 species among 17 islands of the Nicobar archipelago. Cophenetic correlation coefficient is 0.777. Arrows indicate geographically closer islands or island groups that clustered according to the degree of separation by intervening water channels. Shaded area indicates Pleistocene interconnections among islands.

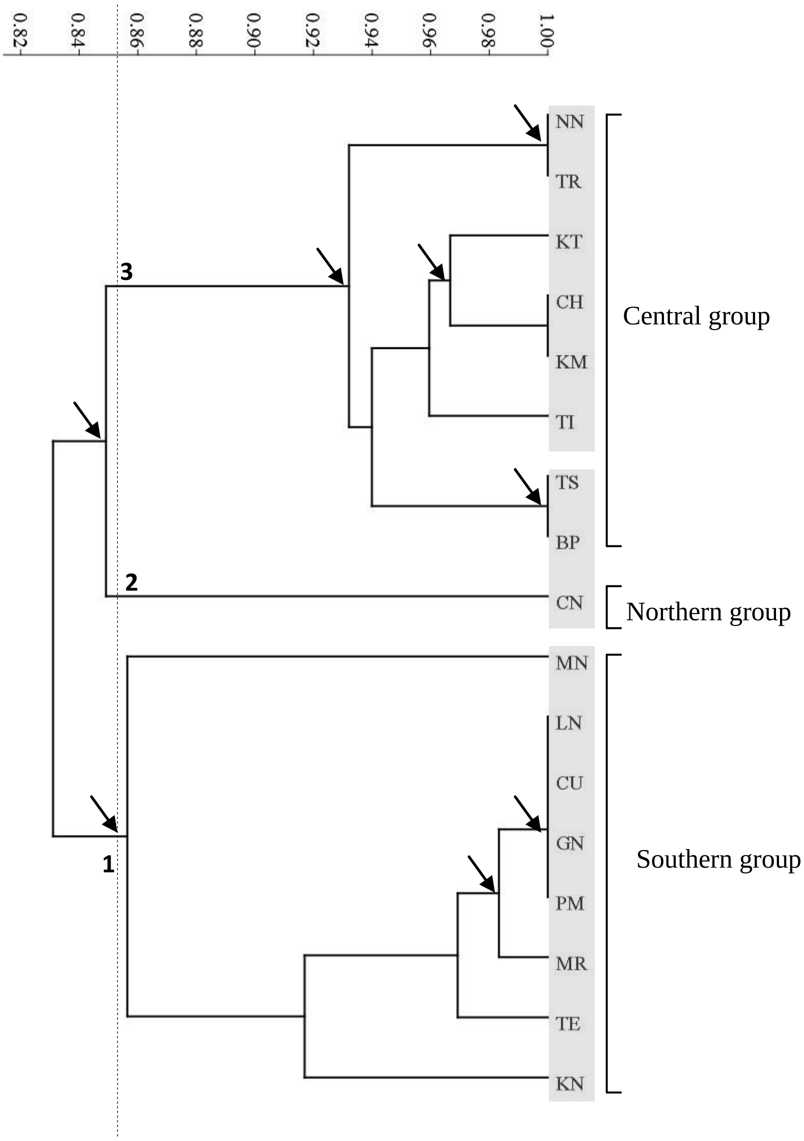

Fig. 6.4. Dendrogram depicting the Simpson's similarity in composition of the selected 38 species among 17 islands of the Nicobar archipelago. Cophenetic correlation coefficient is 0.644. Arrows indicate geographically closer islands or island groups that clustered according to the degree of separation by intervening water channels. Shaded area indicates Pleistocene interconnections among islands.

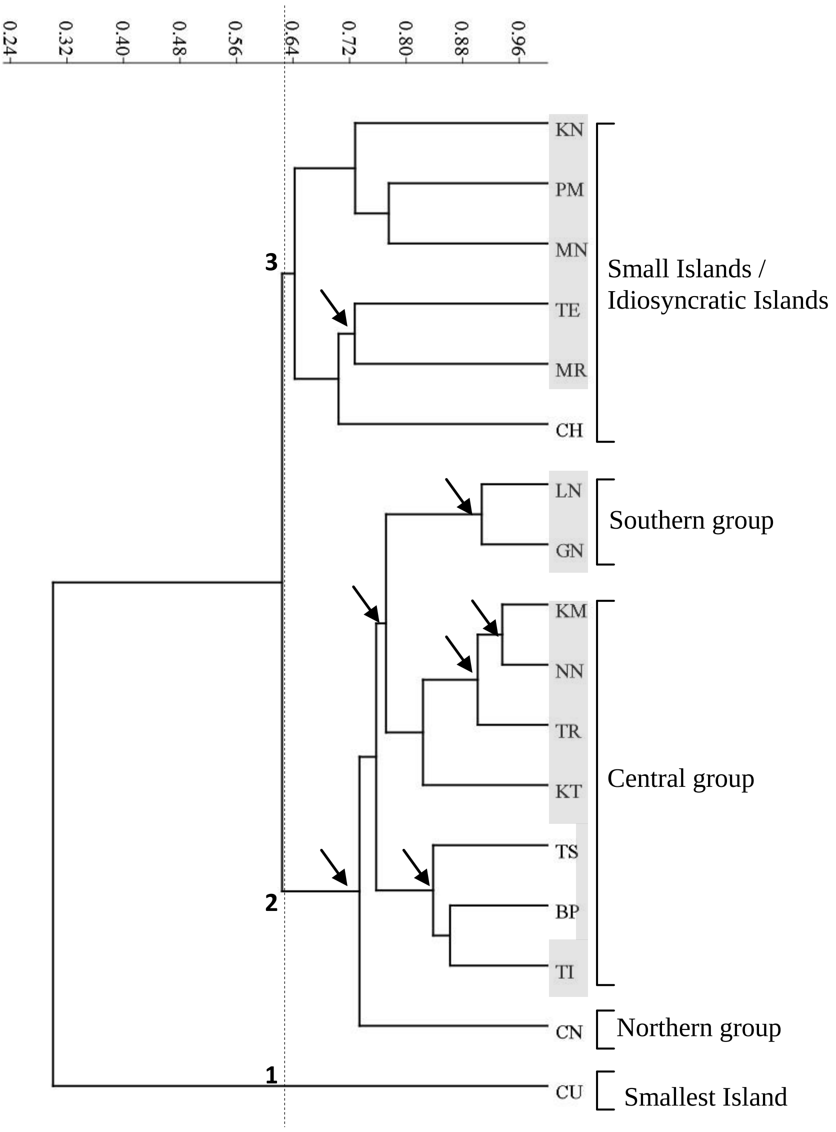

Fig. 6.5. Dendrogram depicting the Sorenson's similarity in composition of all the 59 resident species among 17 islands of the Nicobar archipelago. Cophenetic correlation coefficient is 0.932. Arrows indicate geographically closer islands or island groups that clustered according to the degree of separation by intervening water channels. Shaded area indicates Pleistocene interconnections among islands.

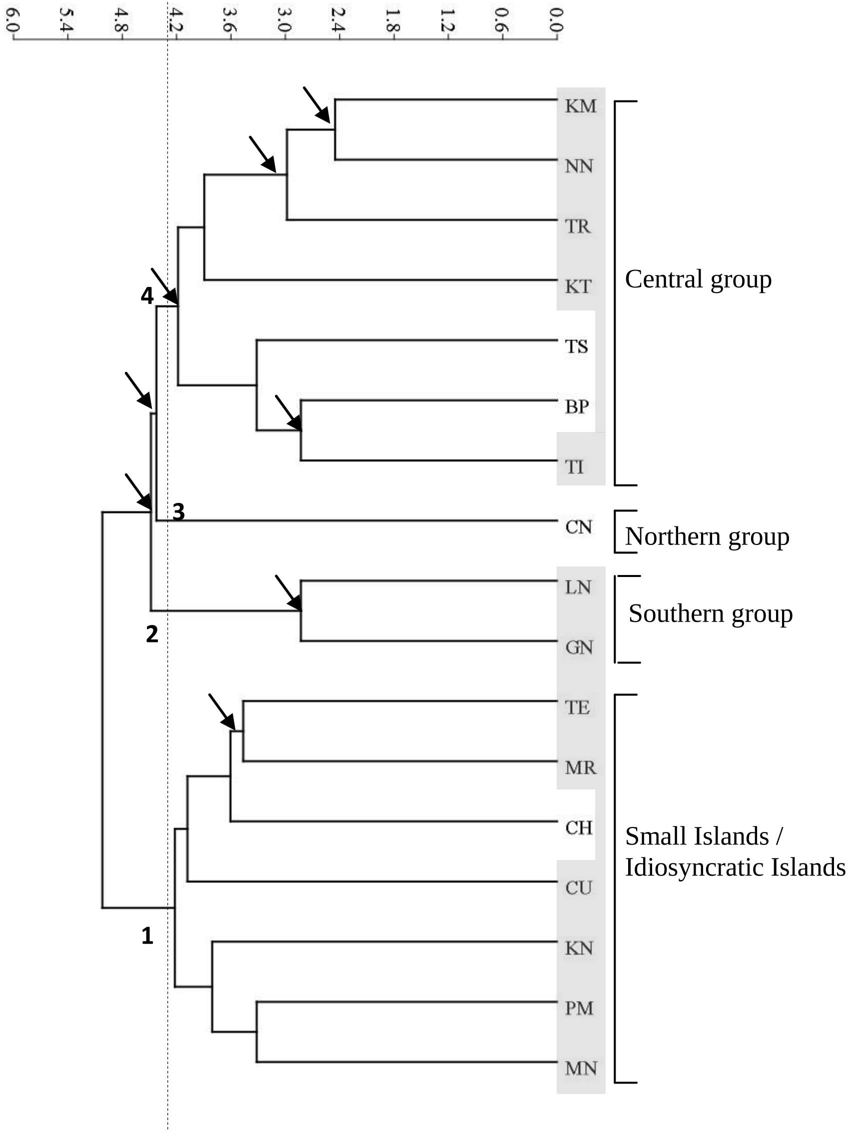

Fig.6.6. Dendrogram depicting the Euclidean dissimilarity in composition of all the 59 resident species among 17 islands of the Nicobar archipelago. Cophenetic correlation coefficient is 0.736. Arrows indicate geographically closer islands or island groups that clustered according to the degree of separation by intervening water channels. Shaded area indicates Pleistocene interconnections among islands.

their relative distance from the largest island in the group with few exceptions. Kamorta grouped with Nancowry which are separated by labyrinth of narrow bays (0.32km). Adjacent Trinket joined subsequently with Kamorta-Nancowry cluster with intervening Beresford Channel (2.5 km). Katchal, which lies west of Nancowry and Kamorta (Revello Channel separate these islands at a minimum distance of 7.7 km), formed a single-leaved branch. Further to north-west, Teressa formed close cluster with adjacent Bompoka (Vinayak Channel separate these islands at a minimum distance of 3.4 km) and Tillanchong, which lies far-east of Teressa-Bompoka cluster (45.7 km), in spite of Tillanchong being geographically closer to Kamorta (23.4 km). A prominent exception to this pattern of clustering of geographically associated islands in the central group is the linkage of Chowra with distinct branch of offshore islands of southern group (Meroe and Treis).

In the southern group, only two large islands which are geographically closer clustered together (St. George Channel separates these two islands: 7.39 km). All the neighbouring satellite islands to them (Pilo Milo, Menchal and Kondul) formed a separate cluster, in spite of these islands' proximity to the two large islands. As mentioned earlier, two offshore islands of southern group (Meroe and Treis) separately clustered with Chowra. These patterns of clustering clearly shows that geographical proximity (degree of distance from the largest or nearest islands based on the length of water channels that separate them) played a varying role in determining similarity or differences among bird distribution between the central and the southern groups.

For selected residents, clustering using Euclidean distance index (Fig. 6.3; cophenetic correlation: 0.777), also showed a qualitatively very similar patterns of clustering, except for Cubra Island, which clumped with idiosyncratic islands.

Clustering using Simpson index which is insensitive to differences in species numbers (Patterson and Brown 1991) showed somewhat different patterns from clustering using other indices, however, with a lower cophenetic correlation coefficient of 0.644. Dendrogram (Fig. 6.4) distinctly identified three clusters comprising of three island groups based on geographical separation, at a lower similarity level (*c.* 0.85) pronouncing the dissimilarity among the three island groups. There were no distinct associations of small or idiosyncratic islands in this case, which were identified in clustering dendrograms using other indices. On the contrary, most of the small and idiosyncratic islands (identified in the nestedness analyses; Chapter V; Table 5.7) formed tight clusters with large islands. For instance, Chowra tightly clustered with the largest island, Kamorta, in the central group. Cubra and Pilo Milo clustered strongly with neighbouring Great and Little Nicobar in the southern group. Nevertheless, a prominent exception is Menchal which showed a high dissimilarity with all other islands despite being relatively closer to the two largest islands in the southern group. Kondul also showed, to a lesser degree, a similar trend. In the central group, Katchal and Tillanchong showed more similarity to Kamorta than closer Trinket and Nancowry. A lower cophenetic correlation value (0.644, which is lower than the preferred value of > 0.75) for the clustering using Simpson's index make it a less significant model for inferring similarity among islands in terms of species composition.

Clustering using Sorenson's similarity index (Fig. 6.5; cophenetic correlation: 0.932) incorporating all 59 residents, differed from the clustering of selected resident subset using the same index in that the two large islands in the southern group (Great and Little Nicobar Islands) clustered from the same branch of the central group, showing their similarity in species composition. Another difference in clustering between these species subsets was that all idiosyncratic and small islands, except Cubra, clustered from the same branch, showing their relatedness in species composition, especially of water-associated resident birds. Clustering dendrogram using Euclidean distance index depicted slightly different patterns for all resident bird distribution data (Fig. 6.6). In this case, the two largest islands (Cluster 2) in the southern group showed more similarity in species composition with the northern group (Car Nicobar; (Cluster 3) than with the islands of the central group (Cluster 4). This lack of distinct division between the southern and the central-northern groups when water-dependent birds were included in the analyses implied wide ranging movements or immigration of these taxa when compared to the less mobile resident land birds.

### 6.3.2 Affinities of the Nicobar archipelago

Cluster analyses using data on shared occurrence of both selected resident and all resident bird species of the entire Nicobar with adjacent biogeographical regions also identified two major clusters (Fig. 6.7). In this case too, the Andamans and the Nicobars clustered together in terms of shared species among them. The two archipelagos, the Andamans and the Nicobars, individually or together didn't show any particular affinity with any of the other regions of potential source pools. This indicates that the subset of resident birds in the Andamans which are shared with the Nicobars, do not show any particularly striking affinity towards Burma, contrary to the proposal by Ripley and Beehler (1989), or any other adjacent regions.

### 6.3.3 Affinities of the Andaman and Nicobar archipelagos

Since analyses of shared number of species of the Nicobars showed an association with the Andaman avifauna, matrix of all residents occurring in the Andaman and Nicobar Islands was used to perform cluster analyses to find whether any association of these two archipelagos, individually or together, to any adjacent source regions. Interestingly, dendrogram showed that of all regions, Burma was the least similar to both the Andamans and the Nicobars in bird species composition (Fig. 6.8). The avifauna of the Nicobars was the most dissimilar from all the biogeogrpahic regions.

Cluster analyses were also done using various subsets of distributional data in order to explore various aspects of avifaunal affinities. When only non-water dependent birds were considered, the same patterns described were found. When all new taxonomic splits of Rasmussen and Anderton (2005) were included in the analyses of all species data set of the Andaman and Nicobar Islands, the Andamans was the most dissimilar group even than the Nicobars from all the regions, and both the region showed, at a very lower degree, similarity to Sumatra than other regions. When only subset of the Nicobars for the same data set was examined, the Andamans and the Nicobars were similar to each other and very distant from all the other groups.

When all endemics which are unique to both the Andamans and the Nicobars were removed from the data set of all residents and examined, the Andamans was found to be more related to Malay-Burma regions, and the Nicobars found to be a distant sample of Sumatra. Similarly, when endemics of the Nicobars were removed from the data set of all residents of the Nicobars and examined, the Andaman and Nicobars showed a close association, and both were more similar to Malay-Burma regions. When newly reviewed endemics (Rasmussen and Anderton 2005) were removed from all resident matrix of the Nicobars, surprisingly, the Nicobars was found to be similar to Burma (both formed a cluster) than the Andamans, which in turn showed a distant similarity with Malaya.

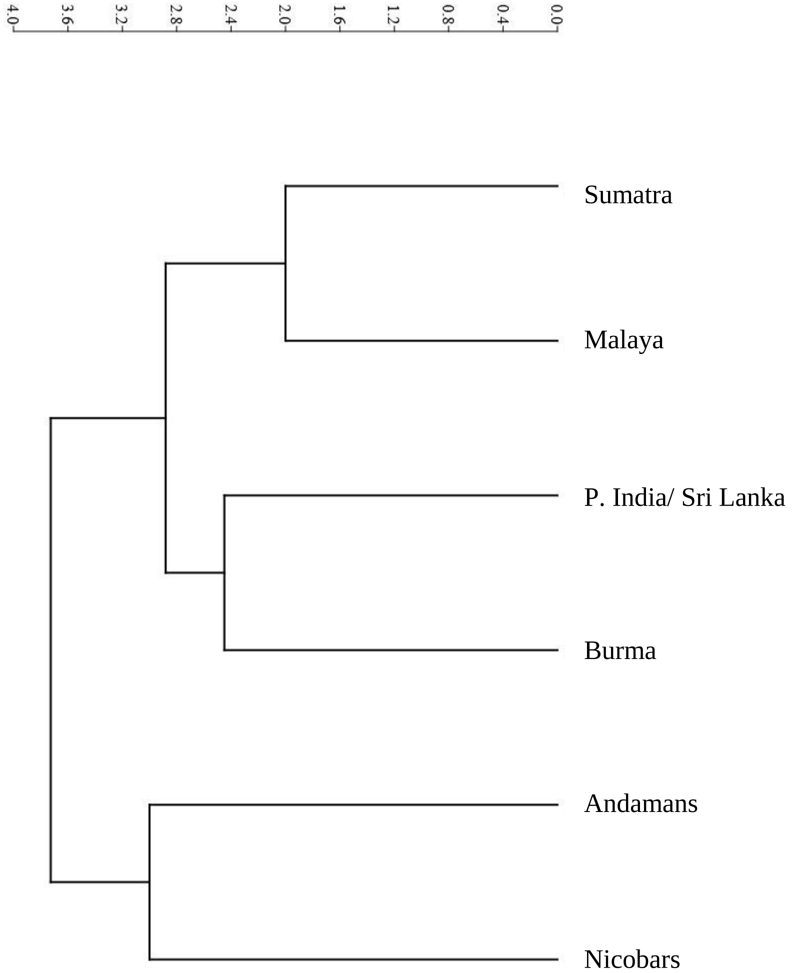

Fig. 6.7. Dendrogram of the Euclidean dissimilarity using data based on shared occurrence of the selected 38 resident birds of the Nicobars with adjacent biogeographical regions. Cophenetic correlation is 0.854.

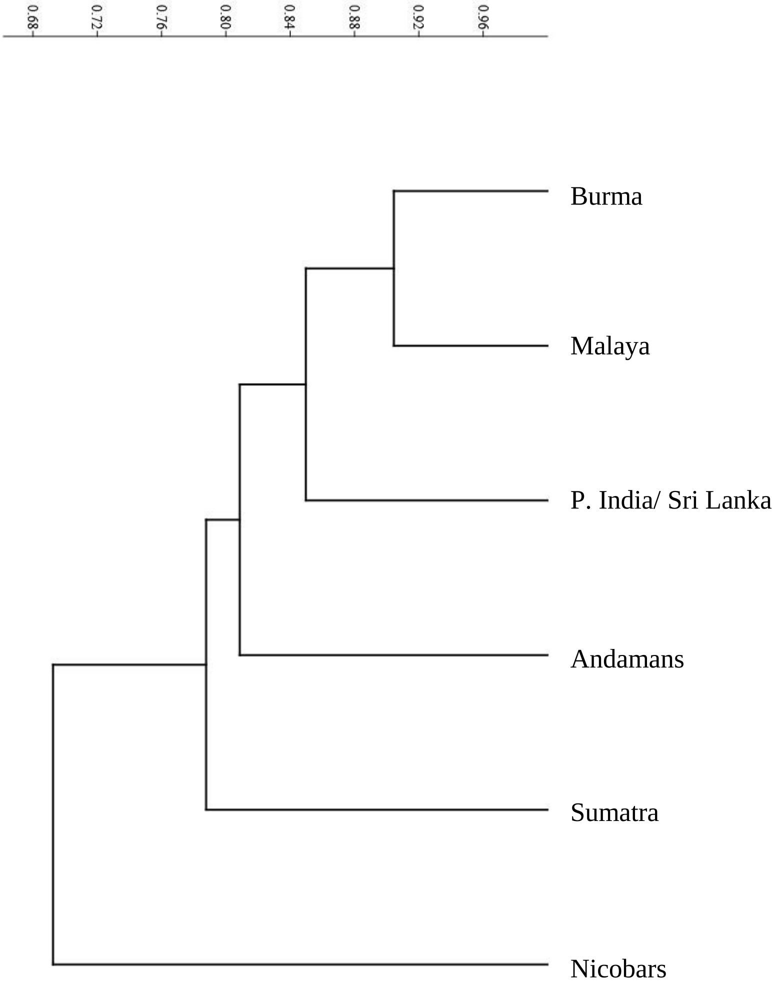

Fig. 6.8. Dendrogram of the Sorenson's similarity using data based on shared occurrence of all the resident birds of the Andaman and Nicobar Islands with adjacent biogeographical regions. Cophenetic correlation is 0.845.

Thus, with all species included in the analyses, the Andamans and / or Nicobars were very dissimilar from Burma and closer to Sumatra and / or Malaya, while with the removal of endemics from the analyses, most species of the Andaman and Nicobar Islands showed an affinity with Malay-Burma region.

## 6.4 DISCUSSION

### 6.4.1 Similarity of islands and island groups

The overall patterns of bird assemblage similarity of selected residents of 17 islands of the Nicobar archipelago showed that each of the three geographically separated island groups, demarcated by deep water channels, were distinct in distribution of many species. This dissimilarity in bird species composition among island groups was more prominent between southern group and central-northern group combined. The island groups were clustered in accordance with their separation by intervening water channels. The geographically closer islands within each group were also clustered together based on their degree of separation. However, the geographical proximity played a varying role in determining similarity or differences among bird distribution between the central-northern and the southern groups. The effect of distance (i.e. degree of separation) between islands, in determining species composition, was more in the central-northern group than in the southern group. The cluster analyses also indicated that the islands which were interconnected to each other during Pleistocene epoch formed close clusters. This makes it very evident that the Pleistocene sea-level changes very much affected the distribution of birds within and across island groups. Pleistocene connection and isolation of islands influencing the distributions of birds have been noted elsewhere (e.g. Peterson et al. 2000).

However, there were exceptions to these patterns of clustering of geographically associated islands. Chowra Island in the central group clustered with distinct branch of offshore islands of the southern group (Meroe and Treis), and southern small satellite islands (Pilo Milo, Menchal and Kondul) clustered together in spite of their proximity to the two large islands (Great Nicobar and Little Nicobar). In Aul and Vijayakumar’s (2003) analysis too, Chowra Island, didn’t conform to the overall pattern which shows the idiosyncratic nature of the island. Chowra (8.2 km$^2$ in area and 11.4 km away from the nearest island) is the smallest island in central group and very unique in having a ‘Table hill’ known as ‘*Tahup’* (at 104 m above MSL) which vertically project out to the sea front. ‘*Tahup’* is covered by mixed evergreen forest on table top of the hill and flanked by caves of coralline origin. The most of the remaining regions of the island are evenly flat and lies within few metres above MSL. Landscape is comprised of a patch of grassland and degraded forest, home gardens and grooves. Chowra is one of the few most densely populated islands in the entire Nicobar group with scarce fresh water sources (Sankaran 2005; *Personal observation*).

Nestedness analyses in the present study also showed prominent idiosyncratic characters in species assemblage of all the small islands (Chapter V; Table 5.7). The deterministic factors that influence species composition on small islands are likely to be very different from large islands (Buskirk 1985). Due to ‘small island effect’, the species richness in small islands was probably determined by inter-island differences in island characteristics such as greater perimeter to area ratio, exposure to stochastic events such as storms (Barrett et al. 2003).

The lack of distinct division between the southern and northern groups when water-dependent birds were included in the analyses implied wide ranging movements or immigration of these taxa when compared to the less mobile resident land birds. Moreover, they are long distance colonists which occur in remotest of islands (e.g. Diamond and Mayr 1976) and may not necessarily breed in the island in which they are seen. Their wide sporadic distribution across all small islands alike was evident in the dendrogram, where all small islands formed a single group.

Much of the Sundaland formed a single land mass during the period of Last Glacial Maximum (Yang 2012). However, even at 120 m bathymetric contours of sea-lowering, most of the islands in Mentawai archipelago (west of Sumatra) and island groups of the Nicobar archipelago were still isolated. Maps charted in Voris (2000) suggested that the central and northern groups were interconnected while southern group of islands in the Nicobars remain isolated throughout the period of Last Glacial Maximum.

This study identified central-northern group and southern group as two biogeographic subdivisions of the Nicobar archipelago based on the cluster analyses of distribution of resident birds, differences in habitat characteristics (presence of grasslands, grassland-forest matrix and dry forest in the central-northern group and more moist forest in the southern group), and the patterns of occurrence of endemic and non-endemic resident bird species. Though the northern group represented by Car Nicobar was distinct in some aspects of bird composition, there were much overlap in ranges of many birds with the central group; hence the central and northern groups were combined to form a single biogeogrpahic category as the central-northern group.

In addition to the outcomes of cluster analyses, following endemic, exclusive, disjunct or widespread distributional patterns of birds were considered (in agreement and disagreement) in the delineation of the two biogeogrpahic subdivisions.

Endemics: Nicobar Parakeet and Great Nicobar Serpent-eagle are restricted to southern group; Nicobar Bulbul and Small Serpent-eagle are restricted to the central group. However, Nicobar Bulbul doesn't occur in Chowra and Car Nicobar (northern group). Nicobar Scops Owl has been reported from the southern group (Great Nicobar) and the central group (Teressa); Nicobar Sparrowhawk is restricted to the central and the northern group; White-headed Starling (endemic shared with the Andamans) show a disjunct distribution in just two islands, in Katchal (central group) and Car Nicobar (northern group); Nicobar Megapode has or had been the only endemic widely distributed throughout all the three island groups in Nicobar archipelago. A seemingly new species of *Rallina* crake has been recently discovered from Great Nicobar Island (Rajeshkumar et al. 2012).

Non-endemics: The distribution of Pied Triller, Oriental Scops Owl, Yellow-legged Buttonquail and Blue Quail are restricted to the central group; Greater Racket-tailed Drongo found throughout the southern group, but only in one forested island in the central group-Katchal, and in the northern island of Car Nicobar. Crimson Sunbird is restricted to the southern group where it is found in all islands except in Cubra. Incidentally, comparatively recent range extension of Red-whiskered Bulbul which had been introduced to the central group and its presence in all the islands of the central-northern groups, barring Bompoka, Chowra and Tillanchong could signal the directional dispersal tendencies of birds during the historic times.

This exclusive distribution to one or two groups of islands or throughout islands or few islands has been reported for plants and other vertebrates such as snakes, lizards, geckos, bats and primates in Nicobar archipelago (Balakrishnan 1989, Das 1999, Aul and Vijayakumar 2003, Hallermann 2009, Harikrishnan et al. 2010). Most of the disjunctly distributed endemic and non endemic birds are phenotypically distinct enough among their constituent populations in different island groups to warrant a subspecies status. Subspecies of birds of Nicobar are listed in Appendix 2. Furthermore, Abdulali (1978) alluded to the possibility of different ‘forms’ or subspecies having evolved in these island groups and remarked about the island groups being different archipelagos or biogeographical units. Recently, Rasmussen and Anderton (2005) has split few bird species of the Nicobars based on these features and identified two more endemics to the Nicobars namely Nicobar Imperial-pigeon *Ducula nicobarica* and Nicobar Jungle-flycatcher *Rhinomyias nicobaricus*, increasing the number of exclusive endemics to the Nicobars from six to eight. Nicobar Jungle-flycatcher is restricted to two large islands in the southern group (Great and Little Nicobar). Aul and Vijayakumar (2003) also identified the central-northern group and the southern group as two biogeogrpahic subdivisions of the Nicobar archipelago based on occurrence of 12 species of bats in 14 islands.

### 6.4.2 Affinities of the Nicobar archipelago

When shared number of residents in the Nicobars was compared with the other regions, the Nicobars showed a striking similarity with the Andamans than any other regions. The subset of resident birds in the Nicobars which are shared with the Andamans, do not show any particularly striking affinity towards Burma, contrary to the suggestion by Ripley and Beehler (1989), or any other adjacent regions. The analyses also couldn’t suggest that the avifauna of the Nicobars is a subset colonised from the Andamans, instead, implied that the unique impoverished assemblage of birds of the Nicobars had largely been in exchange with the Andamans than the other regions.

### 6.4.3 Affinities of the Andaman and Nicobar archipelagos

When all residents data set of the Andaman and Nicobar Islands together was analysed, the Andamans and / or Nicobars was the least similar in compositional similarity to Burma. The Andamans and / or Nicobars were not particularly similar in avifaunal elements to any adjacent regions. Surprisingly, the dendrogram based on Simpson similarity index showed compositional similarity of Andaman with either Sumatra or Malaya, while the Nicobars was entirely different from all the adjacent regions. It is remarkable that the same data set (except with few corrections; Appendix 2) was used by Ripley and Beehler (1989) to argue single-directional colonisation of avifauna from Burma, considering only slightly higher number of shared species of Burma with the Andamans than other regions. Their major contention was that the impoverishment in avifaunal diversity of the Nicobars might be due to lack of major dispersal events from Sumatra, and the Andamans might have been closer to Burma during Pleistocene sea-lowering than the Nicobars to Sumatra.

It is noteworthy that sister species (ss) of two shared endemics of the Andaman and Nicobar archipelagos namely, *Columba palumboides* (ss = *C. argentina* occurs in W. Sumatran Is., i.e. Mentawai archipelago), *Micropygia rufipennis* (*M. Phasianella*, occurs from Sumatra to Australia), two endemics of the Nicobars *Hypsipetes nicobariensis* (ss = *M. Malaccensis* occurs in Malaya and Sumatra) and *Megapodius nicobariensis* (ss = *M. freycinet* occurs in Indonesia and New Guinea) (Ripley and Beehler 1989) occurs in Sundaland region.

The distribution of endemic and non-endemic plants, reptiles, birds and other vertebrates which have very clear affinities with Sundaland region suggest that significant faunal and floral colonisation of the Nicobar archipelago also occurred by dispersal across the Great Channel. The affinities of the Nicobars with the Andamans didn't necessarily show the avifauna as a subset of the Andamans but was indicative of selective dispersal of bird species owing to the general isolation of the Nicobars from the Andamans in the north, Sumatra in the south and Malaya in the east. These patterns of present day distribution of endemic and non-endemic birds and other vertebrates point towards the complex biogeographical history in shaping the existing patterns of distributions of biota of the Nicobar archipelago and adjacent Southeast Asian regions (Outlaw and Voelker 2008).

Interestingly, Shutler and Braches (1986) suggested that Indo-Chinese faunal elements could have reached Java via a route following the Andaman and Nicobar Islands and the Mentawai islands west of Sumatra. The complex distribution of fauna with both Indian, Burmese and Sundaic affinities in both the Nicobar and the Andaman Islands point towards to and fro dispersal of select faunal elements across this chain of archipelago during periods of oscillating contraction and expansion of forest and savanna, known to have occurred during Pleistocene. Incidentally, the Isthumus of Kra, a zoogeographic boundary located on Malay/ Thai peninsula which separates the Indo-Chinese and Sundaic subregions, also fall in the same latitude (between $11^o$ and $13^o$) that lie across the Andaman archipelago. If Shutler and Braches' (1986) allusion is valid, the Andaman and Nicobar Islands could be considered as a transitional zone between Indo-Chinese and Indo-Malayan (Sundaic) subregions, considering these chains of islands as a probable alternate dispersal route other than Malay/ Thai peninsula for select biota across these regions.

Thus, the present analyses signal to more complex geological, climatic and biogeographical events in determining the avifaunal composition of the Andaman and Nicobar Islands. Considering these complex biogeography of the Nicobars, this study suggests a multi-regional hypothesis that the Nicobar avifauna is the result of a confluence of selective over-water colonisation from adjacent regions such Burma (along the Andamans), Sumatra and Malaya when regional historic geographical or environmental settings were different from the modern times. The multi-regional influences on occurrence of birds of the Andamans and / or Nicobars were evident in the analyses of various subsets. The Andamans and / or Nicobars were very dissimilar from Burma, and closer to Sumatra and / or Malaya when all species were included in the analyses, while with the removal of endemics from the analyses, the Andamans and / or Nicobars showed an affinity with Malay-Burma regions in species composition. Moreover, sister species of most of the endemics and species recognised at subspecies level are either widely distributed or, have varied origin in Malaya, Sumatra and Indian Subcontinent, other than Burma.

In the light of these results, it is imperative to explain the probable reasons for impoverishment of avian diversity in the Nicobars in comparison to the Andamans, and biogeographically disjunct distribution of some birds and other taxa. In addition, the presence of exclusive endemics in the Andamans which have sister species in Sundaland, while absent from the intervening Nicobars which is closest to these source regions need to be explained. Similarly, absence of certain species which are endemic to southern group and absent from the central-northern group such as Nicobar Parakeet *Psittacula caniceps*, whose sister species is *Psittacula alexandri* which occurs in Burma and Malaya (Ripley and Beehler 1989), also need to be addressed. Nicobar Bulbul *Hypsipetes nicobariensis*, whose sister species, *M. Malaccensis* occurs in Malaya and Sumatra, is a central group endemic which has no distribution in the intervening southern group.

The terrestrial habitats changed dramatically with the extensive expansion and contraction of land, and climatic variations during Miocene-Pliocene-Pleistocene epochs. Miocene-Pleistocene epochs were especially the times of intense volcanic activity resulting in formation of many islands, while Pleistocene epoch was marked by the periodic glaciations, and consequent sea-level and climatic fluctuations resulting in repeated connection and isolation of land masses and changes in habitats (Voris 2000, Outlaw and Voelker 2008). This has had tremendous influence on the diversification and faunal distribution in the Southeast Asian region (Yang 2012). According to Woodroff (2010) existing habitats in the region are refugial.

The ‘savannah corridor’ hypothesis (Heaney 1991) based on the climatic conditions during Last Glacial Maximum (i.e. low sea levels, dry and very seasonal climate regimes) has been proposed to explain the great biogeographical disjuct distribution of taxa between eastern and western Sundaland (Yang 2012). In the Nicobars too, the ‘savannah corridor’ hypothesis could be evoked as an explanation for the biogeogrpahic disjunct distribution of birds and other taxa (for which such distribution have been reported; e.g. Hallermann 2009). It could also be suggested that the existing grassland-forest habitats had been remnant refugia of intermittent dry and moist (pluvial) periods in the Pleistocene, which could retain grassland-forest associated species in the central-northern group during paleo-climatic fluctuations.

The grassland-forest habitats are unique to the central-northern group and do not occur in the Andaman in the north, and in the southern group of islands in the south, which on the other hand, are hillier and occupy largely homogeneous hill and coastal forest. The avifauna of the central group is largely comprised of wide-ranging species and species with preference for dry forest, forest edge, grassland and scrubland. Similarly, the endemics of the central group such as Nicobar Bulbul and Nicobar Sparrowhawk apparently show preferences to dry mixed forests, forest edges or forest-grassland-scrub matrix. Non-endemic grassland species such Yellow-legged Buttonquail and Blue Quail are also confined to the grasslands of the central-northern group. The species with preference to forest edges and secondary habitats such as Pied Triller and Zitting Cisticola are confined to this island group. Incidentally, dense and wet evergreen forest habitats are less common in the central-northern group, except in Katchal. (Incidentally, absence of grassland in highly forested Katchal Island, which lies within 7.7 km from adjacent Kamorta and Nancowry Islands where grasslands are a major habitat type, may probably indicates the complex geological or climatic and other historical characteristics of the archipelago).

A plausible explanation for this could be that the existing avian diversity of the central-northern group was the result of selective dispersal of faunal elements from the southern group and the Andamans during the Pliocene-Pleistocene oscillation in climate and vegetation. Thus, some Andaman and few southern group forest bird species expanded their range to the central group during the pluvial (wet) periods; while few grassland species of the Andamans (where they eventually became extinct) expanded their range during fluctuating dry periods. Both the forest and grassland species survived in the central-northern group, and maintained a viable population because neither forest nor grassland habitats disappeared completely during later periods of climatic fluctuations, but resulted in a grassland-forest matrix as exist today largely due to soil or climatic characteristics unique to the central-northern group. Moreover, the soil of the central-northern group is largely porous coral sand which absorbs the rainwater very quickly and large patches of this soil probably might have played a key role in maintaining dry forests and grasslands or shrub habitats during wet periods. However, climatological and geographical supports for these explanations need yet to be verified.

Stressmann (1939; cross referred from Meijaard 2009), hypothesised that during a first dry period in the early Pleistocene, grasslands covered much of the tropics resulting in dispersal of grassland species to Sumatra from Burma and Malaya. A first pluvial period with spread of rainforest followed the first dry period, during which grassland habitats disappeared altogether along with grassland-dependent species. A milder second dry period followed, during which only few grassland corridors were opened, as other routes were obstructed by rainforest. Yet another pluvial period followed the second milder dry period. The drying affected the distribution of forest habitats across the entire region of insular Southeast Asia. The existing forested regions of Sundaland were dry grassland habitats during the Pliocene and Pleistocene (Bird et al. 2005).

In the light of this hypothesis, it is possible that dry habitats (grasslands and dry forests) in the central-northern group acted as a historically recent dispersal barrier for wet forest-dependent avifaunal elements from the Andamans to the Nicobars and those from forested southern group of islands to the central-northern group and to further located the Andamans. This could be an argument, along with the isolation of the Nicobars from Sumatra at a wider distance, for impoverished avifauna of the Nicobars in general when compared to that of the Andamans which harbour more diversity of faunal elements from the nearby regions. Consequently, most widespread species both in the Andamans and all islands group of the Nicobars are generalist. Besides geographical isolation, dry landscape of the central-northern group and wet landscape of the southern group might have had a detrimental influence in speciation and divergence of faunal elements that dispersed on to these islands. The effect of dry and wet landscape is evident in the coloration of subspecies of endemics and other birds distributed across island groups. For instance, subspecies of Nicobar Megapode *Megapodius nicobarinensis nicobarinensis* occurring in the central-southern group is more drab coloured than *M. n. abbotti* which occur in the southern group.

The present study makes it evident that various biogeographical analyses employing various techniques (e.g. field surveys for understanding distributions, phylogenetic studies) involving different taxa need to be carried out in order to come to any definite conclusions regarding the complex biogeographical patterns of this fascination archipelago. A reliable model of biogeography of the Nicobar archipelago is required to explain the existing patterns of distributions of habitats and species, and to understand extend of divergence and genetic variations in different taxa across the island groups (e.g. Meijaard 2009, Woodruff 2010). This will help to propose conservation strategies for those regions and taxa which are in need to be considered for conservation programmes.

## Chapter-VII

## SUMMARY AND CONCLUSION

The Nicobar archipelago, which lies in Bay of Bengal comprises of 19 islands, occurs as scattered clusters in three sub-groups separated by deep water channels, and each sub-group has distinct floral, faunal and anthropogenic features. The Nicobars, which is biogeographically distinct from the adjacent Andamans with which it is often clumped inadvertently, deserves a separated treatment in ecological research and analyses. The literature review indicated that studies on bird assemblages of the Nicobars are sparse and baseline information on distributional patterns of many bird species including endemics in the region is either limited or lacking. The limited ornithological exploration in the Nicobars necessitate further studies in the archipelago especially in the wake of mega-earthquake and tsunami of December 2004 and subsequent large scale destruction and inundation of littoral habitats. Moreover, the features of the Nicobar archipelago such as the occurrence of islands in distinct scattered clusters as island groups demarcated by deep water channels, the differences in landscape characteristics between island groups and the high variations in area among constituent islands make the Nicobars an apt insular system to explore the patterns of community assemblage. A study was carried out on bird assemblages in 17 islands of the Nicobars during April 2009 to Sep 2011 with the specific objectives of examining: 1) community structure, 2) island species-area relationships, 3) species co-occurrence patterns, and 4) biogeographical affinities of avifauna of the archipelago.

Bird community structure was studied by conducting a total of 1244 point count systematic surveys in four major habitats (forest, littoral habitat, grassland-scrub habitat and grove) of the three island groups (northern, central and southern) of the Nicobars. Additional exploratory surveys were conducted to record rare and vagrant species and to prepare island-wise presence-absence matrix of birds for examining the island species-area relationships, co-occurrence patterns and biogeographical affinities of birds. Surveys were also carried out for assessing post-tsunami status of endemic Nicobar Megapode *Megapodius nicobariensis* which was one of the worst affected species due to the loss of littoral habitat induced by tsunami.

### Bird community structure

The results show, a total of 112 species of birds belonging to 39 families in 14 orders recorded during the study. The non-parametric estimation of species richness by second order Jackknife estimator, based on point count sampling of different habitats and island groups, reliably predicted the total species richness of the Nicobars to be 115 which is close to the number of birds found throughout the study. The avifauna of the Nicobars was less represented by species in most taxonomic orders and families and found to be 'impoverished' due to the oceanic nature of the archipelago. Consequently, the best represented taxa consisted of strong dispersers which are water associated species such as waders and kingfishers, and also sparrowhawks and pigeons.

Bird communities across different habitats and island groups varied significantly in terms of species richness, abundance and composition. Of the total 112 species recorded during the study, a total of 10,338 individuals of 91 species were encountered from 1244 point counts. The total number of species and individuals per point counts were significantly different among the four habitats and the three island groups. The total number of species per point count was also significantly different among the forest and the littoral habitats across the three island groups which indicated that species richness was not uniform in the similar habitats of different island groups.

The species-abundance data of birds of the Nicobars followed both truncated log-normal and log-series distribution models, but could not decide which model best described the species-distribution data. However, it is apparent that the bird communities of the Nicobars is unsaturated and predominantly follow a log-series distribution considering an impoverished avifauna due to high insularity, high occurrence of rare and uncommon species, less incidence of competitive segregations, and heterogeneity of species diversity and evenness within similar habitats across island groups. The rank abundance curves also suggested the less evenness in species-abundance distributions in the communities.

Littoral habitat harboured highest number of species exclusive to the habitat (34 species), and most of them were water-dependent species. Number of habitat specialist in forest and grassland-scrub habitat was few (5 and 3 respectively). In all, 18 species that were commonly found in all the habitats were wide-ranging generalist species. The diversity indices showed higher diversity in littoral habitat with young secondary vegetation than in natural hill forest. A very significant difference was noted between forest and littoral habitat in bird species richness, abundance and composition in spite of these two habitats being highly connected. The dissimilarity of point count stations across habitats in their major vegetation and microhabitats attributes accounted for the very significant differences in avian richness, abundance and composition.

It seems that loss of littoral habitats has not significantly affected the currently existing population of endemic bird species except Nicobar Megapode. This study indicated that no major change in mound characteristics of the Nicobar Megapode has happened when compared to previous post-tsunami studies, and also suggested that the population of the species has remained stable after initial decline in population due to tsunami.

### Island species-area relationships

The regression analyses for the entire Nicobar archipelago indicated that area, measures of isolation and habitat diversity, in that order, play a role in determining species richness. The island species-area relationship for all resident birds of the Nicobars using the log-log model can be expressed by the equation: $\text{Log } S = 1.284 + 0.162 \text{ Log } A$. Although area proved to be a very powerful predictor of overall bird species richness in the Nicobar archipelago, the relationship was not consistent among island groups and islands of different size categories. Medium sized islands were having strikingly higher number of species disproportionately for their area than Great Nicobar (the largest island comprising of *c.* 53% of total land area of the Nicobars) and Little Nicobar in the southern group and Car Nicobar in the northern group. Similarly, bird community analyses also showed significantly higher species richness in the central-northern group disproportionately for its area (which forms only 27.6% of the total area of the Nicobars) than the southern group (which encompass *c.* 62 % of the total area). The negative relationships of species richness on isolation measures (distance from the largest island, nearest island and Sumatra) were prominent only in the central and central-northern group in comparison to the southern group, and were largely contributed by medium-large islands in the central group. Medium-large islands (ranging in size between 36.3-1045.1 $km^2$) didn’t show a significant species-area relationship.

The exceptional lack of coherence in determining species richness and the existence of disparity in species-area relationships among islands and island groups within the Nicobar archipelago was possibly due to the differences between the island groups in any or combinations of features such as area, heterogeneous landscape (such as unique grassland-forest mosaic in the central-northern group and uniformly forested southern group), inter-island isolation, isolation from source pools, and geological and climatic history. The variations in these characteristics across the island groups consequently also resulted in differential effects of area and isolation on species richness. In the Nicobar archipelago, influence of distance in the central or central-northern group seems to suggest differential colonisation of islands while the effect of area in the southern group seems to suggest the selective extinction processes.

The value of the regression slope of the species-area relationships, *z*, for the Nicobar archipelago is 0.16. The *z*-value varied considerably across island groups and island size classes. The small islands were found to have the highest *z*-value of 0.25. Interestingly, the medium- large island size class didn't adhere to the species-area relationship. Lower values of *z* for different subsets of bird species and the lack of coherence in species-area relationships within the Nicobar archipelago is clearly a prominent departure from the results of numerous studies conducted elsewhere. Almost all archipelagos across the world as a rule follow the same island species-area relationship as their constituent islands, with only few exceptions. The present study suggests that the Nicobar archipelago is one of those exceptions.

### Nestedness and co-occurrence patterns

The whole resident bird assemblage in the Nicobar archipelago did not show a significant nested pattern, unlike many studies in islands and other insular systems where nestedness has been widely reported across a range of taxa. A common and recent biogeographical or evolutionary history among sites, similar contemporary environments and hierarchical organization of niche relationships of species have been suggested as the essential conditions for the nested subset pattern to occur. This clearly indicated that at least two of the island groups within the Nicobar archipelago probably have its own unique biogeographical history, peculiar environments and / or non-hierarchical niche relationships of species.

When subsets of central and northern group were considered together, the bird assemblages didn't show a nested pattern suggesting that the two island groups differed in species composition and underlying processes that determine nestedness. When subsets of central and northern group (Car Nicobar Island) were considered together, the bird assemblages didn't show a nested pattern suggesting that the two island groups differed in species composition and underlying processes that determine nestedness. The lack of nestedness in all resident subset of the southern group, that included more mobile water-dependent species, was probably due to sporadic dispersal of these species among islands in the group. The central group showed significant nestedness only for all resident subset suggesting the less sporadic movements of water-associated species in the group.

A comparison of the present study with that of Davidar et al. (2002) indicates that the bird assemblages of the Andaman archipelago is strikingly highly nested and the overall nestedness within island groups was also higher in the Andamans than in the Nicobars.

The significant correlation of nestedness of bird assemblages in the central group with area, measures of isolations, latitude and habitat distributions point towards interplay of the different underlying mechanisms influencing the community assembly, among which the differential colonisation (as indicated by strong correlation of nestedness with the distance to the nearest island) played the most prominent role. Intra-island distances in the central group were substantial because islands within the group occurred more scattered than in the southern group. In the southern group, the selective extinction and habitat nestedness, as indicated by the significant correlation of nestedness with the island area and number of habitats, apparently were the only mechanisms that determined community assembly. The patterns of nestedness and underlying mechanisms that determine nestedness of the Andamans were similar to the southern group of the Nicobars than to the other island groups or the entire Nicobars. The lack of the effect of isolation on nestedness of selected residents of the southern group was possibly due to high mobility and frequent dispersal of bird species between islands. On the other hand, the species inhabiting the central group were probably less mobile and selective colonisers with respect to the distance between islands.

The prominent effect of isolation in the central group and effect of island area and number of habitats in the southern group as the variables determining species richness and similarity in species composition within island groups has also been clearly shown by regression and cluster analyses. This reinforces the conclusion that the underlying mechanisms, that determined species richness, species composition, nestedness and co-occurrence, were consistently different for the two islands groups. Nevertheless, the present analyses should be considered as only suggestive as it was difficult to resolve to what degree the underlying mechanisms such as selective extinction, differential colonisation, habitat nestedness and other processes influence the nested patterns in the island groups.

The lack of nested subset pattern for the whole assemblage might have also be due to patterns in speciation of endemics exclusive to the island groups, and disjunct, restricted or sporadic distributions of some species in the Nicobars. The idiosyncrasy of species depended on whether analyses were done for whole assemblage or separately for island groups. Majority of idiosyncratic islands were small in size (<10 km$^2$). The inter-island variations in landscape characteristics and inherently unique features of small islands such as large border area could be the causes of non-nestedness of small islands.

The overall species co-occurrence patterns suggest that negative competitive interactions are less common and bird community assemblages are less structured in the Nicobars. The impoverishment of avifauna in general and less representation of species within guilds or families *per se* could be major causes for the random co-occurrence patterns.

### Biogeographical distribution and affinities

The overall patterns of bird assemblage similarity of selected residents of 17 islands of the Nicobar archipelago using cluster analyses showed that each of the three geographically separated island groups, demarcated by water channels, were distinct in distribution of many species. This dissimilarity in bird species composition among island groups was more prominent between southern group and central-northern group combined. The island groups were clustered in accordance with their separation by intervening water channels. The geographically closer islands within each group were also clustered together based on their degree of separation. However, the geographical proximity played a varying role in determining similarity or differences among bird species distribution between the central-northern and the southern groups. The effect of distance between islands, in determining species composition, was more in central-northern group than in southern group. The islands which were interconnected to each other during Pleistocene epoch showed higher similarity in species composition which makes it very evident that the Pleistocene sea-level changes very much affected the distribution of birds within and across island groups.

This study identified central-northern group and southern group as two biogeogrpahic subdivisions of the Nicobar archipelago based on the cluster analyses of distribution of resident birds, differences in habitat characteristics, and the patterns of occurrence of endemic and non-endemic resident bird species.

The subset of resident birds in the Nicobars which are shared with the Andamans didn’t show any particularly striking affinity towards Burma, contrary to the suggestion by Ripley and Beehler (1989). The analyses also couldn’t suggest that the avifauna of the Nicobars is a subset colonised from the Andamans, instead, implied that the unique impoverished assemblage of birds of the Nicobars had largely been in exchange with the Andamans than the other regions. The avifauna of the Andamans and / or Nicobars was also not particularly very similar in avifaunal elements to any adjacent regions of potential source of immigrations. The affinities of the Nicobars with the Andamans were only indicative of selective dispersal of bird species owing to the general isolation of the Nicobars from the Andamans in the north, Sumatra in the south and Malaya in the east. These patterns of present day distribution of endemic and non-endemic birds and other vertebrates point towards the complex biogeographical history in shaping the existing patterns of distributions of biota of the Nicobar archipelago and adjacent Southeast Asian regions. Considering the complex biogeography of the Nicobars, this study suggests a multi-regional hypothesis proposing that the Nicobar avifauna is the result of a confluence of selective over-water colonisation from adjacent regions such Burma (along the Andamans), Sumatra and Malaya when regional historic geographical or environmental settings were different from the modern times. The multi-regional influences on occurrence of birds of the Andamans and/ Nicobars were evident in the analyses of various subsets of birds. Moreover, sister species of most of the endemics and species recognised at subspecies level are either widely distributed or, have varied origin in Malaya, Sumatra and Indian subcontinent, other than Burma.

The probable reasons for impoverishment of avian diversity in the Nicobars in comparison to the Andamans, and biogeographically disjunct distribution of some birds and other taxa, can be better explained by ‘savannah corridor’ hypothesis (Heaney 1991), which is based on the climatic conditions during Last Glacial Maximum. It could also be suggested that the existing grassland-forest habitats had been remnant refugia of intermittent dry and moist periods in the Pleistocene, which could retain grassland-forest associated species in the central-northern group during paleo-climatic fluctuations. However, climatological and geographical supports for this explanation need yet to be investigated and verified.

The present study makes it evident that various biogeographical analyses employing various techniques involving different taxa need to be carried out in order to come to any definite conclusions regarding the complex biogeographical patterns of this fascination archipelago.

A reliable model of biogeography of the Nicobar archipelago will help to propose conservation strategies for those regions and taxa which are in need to be considered for conservation programmes.

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# APPENDICES

Appendix 1. Relative abundance of birds in different habitats in the Nicobars.

| SI No. | Common Names | *Scientific name* | Relative abundance | | | |
|---|---|---|---|---|---|---|
| | | | **Forest** | **Littoral habitat** | **Grassland-scrub** | **Groove** |
| 1 | Green Imperial-pigeon | *Ducula aenea [nicobarica]* | 23.94 | 2.80 | 3.58 | 3.26 |
| 2 | Nicobar Bulbul | *Hypsipetes nicobariensis* | 10.62 | 2.64 | 2.68 | 4.98 |
| 3 | Olive-backed Sunbird | *Nectarinia jugularis* | 7.32 | 16.80 | 24.87 | 27.97 |
| 4 | Black-naped Monarch | *Hypothymis azurea* | 6.80 | 2.97 | 1.07 | 2.49 |
| 5 | Oriental White-eye | *Zosterops palpebrosus* | 6.68 | 12.97 | 4.11 | 10.34 |
| 6 | Long-tailed Parakeet | *Psittacula longicauda* | 6.45 | 4.44 | 0.72 | 2.30 |
| 7 | Red-whiskered Bulbul | *Pycnonotus jocosus* | 4.26 | 7.63 | 18.78 | 2.30 |
| 8 | Black-naped Oriole | *Oriolus chinensis* | 3.64 | 1.90 | 0.18 | 2.68 |
| 9 | Asian Glossy Starling | *Aplonis panayensis* | 3.55 | 14.59 | 0.00 | 8.81 |
| 10 | Collared Kingfisher | *Todiramphus chloris* | 3.23 | 2.80 | 0.72 | 0.38 |
| 11 | Crimson Sunbird | *Aethopyga siparaja* | 3.09 | 0.80 | 0.00 | 6.90 |
| 12 | Nicobar Parakeet | *Psittacula caniceps* | 2.61 | 0.12 | 0.00 | 2.68 |
| 13 | Pompadour Green-pigeon | *Treron pompadora* | 2.36 | 1.45 | 0.00 | 1.34 |
| 14 | Pied Imperial-pigeon | *Ducula bicolor* | 2.33 | 1.41 | 1.43 | 4.60 |
| 15 | Asian Paradise-flycatcher | *Terpsiphone paradisi* | 1.76 | 0.29 | 0.18 | 0.19 |
| 16 | Greater Racket-tailed Drongo | *Dicrurus paradiseus* | 1.67 | 0.49 | 0.00 | 0.77 |
| 17 | Nicobar Megapode | *Megapodius nicobariensis* | 1.12 | 0.49 | 0.00 | 0.77 |
| 18 | Asian Koel | *Eudynamys scolopaceus* | 1.08 | 0.51 | 0.18 | 0.38 |
| 19 | Hill Myna | *Gracula religiosa* | 0.94 | 0.41 | 0.00 | 0.00 |
| 20 | Emerald Dove | *Chalcophaps indica* | 0.94 | 1.39 | 0.00 | 0.57 |
| 21 | Nicobar Pigeon | *Caloenas nicobarica* | 0.87 | 0.08 | 0.00 | 0.00 |
| 22 | White-breasted Waterhen | *Amaurornis phoenicurus* | 0.87 | 1.62 | 0.54 | 2.11 |
| 23 | Andaman Cuckoo-dove | *Macropygia rufipennis* | 0.60 | 0.16 | 0.36 | 0.77 |
| 24 | Andaman Wood-pigeon | *Columba palumboides* | 0.57 | 0.06 | 0.18 | 0.19 |
| 25 | Glossy Swiftlet | *Collocalia esculenta* | 0.37 | 2.17 | 1.61 | 8.05 |
| 26 | Warblers* | *Acrocephalus & Phylloscopus sp.* | 0.30 | 0.25 | 0.18 | 0.00 |
| 27 | Blue-tailed Bee-eater | *Merops philippinus* | 0.25 | 1.00 | 3.22 | 0.00 |
| 28 | Edible-nest Swiftlet | *Collocalia fuciphaga* | 0.23 | 1.76 | 2.68 | 0.00 |
| 29 | Hooded Pitta | *Pitta sordida* | 0.23 | 0.04 | 0.00 | 0.00 |
| 30 | Orange-headed Thrush | *Zoothera citrina* | 0.21 | 0.06 | 0.00 | 0.19 |
| 31 | Brown-chested Jungle-flycatcher | *Rhinomyias brunneatus* | 0.18 | 0.00 | 0.00 | 0.00 |
| 32 | White-bellied Sea-eagle | *Haliaeetus leucogaster* | 0.16 | 0.27 | 0.18 | 0.38 |
| 33 | South Nicobar Serpent-eagle | *Spilornis klossi* | 0.09 | 0.08 | 0.00 | 0.00 |
| 34 | White-rumped Munia | *Lonchura striata* | 0.09 | 2.72 | 12.70 | 3.07 |
| 35 | Stork-billed Kingfisher | *Pelargopsis capensis* | 0.07 | 0.06 | 0.00 | 0.00 |
| 36 | Andaman Hawk-owl | *Ninox affinis* | 0.05 | 0.04 | 0.00 | 0.00 |
| 37 | Besra | *Accipiter virgatus* | 0.05 | 0.00 | 0.18 | 0.00 |
| 38 | Chinese Goshawk | *Accipiter soloensis* | 0.05 | 0.06 | 0.00 | 0.00 |
| 39 | Crested (?) Serpent-eagle | *Spilornis sp.* | 0.05 | 0.02 | 0.18 | 0.00 |
| 40 | Nicobar Sparrowhawk | *Accipiter butleri* | 0.05 | 0.00 | 0.00 | 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 41 | Black-backed Kingfisher | *Ceyx erithaca* | 0.05 | 0.00 | 0.00 | 0.19 |
| 42 | White-headed Starling | *Sturnus erythropygius* | 0.05 | 0.70 | 0.00 | 0.00 |
| 43 | Yellow Bittern | *Ixobrychus sinensis* | 0.05 | 0.49 | 0.00 | 0.00 |
| 44 | Crow-billed Drongo | *Dicrurus annectans* | 0.02 | 0.00 | 0.00 | 0.00 |
| 45 | Forest Wagtail | *Dendronanthus indicus* | 0.02 | 0.02 | 0.00 | 0.00 |
| 46 | Malaysian Night-heron | *Gorsachius melanolophus* | 0.02 | 0.00 | 0.00 | 0.00 |
| 47 | Unidentified Owlet* | Unidentified Owlet | 0.02 | 0.00 | 0.00 | 0.00 |
| 48 | Pied Triller | *Lalage nigra* | 0.02 | 0.20 | 0.00 | 0.19 |
| 49 | Pacific Reef-egret | *Egretta sacra* | 0.02 | 0.02 | 0.00 | 0.00 |
| 50 | Zitting Cisticola | *Cisticola juncidis* | 0.02 | 0.53 | 11.81 | 0.00 |
| 51 | Asian Brown Flycatcher | *Muscicapa dauurica* | 0.00 | 0.04 | 0.00 | 0.19 |
| 52 | Andaman Drongo | *Dicrurus andamanensis* | 0.00 | 0.08 | 0.00 | 0.00 |
| 53 | Ashy Minivet | *Pericrocotus divaricatus* | 0.00 | 0.04 | 0.00 | 0.00 |
| 54 | Barn Swallow | *Hirundo rustica* | 0.00 | 0.41 | 0.36 | 0.00 |
| 55 | Blue Quail | *Coturnix chinensis* | 0.00 | 0.00 | 0.18 | 0.00 |
| 56 | Black-capped Kingfisher | *Halcyon pileata* | 0.00 | 0.02 | 0.00 | 0.00 |
| 57 | Black-crowned Night-heron | *Nycticorax nycticorax* | 0.00 | 0.02 | 0.00 | 0.00 |
| 58 | Black-naped Tern | *Sterna sumatrana* | 0.00 | 0.16 | 0.00 | 0.00 |
| 59 | Brown Shrike | *Lanius cristatus* | 0.00 | 0.47 | 1.97 | 0.77 |
| 60 | Bunting (Yellow-breasted?) | *Emberiza aureola?* | 0.00 | 0.04 | 0.00 | 0.00 |
| 61 | Cattle Egret | *Bubulcus ibis* | 0.00 | 0.31 | 0.00 | 0.00 |
| 62 | Cinnamon Bittern | *Ixobrychus cinnamomeus* | 0.00 | 0.04 | 0.00 | 0.00 |
| 63 | Common Kingfisher | *Alcedo atthis* | 0.00 | 0.06 | 0.00 | 0.00 |
| 64 | Common Redshank | *Tringa totanus* | 0.00 | 0.20 | 0.00 | 0.00 |
| 65 | Common Sandpiper | *Actitis hypoleucos* | 0.00 | 0.37 | 0.00 | 0.00 |
| 66 | Grey Plover | *Pluvialis squatarola* | 0.00 | 0.12 | 0.00 | 0.00 |
| 67 | Grey Wagtail | *Motacilla cinerea* | 0.00 | 0.27 | 0.00 | 0.00 |
| 68 | House Crow | *Corvus splendens* | 0.00 | 0.55 | 0.00 | 0.00 |
| 69 | Little Swift | *Apus affinis* | 0.00 | 0.00 | 0.36 | 0.00 |
| 70 | Intermediate Egret | *Mesophoyx intermedia* | 0.00 | 0.02 | 0.00 | 0.00 |
| 71 | Kentish Plover | *Charadrius alexandrinus* | 0.00 | 0.10 | 0.00 | 0.00 |
| 72 | Great Egret | *Casmerodius albus* | 0.00 | 0.16 | 0.00 | 0.00 |
| 73 | Lesser Crested Tern | *Sterna bengalensis* | 0.00 | 0.06 | 0.00 | 0.00 |
| 74 | Lesser Sand Plover | *Charadrius mongolus* | 0.00 | 0.49 | 0.00 | 0.00 |
| 75 | Striated Heron | *Butorides striata* | 0.00 | 0.68 | 0.00 | 0.00 |
| 76 | Little Stint | *Calidris minuta* | 0.00 | 0.10 | 0.00 | 0.00 |
| 77 | Mugimaki Flycatcher | *Ficedula mugimaki* | 0.00 | 0.04 | 0.00 | 0.00 |
| 78 | Oriental Pratincole | *Glareola maldivarum* | 0.00 | 0.10 | 0.00 | 0.00 |
| 79 | Peregrine Falcon | *Falco peregrinus* | 0.00 | 0.02 | 0.00 | 0.00 |
| 80 | Pacific Golden Plover | *Pluvialis fulva* | 0.00 | 0.59 | 0.00 | 0.00 |
| 81 | Pintail Snipe | *Gallinago stenura* | 0.00 | 0.18 | 0.00 | 0.00 |
| 82 | Plover* | *Charadrius sp.* | 0.00 | 0.06 | 0.00 | 0.00 |
| 83 | Indian Pond-heron | *Ardeola grayii* | 0.00 | 0.08 | 0.00 | 0.19 |
| 84 | Purple Heron | *Ardea purpurea* | 0.00 | 0.10 | 0.00 | 0.00 |
| 85 | Pallas's Grasshopper-warbler | *Locustella certhiola* | 0.00 | 0.20 | 0.00 | 0.00 |
| 86 | Ruddy Turnstone | *Arenaria interpres* | 0.00 | 0.14 | 0.00 | 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 87 | Sparrowhawk* | *Accipiter sp.* | 0.00 | 0.04 | 0.00 | 0.00 |
| 88 | Watercock | *Gallicrex cinerea* | 0.00 | 0.06 | 0.00 | 0.00 |
| 89 | Whimbrel | *Numenius phaeopus* | 0.00 | 1.49 | 0.18 | 0.00 |
| 90 | Inornate Warbler | *Phylloscopus inornatus* | 0.00 | 0.02 | 0.00 | 0.00 |
| 91 | Yellow Wagtail | *Motacilla flava* | 0.00 | 2.70 | 4.65 | 0.00 |
| | | **Total individuals** | **4369** | **4888** | **559** | **522** |

* Birds identified to genus but not to the species level and awaiting confirmation on identity from experts.

Appendix 2. The matrix based on Ripley and Beehler (1989).with distribution of birds of the Andamans and the Nicobars along with the adjacent regions of potential source pools. An. = Andamans, Ni. = Nicobars, Bu. = Burma, Su. = Sumatra, Ma. = Malaya, PI/ Sr. = Peninsular India/ Sri Lanka. Subspecies of birds of the Nicobars are given in brackets.

| ***Species*** | **An.** | **Ni.** | **Bu.** | **Su.** | **Ma.** | **PI/ Sr.** |
|---|---|---|---|---|---|---|
| *Ardea purpurea* | + | + | + | + | + | + |
| *Ardeola striata (spodiogaster)* | + | + | + | + | + | + |
| *Ardeola grayii* | + | + | + | - | - | + |
| *Bubulcus ibis* | + | + | + | + | + | + |
| *Egretta intermedia* | + | + | + | + | + | + |
| *Egretta garzetta* | + | + | + | - | + | + |
| *Egretta sacra* | + | + | + | + | + | - |
| *Nycticorax nycticorax* | + | + | + | - | + | + |
| *Gorsachius melanophus (minor)* | - | + | + | + | + | + |
| *Ixobrychus cinnamomeus* | + | + | + | + | + | + |
| *Ixobrychus sinensis* | + | + | + | + | + | + |
| *Dendrocygna javanica* | + | + | + | + | + | + |
| *Anas gibberifrons* | + | - | - | - | - | - |
| *Aviceda leuphotes* | + | - | + | - | - | + |
| *Haliastur indus* | + | - | + | + | + | + |
| *Accipiter butleri* | - | + | - | - | - | - |
| *Accipiter virgatus* | + | + | + | + | - | + |
| *Spizaetus cirrhatus* | + | - | + | + | + | + |
| *Haliaeetus leucogaster* | + | + | + | + | + | + |
| *Spilornis cheela (davisoni & minimus)* | + | + | + | + | + | + |
| *Spilornis elgini* | + | - | - | - | - | - |
| *Spilornis klossi* | - | + | - | - | - | - |
| *Megapodius nicobarinensis (nicobarinensis & abbotti)* | + | + | - | - | - | - |
| *Coturnix chinensis (trinkutensis)* | - | + | + | + | + | + |
| *Turnix tanki* | + | + | + | - | + | + |
| *Rallus striatus (obscurior)* | + | + | + | + | + | + |
| *Rallina canningi* | + | - | - | - | - | - |
| *Amaurornis phoenicurus (insularis & midnicobariensis)* | + | + | + | + | + | + |
| *Gallicrex cinerea* | + | + | + | + | + | + |
| *Porphyrio porphyrio* | + | + | + | + | + | + |
| *Treron pompadora (chloroptera)* | + | + | + | - | - | + |
| *Ducula aenea (nicobarica & andamanica)* | + | + | + | + | + | + |
| *Ducula bicolor* | + | + | + | + | + | - |
| *Columba palumboides (palumboides & nicobariensis)* | + | + | - | - | - | - |
| *Macropygia rufipennis (rufipennis & tiwarii)* | + | + | - | - | - | - |
| *Streptopelia tranquebarica* | + | - | + | - | + | + |
| *Chalocophaps indica (maxima)* | + | + | + | + | + | + |
| *Caloenas nicobarica (augusta)* | + | + | - | + | + | - |
| *Psittacula alexandri* | + | - | + | - | + | - |
| *Psittacula caniceps* | - | + | - | - | - | - |
| *Psittacula eupatria* | + | - | + | - | - | + |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Psittacula longicauda (tytleri & nicobarica)* | + | + | - | + | + | - |
| *Loriculus vernalis* | + | + | + | - | + | + |
| *Cuculus micropterus* | + | + | + | + | + | + |
| *Chalcites xanthorhynchus* | + | - | + | + | + | - |
| *Eudynamys scolopacea (dolosa)* | + | + | + | + | + | + |
| *Centropus andamanensis* | + | - | - | - | - | - |
| *Tyto alba* | + | - | + | + | + | + |
| *Otus balli* | + | - | - | - | - | - |
| *Otus sunia* | + | + | + | - | - | + |
| *Otus alius* | - | + | - | - | - | - |
| *Ninox affinis (affinis & rexpimenti & isolata)* | + | + | - | - | - | - |
| *Ninox scutulata (obscura)* | + | + | + | + | + | + |
| *Caprimulgus macrurus* | + | - | + | + | + | - |
| *Collocalia esculenta (affinis)* | + | + | + | + | + | - |
| *Collocalia fuciphaga* | + | + | + | + | + | - |
| *Chaetura gigantea* | + | - | - | + | + | + |
| *Alcedo atthis* | + | + | + | + | + | + |
| *Alcedo meninting* | + | - | + | + | + | + |
| *Ceyx erithacus (macrocarus)* | + | + | + | - | + | + |
| *Pelargopsis capensis (osmastoni & intermedia)* | + | + | + | + | + | + |
| *Halcyon chloris (davisoni & occipitalis)* | + | + | + | + | + | - |
| *Halcyon coromanda* | + | - | + | + | + | - |
| *Halcyon pileata* | + | + | + | - | + | + |
| *Halcyon smyrnensis (saturatior)* | + | + | + | - | + | + |
| *Merops leschenaultii* | + | - | + | - | + | + |
| *Eurystomus orientalis* | + | - | + | + | + | + |
| *Rhyticeros plicatus* | + | - | + | + | - | - |
| *Dryocopus javensis* | + | - | + | + | + | + |
| *Picoides macei* | + | - | + | + | - | - |
| *Pitta sordida (abbotti)* | - | + | + | + | + | - |
| *Hirundo tahitica* | + | - | + | + | + | + |
| *Oriolus chinensis (andamensis & macrourus)* | + | + | + | + | - | - |
| *Oriolus xanthornus* | + | - | + | + | + | + |
| *Dicrurus andamanensis* | + | - | - | - | - | - |
| *Dicrurus paradiseus (otiosus)* | + | + | + | + | + | + |
| *Artamus leucorhynchus* | + | - | - | + | - | - |
| *Aplonis panayensis (tytleri & albiris)* | + | + | + | + | + | - |
| *Sturnus erythropygius (erythropygius & andamenensis & katchalensis)* | + | + | - | - | - | - |
| *Gracula religiosa (halibrecta)* | + | + | + | + | + | + |
| *Dendrocitta bayleyi* | + | - | - | - | - | - |
| *Corvus macrorhynchos* | + | - | + | - | + | + |
| *Coracina nigra (davisoni)* | + | + | - | + | + | - |
| *Coracina novaehollandiae* | + | - | + | - | + | + |
| *Coracina striata* | + | - | - | + | + | - |
| *Pericrocotus cinnamomeus* | + | - | + | + | + | + |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Pericrocotus flammeus* | + | - | + | + | + | + |
| *Irena puella* | + | - | + | + | + | + |
| *Pycnonotus atricepts* | + | - | + | + | + | - |
| *Pycnonotus jocosus* | + | - | + | - | + | + |
| *Hypsipetes nicobariensis* | - | + | - | - | - | - |
| *Terpsiphone paradisi (nicobarica)* | - | + | + | + | + | + |
| *Hypothymis azurea (tytleri & idiochroa & nicobarica)* | + | + | + | + | + | + |
| *Pachycephala grisola* | + | - | + | + | + | - |
| *Cettia pallidipes* | + | - | - | - | - | - |
| *Cisticola juncidis* | - | + | + | + | + | + |
| *Copsychus malabaricus* | + | - | + | + | + | + |
| *Copsychus saularis* | + | - | + | + | + | + |
| *Zoothera citrina (andamanensis & albogularis)* | + | + | + | - | + | + |
| *Dicaeum concolor* | + | - | + | + | + | + |
| *Nectarinia jugularis (andamanica & proselia & klossi)* | + | + | + | + | + | - |
| *Aethopyga siparaja (nicobarica)* | - | + | + | + | + | + |
| *Zosterops palpebrosa (nicobarica)* | + | + | + | + | + | + |
| *Lonchura striata (fumigata & semistriata)* | + | + | + | + | + | + |

Appendix 3. Island-wise list of total bird species recorded in 17 islands of the Nicobars during the study.

| **Common Names** | ***Scientific name*** | **GN** | **CU** | **KN** | **LN** | **PM** | **MN** | **TE** | **MR** | **KM** | **NN** | **TR** | **KT** | **TS** | **BP** | **CH** | **TI** | **CN** | **Total occurrence** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Olive-backed Sunbird | *Nectarinia jugularis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 17 |
| Black-naped Monarch | *Hypothymis azurea* | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 16 |
| Emerald Dove | *Chalcophaps indica* | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 16 |
| Long-tailed Parakeet | *Psittacula longicauda* | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 16 |
| White-bellied Sea-eagle | *Haliaeetus leucogaster* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 16 |
| Asian Glossy Starling | *Aplonis panayensis* | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 15 |
| Asian Koel | *Eudynamys scolopaceus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 15 |
| Green Imperial-pigeon | *Ducula aenea [nicobarica]* | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 15 |
| Nicobar Pigeon | *Caloenas nicobarica* | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 15 |
| Pied Imperial-pigeon | *Ducula bicolor* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 15 |
| Black-naped Oriole | *Oriolus chinensis* | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 14 |
| Nicobar Megapode | *Megapodius nicobariensis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 14 |
| Pacific Reef-egret | *Egretta sacra* | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 14 |
| White-breasted Waterhen | *Amaurornis phoenicurus* | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 14 |
| Glossy Swiftlet | *Collocalia esculenta* | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 13 |
| Black-naped Tern | *Sterna sumatrana* | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 12 |
| Collared Kingfisher | *Todiramphus chloris* | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 12 |
| Striated Heron | *Butorides striata* | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 12 |
| Oriental White-eye | *Zosterops palpebrosus* | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 12 |
| Edible-nest Swiftlet | *Collocalia fuciphaga* | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 11 |
| Pompadour Green-pigeon | *Treron pompadora* | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 11 |
| Indian Pond-heron | *Ardeola grayii* | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 11 |
| Andaman Cuckoo-dove | *Macropygia rufipennis* | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 10 |
| Asian Paradise-flycatcher | *Terpsiphone paradisi* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 10 |
| Barn Swallow | *Hirundo rustica* | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 |
| Common Sandpiper | *Actitis hypoleucos* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 10 |
| Yellow Bittern | *Ixobrychus sinensis* | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 10 |
| Brown Shrike | *Lanius cristatus* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 9 |
| Grey Wagtail | *Motacilla cinerea* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 9 |
| Whimbrel | *Numenius phaeopus* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 9 |
| Andaman Wood-pigeon | *Columba palumboides* | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 8 |
| Orange-headed Thrush | *Zoothera citrina* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 8 |
| White-rumped Munia | *Lonchura striata* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 8 |
| Brown Hawk-owl | *Ninox scutulata* | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 8 |
| Cinnamon Bittern | *Ixobrychus cinnamomeus* | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 7 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common Redshank | *Tringa totanus* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 7 |
| Crimson Sunbird | *Aethopyga siparaja* | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| Greater Racket-tailed Drongo | *Dicrurus paradiseus* | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 7 |
| Nicobar Bulbul | *Hypsipetes nicobariensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 7 |
| Purple Heron | *Ardea purpurea* | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| Yellow Wagtail | *Motacilla flava* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 7 |
| Zitting Cisticola | *Cisticola juncidis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 7 |
| Black-capped Kingfisher | *Halcyon pileata* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 6 |
| Blue-tailed Bee-eater | *Merops philippinus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 6 |
| Cattle Egret | *Bubulcus ibis* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 6 |
| Intermediate Egret | *Mesophoyx intermedia* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 6 |
| Pintail Snipe | *Gallinago stenura* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 6 |
| Ruddy Turnstone | *Arenaria interpres* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 6 |
| Red-whiskered Bulbul | *Pycnonotus jocosus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 6 |
| Andaman Hawk-owl | *Ninox affinis* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 |
| Hill Myna | *Gracula religiosa* | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Chinese Goshawk | *Accipiter soloensis* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 5 |
| Common Kingfisher | *Alcedo atthis* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 5 |
| Lesser Sand Plover | *Charadrius mongolus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 5 |
| Pacific Golden Plover | *Pluvialis fulva* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 5 |
| Pallas's Grasshopper-warbler | *Locustella certhiola* | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Warblers* | *Acrocephalus & Phylloscopus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 5 |
| Little Egret | *Egretta garzetta* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 5 |
| Besra | *Accipiter virgatus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| South Nicobar Serpent-eagle | *Spilornis klossi* | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Grey Plover | *Pluvialis squatarola* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 4 |
| Lesser Crested Tern | *Sterna bengalensis* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| Nicobar Parakeet | *Psittacula caniceps* | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Pied Triller | *Lalage nigra* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| Stork-billed Kingfisher | *Pelargopsis capensis* | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Greater Sand Plover | *Charadrius leschenaultii* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| Asian Brown Flycatcher | *Muscicapa dauurica* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Crested Serpent-eagle | *Spilornis cheela* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Forest Wagtail | *Dendronanthus indicus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Hooded Pitta | *Pitta sordida* | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Malaysian Night-heron | *Gorsachius melanolophus* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Watercock | *Gallicrex cinerea* | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Common Greenshank | *Tringa nebularia* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Ashy Minivet | *Pericrocotus divaricatus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| Blue Quail | *Coturnix chinensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brown-chested Jungle-flycatcher | *Rhinomyias brunneatus* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Crow-billed Drongo | *Dicrurus annectans* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| Little Swift (House Swift) | *Apus affinis* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Kentish Plover | *Charadrius alexandrinus* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Little Stint | *Calidris minuta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Black-backed Kingfisher | *Ceyx erithaca* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Oriental Pratincole | *Glareola maldivarum* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| Peregrine Falcon | *Falco peregrinus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 |
| White-headed Starling | *Sturnus erythropygius* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 |
| Sparrowhawk Sp. | *Accipiter sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Oriental Scops-owl | *Otus sunia* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Osprey | *Pandion haliaetus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Red-breasted Flycatcher | *Ficedula parva* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| White-tailed Tropicbird | *Phaethon lepturus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| Andaman Drongo | *Dicrurus andamanensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Black-crowned Night-heron | *Nycticorax nycticorax* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| House Crow | *Corvus splendens* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Great Egret | *Casmerodius albus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Mugimaki Flycatcher | *Ficedula mugimaki* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Nicobar Sparrowhawk | *Accipiter butleri* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Inornate Warbler | *Phylloscopus inornatus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Unidentified Owlet* | Unidentified Owlet | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Bunting (Yellow-breasted?) | *Emberiza aureola?* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Unidentified Plover* | *Charadrius sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Common Myna | *Acridotheres tristis* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Crab Plover | *Dromas ardeola* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Curlew Sandpiper | *Calidris ferruginea* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Grey-faced Buzzard | *Butastur indicus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Large Hawk-cuckoo | *Cuculus sparverioides* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Lesser Whistling-duck | *Dendrocygna javanica* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Oriental Honey-buzzard | *Pernis ptilorhyncus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Pied Cuckoo | *Clamator jacobinus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Red-throated Pipit | *Anthus cervinus* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Terek Sandpiper | *Xenus cinereus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Yellow-legged Buttonquail | *Turnix tanki* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Unidentified Cuckoo* | Unidentified Cuckoo | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Unidentified Shrike* | *Lanius sp.* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | **73** | **6** | **26** | **51** | **25** | **22** | **25** | **21** | **70** | **55** | **61** | **64** | **46** | **36** | **33** | **23** | **29** | |

* Birds identified to genus but not to the species level and awaiting confirmation on identity from experts; probably new records for the Nicobars.

Appendix 4. Locations and characteristics of mounds of Nicobar Megapode recorded during October 2009- August 2011 in the 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 | 06º 47′ 59.9″ | 93º 50′ 39.9″ | Littoral forest (secondary) | B | Inactive | Sand-loam | 50 | 65 | 40 | 2.85 | 0.85 |
| | Chingenh Pasthi | 13/11/2009 | 06º 47′ 59.2″ | 93º 50′ 39.1″ | Littoral forest (secondary) | B | Abandoned | Sand-loam | 50 | 70 | 45 | 2.55 | 0.45 |
| | Chingenh Pasthi | 14/11/2009 | 06º 48′ 10.7″ | 93º 50′ 42.4″ | Littoral forest (secondary) | B | Abandoned | Loam | 100 | __ | 40 | 3.1 | 0.75 |
| | Kopenheat | 21/04/2011 | 06º 57' 57.8" | 93º 44' 18.4" | Littoral habitat | C | Active | Sand | 0 | 30 | 5 | 3.5 | 0.5 |
| | Kasingdon | 22/04/2011 | 06º 57' 12.1" | 93º 45' 08.1" | Mixed forest (unaffected) | A | Active | Loam | 150 | __ | __ | 5.1 | 0.4 |
| | Trinket Bay area | 31/05/2011 | 07º 12' 09.8" | 93º 52' 36.5" | Littoral habitat | C | Active | Sand | 2 | 35 | 30 | 2 | 0.4 |
| Little Nicobar | Reing-Reing | 07/11/2009 | 07º 16′ 19.6″ | 93º 38′ 13.0″ | Mixed hill forest edge | B | Inactive | Loam | 0 | 40 | 40 | 4.5 | 0.65 |
| | Salangéh | 26/10/2009 | 07º 17′ 51.9″ | 93º 42′ 06.4″ | Mixed forest edge (coastal) | C | Inactive | Sand | 2 | 50 | 12 | 3.7 | 0.6 |
| | Lenyih | 26/10/2009 | 07º 17′ 09.6″ | 93º 40′ 42.8″ | Mixed forest (disturbed) | C | Inactive | Sand-loam | 80 | 20 | 45 | 4.2 | 0.8 |
| | Kankohá | 26/10/2009 | 07º 18′ 19.0″ | 93º 42′ 28.1″ | Mixed forest edge (coastal) | C | Inactive | Sand-loam | 5 | 70 | 10 | 4.6 | 0.6 |
| | Chema Weik | 28/10/2009 | 07º 16′ 34.1″ | 93º 40′ 29.0″ | Mixed forest edge | A | Inactive | Sand-loam | 25 | 40 | 10 | 4.85 | 0.65 |
| | Thavai thav | 31/10/2009 | 07º 16′ 19.6″ | 93º 38′ 13.0″ | Littoral forest (secondary) | B | Inactive | Loam | 480 | 40 | 45 | 10.5 | 0.93 |
| | Thavai thav | 01/11/2009 | 07º 16′ 21.3″ | 93º 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 | 07º 23' 40.5" | 93º 43' 34.1" | Littoral habitat | B/C | Active | Sand | 5 | 60 | 7 | 3.8 | 0.4 |
| | School Point | 25/05/2011 | 07º 23' 55.0" | 93º 43' 20.7" | Littoral habitat | A | Abandoned | Sand-loam | __ | 45 | 12 | 7 | 0.45 |
| | Pilo Panja | 25/05/2011 | 07º 23' 48.9" | 93º 43' 25.3" | Littoral habitat | C | Active | Sand | 10 | 70 | 13 | 2.8 | 0.3 |
| Menchal | Menchal | 16/05/2011 | 07º 23' 43.1" | 93º 45' 54.0" | Coconut groove | C | Active | Sand | 3 | 50 | 18 | 4.5 | 0.9 |
| Meore | Meroe | 23/05/2011 | 07º 30' 52.5" | 93º 32' 31.5" | Coconut groove | B | Active | Sand | 3 | 25 | 30 | 3 | 0.4 |
| | Meroe | 22/05/2011 | 07º 30' 53.8" | 93º 32' 44.9" | Littoral habitat | C | Active | Loam | __ | 60 | 16 | 4 | 0.5 |
| Nancowry | Sapa (Hindrah) | 23/02/2010 | 07º 58′ 04.8″ | 93º 31′ 39.7″ | Pandanus growth (littoral) | B | Inactive | Sand | 10 | 60 | 15 | 4 | 0.5 |
| | Lapet (Hindrah) | 23/02/2010 | 07º 58′ 16.3″ | 93º 31′ 28.5″ | Coconut groove | C | Inactive | Sand | 12 | 30 | 7 | 6.5 | 0.5 |
| | Hindrah | 07/01/2011 | 07º 58' 16.9" | 93º 31 28.6" | Littoral forest | C | Active | Sand (black) | 2.5 | 50 | 9 | 5.3 | 0.95 |
| | Mus | 26/02/2010 | 07º 57′ 03.7″ | 93º 34′ 49.6″ | Pandanus growth (littoral) | C | Inactive | Sand | 10 | 80 | 5 | 3 | 0.3 |
| | Mus | 27/02/2010 | 07º 56′ 46.7″ | 93º 34′ 45.0″ | Littoral habitat | C | Inactive | Sand | 10 | 80 | 5 | 4 | 0.3 |
| | Mus | 11/04/2011 | 07º 56' 48.4" | 93º 34' 45.0" | Littoral habitat | A | Inactive | Sand | 25 | 0 | 7 | 2.5 | 0.4 |
| | Mus | 11/04/2011 | 07º 56' 48.3" | 93º 34' 45.4" | Littoral habitat | C | Active | Sand | 10 | 0 | 0 | 2.5 | 0.35 |
| Kamorta | Masala Tapu | 15/01/2010 | 08º 01′ 58.3″ | 93º 29′ 15.5″ | Mixed forest (unaffected) | C | Abandoned | Loam | 100 | 85 | __ | 2.6 | 0.45 |
| | Masala Tapu | 15/01/2010 | 08º 02′ 06.6″ | 93º 28′ 04.6″ | Mixed forest (unaffected) | C | Abandoned | Loam | 100 | 65 | 35 | 2.35 | 0.2 |
| | Remyok | 18/01/2010 | 08º 06′ 36.2″ | 93º 32' 27.9" | Littoral habitat | A | Abandoned | Sand | 8 | 40 | 13 | 16.15 | 0.6 |
| | Dering | 27/12/2010 | 08º 06' 44.7" | 93º 29' 21.4" | Mixed forest (unaffected) | B | Active | Loam (black) | 600 | 70 | 20 | 6.7 | 0.9 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nyikalang | 24/11/2010 | 08º 11' 52.2" | 93º 32' 27.9" | Littoral habitat | A | Abandoned | Loam | 600 | 65 | 14 | 7.05 | 0.65 |
| Trinket | Lahom | 16/11/2010 | 08º 02' 45.4" | 93º 35' 19.5 | Littoral habitat | C | Active | Sand | 6 | 30 | 15 | 4.3 | 0.65 |
| | Trinket | 25/11/2010 | 08º 05' 06.0" | 93º 35' 19.5" | Littoral habitat | B | Abandoned | Sand-loam | 400 | 55 | 11 | 6.8 | 0.85 |
| Katchal | Jansin | 13/01/2011 | 07º 59' 41.9" | 93º 19' 41.8" | Littoral habitat | C | Active | Sand-loam | __ | 70 | 13 | 5.5 | 0.6 |
| | Jansin | 13/01/2011 | 07º 59' 36.1" | 93º 19' 40.1" | Littoral habitat | C | Active | Sand-loam | 200 | 70 | 15 | 4.7 | 0.4 |
| | Jansin | 13/01/2011 | 07º 59' 45.3" | 93º 19' 43.2" | Littoral habitat | B? | Inactive? | Loam | 500 | 70 | 12 | 4.7 | 0.3 |
| | Jansin | 13/01/2011 | 07º 59' 43.3" | 93º 19' 43.0" | Littoral habitat | C | Abandoned | Sand-loam | __ | 75 | 13.5 | 5.5 | 0.8 |
| Teressa | Safed Balu | 15/04/2010 | 08º 14' 30.8" | 93º 09' 12.5" | Littoral habitat | A | Abandoned | Sand-loam | 40 | 40 | 35 | 8.1 | 1 |
| | Kolerue | 18/04/2010 | 08º 12′ 35.6″ | 93º 12′ 05.6″ | Littoral habitat | A | Active | Sand | __ | 35 | 20 | 5.1 | 0.9 |
| | Kolerue | 18/04/2010 | 08º 12′ 36.8″ | 93º 12′ 05.8″ | Littoral habitat | C | Abandoned | Sand-loam | 150 | 20 | 8 | 6 | 0.85 |
| | Kolerue | 18/04/2010 | 08º 12′ 37.0″ | 93º 12′ 06.2″ | Littoral habitat | A | Active | Sand-loam | 140 | 10 | 8 | 4 | 0.75 |
| | Kolerue | 18/04/2010 | 08º 12′ 35.8″ | 93º 12′ 08.9″ | Littoral habitat | C | Active | Sand | 140 | 5 | 8 | 3.55 | 0.7 |
| | Reksal | 01/05/2010 | 08º 20′ 59.8" | 93º 07′ 16.7″ | Littoral habitat | C | Active | Gravel | 25 | 65 | 10 | 4.3 | 0.8 |
| | Reksal | 01/05/2010 | 08º 20′ 54.0" | 93º 07′ 04.5″ | Littoral habitat | A | Active | Gravel | 2 | 40 | 6 | 3.3 | 0.6 |
| | Kolerue | 03/03/2011 | 08º 12' 37.0" | 93º 12' 06.2" | Littoral habitat | A | Active | Sand-loam | __ | 30 | 9 | 5.4 | 1.3 |
| | Kolerue | 03/03/2011 | 08º 12' 43.8" | 93º 12' 11.4" | Littoral habitat | C | Active | Sand-loam | 40 | 45 | 9 | 2 | 0.4 |
| | Reksal | 09/03/2011 | 08º 20' 59.8" | 93º 07' 16.7" | Littoral habitat | A | Active | Sand-loam | 25 | 40 | 38 | 4.2 | 0.75 |
| | Reksal | 09/03/2011 | 08º 20' 54.0" | 93º 07' 04.5" | Littoral habitat | B | Inactive? | Sand | 4 | 20 | 7 | 3.8 | 0.6 |
| Bompoka | Atluch | 22/04/2010 | 08º 12′ 02.5″ | 93º 14′ 28.3″ | Littoral habitat | A | Active | Loam | 150 | 78 | 32 | 5.3 | 1.15 |
| | Atluch | 22/04/2010 | 08º 15′ 05.3″ | 93º 14′ 32.0″ | Littoral habitat | C | Active | Loam | 15 | 20 | 15 | 2.5 | 0.15 |
| | Atluch | 22/04/2010 | 08º 15′ 15.6″ | 93º 14′ 26.7″ | Plantation (second growth) | C | Active | Sand | 9 | 30 | 8 | 4.5 | 0.65 |
| | Atluch | 24/04/2010 | 08º 15′ 43.1″ | 93º 14′ 13.7″ | Littoral habitat | A | Active | Sand-loam | 0 | 30 | 8 | 4.2 | 0.7 |
| | Atluch | 24/04/2010 | 08º 15′ 38.1″ | 93º 14′ 18.2″ | Littoral habitat | B | Active | Loam | 2 | 20 | 28 | 4.2 | 0.6 |
| | Chukmisuyi | 25/04/2010 | 08º 15′ 21.1″ | 93º 14′ 19.9″ | Littoral habitat | A | Active | Sand | 4 | 40 | 28 | 4.2 | 0.45 |
| | Chukmisuyi | 25/04/2010 | 08º 15′ 13.2″ | 93º 13′ 18.1″ | Littoral habitat | A | Active | Sand-loam | 40 | 45 | 28 | 5.4 | 1 |
| | Chukmisuyi | 25/04/2010 | 08º 15′ 11.6″ | 93º 13′ 18.7″ | Littoral habitat | A | Abandoned | Loam | 60 | 20 | 28 | 3.95 | 0.7 |
| | Chukmisuyi | 27/04/2010 | 08º 15′ 01.8″ | 93º 13′ 16.2″ | Littoral habitat | C | Active | Sand-loam | 70 | __ | 13 | 2.3 | 0.6 |
| | Atluch | 18/02/2011 | 08º 15' 05.3" | 93º 14' 32.4" | Littoral habitat | A | Active | Sand-loam | 10 | 70 | 10 | 4.3 | 0.5 |
| | Atluch | 18/02/2011 | 08º 15' 07.0" | 93º 14' 31.6" | Littoral habitat | B | Active | Sand-loam | 4 | 30 | 30 | 3.1 | 0.75 |
| | Atluch | 18/02/2011 | 08º 15' 15.6" | 93º 14' 26.7" | Littoral habitat | C | Active | Sand-loam | 6 | 20 | 8 | 5.2 | 0.9 |
| | Atluch | 19/02/2011 | 08º 15' 41.0" | 93º 13' 45.2" | Littoral habitat | B | Active | Sand-loam | 18 | 45 | 32 | 5.8 | 0.95 |
| | Atluch | 19/02/2011 | 08º 15' 43.7" | 93º 13' 53.1" | Littoral habitat | C | Active | Sand-loam | 3 | 55 | 17 | 5.5 | 0.75 |
| | Atluch | 19/02/2011 | 08º 15' 45.6" | 93º 13' 59.3" | Littoral habitat | C | Active | Loam | 15 | 55 | 40 | 4.2 | 0.95 |
| | Poahat | 19/02/2011 | 08º 15' 28.1" | 93º 13' 25.6" | Littoral habitat | C | Active | Sand-loam | 5 | 70 | 10 | 4.6 | 0.7 |
| | Poahat | 19/02/2011 | 08º 15' 34.4" | 93º 13' 32.8" | Littoral habitat | C | Active | Loam | 15 | 70 | 15 | 3.2 | 0.7 |
| | Poahat | 23/02/2011 | 08º 15' 13.2" | 93º 13' 18.1" | Littoral habitat | A | Active | Sand-loam | 30 | 70 | 22 | 5.3 | 1.2 |
| | Poahat cave | 23/02/2011 | 08º 15' 10.6" | 93º 13' 46.9" | Mixed forest (unaffected) | B | Active | Loam | __ | 80 | 38 | 6 | 1.5 |
| | Poahat cave | 23/02/2011 | 08º 15' 08.2" | 93º 13' 56.6" | Mixed forest (unaffected) | B | Abandoned | Loam (red) | __ | 75 | 35 | 5 | 1 |
| Chowra | Tahup | 12/12/2010 | 08º 26' 36.3" | 93º 03' 24.3" | Mixed forest (unaffected) | C | Abandoned | Loam (hill top) | __ | 75 | 28 | 7 | 0.45 |
| | Tahup | 12/12/2010 | 08º 26' 36.4 | 93º 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± | **146.3** | **22.8** | **12.6** | **2.1** | **0.3** |

* Habitatas with Littoral habitats are littoral areas affected by tsunami

Appendix 5. Locations of detections of Nicobar Megapode during March 2009 to August 2011 in the Nicobar islands.

| **Island** | **Location** | **Date** | **Latitude (N)** | **Longitude (E)** | **No. of individuals estimated** | **Mound located in the whole region** | **Dist_ coast (m)** | **Habitat** |
|---|---|---|---|---|---|---|---|---|
| Great Nicobar | 38 kms | 13/11/2009 | 06º 48′ 19.4″ | 93º 52′ 41.3″* | 2 | No | 100 | Mixed forest (edge) |
| Great Nicobar | Chingampasthy | 14/11/2009 | 06º 47′ 59.9″ | 93º 50′ 39.9″ | 2 | Yes | 50 | Littoral habitat (tsunami affected) |
| Great Nicobar | Near 46 kms | 15/11/2009 | 06º 47′ 26.8″ | 93º 50′ 34.9″ | 1 | No | 500 | Littoral habitat (tsunami affected) |
| Great Nicobar | Pilo Baha | 17/11/2009 | 06º 48′ 52.0″ | 93º 49′ 20.3″* | 1 | No | 400 | Mixed forest (edge) |
| Great Nicobar | Pilo Bakka | 20/11/2009 | 06º 50′ 56.3″ | 93º 48′ 13.2’″* | 1-2 | No | 500 | Mixed forest (edge) |
| Great Nicobar | Ayoam Bay | 28/11/2009 | 07º 06′ 06.0″ | 93º 40′ 11.7″* | 2 | No | 100 | Mixed forest (edge) |
| Great Nicobar | Pethai | 22/12/2009 | 07º 13′ 46.1″ | 93º 48′ 32.8″ | 1-2 | No | 40 | Mixed forest |
| Great Nicobar | Kopenheat | 21/04/2011 | 06º 57' 59.2″ | 93º 44' 23.5″ | 1 | No | 40 | Littoral habitat (tsunami affected) |
| Great Nicobar | Kasingdon | 21/04/2011 | 06º 57' 58.6″ | 93º 44' 20.1″ | 2 | No | __ | Littoral habitat (tsunami affected) |
| Cubra | Cubra | 06/05/2009 | --- | --- | 2 | No | 30 | Mixed secondary vegetation |
| Kondul | Kondul | 28/05/2011 | 07º 13' 07.6″ | 93º 42' 45.2″ | 1 | No | 450 | Mixed forest |
| Kondul | Kondul | 30/05/2011 | 07º 12' 32.4″ | 93º 42' 59.8″ | 1 | No | __ | Mixed forest |
| Kondul | Kondul | 30/05/2011 | 08º 14' 26.1″ | 93º 09' 20.5″ | 1 | No | 350 | Mixed forest |
| Kondul | Kondul | 30/05/2011 | 07º 12' 32.8″ | 93º 43' 00.2″ | 1 | No | 450 | Mixed forest |
| Little Nicobar | Lanaeyi | 25/10/2009 | 07º 17′ 09.6″ | 93º 40′ 42.8″ | 2-4 | Yes | 100 | Disturbed forest |
| Little Nicobar | Rawaiuh (Thavaithau) | 29/10/2009 | 07º 15′ 59.5″ | 93º 38′ 07.1″ | 2 | Yes | 300 | Mixed forest (edge) |
| Little Nicobar | Thavaithau | 31/10/2009 | 07º 16′ 26.5″ | 93º 38′ 15.3″ | 2 | Yes | 350 | Littoral habitat (tsunami affected) |
| Little Nicobar | Komath | 11/05/2011 | 07º 21' 45.0″ | 93º 40' 32.2″ | 1 | No | 400 | Mixed forest (edge) |
| Little Nicobar | Pilo Panja | 25/05/2011 | 07º 23' 27.5″ | 93º 43' 47.0″ | 2 | No | __ | Mixed forest |
| Menchal | Menchal | 20/12/2009 | 07º 23′ 47.1″ | 93º 45′ 55.3″ | 6 | Yes | 200 | Coconut groove |
| Menchal | Menchal | 20/12/2009 | 07º 24′ 03.7″ | 93º 45′ 58.8″ | 4 | No | 50 | Coconut groove |
| Menchal | Menchal | 15/05/2011 | 07º 23' 55.8″ | 93º 45' 48.6″ | 2 | No | 25 | Mixed forest |
| Menchal | Menchal | 15/05/2011 | 07º 23' 50.8″ | 93º 46' 02.1″ | 2 | No | 350 | Mixed forest |
| Pilo Milo | Pilo Milo | 13/05/2011 | 07º 24' 23.1″ | 93º 41' 18.2″ | 2 | No | 200 | Littoral habitat (tsunami affected) |
| Treis | Treis | 06/05/2011 | 07º 28' 23.4″ | 93º 38' 50.7″ | 1 | No | 80 | Mixed forest |
| Treis | Treis | 05/05/2011 | 07º 28' 21.2″ | 93º 39' 04.4″ | 1 | No | 50 | Mixed forest |
| Kamorta | Remyok area | 15/01/2010 | 08º 07′ 15.9″ | 93º 28′ 54.7″ | 1-2 | No | 1800 | Mixed forest |
| Kamorta | Kakana area | 09/02/2010 | 08º 10′ 18.3″ | 93º 30′ 31.9″* | 1-2 | Yes | 50 | Mixed forest |
| Kamorta | Nyikalang | 22/11/2010 | 08º 11' 43.3″ | 93º 32' 29.1″ | 1 | No | __ | Littoral habitat (tsunami affected) |
| Kamorta | Nyikalang | 22/11/2011 | 08º 11' 45.7″ | 93º 32' 30.3″ | 1 | No | 300 | Littoral habitat (tsunami affected) |
| Kamorta | Dering | 23/12/2010 | 08º 05' 57.1″ | 93º 29' 20.8″ | 1 | No | __ | Mixed forest (edge) |
| Kamorta | Ol-hin-pun | 29/12/2010 | 08º 08' 46.9″ | 93º 27' 34.4″ | 1 | No | __ | Mixed forest (edge) |
| Kamorta | Ol-hin-pun | 29/12/2010 | 08º 08' 48.1″ | 93º 27' 33.2″ | 1 | No | __ | Mixed forest (edge) |
| Nancowrie | Sapa (near Hindrah) | 23/02/2010 | 07º 58′ 08.0″ | 93º 31′ 41.3″* | 2 | Yes | 150 | Mixed forest |
| Nancowrie | Mus | 25/02/2010 | 07º 57′ 03.7″ | 93º 34′ 49.6″* | 1-2 | Yes | 50 | Mixed forest |
| Nancowrie | Hindrah | 05/01/2011 | 07º 58' 10.5″ | 93º 31' 33.5″ | 1 | No | 50 | Mixed forest |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nancowrie | Hindrah | 07/01/2011 | 07º 58' 16.9″ | 93º 31' 28.6″ | 2 | Yes | __ | Littoral habitat (tsunami affected) |
| Nancowrie | Hindrah | 07/01/2011 | 07º 58' 16.8″ | 93º 31' 29.5″ | 1 | No | 50 | Mixed forest |
| Nancowrie | Hindrah | 07/01/2011 | 07º 58' 19.7″ | 93º 31' 28.1″ | 1 | No | 120 | Mixed forest |
| Nancowrie | Mus | 09/04/2011 | 07º 56' 42.6″ | 93º 34' 44.8″ | 1 | No | 80 | Mixed forest |
| Nancowrie | Mus | 09/04/2011 | 07º 56' 48.9″ | 93º 34' 44.7″ | 1 | Yes | __ | Littoral habitat (tsunami affected) |
| Trinket | Trinket settlement | 31/01/2010 | 08º 04′ 58.6″ | 93º 35′ 10.4″ | 1-2 | No | 500 | Littoral habitat (tsunami affected) |
| Trinket | Thavai oank | 14/11/2010 | 08º 02' 41.8″ | 93º 35' 30.6″ | 1 | No | 300 | Mixed forest (edge) |
| Trinket | Thavai oank | 15/11/2010 | 08º 02' 36.5″ | 93º 35' 31.8″ | 2 | No | __ | Mixed forest |
| Katchal | West Bay | 19/03/2010 | 07º 55′ 42.2″ | 93º 21′ 34.5″ | 1 | No | 300 | Coconut groove |
| Katchal | Jansin | 31/03/2010 | 07º 59′ 02.5″ | 93º 19′ 44.0″ | 2 | No | 250 | Littoral habitat (tsunami affected) |
| Katchal | Jansin | 13/01/2011 | 07º 59' 36.6″ | 93º 19' 41.0″ | 2 | No | 200 | Littoral habitat (tsunami affected) |
| Katchal | West Bay | 23/01/2011 | 07º 57' 58.9″ | 93º 19' 45.6″ | 2 | No | __ | Mixed forest |
| Teressa | Kolearu | 17/04/2010 | 08º 12′ 34.1″ | 93º 12′ 05.3″ | 4 | Yes | 150 | Littoral habitat (tsunami affected) |
| Teressa | Kolaeru | 17/04/2010 | 08º 12′ 18.5″ | 93º 12′ 38.1″ | 4 | Yes | 120 | Littoral habitat (tsunami affected) |
| Teressa | Reksal | 29/04/2010 | 08º 20' 22.2″ | 93º 06' 50.5″ | 1 | No | 300 | Mixed forest |
| Teressa | Kalasi | 27/02/2011 | 08º 15' 39.8″ | 93º 07' 14.5″ | 1 | No | __ | Mixed forest |
| Teressa | Kalasi | 27/02/2011 | 08º 15' 39.0″ | 93º 07' 29.2″ | 5 | No | __ | Mixed forest |
| Teressa | Kolerue | 03/03/2011 | 08º 12' 41.0″ | 93º 12' 10.4″ | 1 | No | 80 | Littoral habitat (tsunami affected) |
| Teressa | Reksal | 07/03/2011 | 08º 21' 00.4″ | 93º 07' 17.1″ | 1 | No | 20 | Littoral habitat (tsunami affected) |
| Teressa | Reksal | 08/03/2011 | 08º 20' 39.7″ | 93º 06' 41.7″ | 1 | No | 250 | Mixed forest |
| Bompoka | Atluch (N) | 20/04/2010 | 08º 15′ 13.5″ | 93º 14′ 26.8″ | 4 | No | 30 | Littoral habitat (tsunami affected) |
| Bompoka | Atluch (NE) | 20/04/2010 | 08º 15′ 34.7″ | 93º 14′ 18.5″ | 2 | No | 10 | Mixed forest (coastal) |
| Bompoka | Atluch | 21/04/2010 | 08º 15′ 21.7″ | 93º 14′ 08.7″ | 1 | No | 900 | Mixed forest (interior) |
| Bompoka | Atluch | 22/04/2010 | 08º 15' 04.8″ | 93º 14' 32.0″ | 2 | No | 15 | Littoral habitat (tsunami affected) |
| Bompoka | Atluch (N) | 23/04/2010 | 08º 15′ 37.8″ | 93º 13′ 57.3″ | 1 | No | 250 | Mixed forest |
| Bompoka | Atluch (N) | 23/04/2010 | 08º 15′ 45.3″ | 93º 14′ 12.4″ | 1 | No | 15 | Littoral habitat (tsunami affected) |
| Bompoka | Chukmisuyi | 25/04/2010 | 08º 15' 08.5" | 93º 13' 17.1″ | 2 | Yes | 40 | Littoral habitat (tsunami affected) |
| Bompoka | Chukmisuyi | 27/04/2010 | 08º 14′ 56.0″ | 93º 13′ 14.1″ | 2 | Yes | 50 | Littoral habitat (tsunami affected) |
| Bompoka | Chukmisuyi | 27/04/2010 | 08º 15' 01.6″ | 93º 13' 28.2″ | 4 | Yes | 45 | Mixed forest |
| Bompoka | Poahat | 17/02/2011 | 08º 15' 05.1″ | 93º 13' 30.7″ | 2 | No | __ | Mixed forest |
| Bompoka | Poahat | 17/02/2011 | 08º 15' 04.4″ | 93º 13' 20.4″ | 2 | No | 150 | Mixed forest |
| Bompoka | Poahat | 17/02/2011 | 08º 15' 03.5″ | 93º 13' 16.9″ | 2 | No | 80 | Littoral habitat (tsunami affected) |
| Bompoka | Atluch | 18/02/2011 | 08º 15' 17.7″ | 93º 14' 25.5″ | 2 | No | 15 | Littoral habitat (tsunami affected) |
| Bompoka | Atluch | 18/02/2011 | 08º15' 20.8″ | 93º 14' 24.6″ | 2 | No | 10 | Littoral habitat (tsunami affected) |
| Bompoka | Atluch | 18/02/2011 | 08º 15' 23.7″ | 93º 14' 22.4″ | 2 | No | 25 | Littoral habitat (tsunami affected) |
| Bompoka | Atluch | 18/02/2011 | 08º 02' 36.5″ | 93º 35' 31.8″ | 1 | No | 25 | Mixed forest |
| Bompoka | Atluch | 18/02/2011 | 08º 15' 04.8″ | 93º 14' 32.0″ | 1 | Yes | 25 | Mixed forest |
| Bompoka | Atluch | 19/02/2011 | 08º 15' 44.0″ | 93º 14' 12.6″ | 1 | No | 15 | Mixed forest |
| Bompoka | Atluch | 19/02/2011 | 08º 15' 21.8″ | 93º 13' 43.4″ | 1 | No | 600 | Mixed forest |
| Bompoka | Poahat | 19/02/2011 | 08º 15' 29.5″ | 93º 13' 26.8″ | 2 | Yes | __ | Littoral habitat (tsunami affected) |
| Bompoka | Poahat | 23/02/2011 | 08º 15' 10.4″ | 93º 14' 02.6″ | 2 | No | __ | Mixed forest |
| Bompoka | Poahat | 23/02/2011 | 08º 15' 14.7″ | 93º 13' 31.5″ | 1 | No | __ | Mixed forest |

**approximate location (>100m away from the GPS location)

## Appendix 6. Checklist of birds of Nicobar Islands (Classification follows BirdLife International 2012).

| SI # | **Common name** | **Scientific name** | **RedList Category** | **Status** (Kazmierczak & Van Perlo 2000 & other sources) |
|---|---|---|---|---|
| **Fam: Megapodiidae** | | | | |
| 1 | Nicobar Megapode | *Megapodius nicobariensis* | VU | Endemic to the Nicobars |
| **Fam: Phasianidae** | | | | |
| 2 | Blue Quail (Blue-breasted Quail) | *Coturnix chinensis* | LC | Resident |
| **Fam: Anatidae** | | | | |
| 3 | Lesser Whistling-duck | *Dendrocygna javanica* | LC | Resident |
| **Fam: Hydrobatidae** | | | | |
| 4 | ?Black-bellied Storm-petrel | *Fregetta tropica* | LC | Doubtful record |
| **Fam: Ardeidae** | | | | |
| 5 | Yellow Bittern | *Ixobrychus sinensis* | LC | Resident |
| 6 | Cinnamon Bittern | *Ixobrychus cinnamomeus* | LC | Resident |
| 7 | Malaysian Night-heron | *Gorsachius melanolophus* | LC | Resident |
| 8 | Black-crowned Night-heron | *Nycticorax nycticorax* | LC | Resident |
| 9 | Striated Heron (Little Heron) | *Butorides striata* | LC | Resident |
| 10 | Indian Pond-heron | *Ardeola grayii* | LC | Resident |
| 11 | Cattle Egret | *Bubulcus ibis* | LC | Resident |
| 12 | Grey Heron | *Ardea cinerea* | LC | Winter visitor |
| 13 | ?Great-billed Heron | *Ardea sumatrana* | LC | Doubtful record |
| 14 | Purple Heron | *Ardea purpurea* | LC | Resident |
| 15 | Great Egret | *Casmerodius albus* | R | New record to the Nicobar |
| 16 | Intermediate Egret | *Mesophoyx intermedia* | LC | Resident |
| 17 | Little Egret | *Egretta garzetta* | LC | Resident |
| 18 | Pacific Reef-egret | *Egretta sacra* | LC | Resident |
| **Fam: Phaethontidae** | | | | |
| 19 | White-tailed Tropicbird | *Phaethon lepturus* | LC | New record to the Nicobars |
| 20 | ?Red-tailed Tropicbird | *Phaethon rubricauda* | LC | Doubtful record |
| **Fam: Pelecanidae** | | | | |
| 21 | ?Spot-billed Pelican | *Pelecanus philippensis* | NT | Doubtful record |
| **Falconidae** | | | | |
| 22 | Peregrine Falcon | *Falco peregrinus* | LC | Isolated record |
| **Fam: Accipitridae** | | | | |
| 23 | Osprey | *Pandion haliaetus* | LC | Isolated record |
| 24 | Grey-faced Buzzard | *Butastur indicus* | LC | New record to the Nicobars |
| 25 | Oriental Honey Buzzard | *Pernis ptilorhynchus* | | New record to the Nicobars |
| 26 | White-bellied Sea-eagle | *Haliaeetus leucogaster* | LC | Resident |
| 27 | Crested Serpent-eagle**@** | *Spilornis cheela* | LC | Resident |

| | | | | |
|---|---|---|---|---|
| 28 | South Nicobar Serpent-eagle**@** | *Spilornis klossi* | NT | Endemic to the Nicobars |
| 29 | Nicobar Sparrowhawk | *Accipiter butleri* | VU | Endemic to the Nicobars |
| 30 | Chinese Goshawk | *Accipiter soloensis* | LC | Winter visitor |
| 31 | Japanese Sparrowhawk | *Accipiter gularis* | LC | Isolated record |
| 32 | Besra | *Accipiter virgatus* | LC | Resident |
| **Fam: Rallidae** | | | | |
| 33 | Slaty-breasted Rail | *Gallirallus striatus* | LC | Resident |
| 34 | White-breasted Waterhen | *Amaurornis phoenicurus* | LC | Resident |
| 35 | Watercock | *Gallicrex cinerea* | LC | Resident |
| 36 | Purple Swamphen | *Porphyrio porphyrio* | LC | Resident |
| **Fam: Turnicidae** | | | | |
| 37 | Yellow-legged Buttonquail | *Turnix tanki* | LC | Resident |
| **Fam: Burhinidae** | | | | |
| 38 | ?Beach Thick-knee | *Esacus giganteus* | NT | Doubtful record |
| **Fam: Dromadidae** | | | | |
| 39 | Crab Plover | *Dromas ardeola* | LC | Winter visitor |
| **Fam: Charadriidae** | | | | |
| 40 | Pacific Golden Plover | *Pluvialis fulva* | LC | Winter visitor |
| 41 | Grey Plover | *Pluvialis squatarola* | LC | Winter visitor |
| 42 | Kentish Plover | *Charadrius alexandrinus* | LC | Isolated records |
| 43 | Lesser Sand Plover | *Charadrius mongolus* | LC | Winter visitor |
| 44 | Greater Sand Plover | *Charadrius leschenaultii* | LC | Winter visitor |
| **Fam: Scolopacidae** | | | | |
| 45 | Pintail Snipe | *Gallinago stenura* | LC | Winter visitor |
| 46 | Bar-tailed Godwit | *Limosa lapponica* | LC | Isolated records |
| 47 | Whimbrel | *Numenius phaeopus* | LC | Winter visitor |
| 48 | Common Redshank | *Tringa totanus* | LC | Winter visitor |
| 49 | Common Greenshank | *Tringa nebularia* | LC | Winter visitor |
| 50 | Terek Sandpiper | *Xenus cinereus* | LC | Winter visitor |
| 51 | Common Sandpiper | *Actitis hypoleucos* | LC | Winter visitor |
| 52 | Ruddy Turnstone | *Arenaria interpres* | LC | Winter visitor |
| 53 | Sanderling | *Calidris alba* | LC | Isolated record |
| 54 | Little Stint | *Calidris minuta* | LC | Winter visitor |
| 55 | ?Red-necked Stint | *Calidris ruficollis* | LC | Doubtful record |
| 56 | Curlew Sandpiper | *Calidris ferruginea* | LC | Winter visitor |
| 57 | Broad-billed Sandpiper | *Limicola falcinellus* | LC | Isolated record |
| **Fam: Glareolidae** | | | | |
| 59 | Oriental Pratincole | *Glareola maldivarum* | LC | Winter visitor |
| **Fam: Laridae** | | | | |
| 60 | Lesser Crested Tern | *Sterna bengalensis* | LC | Winter visitor |
| 61 | Great Crested Tern | *Sterna bergii* | LC | Isolated record |

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|---|---|---|---|---|
| 62 | Black-naped Tern | *Sterna sumatrana* | LC | Resident |
| 63 | ?Bridled Tern | *Sterna anaethetus* | LC | Doubtful record |
| 65 | Brown Noddy | *Anous stolidus* | LC | Isolated record |
| **Fam: Columbidae** | | | | |
| 66 | Rock Pigeon | *Columba livia* | LC | Introduced |
| 67 | Andaman Wood-pigeon | *Columba palumboides* | NT | Endemic to A&N |
| 69 | Andaman Cuckoo-dove | *Macropygia rufipennis* | NT | Endemic to A&N |
| 70 | Emerald Dove | *Chalcophaps indica* | LC | Resident |
| 71 | Nicobar Pigeon | *Caloenas nicobarica* | NT | Resident |
| 72 | Pompadour Green-pigeon | *Treron pompadora* | LC | Resident |
| 73 | Green Imperial-pigeon# | *Ducula aenea [nicobarica]* | LC | Resident |
| 74 | Pied Imperial-pigeon | *Ducula bicolor* | LC | Resident |
| **Fam: Psittacidae** | | | | |
| 75 | ?Vernal Hanging-parrot | *Loriculus vernalis* | LC | Doubtful record |
| 76 | Nicobar Parakeet | *Psittacula caniceps* | NT | Endemic to the Nicobars |
| 77 | Long-tailed Parakeet | *Psittacula longicauda* | NT | Resident |
| **Fam: Cuculidae** | | | | |
| 78 | Pied Cuckoo | *Clamator jacobinus* | LC | New record to the Nicobars |
| 79 | Large Hawk-cuckoo | *Cuculus sparverioides* | LC | New record to the Nicobars |
| 80 | Indian Cuckoo | *Cuculus micropterus* | LC | Isolated record |
| 81 | Himalayan (Oriental) Cuckoo | *Cuculus saturatus* | LC | Summer visitor |
| 82 | Asian Emerald Cuckoo | *Chrysococcyx maculatus* | LC | Winter visitor (former range?) |
| 83 | Drongo Cuckoo | *Surniculus lugubris* | LC | Isolated record |
| 84 | Asian Koel | *Eudynamys scolopaceus* | LC | Resident |
| 85 | ?Brown Coucal | *Centropus andamanensis* | LC | Doubtful record |
| **Fam: Strigidae** | | | | |
| 86 | Oriental Scops-owl | *Otus sunia* | LC | Resident |
| 87 | Nicobar Scops-owl**@** | *Otus alius* | DD | Endemic to the Nicobar |
| 88 | Brown Hawk-owl | *Ninox scutulata* | LC | Resident |
| 89 | Andaman Hawk-owl | *Ninox affinis* | NT | Endemic to A&N |
| **Fam: Apodidae** | | | | |
| 90 | Glossy Swiftlet | *Collocalia esculenta* | LC | Resident |
| 91 | Edible-nest Swiftlet | *Collocalia fuciphaga* | LC | Resident |
| 92 | Little Swift (House Swift) | *Apus affinis* | LC | Isolated record |
| **Fam: Alcedinidae** | | | | |
| 93 | Stork-billed Kingfisher | *Pelargopsis capensis* | LC | Resident |
| 94 | Black-capped Kingfisher | *Halcyon pileata* | LC | Resident |
| 95 | Collared Kingfisher | *Todiramphus chloris* | LC | Resident |
| 96 | Black-backed (Oriental Dwarf) Kingfisher | *Ceyx erithaca* | LC | Resident |
| 97 | Common Kingfisher | *Alcedo atthis* | LC | Resident |
| **Fam: Meropidae** | | | | |

| | | | | |
|---|---|---|---|---|
| 98 | Blue-tailed Bee-eater | *Merops philippinus* | LC | Winter visitor |
| **Fam: Pittidae** | | | | |
| 99 | Hooded Pitta | *Pitta sordida* | LC | Winter visitor |
| **Fam: Campephagidae** | | | | |
| 100 | Pied Triller | *Lalage nigra* | LC | Resident |
| 101 | Ashy Minivet | *Pericrocotus divaricatus* | LC | Isolated record |
| **Fam: Laniidae** | | | | |
| 102 | Brown Shrike | *Lanius cristatus* | LC | Winter visitor |
| **Fam: Oriolidae** | | | | |
| 103 | Black-naped Oriole | *Oriolus chinensis* | LC | Resident |
| **Fam: Dicruridae** | | | | |
| 104 | Crow-billed Drongo | *Dicrurus annectans* | LC | Isolated record |
| 105 | Andaman Drongo | *Dicrurus andamanensis* | NT | Isolated record; Endemic to A&N |
| 106 | Greater Racket-tailed Drongo | *Dicrurus paradiseus* | LC | Resident |
| **Fam: Monarchidae** | | | | |
| 107 | Black-naped Monarch | *Hypothymis azurea* | LC | Resident |
| 108 | Asian Paradise-flycatcher | *Terpsiphone paradisi* | LC | Resident |
| **Fam: Corvidae** | | | | |
| 109 | House Crow | *Corvus splendens* | LC | Introduced? Resident; New record |
| 110 | Large-billed Crow | *Corvus macrorhynchos* | LC | Introduced; formerly present |
| **Fam: Hirundinidae** | | | | |
| 111 | Barn Swallow | *Hirundo rustica* | LC | Winter visitor |
| 112 | ?Pacific Swallow | *Hirundo tahitica* | LC | Doubtful record |
| 113 | ?Red-rumped Swallow | *Hirundo daurica* | LC | Doubtful record |
| 114 | [?Striated Swallow] | *Hirundo striolata* | LC | Doubtful record |
| **Fam: Cisticolidae** | | | | |
| 115 | Zitting Cisticola | *Cisticola juncidis* | LC | Resident |
| **Fam: Pycnonotidae** | | | | |
| 116 | Red-whiskered Bulbul | *Pycnonotus jocosus* | LC | Introduced; resident |
| 117 | Nicobar Bulbul | *Hypsipetes nicobariensis* | NT | Endemic to the Nicobars |
| **Fam: Sylviidae** | | | | |
| 118 | Pallas's Grasshopper-warbler | *Locustella certhiola* | LC | Isolated record |
| 119 | Oriental Reed-warbler | *Acrocephalus orientalis* | LC | Winter visitor |
| 120 | Thick-billed Warbler | *Acrocephalus aedon* | LC | Winter visitor |
| 121 | Inornate (Yellow-legged) Warbler | *Phylloscopus inornatus* | LC | Isolated record |
| 122 | Pale-legged Leaf-warbler | *Phylloscopus tenellipes* | LC | Isolated record |
| **Fam: Zosteropidae** | | | | |
| 123 | Oriental White-eye | *Zosterops palpebrosus* | LC | Isolated record |
| **Fam: Sturnidae** | | | | |
| 124 | Asian Glossy Starling | *Aplonis panayensis* | LC | Resident |
| 125 | Hill Myna | *Gracula religiosa* | LC | Resident |

| | | | | |
|---|---|---|---|---|
| 126 | Common Myna | *Acridotheres tristis* | LC | Introduced; resident |
| 127 | White-headed Starling | *Sturnus erythropygius* | LC | Resident |
| 128 | Purple-backed Starling | *Sturnus sturninus* | LC | Doubtful record |
| **Fam: Turdidae** | | | | |
| 129 | Orange-headed Thrush | *Zoothera citrina* | LC | Resident |
| 130 | Eyebrowed Thrush | *Turdus obscurus* | LC | Isolated record |
| **Fam: Muscicapidae** | | | | |
| 131 | Blue Rock-thrush | *Monticola solitarius* | LC | Isolated record |
| 132 | Brown-chested Jungle-flycatcher**#** | *Rhinomyias brunneatus* | VU | Winter visitor? **[**Endemic?**]** |
| 133 | Asian Brown Flycatcher | *Muscicapa dauurica* | LC | Winter visitor |
| 134 | Mugimaki Flycather | *Ficedula mugimaki* | LC | New record to the Nicobars |
| **Fam: Nectariniidae** | | | | |
| 135 | Olive-backed Sunbird | *Nectarinia jugularis* | LC | Resident |
| 136 | Crimson Sunbird | *Aethopyga siparaja* | LC | Resident |
| **Fam: Passeridae** | | | | |
| 137 | House Sparrow | *Passer domesticus* | LC | Isolated record |
| **Fam: Estrildidae** | | | | |
| 138 | White-rumped Munia | *Lonchura striata* | LC | Resident |
| **Fam: Motacillidae** | | | | |
| 139 | Forest Wagtail | *Dendronanthus indicus* | LC | Isolated records |
| 140 | Yellow Wagtail | *Motacilla flava* | LC | Winter visitor |
| 141 | Grey Wagtail | *Motacilla cinerea* | LC | Winter visitor |
| 142 | Red-throated Pipit | *Anthus cervinus* | LC | Winter visitor (old record) |
| **Fam: Emberizidae** | | | | |
| 143 | Yellow-breasted Bunting | *Emberiza aureola* | VU | Winter visitor |

IUCN RedList Categories: NT= Near Threatened; VU= Vulnerable; LC= Least Concern; DD= Data Deficient.
@ indicates taxonomic revision by Rasmussen & Anderton (2005) that are accepted by BirdLife International.
# species considered as endemics by Rasmussen & Anderton (2005).