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AVIFAUNAL DIVERSITY OF THE ANDAMAN ISLANDS AND THEIR CONSERVATION

Thesis

submitted to the

Bharathiar University, Coimbatore

for the award of the Degree of
Doctor of Philosophy
in Zoology



by

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November 2010

CERTIFICATE

This is certify that the thesis, entitled "Avifaunal diversity of the Andaman Islands and their conservation" submitted to the Bharathiar University, in Partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original research work done by Mr. M. A. RajaMamannan during the period April 2003 to November 2010 of his research in the Department of Zoology at Sálím Ali Centre for Ornithology and Natural History, Anaikatty, Coimbatore - 641 108 under my supervision and guidance and the thesis has not formed the basis for the award of any Degree/Diploma/Associateship/Fellowship or other similar title of any candidate of any University.

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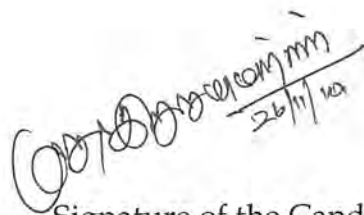
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DECLARATION

I, **M. A. RajaMamannan** hereby declare that the thesis, entitled "**Avifaunal diversity of the Andaman Islands and their conservation**" submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original research work done by me during April 2003 to November 2010 under the supervision and guidance of **Dr. Lalitha Vijayan**, Department of Zoology at Sálím Ali Centre for Ornithology and Natural History, Anaikatty, Coimbatore - 641 108 and it has not formed the basis for the award of any Degree/Diploma/Associateship/Fellowship or other similar title to any candidate in any University.

A handwritten signature in black ink, appearing to read 'M. A. Rajamamannan', with a date '26/11/10' written below it.

Signature of the Candidate

(**M. A. RAJAMAMANNAN**)

Thesis Dedicated...



*also to the
Immortals of
my Grandmother,
Dr. Ravi Sankaran
and*



Maaveerarkal...

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EXECUTIVE SUMMARY

Biodiversity is the natural wealth, where the variability among living things and ecological systems presents and maintains the life sustaining systems provided with vital goods and services in the world. In, recent decades due to hysterical development of many anthropogenic activities, the world is changing as fast as humans appropriate more and more of its resources, over drawing on the earth's renewable supplies and eating heavily into natural capital caused the effect of massive deforestation. In a current scenario, we have cleared half of the world's natural habitats and a third of what is left will go within a human generation, if current trends continue. Which resulting 16 million km² of tropical rainforest habitat that originally existed worldwide, less than nine million km² remain today.

Biodiversity hotspots in the world are chiefly tropical region is featuring high concentration of endemic species and has claimed half of the world's terrestrial species, if all hotspots are combined. These natural habitats are under threat now due to habitat loss and destruction. Consistently the islands, a small body of landmass are having a major role of its high endemism in the world. Nevertheless, the increasing demands on resources in the islands have resulted in their ecosystems being severely threatened and facing in its extreme habitat destruction. For example over 12.1% of all bird species in the world are threatened with extinction today in which the majority of these are found in tropical forest and islands.

There is little disputing that global biodiversity is declining, but accurate measures are very hard to come by. Birds, the best known major group of organisms and just one component of biodiversity and far from the most significant in species numbers or biomass can help us to understand the problems and piece together the solutions, where the maintenance or restoration of the biological integrity of urban and suburban areas must begin with a comprehensive study of the links between biota and land use. In this context bird communities are often used in investigations of habitat changes as the best indicators of the environment.

Though the Indian mainland harbors rich avifaunal diversity the Andaman and Nicobar Islands form one of the 218 endemic bird areas (Andaman islands: EBA-125 and Nicobar Islands: EBA-126) of the world. The information on community

structure and general bird ecology of these islands are little known and very few attempts have been made to study the bird community along their island distribution. Hence, the present study was initiated with the major objectives to: i) document the avifaunal diversity and status in different islands/vegetations, ii) observe the bird species distribution pattern in the Andaman Islands with their biogeographical importance, iii) study the nested-subsets of the birds in different outer islands in terms of their presence/absence which will be providing a risk assessment of the extinction probability of the various species' populations isolated on the islands of fragmented habitat, and iv) understand the insular biology of the endemic and threatened species in Andaman Islands as of baseline information for their conservation.

Andaman and Nicobar Islands the Union Territory of India, a group of archipelagic islands stretches over 800 km in Bay of Bengal. The geographical landscape is characterized by high and low formations, sloping down to coast of the Andaman Sea in the east. This archipelago comprises 572 islands, reefs and rocks. The entire island group covers 8249 km² with a total coastline of about 1962 km. The Andaman group has more than 325 islands (21 inhabited) covering 6408 km² and the Nicobar group with over 24 islands (13 inhabited) has an area of 1841 km². It is a storehouse of unique flora and fauna showing great diversity, and high level of endemism in its floral component. Both these island groups are a distinct eco region and are classified as one of the 12 biogeographical zones of India. Biogeography values of the intensive study area of Andaman Islands are comes under the Indomalaya Ecozones, one of the richest bird species areas (about 17.6% of the total number) in the world. These offshore islands lie in the Indo-Burma Biodiversity hotspot; mostly differ from the closest and large landmass of Burma, and Malaysia.

Bird survey was carried out in 52 outer (islands lying separated from main islands) and five major islands, namely North, Middle, South (incl. Rutland Island) and Little of Andaman Islands during the periods from November to December 2003; January to May 2004 and August to October 2004. Due to the poor climatic climax during the month of June and July 2004 the bird survey was leave out for the next month. To assess the bird species abundance, diversity, habitat use, population trends and habitat association within the bird population in Andaman Islands across all forest types *Point survey method*, is most appropriate method in island terrains was employed.

Variable Distance method one of the point count type, which estimates the radial distance to the detected each species in each points, was attempted for absolute abundance estimation of birds either seen or heard/actively used study area. Observations were made the number of individuals, distance from the observer, vertical position and major activity for estimating density. Most of the points were replicated 1-3 during the study period irregularly (not in temporal).

Since, the present study aimed for a wider bird survey across the islands within the short period of time vegetation sampling was not done. However for vegetation analysis data of land cover and land use pattern of the Andaman Islands was acquired. Nevertheless the direct observations of major plant/tree species present in each point were recorded and the habitats were classified into eleven types.

Anticipated results drawn by the present study collected bird data were documented in detail by region and habitat wide. Primarily checklist of birds in the Andaman Islands includes the status, migratory and conservation details were preferred. While concentrating on the distribution of endemic birds to the Andaman Islands recently promoted endemic species were also taken for consideration

A total of 26487 individuals belonging to 153 species which includes twenty rare/vagrant and new birds were recorded during 473 working hours between November and December 2003, January and October 2004 (excluded June and July 2004). The species accumulation curve from pooled data sampled throughout the Andaman Islands begins with the total 79 species and end up with 153 during the present study. It shows increase of species from the second month of survey and became almost stable at the end. In regional-wise documentation of birds out of 153 species highest number was recorded from South Andaman (126) followed by North (110), Little (96) and Middle (80) where the species abundance also followed the same pattern, however. Though 56 endemic species (including subspecies) among the bird community of Andaman Islands were found, the present study recorded 11 of 12 species endemics from different habitats and an addition of 7 of 9 recently considered as species endemics, overall 18 full species endemics was observed.

Total of twenty rare, secondly recorded and new birds from the Andaman Islands each species status and distribution were discussed in the results by reviewing the available

ornithological literatures. Among the ten new birds recorded from these islands only three were confirmed literally such as Tickelle's Blue Flycatcher *Muscicapa (Cyornis) tickelliae*, Grey-headed Flycatcher *Culicicapa ceylonensis* and Blue-fronted Robin *Cinclidium frontale*, perhaps the status of other rare, vagrant or passage migrants and winter visitors yet to be confirmed.

The collective bird sampling data has been studied for its community attributes such as species richness and abundance. However, classification has been made into forest/land and wetland/water birds, based on the habitat preference mainly to execute in different analysis in the following chapters. Species diversity across the habitats also followed. From the bird community total eight categories, based on the guild structure have been studied for better understanding of habitat-species association in the Andaman Islands. To identify the natural group of bird species among the bird community in Andaman Islands the systematic way of phylogenetic classification has been performed.

In contrary to superficial appearances of the Andaman Islands this diversified archipelago is a complex mosaic of different size of islands-islands which vary from isolated forests in more or less same vegetation. Hence the completeness of sampling and observed species either from the region or habitat is necessary. To avoid the sampling bias on the empirical data set from different region/habitats in Andaman Islands different extrapolating methods for species richness and accumulation patterns were performed used by Estimate S: Chao1, Chao2, Jackknife1, Jackknife2, Bootstrap, Cole, Abundance-based Coverage Estimator or ACE and Incidence-based Coverage Estimator or ICE. The results showed that the completeness of sampling by means of the estimated species richness accumulation curves, across the region/habitats were perfectly approached asymptote against the effort (point count).

While discussing the distribution of individual species among the population the species abundance follows the lognormal distribution pattern was observed in which the determination of bird community structure is involved various independent factors. The model exhibits the equilibrium in natural habitats (undisturbed) rather than disturbed habitats of Plantation, Forest edge, Field and Degraded. The present study showed very few rare and common species in arrangement of species with

moderate abundance and the model fits well, where the community is at equilibrium or free from disturbance. The study has been over viewed with the major perspectives by locally of relationship between the number of species and the internal structure of the habitat. Nevertheless, the structural complexity of the habitat and disturbance mechanisms, along with competition process, would explain the abundance of species.

Samples from eleven habitats of the Andaman Islands were scrutinized and computed for bird species diversity, richness and evenness. The various diversity indices showed greater diversity in all natural and disturbed habitats by means of species richness and abundance at 5% significant level. However, Sorensen indices were analyzed to find similarity of bird communities between forest types. The most similarity species were found between evergreen and semi-evergreen followed by evergreen and moist deciduous rather than disturbed habitats. The greatest difference of species, among the bird assemblages and habitat were found between evergreen and coastal habitats which is apparent. This is not unexpected because the samples showed most of the forest dwelling birds are natural forest dependents rather than disturbed habitats.

In order to know the biogeography of bird community in Andaman Islands the Nestedness pattern was studied considering the “nested subsets” where the species in smaller biotas comprise a proper subset of those in richer assemblages. The Nestedness would assessed a ‘temperature’, ranged between 0 and 100° where the temperature close to 0° is very nested and one that is near 100° is decidedly not nested. Further the pattern will execute results from the predictable sequences of species undergoing extinction from fragments: where the species that need vast areas to sustain minimum viable populations would go extinct quickly from each of the patches, notoriously the less needy species would find sufficient resources on a larger proportion of fragments. However the Nestedness calculator was used to provide a risk assessment of the extinction probability of the various species’ populations isolated on the islands of fragmented habitat by presence-absence data of the species from different islands.

In Nestedness calculator the presence/absence matrix of species distribution in 52 outer islands from the Andaman was analyzed where the islands arranged by in rows and species in columns. The species ranged from 7 to 39 among 52 islands in the matrix the composition of these ranges is highly nested ($T=19.78^\circ$, $p<<0.0001$) which indicates a strongly ordered pattern of bird species distributions in the Andaman Islands. The categorization of species with scores was resulting as 30 out of 95 species with strongly nested, five with distinctively idiosyncratic and 23 are generally confined to the 14 islands, which are richest in species.

Species that exhibits a nested pattern were divided into two main groups as their probability of state occupancy: i) 21 of 95 species were nested at 10-20% and below probability of state occupancy in the matrix, includes three near-threatened species and ii) nine of 95 were strongly nested between 50-100% probability of state occupancy in the matrix. Roughly a five of 95 species in this archipelago exhibited pronounced idiosyncratic distributions. With regard to the islands ($n=52$) the most distinctively nested were the Redskin, Table (Excelsior), Bluff, Thorn Hill, Table (Dalgarne), Stewart, Anderson, West, Ox, Trilby and Benette, whereas the species poor islands Brush, Boat, East, South Reef, Helicopter, Avis, Oyster 1, Oyster 2, Mayo, Oliver supported relatively idiosyncratic avifauna. Results of this analysis showed that the level of observed nestedness was still highly significant ($p<0.0001$), but the temperature increased to 52° .

For ornithobiogeographic affinities of the Andaman Islands total of 153 species, belongs to 36 families of 16 orders recorded during the study period was used. The species similarity in terms of occurrence amongst the mainland's of Southeast Asia and India was performed. In which out of 136 species (consist of 43 endemics and 93 non-endemics) having affinity with Southeast Asia, 129 species (consist of 37 endemics and 92 non-endemics) affinity with mainland India, and 124 species (consist of 36 endemics, 88 non-endemics) affinity with together Southeast Asia and mainland India, was found. There is no subspecies affinity was found from Southeast Asia and mainland India together.

In biogeographic distribution, classification of islands based on the area has been made. Accordingly the bird species richness and abundance were scrutinized

considering with different vegetation structure available in all major and outer islands. Overall the high bird abundance from the littoral habitat, which presents in various classes of islands, was found as follows: in very small (703), small (939), medium (1012) and very large (4514) islands. Inherently in large island groups the evergreen habitat harbored more number of birds (560).

To acquire the knowledge on avian population biology, community ecology and conservation of Andaman island bird community the size/density of the population was estimated by using variable circular-plot (VCP) method, which also known as variable area surveys or point transects. From a fixed 10-min sampling period and 200m intervals between the stations each bird seen or heard was counted particularly those birds which were actively using the study area and the birds flying overhead which actively used area. The straight-line distance from the station centre to the birds was estimated. The birds that were flushed while approaching the station were counted and their distance from the station centre was estimated. The raw data was consisted a list of birds, observed with individuals and their estimated distance from the station centre.

The estimation of density (bird/m²) for each species the bird abundance vs distance, within the concentric bands (minimum 0 to 10m and maximum 50 to 60m width) was plotted. The calculated area for 10m concentric bands are as follows: 0-10m = 314m², 10-20 = 943m², 20-30m = 1570m², 30-40m = 2200m², 40-50m = 2827m², 50-60m = 3456m². Further the population density (birds/km²) for each species in region/habitat-wise was then estimated by summing the densities (both the number of individuals and the areas was summed). Since the greater than one station was used the estimated bird densities for all stations was divided by total number of stations, to provide an estimate of density for the species as a whole.

Totally 144 bird species were counted, which actively used the study area. Overall the estimated bird species density (birds/km²) in the Andaman Islands was ranged between >0.05 and <133.7, where the occurrence of 58 species to all four regions, 16 from three regions, 31 from two regions and 39 in one region. Importantly more attention has been given to estimate the density for red listed species, twelve near-threatened birds from Andaman Islands.

After tsunami the habitat assessment in select wetlands (inland and coastal) of Andaman Islands during non-monsoon period (from December 2007 to May 2008) was conducted. During the rapid survey, covering 14 sites the status and population of the Andaman Teal was recorded by total count method. Based on the habitat information gathered most of the major habitats of Andaman Teal in Andaman Islands were drastically affected due to the major earthquake 2004 occurred in Indian Ocean followed by tsunami. Further a qualitative assessment of damages was looked at: a) whether the water marshes and wetlands were functioning or destroyed and dried up and, b) whether the vegetation in nalla's and tidal creeks was green or scorched and vanished. Further select wetlands was categorized by the level of damage occurred.

A total of 99 individuals of the Andaman Teal were recorded from 14 sites. Among the three major island groups maximum of 73 birds was counted from North Andaman, whereas no birds were found in Little Andaman including some inland wetlands. Among the eight coastal wetlands from Little and South Andaman Islands no birds were found except at Sippighat (11).

Of total 153 bird species detected in Andaman Islands during the present study is representing 66.52% from the overall 237 bird species reported in Andaman Islands by various studies in the earlier decades. The present study executes the birdlife and their importance of these Islands. Particularly in the outer islands, though most of them are under protected network programme till pressure on the natural resources and bird populations was observed. Whereas in the major islands habitat alteration and destruction causes high damage to the bird population in these islands was found and this serious problem should be controlled. During the study period implementation of immediate conservation measures for the protection of avifauna considering all the above facts has been recommended to the department of environment and forests, Andaman and Nicobar Administration. Moreover the necessary protection to the endemic birds and important bird areas, which are not in the protected network programme, has been suggested.

CHAPTER ONE INTRODUCTION

BACKGROUND

Biodiversity is the world's natural wealth, where the variability among living things and ecological systems presents and maintains the life sustaining systems provided with vital goods and services. Due to recent hysterical development of many anthropogenic activities the world is changing as fast as humans appropriate more and more of its resources (Goudie 2000, Laurance and Peres 2006, Overpeck and Cole 2006). We are now overdrawing on the earth's renewable supplies and eating heavily into its natural capital. In the current scenario, we have cleared half of the world's natural habitats and a third of what is left will go within a human generation, if current trends continue. Notably, the tropical rainforests have received most of the attention concerning the destruction of habitats. From the approximately 16 million km² of tropical rainforest habitat that originally existed worldwide, less than 9 million km² remain today (Primack 2006). The current rate of deforestation is 160,000 km² per year, which equates to a loss of approximately 1% of original forest habitat each year (Laurance 1999).

Biodiversity hotspots are chiefly in the tropical regions (Fig. 1.1) that feature high concentrations of endemic species and, when all hotspots are combined, may contain over half of the world's terrestrial species (Cincotta and Engelman 2000). These hotspots are suffering from habitat loss and destruction (Brooks *et al.* 2002). Human induced climate change (Sekercioglu *et al.* 2007) is set to cause far reaching impacts on global biodiversity. Spurred on by climate change, alien invasive species are damaging and impoverishing ecosystems around the world. Because of these and other pressures, species are vanishing rapidly at many times their natural extinction rate (BirdLife International 2004).

Most of the natural habitats on islands and in areas of high human population density have already been destroyed (WRI 2003). Islands suffering extreme habitat destruction include New Zealand, Madagascar, the Philippines, and Japan (Primack 2006). South and east Asia especially China, India, Malaysia, Indonesia, and Japan

and, many areas in West Africa have extremely dense human populations that allow little room for natural habitat. Marine areas close to highly populated coastal cities also face degradation of their coral reefs or other marine habitat. These areas include the eastern coasts of Asia and Africa, northern coasts of South America, and the Caribbean Sea and its associated islands (Primack 2006).

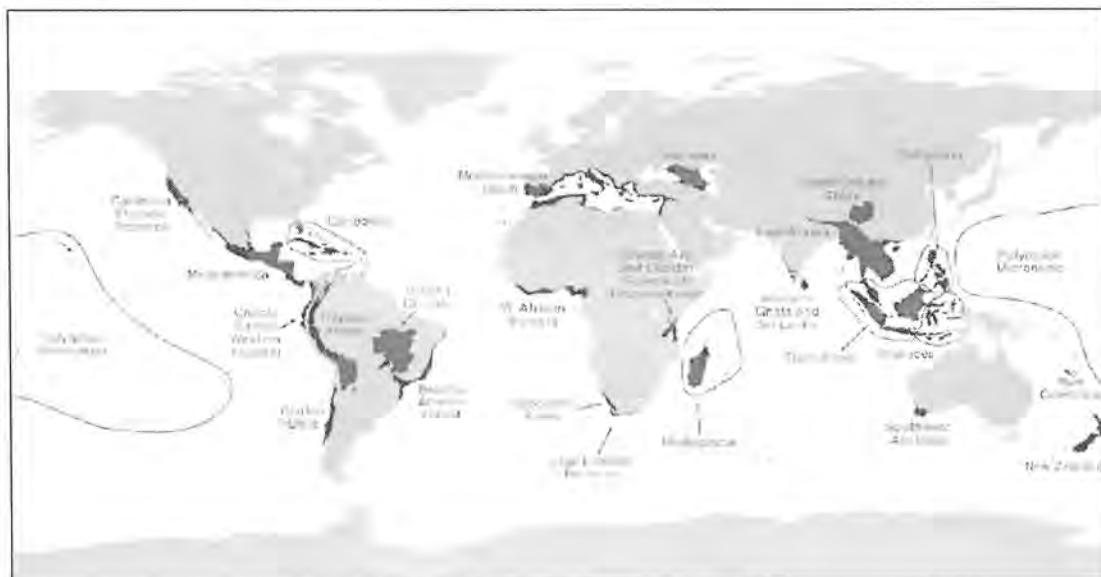


Figure 1.1: The 25 hotspots, expanses comprise 30% - 3% of the dark areas (Myers *et al.* 2000).

Regions of unsustainable agriculture or unstable governments, which may go hand-in-hand, typically experience high rates of habitat destruction. Central America, Sub-Saharan Africa, and the Amazonian tropical rainforest areas of South America are the main regions with unsustainable agricultural practices or government mismanagement (Primack 2006). Areas of high agricultural output tend to have the highest extent of habitat destruction. In the U.S., less than 25% of native vegetation remains in many parts of the East and Midwest (Stein *et al.* 2000). Only 15% of land area remains unmodified by human activities in all of Europe (Primack 2006).

There is little dispute that global biodiversity is declining, but accurate measures are very hard to come by. Birds, the best known major group of organisms and just one component of biodiversity and far from the most significant in species numbers or biomass can help us understand the problems and piece together the solutions. Birds are found almost everywhere on Earth, from the oceans to the mountaintops, from tropical forests to the polar ice caps. Their extraordinary migrations knit the world

together (BirdLife International 2004). Their fascinating diversity and behaviour have great public appeal, especially the bird-watching connects people with the natural world around them (Sekercioglu 2002), and provides a window on the environment. They have a substantial role in many economies and the economic contribution that birds make through ecological services such as pest control, pollination, seed dispersal and carrion consumption has never been quantified, but must, in many cases, be enormous (BirdLife International 2004).

Ecologically, declines and extinctions of distinct populations are as important as the losses of species (Chapin *et al.* 1998, Sodhi *et al.* 2004). The rapid degradation of ecosystems from the tropics causes the massive reduction in biodiversity in the regions (Laurence and Bierregaard 1997, Vitousek *et al.* 1997, Brooks *et al.* 1999a, Pimm and Raven 2000, Dirzo and Raven 2003) which is documented very clearly in about hundreds of birds and their extinctions and population declines (Bennet and Owens 1997, Brooks *et al.* 1997, Anon 2006b, 2004d, Sekercioglu *et al.* 2004, Sodhi *et al.* 2004). Totally around 21.5% of bird species are considered as “extinction-prone” today, a category that includes species that are extinct (1.4%), threatened (12.1%) or near threatened (8.0%) with extinction (Anon 2006c) and providentially, birds are the best known class of organisms (Anon 2004d), and their conservation status has been assessed multiple times (Anon 2006c).

The various studies on frugivorous, nectarivorous, and insectivorous birds have established their significance in the dynamics of diverse natural and human-dominated ecosystems (Stiles 1978, 1985, Proctor *et al.* 1996, Westcott and Graham 2000, Mols and Visser 2002, Sekercioglu 2002, Sodhi *et al.* 2004, Croll *et al.* 2005). Although precise understanding of the ecological consequences of bird population losses will be impossible to achieve (Brooks *et al.* 1997, Sekercioglu 2007), there is a pressing need to assess avian ecosystem services and estimate the potential ecological effects of differential extinctions in various functional groups (Sekercioglu *et al.* 2004).

Nevertheless, various studies on the avifaunal community over a period from the last half century reported the considerable attention on the structure (MacArthur and MacArthur 1961, MacArthur 1969, Cody 1974, Wiens 1989a), ecology (Perrins and Birkhead 1983, Terborgh *et al.* 1990, Thiollay 1994, Willson and Comet 1996a,b, Odum 1996, Robinson *et al.* 2000, Sodhi *et al.* 2004, Latta *et al.* 2003, Begon *et al.*

2006, Blake 2007) and species area relationship (Blake and Karr 1984) of the bird communities.

The study of community is one and a half centuries old since Hilaire defined ethology as “the study of the relations of the organisms within the family and society in its aggregate and in the community” (Anderson and Kikkawa 1986) and, the “...plant communities may be considered (as) subdivisions of a vegetation cover; whenever the cover shows more or less obvious spatial changes, one may distinguish a different community” as reported by Muller-Dombois and Ellenberg (1974). Poore (1964) states that: “...it is an ecological maid-of-work with undefined duties and responsibilities...”, or definable conditionally. According to Hairston (1964) “animal communities may be considered organized if any property of a natural assemblage of species can be predicted” and that the concept of ‘community’ developed from a clearly appreciated social structure of plant and animal groupings in the wild seems clear from the distinction already made between autecology and synecology by the turn of the century, “Much ecological understanding can be integrated also around the concepts of communities as assemblages of different species which interact with one another, and ecosystems as functional systems formed by communities and their environments” as viewed by Robert Whittaker (1975). Clements (1916) argued that communities were discrete, repeatable assemblages of species that were so closely integrated in their functioning that the communities as a whole possessed property paralleling those of individual organisms.

Island ecosystems in their natural state tend to be finely tuned, as the limits on the resource base are acute (Carew-Reid 1990). This ecological refinement makes them particularly vulnerable to changes and ecologically fragile. The increasing demands on resources in the islands have resulted in these ecosystems being severely threatened. Over 12.1% of all bird species in the world are threatened with extinction today, and a majority of these are found in tropical forests and islands (Mountfort 1988, Collar *et al.* 1994, Stattersfield *et al.* 1998, Manne *et al.* 1999, BirdLife International 2000, 2001, 2004, Sodhi *et al.* 2004). The single most important forest type is tropical lowland moist forest with about 70% of threatened forest birds (BirdLife International 2001). Overall 93% of all avian extinctions since AD 1600 have been of island species, and most endangered avian taxa are island endemics (King 1981).

According to the BirdLife International (Stattersfield *et al.* 1998) 31% of the endemic or restricted range bird species of the world is threatened and 19% near-threatened. Insular endemics with well defined species boundaries, when in smaller populations, have greater probabilities of early extinction (Jarvinen 1985, Gilpin and Soule 1986, Pimm *et al.* 1995, Brooks *et al.* 1999b). Although the theory of Island biogeography (MacArthur and Wilson 1967) has been used in general in the planning of nature reserves, there is no substitute for a study on the ecology of the species or the community whose conservation is intended (Begon *et al.* 1990).

Nevertheless, the studies on the bird assemblages in a prescribed area or habitat (Gill 1995, Odum 1996) are very effective in understanding environmental problems and are critical in planning area-based conservation management (Simberloff 2004). Especially the properties of communities namely species richness, diversity, relative abundance and guild structure of particular taxa and its interaction within and among the community as well as with environment (Pianka 2000) results in the spatial and temporal variations across the habitats and regions (Karr 1976a, b, Johnsingh and Joshua 1994, Blake 2007).

India has two main groups of islands, the Andaman and Nicobar Islands off the eastern coast and Lakshwadeep Islands off the western coast. The increase, over recent decades, in human activity in these islands has resulted in grave concern for the endemic taxa (Sankaran and Vijayan 1993). In the Andaman and Nicobar Islands, over the last 20 years, dramatic increases in urban populations of non-islanders have brought out changes in the biological balance between human and avian communities (Sekercioglu 2002). Natural forests have become fragmented due to large areas cleared by logging for settlement and encroachments. The subsequent changes in land use, hunting or poaching, logging, introduction of exotics, and natural processes such as global warming and sea level rises are impact these island ecosystem (Vijayan *et al.* 2000, BirdLife International 2001).

1.1. WHY SURVEY BIRDS?

The maintenance or restoration of the biological integrity of urban and suburban areas must begin with a comprehensive study of the links between biota and land use, and in this context bird communities are often used in investigations of habitat changes (Koskimies 1989). Birds form an important component of the diverse fauna of any

region and are considered as the best indicators of the environment (Cody 1985, Morrison 1986, Wiens 1989a, Lawton 1996, Ligon and Stacey 1996, Canterbury *et al.* 2000) and hence, widely used for ecological evaluation (Jarvis 1994), monitoring human impacts on the ecological systems and conservation planning (Miller *et al.* 1987, Belbin 1993, Daniels 1994, Williams *et al.* 1996, Prasad *et al.* 1998, Vijayan 2004, Vijayan *et al.* 2005).

With the growth of metropolitan areas, it is becoming increasingly important to study the ways in which urbanization influences ecosystems (McDonnell and Pickett 1990). Birds have been found to be useful biological indicators in this respect, because they are ecologically versatile, respond to secondary changes resulting from primary causes, and can be monitored relatively inexpensively (Koskimies 1989). Also, because of their high mobility, birds react very rapidly to changes in their habitat (Morrison 1986, Fuller *et al.* 1995, Louette *et al.* 1995). It is at the edges of urban areas, where the vegetation structure is highly developed and diversified (Curry 1991, Smith and Schaefer 1992), that relations between human and bird communities are easiest to study (Cody 1985).

Birds are sensitive indicators of the health of the environment and sustainability, reflecting trends in other biodiversity, being responsive to change, high in food chains, inexpensive to survey and the best known and most popular component of wildlife and some other important reasons such as:

- The public notices birds and often becomes concerned when they die or disappear.
- Birds can indicate the integrity (health or condition) of a landscape in addition to the integrity of individual wetlands. Assessing integrity of landscapes (watersheds or other areas many square miles in size) is vital to assessing the cumulative effects of human activities.
- Most birds are easy to survey: there is no need to collect and analyze samples or struggle with complex taxonomic keys.

1.2. BIRD STUDIES IN ANDAMAN & NICOBAR ISLANDS

Many surveys have been conducted on birds in the Andaman Islands during the 20th century Chandra and Rajan 1996, Davidar *et al.* 1993, 1995, 1996, 1997, 2001, Yahya

and Zarri 2002 have analyzed the birds of a few islands in Andamans. The various studies in biodiversity carried out from Andaman and Nicobar Islands (Rao 1986, Lakshminarasimhan and Rao 1996, Rao 1989, Chandra 1999) in the recent decades are fascinated with their high degree of endemism especially in birds. About 39% including subspecies was recorded by Sankaran and Vijayan (1993). Though the Island groups account for only 0.2% of land mass of south Asia, they have 12% of the endemic avifauna of the region, thus making the islands a high priority area in the conservation of India's avifauna as reported by Sankaran (1998) and Vijayan *et al.* (2000, 2005).

However, there has been very little effort to assess the exact status of many such species or to study their ecology. A short-term survey was conducted in the Nicobar Islands by Sankaran (1995, 1998) while doing a reconnaissance survey for studying the Nicobar Megapode and brought out the status of avifauna in the Nicobar Islands. A survey was conducted during 1992-95 on the status and ecology of the rare Andaman Teal (Vijayan 1993, 1996, Vijayan *et al.* 2005) specifically looking at the areas of previous sightings of this species (Vijayan *et al.* 2000, 2005, 2006). There were very few systematic surveys covering various habitats in different islands. A major initiative of the Ministry of Science and Technology of the Government of India, the Jai Vigyan Mission Project in the Andaman and Nicobar Islands involving remote sensing and GIS techniques, mapped the habitats and, biodiversity characterization done at landscape level using detailed analysis of the vegetation (IIRS 2003). As a supplement to this Vijayan *et al.* (2005) worked out the prioritization of sites using data on the fauna, especially birds and flora as has been done for conservation in several regions in the Andaman Islands with respect to various ecosystems (Myers *et al.* 2000). Similar studies have been conducted using birds in the Western Ghats for planning conservation of biodiversity (Daniels *et al.* 1991, Daniels 1994, Pramod *et al.* 1997, Prasad *et al.* 1998).

Due to the lack of spatial information and the gaps identified in data, it is necessary for detailed information on the distribution and ecology of the species in order to take proper steps for their conservation and management (BirdLife International 2001, 2003). Fresh surveys were needed to complement the existing data to get island-wise information on the avifaunal diversity and status of the endemic birds. Hence, the present work was undertaken with the major objectives as given below.

1.3. OBJECTIVES

Major objectives of the present study were to:

- a) assess the avifaunal diversity and status of the endemic birds in different islands of Andamans,
- b) examine the bird community in terms of species richness, abundance and diversity and the factors regulating them,
- c) evaluate habitat associations of resident species; and provide baseline information of avifauna of Andaman Islands for avifaunal diversity conservation,
- d) estimate density of the more common species at each site,
- e) find the ornithobiogeographic affinities of Andaman Islands, species/subspecies wise with mainland India and nearby Southeast Asian land mass,
- f) identify and prioritize important sites for conservation; and conservation problems of the rare birds and the island ecosystem,
- g) assess the impact of disturbances on the birds and the island ecosystem,
- h) suggest measures for the conservation of the rare endemic birds.

1.4. ORGANISATION OF THESIS

- Chapter one: offers the information on the background, a short review on studies undertaken in Andaman & Nicobar Islands and objectives of the present work.
- Chapter two: describes the study area and methods which provides information on the vegetation structure of various landscapes and Land Use/land cover of Andaman Islands.
- Chapter three: ascertains the status and distribution of the avifauna in Andaman Islands, with respect to region, habitat, systematics and guild. Abundance and richness of the endemic, non-endemic, rare, vagrant or new bird records to the islands are focused.
- Chapter four: explains the aspects of population ecology (species richness and diversities), species richness and abundance based estimated values and species distribution patterns between the habitats (*Soresnsen's* qualitative and quantitative indices).

- Chapter five: resolves the completeness of bird sampling by non-parametric species estimators, for the area-species-habitat relationship through the pattern of biogeography: nestedness and the ornithobiogeographic affinities of Andaman avifauna with mainland India and Southeast Asia.
- Chapter six: serves the information of insular biology: on the population sizes of Endemic and near threatened avifauna in terms of species account, region wise density and in the addition of the distribution of the Andaman Teal and Post *tsunami* effects on their coastal habitats.
- Chapter seven: provides the conclusion, with respect to conservation priorities and implications from the present study.

CHAPTER TWO

STUDY AREA PROFILES AND VULNERABILITY

2.1. INTRODUCTION

Andaman and Nicobar, a group of archipelagic islands, stretches over 800 km in Bay of Bengal, India. The geographical landscape is characterized by high and low formations, sloping down to coast of the Andaman Sea. The isles are lying between 6°45' to 13°41' N and 92°12' to 93°57' E and at a distance of approximately 1220 km southeast of the coast of Kolkata and 1190 km east of Chennai. This archipelago comprises 572 islands, reefs and rocks. The entire island group covers 8249 km² with a total coastline of about 1962 km. The Andaman group has more than 325 islands (21 inhabited) covering 6408 km² and the Nicobar group with over 24 islands (13 inhabited) has an area of 1841 km² (Fig. 2.1). It is a storehouse of unique flora and fauna showing great diversity, and high level of endemism in its floral component.

These are highly volcanic islands, arising from a submerged mountain chain that follows southward extension of the continental shelf. Active volcanism with major eruptions was reported on Barren Island in 1991 and 1994 (IIRS 2003). Concurrently these Islands are the summits of a submarine range of hills 1120 km long that connects the Arakan Yoma of Myanmar with Achin head in Sumatra. The oceanic trench more than 1000 fathoms deep runs between Nicobar and Sumatra and extends upto Narcondam. The Andaman Islands are separated from the Nicobar by a 155 km long channel known as the Ten Degree channel (N 10°).

2.2. INTENSIVE STUDY AREA

The intensive study area of Andaman Islands (6408 km²) are administratively divided into North (1348 km²), Middle (1070 km²), South (3990 km²) and Little Andaman (731.6 km²). From Rutland Island to Baratang Island and the other islands lying nearby comprise the South Andaman and, from Interview Island up to Landfall Island and the distant Narcondam Island form North Andaman. Middle Andaman lies in between North and South Andaman (Fig. 2.2).

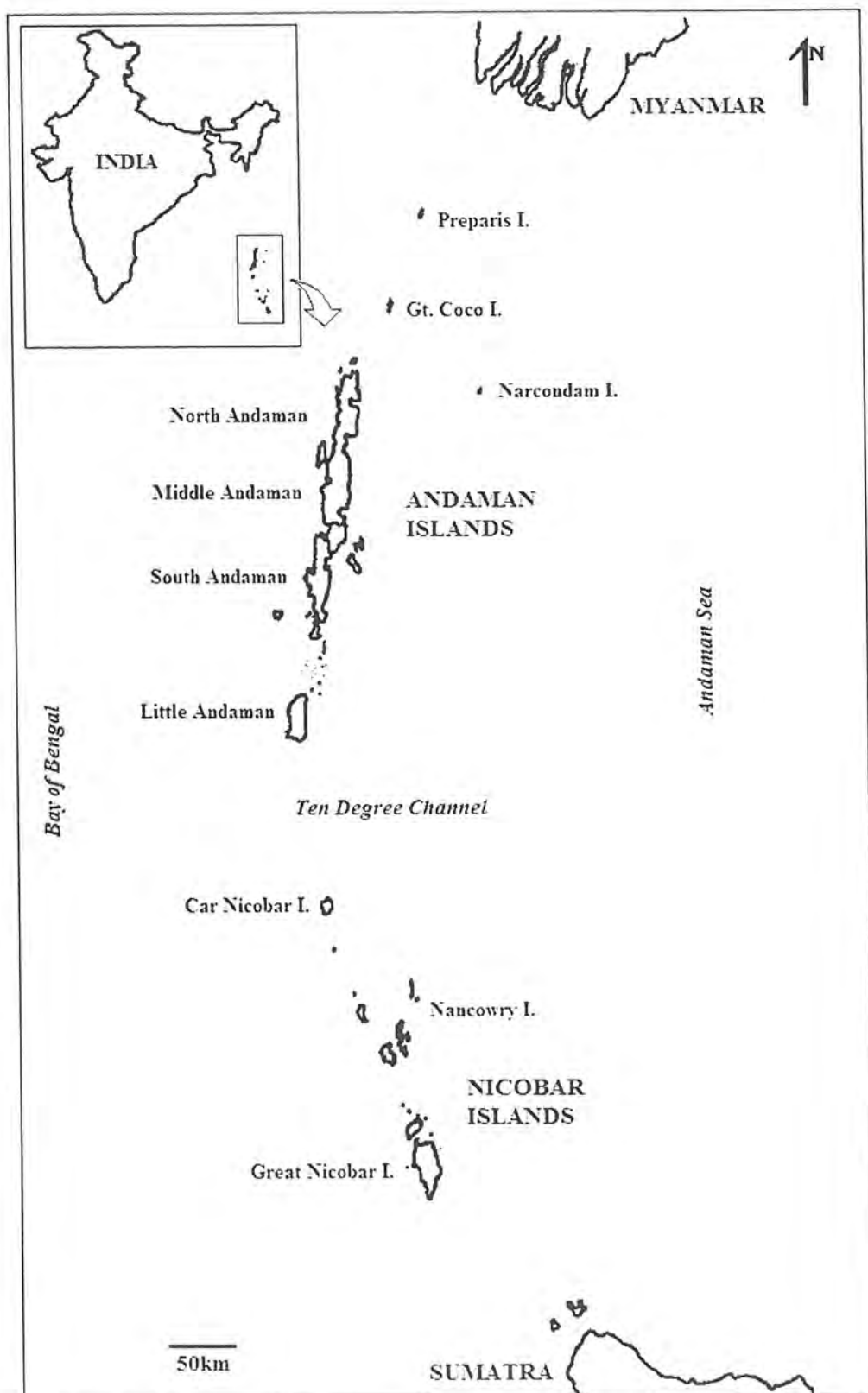


Figure 2.1: Location of the Andaman and Nicobar Islands.

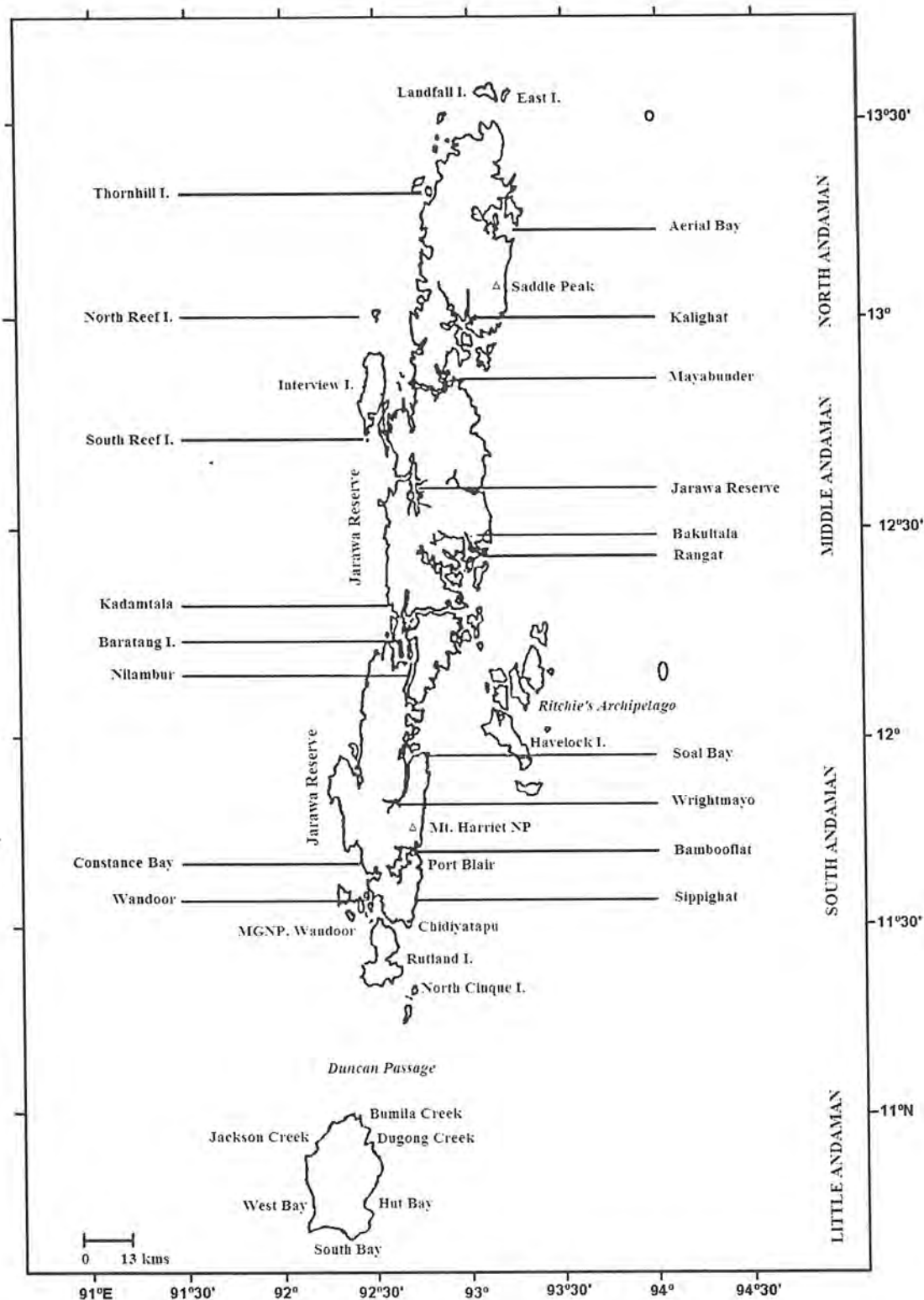


Figure 2.2: Andaman Islands, intensive study area.

2.3. PHYSICAL PROFILES

2.3.1. Topography

The topography of the bay islands is generally hilly and undulating. The main hill range runs from North to South. The Saddle Peak in North Andaman, at the height of 732m above sea level is the highest point in Andaman and the Mount Thullier of 670m height is the highest in Nicobar group. The slopes are moderate to steep and rugged. Flat lands are comparatively less in the Andaman group. The islands of Ritchie's Archipelago, Little Andaman and most of the North and central Nicobars are almost flat with slightly indented coastline, surrounded by coral reefs and shallow seas. Long and narrow stretches of sandy beaches are salient features of the topography here.

2.3.2. Geology, Rock and Soil

The geological evolution of the island appears to be genetically linked with the Himalayan chain. There are two organic events that link the evolution of the Andaman Arc system, namely (i) *Pre-Neogene evolution of the Island arc*: contemporaneous with destruction of the Tethys and culmination of marine sedimentation in the Himalayas; and (ii) *Neogene evolution of Island arc*: contemporaneous with opening of the Andaman Sea and major uplift of the Himalays (Srinivasan 1986). These island arcs can be separated into two concentric arcs geologically, an outer (western) sedimentary arc comprising major islands of the Andaman and Nicobar and extending to the inner (eastern) volcanic arc showing up above sea level as the conical volcanoes of Narcondam and Barren Islands (ANI F&E 2001). Narcondam, a 7 km² island and which is 710m above MSL, is an extinct volcano, situated ca 70 km south of Irrawady delta shelf and east of North Andaman Island, whose origin is believed to be from a single eruption dated Late Pliocene to Pliocene (Chibbers 1934, Das 1999). Barren Island (12°17' N - 93°50' E), with an active volcano, lies 135km south-southwest of Narcondam. These two are the only true volcanoes known in India. The only mud volcano associated with oil and gas seeps known in India is from the Baratang Island. A third Islands arc to the west of the Andaman Nicobar Islands is in the process of emergence (Eremenko and Sastri 1977).

Late Mesozoic and Cenozoic phases are well developed in the Bay islands. The rocks occurring in these islands are marine deposits and highly folded due to frequent

tectonic movement in the past. The geological formations represent a period of sedimentation ranging from the Cretaceous to Sub-recent period (Srinivasan 1978, Mukhopadyay and Krishna 1991). New chronostratigraphic divisions for Andaman and Nicobar late Cenozoic sequences have been based on planktonic foraminiferal events (Srinivasan 1986; *Annexure 2.1*).

The earlier geological investigations carried out by Karunakaran *et al.* (1964), Srinivasan and Srivastava (1975), Srinivasan and Chatterjee (1981) and Mukhopadyay and Krishna (1991) tried to establish the Geological sequence and then to compare and correlate the rocks of Andaman and Nicobar Islands with Geological Synchronous beds in the Sumatra, Java (Indonesia area) to the South-east Burma (Burmese area) to the North (**Table 2.1**).

Table 2.1: Geological succession of Andaman and Nicobar Islands.

Group	Formation	Epoch/Age in Million year (M.Y)
Recent to sub- recent group Archipelago Group (1500 m)	Shell Limestone, coral rags, Beach sands. Neil & Guitar	Recent to sub-Recent Pliocene (1.95-3 M.Y)
	Swai Bay formation	Pliocene (10-3 M.Y)
	Long Island formation	Middle-late Miocene (13-5 M.Y)
	Inglis formation	Early-Middle Miocene (17-13 M.Y)
	Strait formation	Early-Middle Miocene (22.5-17.5 M.Y)
Port Blair Group	Alternately bedded grey sandstones, shales conglomerates & Grits	Late Eocene-Oligocene (45-25 M.Y)
Baratang Group (2000 m)	Gray shales, siltstones Gray Impure limestones.	Late Cretaceous - Paleocene (70-45 M.Y)
Serpentine Group	Serpentines, Ultra-basic and Intermediate volcanic and Agglomerates.	Late Cretaceous - Eocene (75-45 M.Y)
Porlob Group	Older sedimentaries, quartzites Jasper, Cherts, Limestones and Phyllites	Late Cretaceous (100 M.Y)

Source: Working Plan for Middle Andaman forest division 2005 to 2015.

Porlob group: At places the argillaceous rocks in contact with ultra basic rocks have given rise to pyllites. Such rocks are met in Porlob, Chengappa and Great Nicobar Islands. On weathering, these rocks have given rise to bright red lateritic soil that characterizes the red soils of Porlob Island.

Serpentine group: comprising ultrabasic and basic rocks such as gabbros, peritidotes, dunites and serpentinites, *etc.* are widely distributed in the North, Middle and South (Rutland, Cinque and Sister) Andamans and Teressa in Nicobar Islands. The associated rocks consist of red and green jaspers, purple porcellantic limestone, hard gray and yellow quartzites together with occasional out crops of Calcareous gneiss. In Little Andaman, Nancowry and Camorta Islands, these rocks vary from porphyritic basalt to typical dolerite. No mineral deposits of economic value have so far been encountered in these Islands. However, some coal, chromites, gypsum and sulphur deposits have been found but they are only of academic interest (Srinivasan 1986).

Baratang Group: consisting of marine grey argillaceous shales inter bedded lime stones and silt stones and it is exposed in the Baratang Island. The sediment of the Baratang Group in Andaman represents a typical deep water facies in contrast to other basins in the mainland of Indian peninsula.

Port Blair Group: greater part of the Andaman and Nicobar Islands is covered by the rocks belonging to the Port Blair Group. Lithologically, the group consists of vast thickness of alternating sequences of grey sandstones and black shales with subordinate grits and conglomerates and this group has similarity with Barails of Assam and Nagaland. The pre-tertiary group of Sumatra comprising sandstone, shales and conglomerates appears to be continuation of the Port Blair Group of the Andaman and Nicobar to the South-east.

Archipelago Group: consisting of deep water marine sediments of variable thickness, much of it, fossil assemblage. The sediments of the groups are found in two broad regions, in North and South. The Northern region consists of Ritchie's Archipelago, Guitar, Strait, Colebrooke and other Islands. It comprises the sediments of siliceous including volcanic ash layers with subordinate calcareous silt stones, chalk and lime stones. The southern region includes Labyrinth, Brother and Nicobar Islands. Their strata are pre-dominantly calcareous being composed mainly of a monotonous sequence of mudstones, coral rocks, beach-sands which occur as local caps overlying uncomfortably the Archipelago group and the older rocks. Along the coastal line the

limestone and coral rags dip gently towards the sea. The occurrence of recent to sub-recent coral beds in-situ above the present sea level bears the evidence of recent eutectic sea level changes.

The soils have developed under the dominant influence of vegetation and climate over diverse parent materials. The uplands where forest cover has been removed have soils severely eroded and support scanty bushy growth and grass vegetation; the valley floors comprise depositional land forms and have been termed lowlands. These soils have developed from the surrounding well drained ridges and subject to seasonal fluctuations in ground water. Morphological characteristics of the soils of the flat lands, hill slopes and on gentle slopes and uplands have been described in detail by Singh *et al.* (1988).

The well leached soils of the humid tropics are generally poor in plant nutrients. The primary nutrients, nitrogen and phosphorous, and to some extent potassium are often deficient. The secondary nutrients, Sulphur (S), Calcium (Ca) and Magnesium (Ma) are also in short supply. A well known characteristic of soils of the humid tropics is their ability to hold phosphate ions strongly. Alluvial soils of the tropics show great variation in chemical fertility which is directly related to the source of the material from which they are formed. Most areas of alluvial soils are of mixed origin and are generally moderately well supplied with plant nutrients.

The luxuriant forest vegetation of the humid tropics led to the misconception that the soils underneath were inherently fertile. However, when the forests were cleared and arable farming taken up, the fertility status of soils started declining as a result of erosion, leaching of soluble nutrients and loss of organic matter. Humid climate is very conducive to rapid mineralization of organic matter. Therefore, in spite of large litter fall, the proportion of carbon in the profile is usually low, being about one percent; the litter, woody residues, and roots are rapidly attacked by ants, termites, fungi and other organisms and decomposed to release nutrients. Generally, the surface soil contains about 2 to 5% of the organic matter the bulk of which is usually concentrated in a thin superficial layer in the surface soil (Mongia *et al.* 1989).

Soil Erosion Problem: Soil depth varies depending upon topography and plays important role with regard to forest type. There is no problem of natural soil erosion due to thick vegetative cover mostly of evergreen nature.

2.3.3. Climate

The Andaman and Nicobar Islands are located in the equatorial belt and are exposed to maritime influences. The climate is wet tropical. It is warm and humid for most of the year. The seasons can be divided into dry and rainy. Extreme winter and summer are practically unknown but there is a general nip in the air during three months i.e. December, January and February, particularly in the interior forest camps. Mists hang over the forests, particularly over opening in the forests during these months. March, April, May and October can be uncomfortable because of high humidity and temperature (Fig. 2.3, Annexure 2.2).

Temperature: Climate is the most important determinant of soils and vegetation, the islands have a hot humid tropical climate (Saldanha 1989, Dagar *et al.* 1991) with mean temperatures ranging from 20-40° C and the differences between the annual maximum and minimum temperatures are rather small. The peak temperature occurs during dry months when evapotranspiration losses are the highest and the period between December and April is moisture deficit (Fig. 2.3). The proximity of the sea and the abundant rainfall prevent extremes of heat.

Humidity: The relative humidity varies from 68% to 86% being the highest during May to October, i.e. during the south-west and beginning of the north-east monsoon. However, the percentage of month-wise relative humidity is recorded greater in the evening than in the morning (Fig. 2.3). The monthly mean relative humidity (in percent) during 2003 to 2007 is in Annexure 2.2.

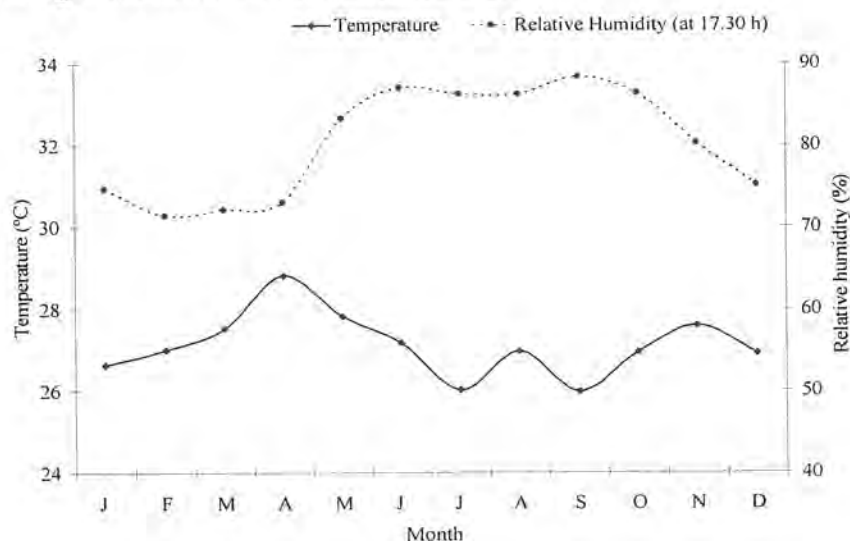


Figure 2.3: Monthly mean temperature and humidity of Andaman Islands during 2003 to 2007.

Rainfall: The Andaman group of islands is at the fringe of typical equatorial tropical humid climate with high but uneven distribution of rainfall throughout the year. The average annual rainfall is 3700mm (recorded in 2005). The southwest monsoon that brings most of the rain begins in May and ends in August. After the southwest monsoon there are variable and mostly light winds from the south or southeast. The northeast monsoon starts in September. From the later half of November till end of December, the wind at first blows from southeast and later veering to northeast is very strong and is frequently accompanied by rain. January to April is the calmest and driest period of the year. The average rainfall of 5 years from 2003 to 2007, showed minimum of 27.3mm in January and maximum of 402.5mm in September (**Fig 2.4, Annexure 2.2**), which varied in different groups of Islands (**Table 2.2**).

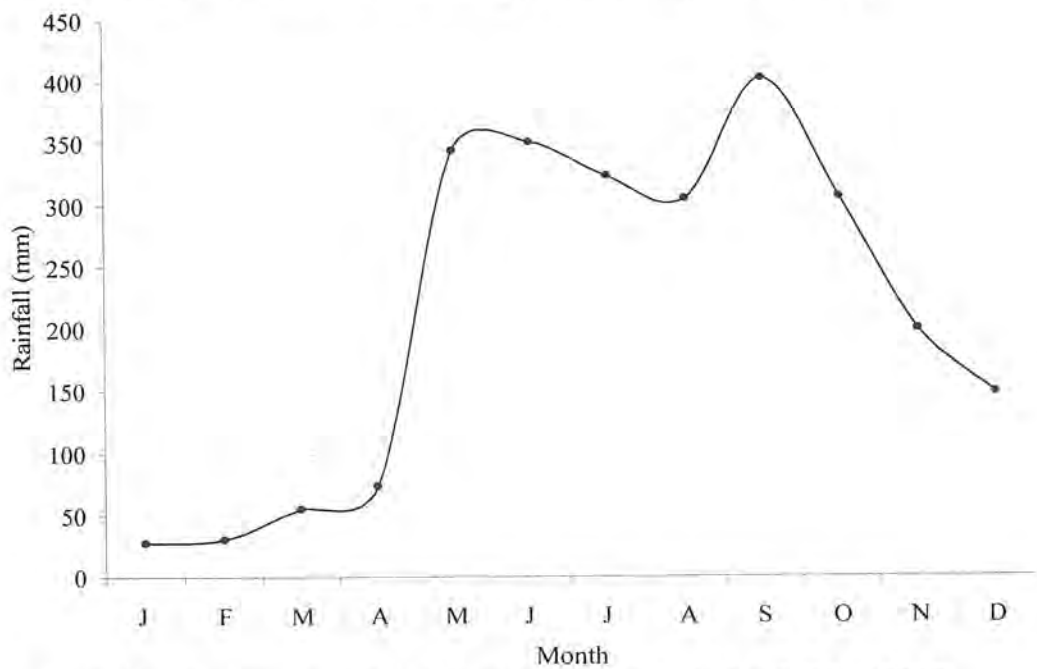


Figure 2.4: Monthly mean rainfall of Andaman Islands during 2003 to 2007.

The five-year annual average rainfall recorded a considerable fluctuation and varied in different stations of Andamans. For example, at Long Island the rainfall exceeded 1583.3 mm in 2004 but was as high as 2677.9mm in 2007. Between 2003 and 2005 among different stations, Port Blair, South Andaman (SA) received the maximum of 3773.8mm and minimum of 1418.1mm was recorded from Long Island, Middle Andaman (MA). Overall the highest mean precipitation (2806.4mm) was during 2005 and the lowest (2513.6mm) in 2004. Perusal of five-year rainfall data in various stations showed that the number of rainy days ranged between 130 and 153 (**Table 2.2**).

Table 2.2: Year-wise mean rainfall at various stations in Andaman Islands.

Year	Maya- bunder, NA	Long Island, MA	Port Blair, SA	Hut Bay, LA	Over all	# Rainy Days
2003	2658.2	NA	2443.0	2642.4	2581.2	130
2004	2836.2	1583.3	3188.7	2446.3	2513.6	147
2005	2959.1	1540.1	3773.8	2952.4	2806.4	153
2006	2842.6	1418.1	3004.2	2807.3	2518.0	149
2007	3021.7	2677.9	2556.0	2862.5	2779.5	145

NA- not available.

Source: AN DE & St. 2008, Port Blair.

Cyclones: Cyclones seldom pass over the Islands, although most of them form in the Andaman Sea. While passing north, however, they affect weather conditions in the Islands. During 1792, 1844, 1891, 1941, 1969, 1978, 1987 and 1989 cyclones passed over certain parts of these Islands causing damage to the growing stock. The monthly mean wind speed between 5.8 to 9.5 Km/hr was recorded in Port Blair during 2003-2007 (*Annexure 2.2*).

Seismicity: The Andaman and Nicobar group of Islands coincide with the seismic belt passing from the Southeast Asia to Gibraltar through the Himalayas, the Mediterranean-Asiatic belt. The Andaman-west Sunda arc region could be divided into 8 broad seismogenic sources of homogeneous deformation and it is shown that while compressional stresses dominate the entire fore arc and the northern Sumatra region, tensional stresses prevail in the back arc spreading Andaman sea region. North of 8° N where the 90° E Ridge partially subducts below the arc, the fore arc region is characterised by the deficiency of moment release and absence of large magnitude earthquakes (Radhakrishna and Sanu 2002). These Islands experience minor earthquakes occasionally and a major earthquake was felt on 26th December 2004.

Volcanic activity: Barren Island (12°17' N - 93°50' E), which falls within the territorial limit of Baratang division is on the Volcanic Arc which extends from Burma-Narcondam-Barren to Sumatra. According to Geologists, the island probably emerged during the late tertiary period out of lava discharged by an underwater volcano. The earliest detailed report from Barren Island dated February 1887, prepared by the geologist F.R. Mallet speaks of the volcanic activity lasting for several years, from 1787 to 1884. In, 1991 there was an eruption recorded from Barren Island lasting about 9-10 months causing considerable damage to the flora and fauna of Barren Island and adjoining sea.

2.4. ECOLOGICAL PROFILES

The Andaman and Nicobar Islands (ANI) consist of very fragile island ecosystems and some of the most pristine in the world. These ecosystems are very diverse and support very unique flora and fauna. Both these island groups are distinct eco-regions and are classified as one of the 12 biogeographical zones of India (10A/B) by Rodgers and Panwar (1988). It is also one of the eco-regions listed in the Global 200 list by World Wide Fund for Nature (WWF), due to biological richness and endemism. The landscape for large islands emerges from sea-grass beds, coral reef or rocky outcrops, to beaches, littoral forest, Andaman slope forests, hilltops, into valleys and streams. Some of the dominant tree species in these luxuriant forests reach heights of 40-60 m. In some areas in the Andamans along the west and the east coast, the landscape starts from reefs or rocky outcrops to steep rock faces with wind blown vegetation. The topography of all large islands in the Andamans, Little Andaman, Little Nicobar and Great Nicobar Islands, is mostly interlaced with perennial and seasonal freshwater streams and in some areas a matrix of mangrove creeks extending into marshes. Little Andaman Island has ecosystems that do not occur anywhere else in the Andamans or the Nicobars, mainly extensive fresh and saline water marshes and peat (Mahadevan and Easternson 1983, Andrews 2000). There are no large rivers in the ANI; mangrove creeks lead out of the islands and mostly fresh water streams drain into these creeks (Jayaraj and Andrews 2005).

Grasslands are unique to the central group of the Nicobars and occur on low hillsides of Teressa, Bompoka, Nancowry and Camorta and in the central part of Trinket. Lowland grasslands are restricted to Great Nicobar Islands mainly on the inland riverbanks (Pande *et al.* 1991, Sankaran 1995, Jayaraj and Andrews 2005). About 50% of the forests have been set aside as Tribal Reserves, National Parks and Wildlife Sanctuaries, which are inviolate. The coastal and inland forest vegetation is largely undisturbed throughout most of these islands.

The Andaman and Nicobars are fringed by one of the most spectacular reefs in the world and, currently they are not only significant for the Indian Ocean region, but are also globally significant (Kulkarni 2000, 2001, Vousden 2000, Turner *et al.* 2001, Andrews and Sankaran 2002). These same authors have reported that the Andaman reefs consist of about 83% of maximum coral diversity found anywhere in the world

and is equal to the “Coral Triangle” of Indonesia and, about 400 species could emerge after further surveys.

2.4.1. *Flora*

The flora and the history of early botanical explorations of these islands were first described by Parkinson (1923) and more recently by the Botanical Survey of India (Hajra *et al.* 1999, Hajra and Rao 1999). Floristically, the ANI show elements from the Indo-Chinese and Indo-Malayan and 3552 plants species have been so far reported (Hajra *et al.* 1999, Sreekumar 2002, Padalia *et al.* 2004). The flora of Andaman Islands shows the striking dissimilarities with that of the Nicobar Islands. While the taxa of Andaman Islands show general affinities towards north-east India, Burma (Myanmar) and Thailand; those of the Nicobar have affinities towards Malaysia and Indonesia. For example Dipterocarps are represented in the Andamans group and are absent in the Nicobars (Chaudhuri 1992). On the other hand, the Nicobars have tree ferns and other groups of plants that are of Indo-Malayan and Indonesian affinities (Lakshminarasimhan and Sreekumar 1995). Many of the species are rare, only known from type specimens and type localities (Rao 1986, Balakrishnan 1989). Padalia *et al.* (2004) have discussed in detail the tree species diversity, density and distribution in the Andaman Islands.

Sinha (1999) has reported 422 floral genera for the Great Nicobar Island, belonging to 142 families of which 14% is endemic. Total of 110 wild orchids are reported from Andaman Islands of which 19 genera with 25 species are endemic. Ellis in 1987 reported 120 pteridophytes species for the Andaman and Nicobar Islands, 50% of which is from Great Nicobar Island alone. Of the reported 24 species of rare and six common orchids, eight are found only on Great Nicobar Island (Ellis 1987) and Sinha *et al.* (1999) in their study of the great Nicobar Island recorded two more endemic and two genera and four species as new records for India. Currently Gupta *et al.* (2004) have reported four new records from Great Nicobar Island.

Aroids, ferns, mosses and climbers are mostly conspicuous in the semi evergreen and deciduous forests, besides six species of bamboo and 19 species of cane found in the islands. The vegetation for several areas and islands in the Andaman group were studied and 120 species of pteridophytic flora from 36 families for both island groups were reported by Ellis (1987) and Jayaraj and Andrews (2005). Awasthi and John

(1987) recorded 51 resource potential species from Great Nicobar Island as having 21 uses and Ellis (1988) and Ellis and Vishnoi (1989) reported some more exploitable plant species. Dixit and Sinha (2001) have reported 37 families representing the fern flora and divided them into three ecological groups; of which 58 are terrestrial species, 31 are lithophytes and 37 are epiphytes. Awasthi (1987) reported over 86 species used by the various aboriginal inhabitants. Tigga and Sreekumar (1996) reported 76 species of wild edible fruits for the ANI and of these, 45 are known to be utilized by the indigenous people of both the island groups. Srivastava and Sinha (1995) have discussed 26 poisonous plants from the Andaman Islands. A recent survey has identified and recorded 406 medicinal plant species including introduced ones, many of which are used by the indigenous tribes (NBRI 2003).

Gopal (1990) reported 107 epiphyte species for two localities in South Andaman and 79 epiphyte species on 72 host trees on Mount Harriet; this is in comparison to two other sites sampled where the author found only 29 and 33 species. The same author also reported the maximum epiphyte species found on one host tree from Mount Harriet.

Dagar and Sharma (1989) have classified the mangrove types into 19 communities and associations on the basis of structure and species composition. Earlier a total of 34 exclusive mangrove species among 17 genera and 13 families were recorded for the ANI (Dagar *et al.* 1991). More recently Debnath (2004) reported 59 species from both island groups. Dagar *et al.* (1991) have previously reported the distribution pattern in the Andamans and the Nicobar group of islands. Singh and Garge (1993) and Dam-Roy (1995) have discussed the mangrove ecology and distribution pattern for the South Andaman Island. Dagar and Dagar (1986) and Dagar (1989a, b) have discussed several mangrove and coastal plant and tree species, including seeds and fruits used by the tribal people.

There are also several introduced species, besides agricultural crops and fruit trees, including Australian trees such as *Acacia auriculiformis* and *Eucalyptus*. Others include large palms, bamboos, fence plants, and ornamental garden plants; Dagar *et al.* (1989) identified 250 species and Dagar and Gangwar (1989) have reported about *Mikania cordata*, one of the world's worst weed that has spread in agricultural lands and in forest areas and also have reported 24 other deadly weeds introduced into the islands and their related problems. Balachandran (1998) during a floristic survey of

the Mount Harriet NP reported 51 introduced species and more recently Karthikeyan *et al.* (2004) have discussed the extensive problems of *Limnocharis flava*, a South American species, which is now widespread in the Andaman Islands. The Central Agricultural Research Institute (CARI) has recorded over 600 introduced plant and tree species (Mohanraj *et al.* 1999).

Currently 40 plants species are extremely localized and not known from more than one locality. 85 species are recorded as rare, endangered and threatened, and the World Conservation Monitoring Centre (WCMC) has classified 365 as threatened (WCMC 1994, Sreekumar 2002, Andrews and Sankaran 2002, Jayaraj and Andrews 2005). The IUCN Red List of 'Threatened Species' lists 397 animals and plant species for the Andaman and Nicobar Archipelago. Of the 630 species of higher plants in the Red Data Book, 46 species occur in the ANI (Sinha 1999).

Nearly 2,100 species of indigenous and exotic angiosperms have been reported from these islands, of which 11% are strictly endemic (Balakrishnan and Ellis 1996). Representing of the 700 genera belonging to 140 families, about 14% of the angiosperm species are endemic to the islands, whereas in non-endemic about 40% are not found in mainland India, but have only extra-Indian distribution in South East Asia (Rao 1996). Report on the status of the flora by Lakshminarasimhan and Rao (1996) shows 1598 taxa of angiosperms including 267 endemics; while 26% of the total species are common to both the Andaman and Nicobar islands, 47% occur in Andamans and the rest in Nicobar alone.

2.4.2. Fauna

Though there have been several studies on the flora and fauna of the Andaman and Nicobar Islands (Dasgupta 1976, Chatterjee 1977, Saldanha 1988), many animals are yet to be catalogued (Rao 1989) and more species are being added to the list every year. The only primate, the Nicobar crab eating macaque (*Macaca fascicularis umbrasa*) occurs in the southern group of the Nicobar Islands. Miller (1902) was the first to list most of the mammals for both island groups. Since then, over 60 species have been reported; and these include several species of shrews that are endemic, rats and a palm civet (*Paguma larvata tyleri*). Others include bats of 32 species in the Andamans and Nicobars (Nath and Chaturvedi 1975, Saha 1978, Das 1997; 1998, Aul 2003, Aul and Vijayakumar 2003). Invertebrate groups represented include spiders (62 species);

dragonflies (36 species), termites (26 species), holothurians (68 species), chitons (13 species), hermit crabs (38 species), copepods (172 species), amphipods (110 species), polychaetes (186 species) and nematodes (54 species). The butterfly diversity is very high and 298 species and 236 subspecies in 116 genera have been reported (Rao and Devroy 1985, Khatri 1989; 1993; 1994; 1998, Devy *et al.* 1995, Khatri and Chandra 1995).

The reptile and amphibian fauna comprises over 125 species and is diverse with an assemblage of several species of frogs and toads. Reptiles include several species of lizards, geckos, snakes and four species of marine turtles. The mega species in the Andamans include the king cobra (*Ophiophagus Hannah*), the Andaman cobra (*Naja sagittifera*), water monitor lizard (*Varanus salvator*), and saltwater crocodile (*Crocodylus porosus*). In the Nicobars the mega herpetofauna includes the Malayan box turtle (*Cuora amboinensis*) on Great and Little Nicobar Islands, the sunbeam snake (*Xenopeltis unicolor*), the saltwater crocodile (*Crocodylus porosus*), the reticulated python (*Python reticulatus*) in the southern Nicobar group, besides several species of pit vipers in the central Nicobars (Das 1994, Krishnan 2003, Vijaykumar 2003, Whitaker and Captain 2004). Four species of marine turtles, leatherback turtle (*Dermochelys coriacea*), hawksbill turtle (*Eretmochelys imbricata*), green sea turtle (*Chelonia mydas*), and the olive ridley turtle (*Lepidochelys olivacea*) also feed and nest around the Andaman and Nicobars (Bhaskar 1993, Das 1994, Daniels and David 1996, Das 1999, Andrews and Whitaker 1998, Andrews and Tripathy 2003, Jayaraj and Andrews 2005, Andrews and Vaughan 2005).

Of the 27 species of reptiles and amphibians recorded for Mount Harriet National Park, 12 are endemics which are representing 80% in Andaman Islands (Das 1997). Chandra (1996, 1997) reported 120 species of moths for the same park with new additions to the moth fauna of India. The avifauna in Saddle Peak National Park is also diverse; of the 88 species recorded 49 are endemic (Chandra and Rajan 1996). Since 1964, ten new species of birds, three species of snakes, two amphibians, one species of mammal and many species of insects (eg. as many as 33 species of termites) have been added to the list of the fauna of these islands (Rao 1989). Recently, one new bird species from Nicobar (Rasmussen 1998) and three new birds as additions to the Andaman Islands (RajaMamannan and Vijayan 2009) were reported. Balachandran (1998) recorded 393 plant and tree species for Mount Harriet National Park of which 74 are endemic.

Aul (2003) reported 13 species of bats for the Rani Jhansi Marine National Park and this is 50% of the 26 species reported for the Andaman Islands and these included three new records and an endemic. Two freshwater fishes have been recorded for the first time from Saddle Peak National Park; a secondary freshwater fish *Sicyopterus microcephalus* could turn out as an endemic while the other species identified *Belobranchus belobranchusa* from the same park is a new record for the islands. Likewise, several other species have been recorded from Mount Harriet National Park and some of these will be new species descriptions and new records for the islands (Lim and Das *in prep.*, Ali *et al.* 2002). Kulkarni *et al.* (2000, 2004) have reported 222 coral species within the Mahatma Gandhi Marine National Park and Turner *et al.* (2001) has reported high coral diversity, 42-88 coral species around five islands in this national park. Das (1996) has recorded the sea grass meadows in the Ritchie's Archipelago to be the most extent in the Andamans, with meadow sizes ranging from 300-3000m long and accounting for the highest species richness, when compared to the rest of the Andamans.

Of the approximately 5357 species of fauna covering all major island groups 487 (9%) are endemic (Rao 1989). Jayaraj and Andrews (2005) reported that 9% of the fauna is endemic to these Islands. If marine forms are excluded as none of them are endemic, 487 (13%) of 3704 species are endemic. The diversity and endemism of the butterfly is very high, the total of 214 species and 236 subspecies in 166 genera, over 50% are endemics (Khatri 1993). Later, Chandra (1999) has given the total of 5988 species. He explains the higher degree of endemism in butterflies *ie.* above 70% at subspecies level. This high degree of endemism is reflected in faunal groups such as birds (Sankaran and Vijayan 1993, Sankaran 1995, Vijayan *et al.* 2000).

Of about 270 species and subspecies of avifauna recorded from the Andaman and Nicobar islands, 105 are endemic. This high proportion of endemics (39%) is due to a high number of endemic subspecies. Of the endemic species and subspecies, 82 (or 78%) are subspecies of species found in neighboring mainlands (Sankaran and Vijayan 1993). Other vertebrates also show high levels of endemism; 60% of 58 species of mammals, 31.94% of 83 species of reptiles and 20% of 10 species of amphibians recorded are endemic to Andaman and Nicobar Islands (Rao 1989). Another report on the amphibians shows 15% of the 13 species as endemic and only one inland fish out of 34 species as endemic (Daniels *et al.* 1997). Currently seven

amphibians and 16 reptile species are endemic to the Andamans and 2 amphibians and 15 reptiles are endemic to the Nicobars (Das 1994, Andrews and Whitaker 1998, Das 1999, Andrews 2001, Andrews and Sankaran 2002). There are several small mammals and several of these are endemic (Jayaraj and Andrews 2005). This endemism is due to the isolation from mainland Asia (Das 1999).

2.5. VEGETATION

2.5.1. Classification

The variation in elevation in Andaman Islands is very small and hence the islands are more or less uniform climatically. Therefore, the vegetation of these islands is mainly the function of climatic or edaphic factors. The forests are divided into two categories (Working Plan, AN DE & F 2007):

- I) Edaphic Pre-Climax forests (influenced by site factor, in addition to climate):
 - 1. Tidal Swamp Forests (Mangrove Forests)
 - 2. Littoral Forests (Beach Forests)
 - 3. Andaman Semi-evergreen Forests (Low level evergreen Forests)
- II) Tropical Climatic Forests:
 - 1. Andaman Moist Deciduous Forests
 - 2. Andaman Tropical Evergreen Forests
 - 3. Giant Evergreen Forests

Forest vegetation of the Andaman Islands can be broadly differentiated into following types based on Champion and Seth (1968) classification of forests. 1) Andaman tropical evergreen forest (E), 2) Andaman semi-evergreen forest (SE), 3) Andaman moist deciduous forest (MD), 4) Mangrove forest (M) and, 5) Littoral forest (L) (see also *Annexure 2.3*). Evergreen and semi-evergreen forests dominate the area (see *Plate 2.1*). Mangroves are extensive in the Andaman Islands, about 15% of the geographic area (FSI 1999). A few other habitats such as rivers, streams, reservoirs, ponds and marshes are also available to a less extent, but important for a few endemics (Vijayan *et al.* 2000, BirdLife International 2001) (see *Plate 2.2*).

Since, the present study aimed for a wider bird survey across the islands within the short period of time vegetation sampling was not done. Nevertheless the direct observations of major plant/tree species present in each point were recorded (see *Annexure 2.3*). However for vegetation analysis data of land cover and land use pattern of the Andaman Islands was acquired (in *Chapter 2.5.2 & 2.5.3*). The habitats

were further classified into eleven types, namely Evergreen (E), Semi-evergreen (SE), Moist deciduous (MD), Littoral (L), Mangrove (M), Forest edges (FE), Plantation (P), Field (F), Degraded areas (D), Wetland (W) and Coastal (C) (**Plate 2.1 & 2.2**). Since the Giant Evergreen Forests have species similarity with evergreen forests both are classified under the Evergreen type. Brief descriptions of the above forest types are given below (Working Plan, AN DE & F 2007).

a) Giant Evergreen

The most luxuriant type of forests named Giant evergreen forests form the climatic climax, where the site conditions are optimum for tree growth and the top canopy attain a height of 50 to 55m. Unfortunately, most of the areas having this type of forests have been cleared for human settlements and agriculture. *Distribution*: in small areas near the banks of largest stream where soil is deep alluvial. *Locality Factor*: rainfall of above 3000mm well distributed and a sufficiently retentive soil is deep alluvial.

Floristics: so intimately mixed with the semi-evergreen forests that delineation is difficult. Some of the evergreen association includes *Dipterocarpus grandiflorus*, *Xanthophyllum andamanicum* and, *Dinorchloa andamanica* and *Calamus* spp. in lower storeys. Epiphytic ferns and high woody climbers are common.

b) Andamans Tropical Evergreen (E)

Not as luxuriant as the giant evergreen forests, particularly in height, density and size of the giant top storey which is very irregular and incomplete, but otherwise similar in composition. There are fewer species in the top canopy. *Distribution*: mainly occur in the top of hills forming cap with moist deciduous forest on slopes.

Floristics: *Dipterocarpus grandiflorus*, *D. pilosus* (almost forms pure stand but found in all layers) *Xanthophyllum andamanicum*, and *Dinorchloa andamanica*, *Calamus* spp.

c) Andamans Semi-evergreen (SE)

A luxuriant type of forest with many giant trees which include both deciduous and evergreen species often intimately mixed but frequently in groups particularly in evergreen; climbers are often heavy. Bamboos peculiarly are not present in Little Andaman except climbing bamboo. *Distribution*: in the main valleys. *Locality Factor*: the chief characteristics is the immature alluvial soil sufficiently old and raised above

flood level to be able to progress to the climatic climax but with a good sub-soil water supply and well drained soil.

Floristics: Major species include *Dipterocarpus alatus*, *D. pilosus*, *Pterocymbium tinctorium*, *Terminalia bialata*, *T. procera*, *Albizia lebbek*, *Bombax insigne*, *Artocarpus chaplasha*, *Tetrameles nudiflora* etc. occupy the top storey. The lower stories are composed of *Lagerstroemia hypoleuca*, *Dillenia pentagyna*, *Pometia pinnata* and climbers such as climbing bamboo (*Dinochola andamanica*), canes and *Combretum* spp.

d) Andamans Moist Deciduous (MD)

There is typically a somewhat irregular top storey of predominantly deciduous trees about 40m or more in height. Many of the trees are of very large girth and heavily buttressed. Beneath these trees, is a rather definite second storey of numerous species including some evergreen, though most are deciduous and there is fairly complete shrubby under-growth. Climbers are heavy and often include cane. **Distribution:** the type of forest is commonly found on hilly ground having elevation up to 100m. **Locality Factor:** the underlying rock is chiefly rather hard, coarse grained sand stone with bands of shale and conglomerate and the sandy/clayey loam soil which is often shallow.

Floristics: Top storey is composed of *Terminalia bialata*, *T. manii*, *T. procera*, *Pterocymbium tinctorium*, *Bombax insigne*, *Pterocarpus dalbergioides* etc. The lower storey consists of *Lannea cormandelica*, *Dillenia pentagyna*, *Semicarpus* spp. and climbers such as *Entada phaseolides* and canes.

e) Littoral Forest (L)

The most characteristic species is the tall evergreen *Manilkara littoralis* (bullet wood) that often forms an almost pure fringe on sandy beaches and dunes along sea face. Scattered smaller evergreen trees occur with fewer deciduous trees and these form the dominant canopy. There are numerous shrubs and where the under growth is light maritime grasses and surface creepers are conspicuous binding the sand. In the depressions, which are swampy usually with saline water fresh, tall grasses occur. **Distribution:** All round the coast wherever a fair width of sandy beach occurs. **Locality Factor:** The habitat is exposed with pronounced characteristics. The soil is sea sand often blown and accumulating in low dunes, with adequate lime from shell

fragments but poor in nitrogen and mineral nutrients. It is very coarse, porous and dry on the surface, but the water table is usually a few feet down. The water is fresh water than expected but often brackish. Strong winds, often salt laden, act as desiccating agents with strong insulation and radiation from the bare sand rendering conditions pronouncedly xerophytic.

Floristics: *Manilkara littoralis* forms almost a pure fringe in the top storey. *Pongamia pinnata*, *Morinda citriflora*, *Calophyllum inophyllum*, *Barringtonia asiatica*, *Thespesia populnea*, *Hibiscus tiliaceus*, *Pandanus tectorius* etc occupy lower storey; creepers such as *Ipomea pes-caprae*, *Caesalpinia bonducella* bind the sand.

f) Mangrove Forest (M)

Typically a closed evergreen forest of moderate height composed of trees specially adapted to survive on tidal mud which is permanently wet with salt water and submerged in every tide. Stilt roots are very typical so also leathery leaves and vivipary. *Distribution:* In the stream deltas along the edge of water ways and intertidal sheltered muddy coast. *Locality Factor:* This type is found on the mud banks of the delta streams, the tails of Island and over more extensive areas near the sea face, wherever accretion is in progress. It does not develop on the sandy bank at the sea face. The ground is flooded daily by salt water and never has time to dry up.

Floristics: *Rhizophora mucronata*, *R. apiculata*, *R. candelaria*, *Bruguiera gymnorhiza*, *B. parviflora*, *Xylocarpus moluccensis*, *Avicennia officinalis*, *Ceriops tagal*, *Kandelia candel*, *Sonneratia caseolaris*, *Excoecaria agallocha* and *Heritiera littoralis*.

g) Forest Edges (FE)

The area available between forest boundaries and agricultural or barren lands form edges dominated by shrubs also secondary growth (after clearing), approximately two to three meter height.

h) Plantation (P)

The region is planted with unique species, mainly after tree felling in the forested area and maintained by human for commercial purposes. Species include Padauk *Pterocarpus dalbergioides*, Teak *Tectona grandis*, Red Oil Palm *Elaeis guinensis* in Little Andaman, and Coconut *Cocos nucifera* in settlement areas.

Red Oil Palm Cultivation: In 1976 the Andaman Forest Department took up the Red Oil Palm (*Elaeis guineensis* Jacq.) plantation scheme in Little Andaman, covering an area of 160 ha. The feasibility report of this project was further revised by the Directorate of Coconut Development in the Ministry of Agriculture & Irrigation, Government of India, and approved by Government of India. Accordingly, the newly established Little Andaman Forest Division planted Red Oil Palm in an area of 160 ha within 31 March 1977. This plantation grew up luxuriantly extending to 1593 ha till 1985. The production of oil in the Oil Palm factory in Little Andaman was mostly progressive in the early nineties. After 10 years of the initiation of Red Oil Palm Plantation, Government of India imposed a ban against introduction or expansion of any exotic plants in the virgin forests of the island. Therefore, from 1987, the expansion of Oil Palm plantation in the forests of Little Andaman has been stopped. (Source: ENVIS Newsletter, BSI, Vol. 8, December 2002).

i) Field (F)

The area of lowlands and wetlands which was provided to all settlers in early periods of these Islands was turned into crop fields of paddy, areca *etc.*

j) Degraded area (D)

The forest area changed due to frequent usage by human beings, are subjected to severe anthropogenic pressures.

k) Wetlands (W)

India's wetlands are generally differentiated into 8 categories depending on their regional presence (Scott 1989), in Andaman and Nicobar Islands categorized under the mangroves and other wetlands (**Plate 2.2**). The island area which holds water over a period of time includes coastal and inland water bodies. Much the most extensive wetland habitats in the Andaman and Nicobar Islands are mangrove swamps, but there are many small freshwater ponds and marshes throughout the islands of considerable interest in a regional context.

l) Coastal (C)

Beaches with smooth, sandy stretches or shell and coral-littered lengths are the characteristic feature of the coastal ecosystem. At low tide, large areas of the intertidal zone get exposed, revealing some species of corals, boulders, and the attached mussels, limpets, and other such organisms (**Plate 2.2**).

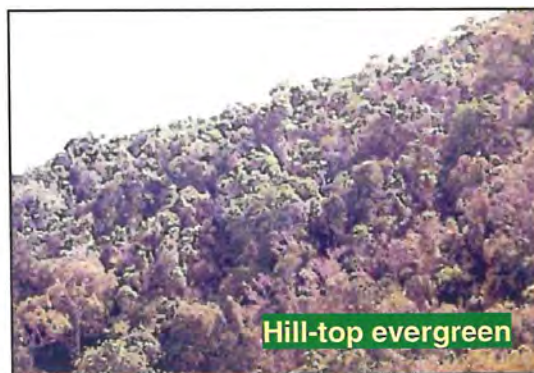


Plate 2.1: Major vegetation types in Andaman Islands.



Plate 2.2: Disturbed forests and wetlands in Andaman Islands.

2.5.2. Land use & Land cover of the Andaman Islands

The Andaman Islands retained most of its forest cover till independence in 1947. There was very little demand for timber during the colonial period; a saw mill established in 1883 supplied timber to settlers around Port Blair. Later in 1926 WIMCO set up a matchstick factory in Port Blair. There were only small areas during this period that had been cleared, in extreme South, Middle and North Andaman Islands (Khan 1983). The 1950's saw an explosion of settlements as people flooded in. The tribal reserves for Jarawa and the Onge that were notified in 1957 had large portions de-notified in the 60's and 70's as there was pressure for land for settlement. A second de-notification was for the construction of Andaman Trunk Road (ATR) (Sarkar 1990, Reddy 1994). Later, 20,000 ha from the Onge Reserve protected forests in Little Andaman Island were de-notified of which 1600 ha was used for Red oil palm plantations (Basu 1990, Reddy 1994, Andrews 2000).

Out of the total geographical area of 8,249 km², forests occupy 7,171 km² or 86.93% of the area (5,628.62 km² in the Andaman group of Islands and 1,542.07 km² in the Nicobar group) and the tribal reserves constitute 41% of this area. Reserved forests constitute 2,929 km² (40.84%) and Protected forests 4,242 km² (59.16%) of the total forest area (FSI 2009). The protected area includes 9 National Parks and 96 Wildlife Sanctuaries covering an area of 0.15 million ha which constitutes 18.71% of the total geographical area. The Great Nicobar Biosphere Reserve having an area of 88,500 ha is located in the territory (FSI 2009) (**Table 2.3**).

The remaining 14% of land is revenue land and is used for human settlements, agriculture and of other human based activities. Most of the revenue land is along coastal areas where people are settled (Jayaraj and Andrews 2005). The entire rural/revenue area is under CRZ-IV (Coastal Regulation Zone-Category IV), except very small area under CRZ-II. No new construction is permissible within 200 metres of the High Tide Line in CRZ-IV area (ANI F&E 2001). Only 21% of revenue land is under intense cultivation and another 11% is classified as fallow lands and cultivable waste land; plantation crops cover 45% of the revenue land (Sirus 1999). Over all the area classification of the land utilization statistics of Andaman and Nicobar Islands forest cover among the divisions showed the maximum in Little Andaman (96.52%) and minimum South Andaman (79.75%) (ANI F & E 2001, Anon 1999) (**Table 2.4**).

Table 2.3: Area classification of Land Utilization Statistic (in km²) in Andaman and Nicobar Islands.

S. No.	Particulars	Island groups		Total	% total
		Andaman	Nicobar		
1.	Geographical area	6408.00	1841.00	8249.00	
2.	Forest land	5628.62	1542.07	7170.69	86.93
i)	Reserved	2928.76	-	2928.76	40.84
ii)	Protected	2699.86	1542.07	4241.93	59.16

Source: Statistical Cell, Dept. of Env. & Forests, A&N Admn., Port Blair, 2000.

Table 2.4: Area classification of Land Utilisation Statistics (in km²) in major islands of Andaman and Nicobar Islands.

S. No.	Forest Division	Area (in km ²)			Total forest land	% forest land
		Geogra-phical	Reserve forest	Protected forest		
1.	Andamans					
	i) North	2325	314.41	1784.15	2098.56	90.26
	ii) Middle	965	53.07	804.05	857.12	88.82
	iii) South	1655	1208.28	111.66	1319.94	79.75
	iv) Baratang	721	646.51	-	646.51	89.67
	v) Little (Project Area)	732	706.49	-	706.49	96.52
2.	Nicobars	1841	-	1542.07	1542.07	83.76
	Total	8249	2928.76	4241.93	7170.69	86.93

Source: Statistical Cell, Dept. of Env. & Forests, A&N Admn., Port Blair, 2000.

Studies by SACON (Vijayan *et al.* 2005) have brought out the extent of major habitats occurring in the Andaman Islands (**Plate. 2.3 to 2.8, Table 2.5**). Twelve Land cover classes are identified and have relevance to the objectives of the present study. The total forest cover was very high (90%) and the moist deciduous forest was dominant (40%) with slight increase, might be because of the mixing of habitats such

as Teak and Padauk plantations. While comparing the areas in different major island groups, evergreen forest was found more in South Andaman and mangrove in Middle Andaman. Agriculture and settlements are less in the Little Andaman because of the Tribal reserve (Onge) (Vijayan *et al.* 2005). However, increasing moist deciduous biome indicates the role of humans in altering the plesioclimax of the vegetation. It would obviously mean that other biotic communities including the avian communities would have been affected substantially (Vijayan *et al.* 2005).

Table 2.5: Overall extent and land cover of different vegetation classes in the Andaman Islands.

S. No.	Classes	Andaman Islands (in Km ²)				Total	% Area
		North	Middle	South	Little		
1	Evergreen	180.96	223.75	386.09	102.17	892.30	15.63
2	Semi-evergreen	245.58	157.99	349.12	225.70	981.33	17.19
3	Moist Deciduous	596.90	665.46	743.57	245.97	2261.82	39.63
4	Mangrove	239.59	358.79	334.41	42.66	975.45	17.09
5	Littoral Forest	6.55	3.80	5.41	0.65	16.41	0.29
6	Degraded forest	0.04	0.04	8.03	8.07	16.17	0.28
7	Plantation	2.22	1.20	0	12.15	15.58	0.27
8	Mud Flats	33.60	8.17	26.36	1.90	70.03	1.23
9	Agriculture / Settlements	88.50	91.75	131.74	21.56	333.56	5.84
10	Creek	31.00	15.43	3.24	12.43	62.09	1.09
11	Water Body	5.48	4.02	2.36	0.45	12.31	0.22
12	Sand	11.23	10.69	23.11	13.22	58.25	1.02
13	Cloud cover	0	0	3.49	8.78	12.27	0.21
Total		1441.63	1541.09	2016.94	695.72	5707.56	100

Forest Survey of India (FSI) reported in 1999 that 94% area of the Andaman Islands was forest land with 77.6% dense forest and 14.8% mangrove. According to IIRS (2003) the total forest was 86% with moist deciduous (14%) and mangrove (12%) forest. FSI report in 2003 shows 42.1% as very dense forest 34.1% moderately dense forest, making a total of 76.2% of dense forest which shows 1.4% decrease.

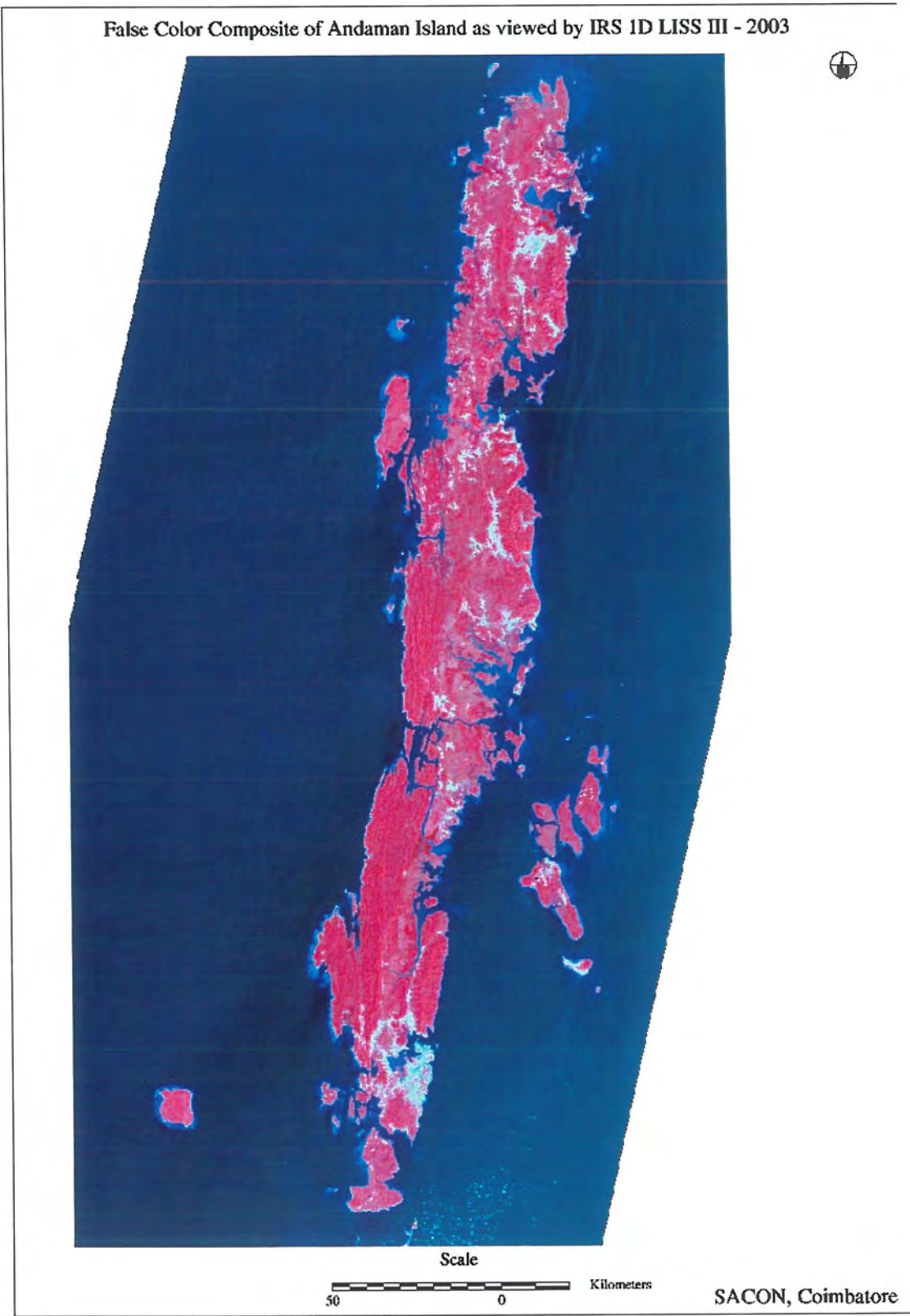


Plate 2.3: FCC (False Color Composite) of Andaman Islands.

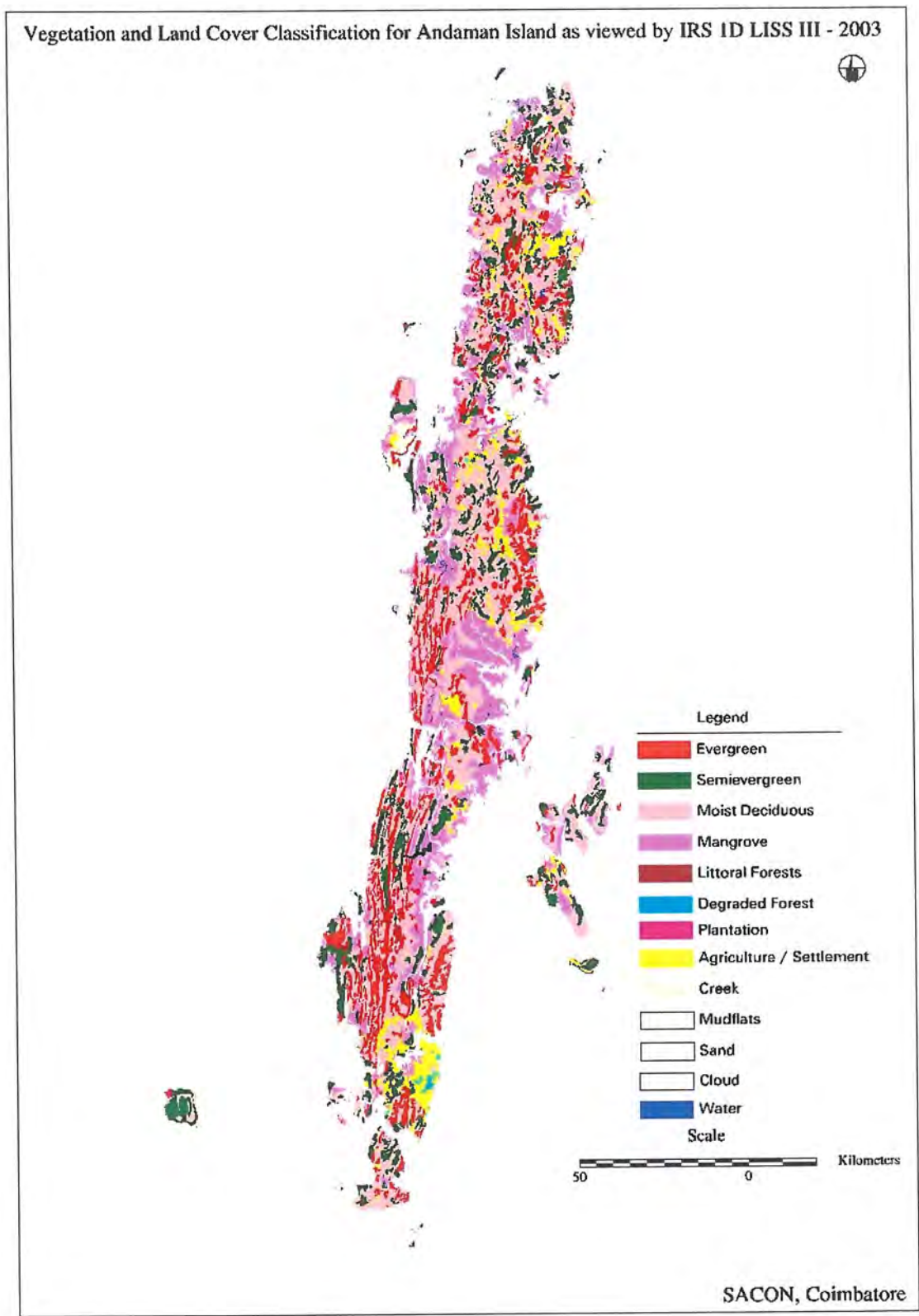


Plate 2.4: Vegetation cover of Andaman Islands.

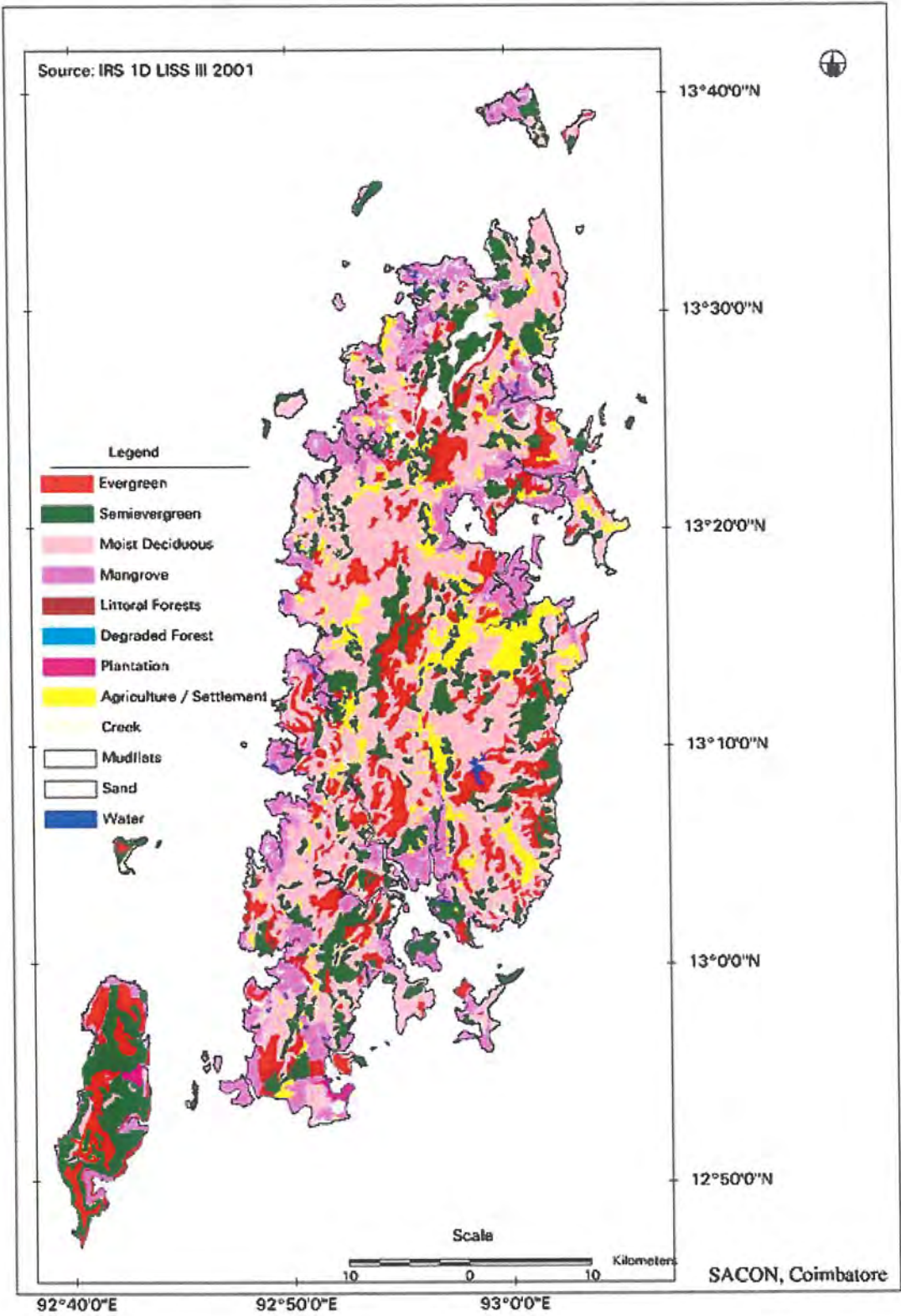


Plate 2.5: Vegetation cover of North Andaman Islands.

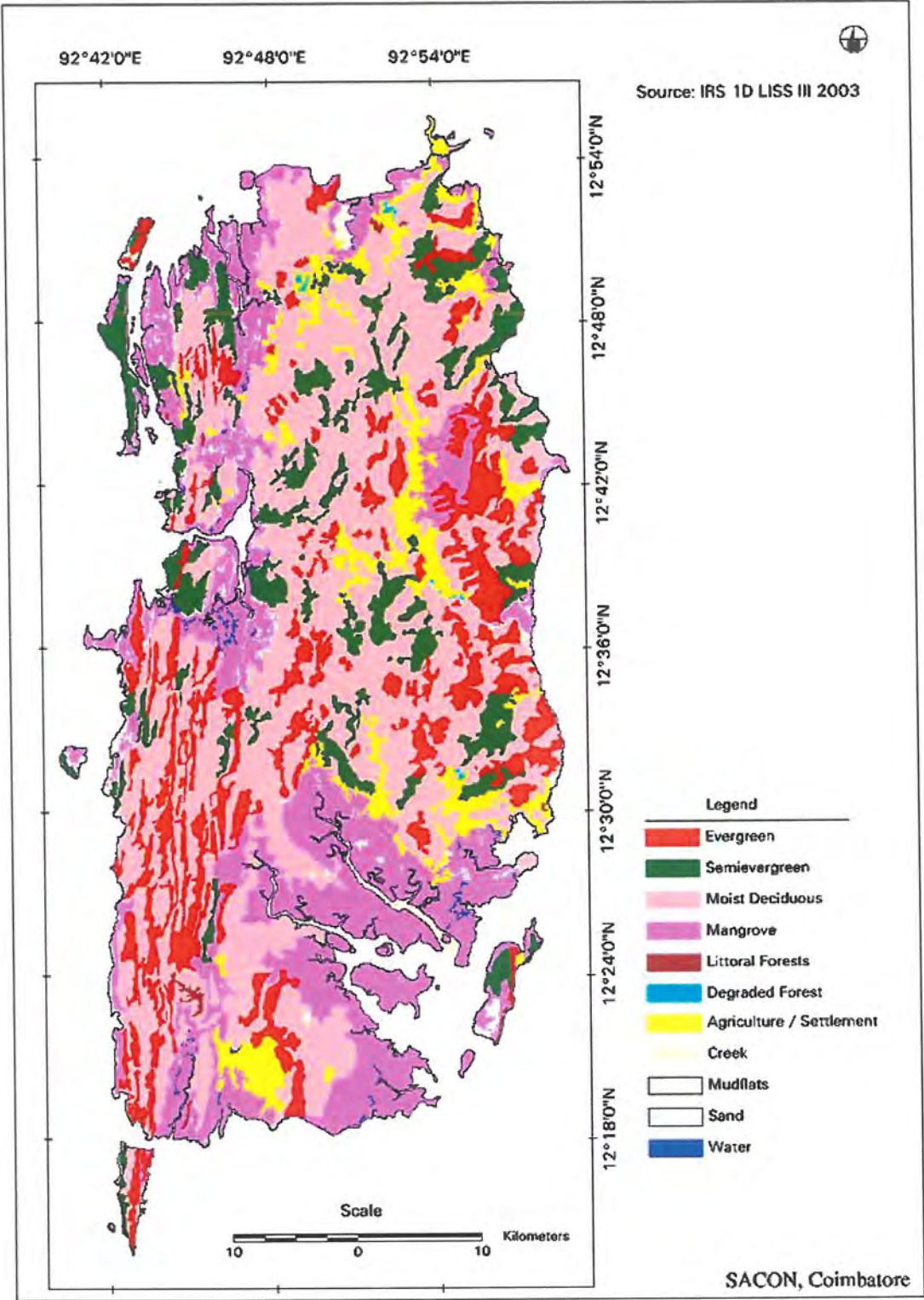


Plate 2.6: Vegetation cover of Middle Andaman Islands.

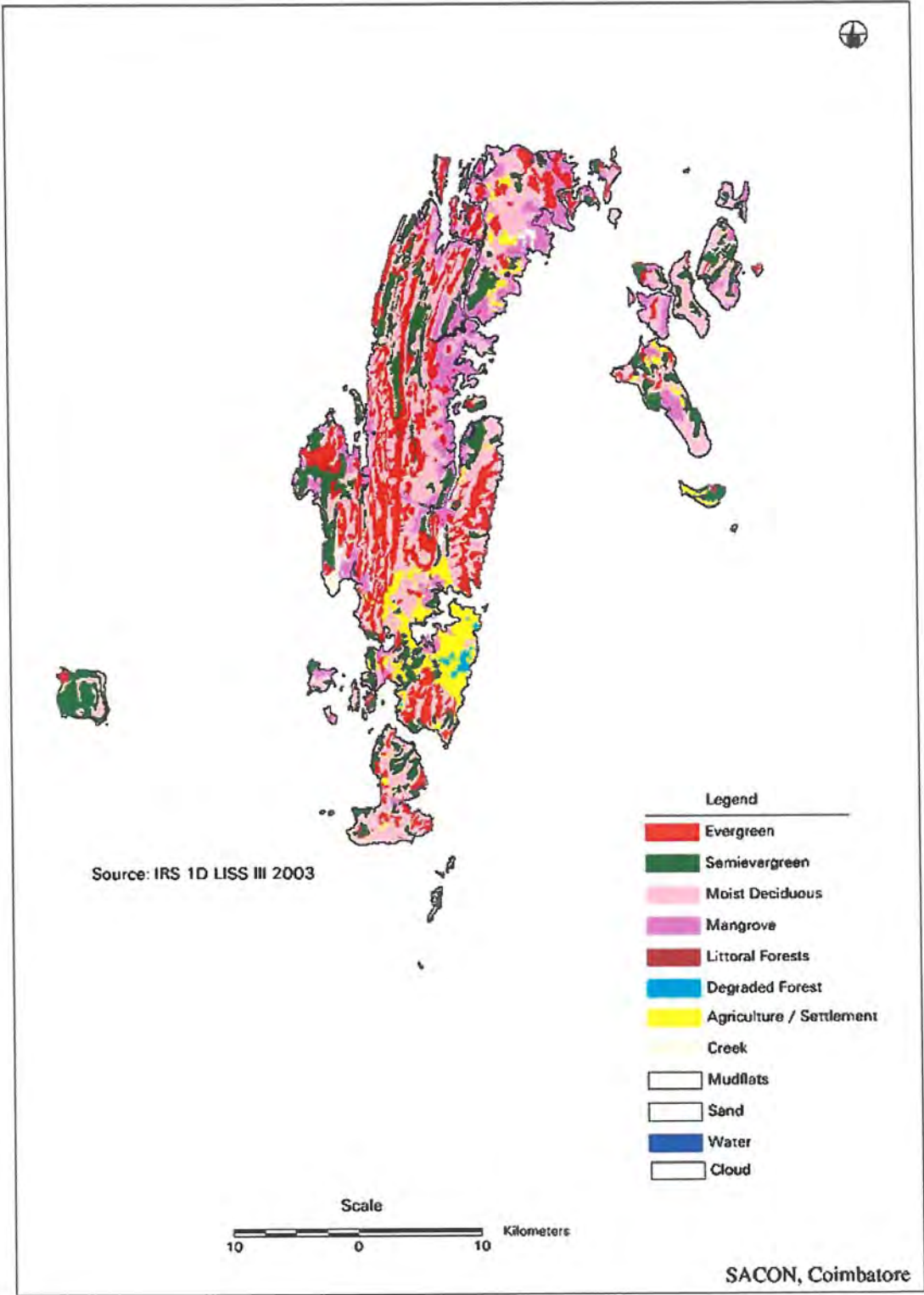


Plate 2.7: Vegetation cover of South Andaman Islands.

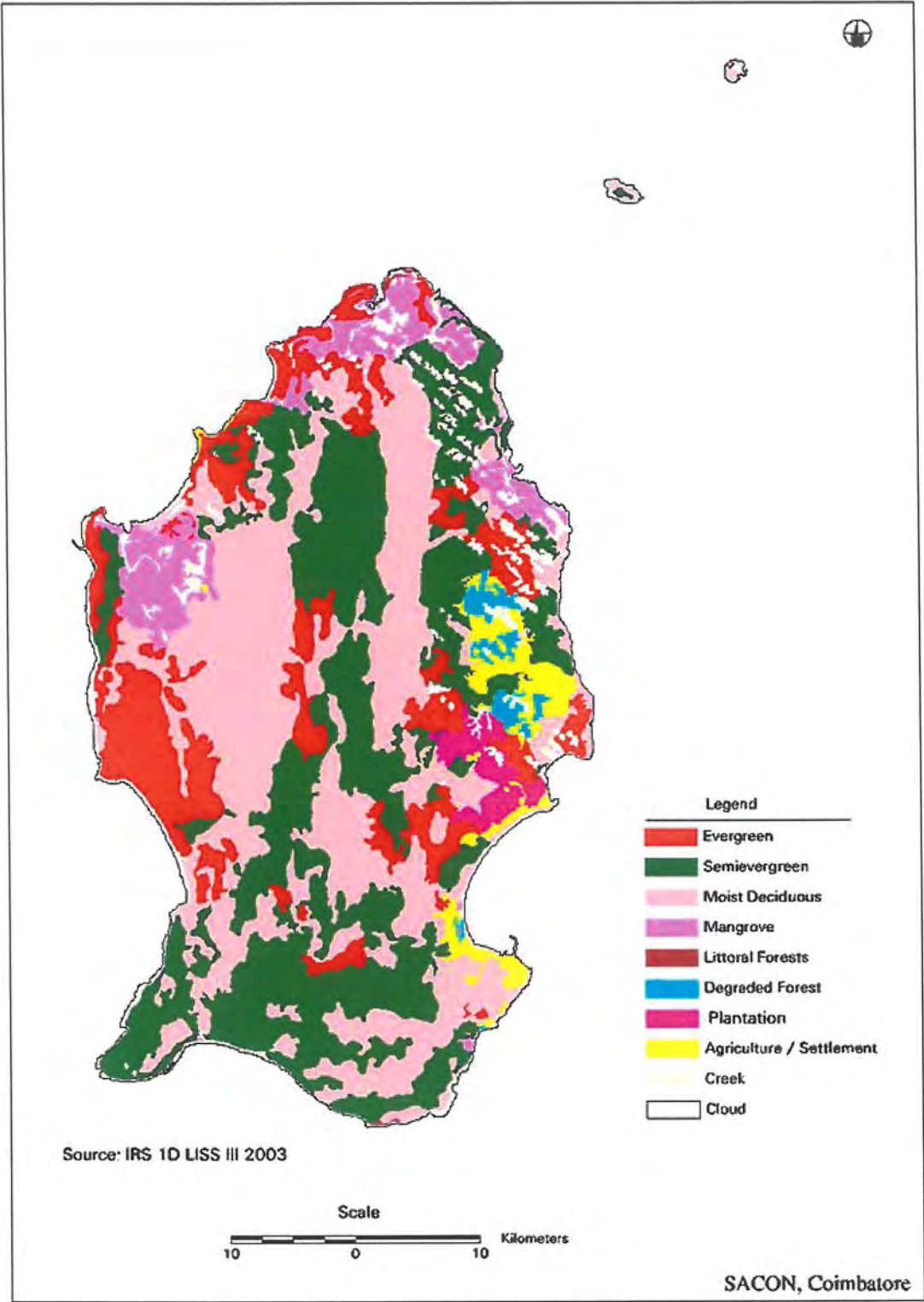


Plate 2.8: Vegetation cover of Little Andaman Island.

A decrease in 7 km² forest area was recorded by the FSI (1999) which had happened during a period of four years (1994-98) and attributed to encroachments in Diglipur, Havelock and Little Andaman. The FSI reports of 1999 and 2003 shows a total decrease of forest cover to the extent of 642 km² (from 7606 to 6964 km²). This is of great concern, as species extinctions are predicted at a higher rate because of habitat loss, degradation and fragmentation, especially as the islands function as fragments (Pimm *et al.* 1995, Brooks *et al.* 1999a, b).

A decrease of 118 km has been reported in the mangrove cover of A&N Islands in 2003 assessment as compared to 2001 assessment. This is not a real loss of Mangrove Forests. This has happened mainly because of correction of classification in interpretation during 2003 assessment. Considerable forest area adjoining mangrove vegetation in Andaman Islands had been earlier classified as mangrove. In 2003 assessment, there has been refinement in the methodology of mangrove delineation where SWIR (short Wave Infra-Red) band has been used which improves delineation of mangroves from adjoining vegetation. Those areas which were earlier classified as mangroves have now been correctly classified as forest cover, resulting in an apparent decrease in mangrove area. This is only an internal change from mangrove area to forest cover. This is evident by the fact that forest cover (which also includes mangrove areas) of Andaman and Nicobar Islands has not shown any decrease. Rather there is a marginal increase by 34 km in forest cover in 2003 assessment (Table 2.6, GoIPC 2007).

Table 2.6: Mangrove Cover (area in km²) of Andaman and Nicobar Islands as per 'State of Forest Report 2009' of Forest Survey of India (FSI 2009).

Region (State / UT)	Mangrove cover				Change* w.r.t. 2005 Assessment
	Very Dense	Moderately Dense	Open	Total	
Andaman Islands	285	260	67	612	-11
Nicobar Islands	0	2	1	3	-9
Total	285	262	68	615	-20
Total in India (all State/UT)	1,405	1,659	1,575	4,639	58

* The change in the above table refers to change in the area w.r.t. revised assessment of 2005.

2.5.3. Status of forest cover

Although the total forest cover of the Islands is still around 84% (according to FSI), there has been a continuous decline in forest cover over successive assessments in 1990's by FSI. The extent of forest reported over different assessments between 1987 and 1999 are: 1987-7601 km²; 1989-7622 km²; 1991-7622 km²; 1993-7624 km²; 1995-7615 km²; 1997-7613 km²; and 1999-7606 km². The 2001 assessment has shown a forest cover of 6930 km², but the decline is mainly due to change in the scale of satellite data interpreted from 1:125,000 to 1:50,000 and method of interpretation from visual to digital. However, the 2003 assessment shows an increase to 6964 km² of forest cover (Jayaraj and Andrews 2005). It is heartening to note that with the intervention of the Judiciary commercial forestry operations have been stopped and recent encroachments removed.

The forest cover in the Andaman and Nicobar Islands, based on interpretation of satellite data of January-March 2007, is 6,662 km², which is 80.76% of the total geographical area. In terms of forest canopy density classes these islands has 3,762 km² very dense forest, 2,405 km² moderately dense forest and 495 km² open forest. Comparison of the current forest cover (satellite data of January-March 2007) with the previous assessment (satellite data of January-February 2005) shows a loss of 1 km² of forest cover (FSI 2009).

The forest cover change matrix by FSI (2009) reveals that there has been a decrease of 17 km² in the very dense forest and 9 km² in moderately dense forest and an increase of 25 km² in open forest. The main reason for the net decreases in forest cover was loss in mangroves in both districts and that is due to the after-effects of *tsunami*. The increase in open forest is due to casuarina plantations. While in the tree cover of these Islands has been estimated using sample data of TOF inventory collected over a period of six years i.e. 2002-2008 is 44 km² which is 0.53% of the geographical area of these islands (FSI 2009).

The December 2004 *M* 9.0 earthquake and the subsequent *tsunami* caused immense ecological changes to both island groups, including taking a toll on human life, human life patterns for indigenous groups in the Nicobars, infrastructure and permanent change to agricultural land and plantations (Jayaraj and Andrews 2005). Nevertheless, the tectonic plate shifts resulted in upheaval of most Andaman Islands including Little

Andaman Island, causing upliftment of reef flats, drying of mangrove stands and shifting of stands into creeks, and is a clear proof of the upheaval of the island's land mass by an average of one meter (Andrews and Vaughan 2005). The mangroves on the eastern side of Middle Andamans, from Rangat Bay, east of Long Island and from north Baratang Island and in the entire Shoal Bay area remains submerged during high and low tides. This caused drying of mangrove trees and shifting of sand into the creeks. The impacts on mangroves in areas of Rangat Bay, west of Long Island, east Middle Strait Island, Baratang Island, Shoal Bay and around southern South Andaman Island along west coast to Port Mouat, is a clear indication of the subsidence of the land mass by 0.75 to 1.0m.

No major impacts were observed along coastal forests in the Andamans, there is scope for quick regeneration in impacted areas on the main and small islands, including Little Andaman Island (Jayaraj and Andrews 2005). The subsidence of the southern South Andaman Island and the Nicobars have caused major impacts on coastal ecosystems, besides most marine turtle nesting beaches have been washed away. The impacts, ecological changes, implications and recommendations have been discussed by several authors (Andrews and Vaughan 2005, Chadha *et al.* 2005, Banerjee 2005, Ramachandran *et al.* 2005, Ramanamurthy *et al.* 2005, Sankaran 2005, Malik and Murty 2005, Mishra and Rajasekar 2005, Nath *et al.* 2005).

2.6. ISLANDS AT RISK

Anthropogenic pressures and natural calamities

The population of Andaman & Nicobar Islands was 24649 in 1901; a century later, it stood at 356,265. Further it was raised to the level of 400,000 in recent decades by the settlers from Indian mainland, mostly Bengalis and Tamils. This population explosion was supported by colonial and post-colonial policy but this has been disastrous for the local aboriginals and environment. Nevertheless, this rising population of settlers from mainland India has led to mindless logging, both by private groups and government till the recent Judiciary intervention by which commercial forestry operations have been stopped.

The coast has become too dangerous to stay after 26 December 2004 *tsunami*, a great natural disaster of these islands. Due to this natural calamity many farmlands from 38 islands have been largely destroyed and saline water in farms has made cultivation

impossible at least for several years. Hence, many settlers may try to move into the hills and jungles where the aboriginals live. For example, during the year of 1957 Hut Bay which is located at the eastern edge of the Little Andaman Island was declared as a tribal reserve for the Onge aboriginals, but 30% of the island was freed up for settlers in the 1970s.

Since the killer waves hit and devastated this island, a huge area of the forests in higher ground has been cleared for the settlement of *tsunami* victims. Many of the homeless villagers have started to move into and clear the forests to build their homes following the *tsunami*. And some of the coastal villages have been relocated on higher grounds of forests cleared to settle the *tsunami* victims which will be the final nail in the coffin for the aboriginals and the archipelago's unique biodiversity. In addition, demand on the development of tourism resulted in the increase of various resorts, and buildings near the forests and protected areas which when unmanaged create problems (see also 2.5.2. land use patterns).

Exotic species

Oceanic islands have considerable ecological devastation caused by many exotic species. Andaman and Nicobar Islands have also had their share of introduction in the early 19th century. Amongst birds two potentially disastrous introduced species, the Common Myna and House Sparrow (Whitaker 1985) might drive out the native species occupying the same ecological niches. In addition, studies by Sankaran (1997, 1998), found a major problem of locally introduced Andaman Red-whiskered Bulbul to Nicobar Islands (**Table 2.7**), which has spread throughout the Nancowry group and has probably resulted in the rarity of endemic and globally threatened Nicobar Bulbul because of competition for the same ecological niche (Collar *et al.* 1994, Sankaran 1995, BirdLife International 2008, 2009). The status and impact of the introduced species to Andaman Islands have not yet been studied.

To understand the conservation issues of the avifauna of the Andaman Island, it is necessary to monitor the increase of settler's population and various natural and man made problems and their impacts on the biodiversity in various modes. Global warming and sea level rise form an impending danger to these island ecosystems (Vijayan *et al.* 2000). A detailed conservation management plan for this island avifauna is an urgent need.

Table 2.7: Some of the birds introduced in Andaman and Nicobar Islands.

S. No.	Common name	Island/s	Year	Status
1	Grey Partridge	Andamans	1890	Uncommon
2	Indian Peafowl	Andamans	1868	Uncommon
3	Blue Rock Pigeon	Andamans, Car Nicobar	?	Common
4	Little Brown Dove	Andamans	1899	?
5	Rose-ringed Parakeet	Andamans	1863	Died out
6	Andaman White-headed Myna	Comorta	?	Common
7	Indian Myna	Andaman, Nicobar	1867	Very common
8	Andaman Red-whiskered Bulbul	Camorta, Trinkat	?	Very common
9	House Sparrow	Andamans	1892, 1895	Very common
10	Tree Sparrow	Andamans	< 1866	Died out
11	Red Munia	Andamans	< 1873	Died out
12	Black-headed Munia	Andamans	< 1906	Died out

Source: Whitaker (1985), Sankaran & Vijayan (1993).

CHAPTER THREE

STATUS AND DISTRIBUTION OF AVIFAUNA

3.1 INTRODUCTION

The ornithological study frequently deals with the baseline information on three factors, namely status and distribution of species, communities and habitat quality. The knowledge on these factors would help conservation of the rare and endemic avifauna in a particular region. Recent information by BirdLife International (2008) shows that at least 11% of all bird species in the world and about 12% in Asia are threatened with extinction today; majority of these species are found in tropical forests and islands (Collar *et al.* 1994, Stattersfield *et al.* 1998, BirdLife International 2000, 2001). Although the Andaman and Nicobar Island groups account for only 0.2% of the landmass of South Asia, they have 12% of the endemic avifauna of the region, thus making the islands a high priority area in the conservation of India's avifauna (Sankaran 1998, Vijayan *et al.* 2000).

Studies conducted in the recent decades have reported that these Island groups are rich in biodiversity (Rao 1986, Rao 1989, Lakshminarasimhan and Rao 1996, Chandra 1999) with a higher degree of endemism, especially in birds about 39% including subspecies (Sankaran and Vijayan 1993). One of the Endemic Bird Areas (EBA 125) in the world, the Andaman Islands harbours twelve endemic bird species (Stattersfield *et al.* 1998) while Rasmussen and Anderton (2005) described 21 endemics. A new species has been described from Nicobar by Rasmussen (1998) which was collected earlier by Abdulali (1976, 1978). Andaman and Nicobar Islands are rich in large tracts of native forest and a variety of disturbed and non-native forests. Many studies have emphasized the effect of habitat diversity on species richness (Boecklen 1986, Weins 1989, Kohn and Walsh 1994). The presence of well defined and easily recognizable forest types (Champion and Seth 1968) makes analyses of habitats and the biogeographical history of birds possible (Ripley and Beehler 1989, Yoganand and Davidar 2000).

However, till recently there have been very little efforts to assess the exact status of many bird species or to study their distribution and ecology. Records of the travellers from Hume (1873) and Kloss (1903) have the sightings and description of many birds in Andaman and Nicobar Islands. The bird survey has been started from the middle of

20th century in these islands, but there were very few systematic surveys covering various habitats in different islands of Andamans. Totally 214 species and subspecies of birds including 63 endemics have been recorded earlier from Andamans (Abdulali 1964, 1967, Das 1971, Ali and Ripley 1983, Vijayan *et al.* 2000). A survey was conducted during 1992-95 (Vijayan 1996) for the endemic birds and more specifically for the rare Andaman Teal and hence looked at mainly the areas of previous sightings of this species (Vijayan *et al.* 2000). Davidar *et al.* (1995, 1996, 2001) have analyzed the birds of a few islands in Andaman.

Fresh surveys were needed to complement the existing data to get island-wise information on the avifauna and assess the status of the birds with respect to taxonomy, food habits, habitat used and movement. BirdLife International (2001, 2003) has identified the gaps in data and the necessity for detailed information on the distribution, habitat requirements and ecology of the species in order to take proper steps for their conservation and management. Hence, this study was taken up with the following major objectives:

- Understand the systematic status of avifauna,
- Assess the status of birds in different island groups and habitats,
- Examine the guild-wise status of avifauna in the Andaman Islands

3.2. MATERIALS AND METHODS

3.2.1. Bird survey

In order to know the status and distribution of birds in different habitats a total of 1650 points were surveyed in 254 locations in different island groups (Table 3.1).

Table 3.1: Number of point count stations from different regions in Andaman Islands.

Particulars	North	Middle	South	Little	Total
Locations	76	29	116	33	254
Points covered	455	122	873	200	1650
Time spent	32:42:10	38:40:10	241:45:54	60:29:20	473:10:06

Methods for assessing abundance

Point Survey Method: Point count (Bibby *et al.* 2000) for birds was attempted across all forest types from the major and outer islands to measure their abundance, diversity, habitat use, population trends and habitat association within the populations

(Ralph and Scott 1981, Verner 1985). Point count method is the most efficient and data-rich method of counting land birds and widely used (Rosenstock *et al.* 2002) in forested habitats or difficult terrain, to estimate the species population and richness in different habitats.

Variable Distance method: The sampling of birds used Variable distance method, one of the point count type, which estimates the radial distance to the detected birds in each points (Galela and Roscom 2004). Such a method is used for absolute abundance estimation of birds (Pollock *et al.* 2002) either seen or heard. Birds seen or heard were identified using Grimmett *et al.* (1998), Kazmierczak and van Perlo (2000), and Ali and Ripley (2001).

3.2.2. Habitats surveyed

The vegetation classification in Andaman Islands by Champion and Seth (1968) was followed and is discussed in *Chapter two* (see 2.5.1). The actual forest cover and area surveyed (Vijayan *et al.* 2005) from different habitats were analysed. The proportions of natural habitats throughout the Andaman Islands showed majority of Moist deciduous (41.09%) forests followed by Semi-evergreen, Mangrove and Evergreen, whereas in the Disturbed vegetation, Field scored the maximum followed by Degraded forests and Plantations (**Fig. 3.1**).

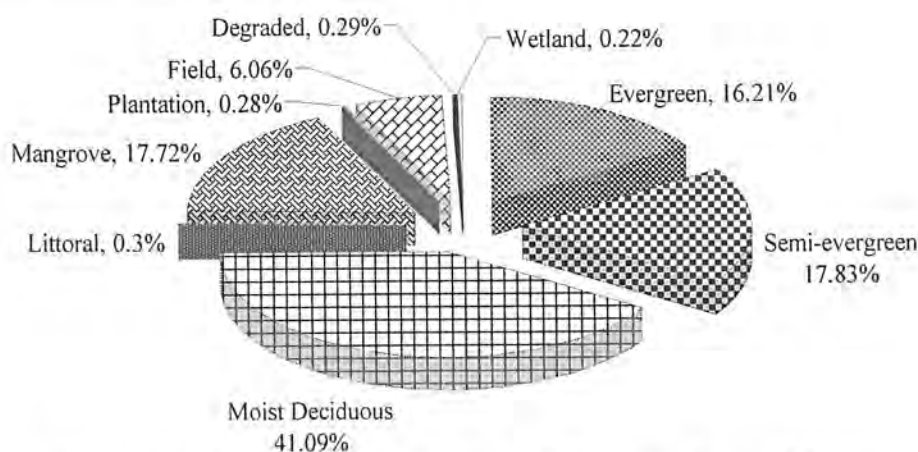


Figure 3.1: Proportion of habitats available in Andaman Islands.

During the survey most number of sites with maximum points was covered from Littoral forests (471) followed by Evergreen and Semi-evergreen. The minimum number of sites and points counted was in the wetlands followed by coast (**Table 3.2**). The major forest types surveyed were above 10% of the available area with the maximum in littoral forests (24%) and minimum in coast (**Fig. 3.2**).

Table 3.2: Habitat-wise sampling size and area covered during the study period.

Habitat (code)	# sites	# points	area covered (in ha)
Evergreen (E)	31	384	81.96
Semi-evergreen (SE)	29	259	73.93
Moist Deciduous (MD)	17	170	42.17
Littoral (L)	104	471	104.68
Mangrove (M)	31	123	28.88
Forest edges (FE)	8	49	21.61
Plantation (P)	11	69	14.19
Field (F)	4	51	15.75
Degraded (D)	9	36	6.88
Wetland (W)	3	16	33.27
Coastal (C)	7	22	5.94
Total	254	1650	429.26

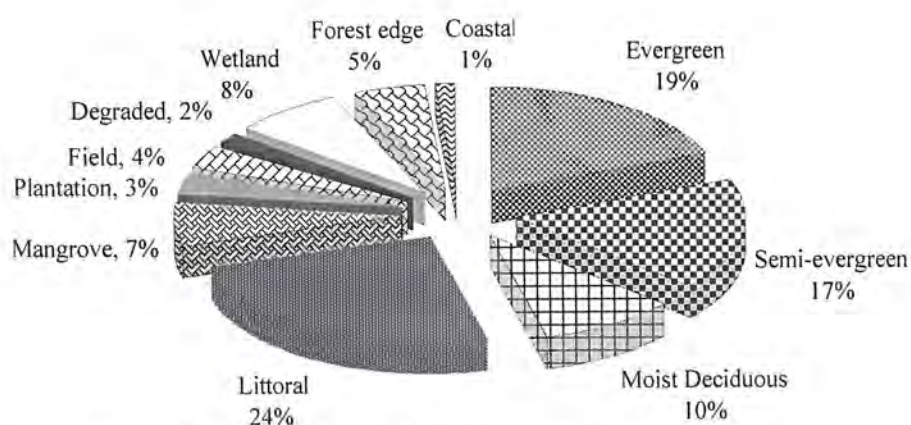


Figure 3.2: Proportion of the habitats covered during bird survey.

Some of the habitats with minimum area surveyed were clumped to the primary habitats for further analysis: Mangrove creeks with Mangrove, Grassland with Forest edges, Forest clearing and Habitation with Degraded areas, Reservoir and Coastal wetlands with Wetlands, and Tidal creek, Sea route (while travel between islands), Rocky shore, Sandy shore and Reefs were included under the Coastal habitats.

3.2.3. Data analysis

The bird data obtained from detailed ornithological survey carried out in Andaman Islands during the study period was analysed in detail. Species accumulation curve was generated for the total data set month-wise to illustrate the rate at which new species are found. The documentation of region-wise species richness and abundance has been made which included recently promoted endemic species of these Islands by Rasmussen and Anderton (2005). Importantly, the status and distribution of total endemic, rare and vagrant species recorded from the Andaman Islands are stated, reviewed by referring Grimmett *et al.* (1998), Kazmierczak and Van Perlo (2000) and Ali and Ripley (2001).

Further, habitat-wise species accumulation curves (excluding wetland and coastal habitats) were generated, against the effort to understand the distribution of species in the natural and disturbed habitats. Also, the species richness and abundance of all land/forest and wetland/water birds were estimated. Based on the presence/absence data forest or land birds observed only in particular habitats were classified as specialist (sighted in only one habitat) and generalist (birds sighted in more than one habitat); no such classification was made for the wetland birds.

The information of the food of the bird species and groups given by Ali and Ripley (2001) was referred to produce guild classification in each habitat since it is a useful tool for analysing the community structure (MacNally 1994). The collected samples represented eight trophic categories, namely Insectivore (I), Carnivore (C), Frugivore (F), Granivore (G), Nectarivore (N), Omnivore (O), Piscivore (P) and Vegetarian (V). The species with mixed dietary habits were categorised based on major part of the diet. The species foraging on fruits, nectar and insects were included in class Omnivores (Latta *et al.* 2003). The prominent plant matter foragers from Anatidae (Teals and Ducks) and Rallidae (Watercock and Moorhen) by means of availability and requirements were classified under Vegetarian.

The systematic grouping by order and family was done of the bird community of Andaman Islands. This systematic status is further classified according to the phylogenetic classification made by Cracraft (1981) based on the content of natural groups, that is taxa that are our best estimates of genealogically related groups of species.

3.3. RESULTS

A total of 26487 individuals belonging to 153 species were recorded including twenty rare, vagrant and new records during 473 working hours. Maximum area surveyed was in South and minimum in Middle Andaman (**Table 3.3**).

Table 3.3: Summary of the area surveyed in different regions of the Andaman Islands.

Particulars	Total	North	Middle	South	Little
Actual area (ha)	640800	145800	153560	145672	73160
Area surveyed (ha)	429.26	120.77	24.99	201.83	81.67

Species accumulation curve from the pooled data sampled throughout the Andaman Islands begins with the total 79 species and ends up with 153 during the present study. It shows increase of species every month of survey and became almost stable at the end (**Fig. 3.3**).

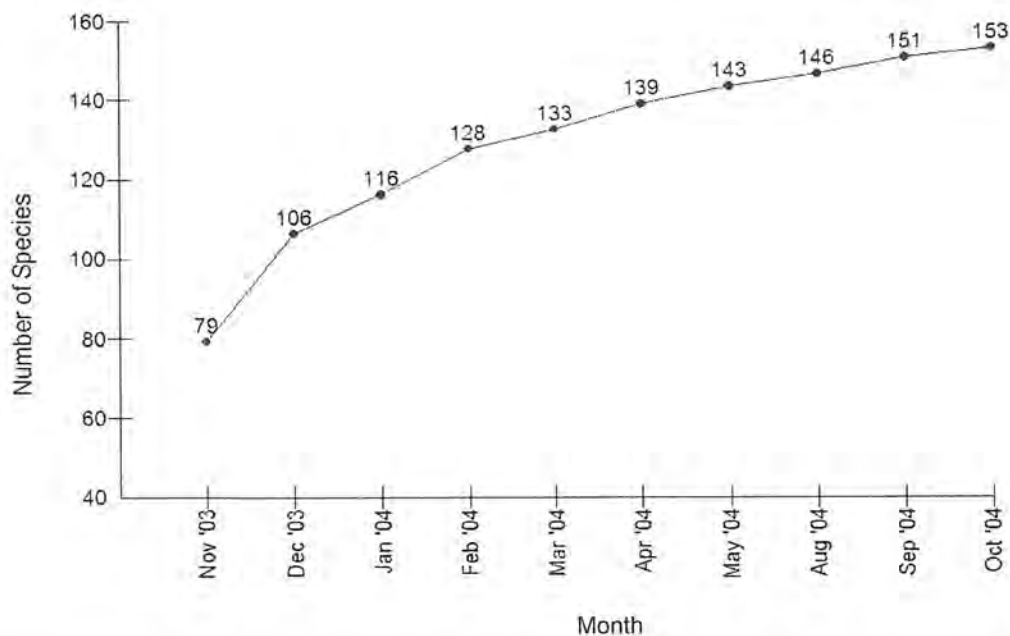


Figure 3.3: Cumulative total of bird species recorded across the habitats during 2003-2004.

3.3.1. Regional status

Out of 153 bird species 126 were recorded from South Andaman followed by North (110), Little (96) and Middle (80) Andaman across all eleven habitats; abundance also followed the same pattern (Table 3.4). Totally 56 endemic species (including subspecies) were recorded and, all four regions had good richness. However, in full species endemics North and South Andaman scored 18 out of 21 of Rasmussen and Anderton (2005), followed by Middle (16) and Little (14) (Table 3.4, 3.5).

Table 3.4: The status of avifauna recorded during the study in the Andaman Islands.

Region	Overall		Endemic (subspecies)		Endemic (species)	
	Species Richness	Abundance	Species Richness	Abundance	Species Richness	Abundance
North	110	7118	52	5298	18	885
Middle	80	1935	44	1348	16	253
South	126	13065	51	10328	18	2740
Little	96	4369	45	3169	14	508
Total	153	26487	56	20143	18	4386

Totally 56 endemic species (including subspecies) were found during the present study which included 11 of 12 species endemics from different habitats in Andaman Islands as per Stattersfield *et al.* (1998) and an additional 7 of 9 recently considered as species endemics by Rasmussen and Anderton (2005) (Table 3.5). However, the earlier distribution records of Ali and Ripley (2001) stated that Andaman Dark Serpent Eagle *Spilornis elgini*, Andaman Wood Pigeon *Columba palumboides*, Andaman Cuckoo-Dove *Macropygia rufipennis*, Andaman Hawk Owl *Ninox affinis*, Andaman White-headed Myna *Sternus erythropygius* and Andaman Grey-fronted Green Pigeon *Treron chloropterus* are shared with Nicobar Islands (Table 3.5).

From the 21 endemics 14 were detected from all four regions in Andaman Islands (Table 3.5). During the survey period full species endemics the Andaman Cuckoo-Dove *Macropygia rufipennis*, Andaman Nightjar *Caprimulgus andamanicus* were not reorded from Little Andaman and both Andaman Scops Owl *Otus balli* and Andaman Hawk Owl *Ninox affinis* were not detected from Middle and Little Andaman. Further the population and distribution of the endemic species across the regions are given in Chapter 6.

Table 3.5: Distribution of the endemic birds in Andaman Islands.

S. No.	Common name	Scientific name	Region
<u>Species Endemics</u>			
1	Andaman Dark Serpent Eagle [#]	<i>Spilornis elgini</i>	1,2,3,4
2	Andaman (Banded) Crane [#]	<i>Rallina canningi</i>	1,2,3,4
3	Andaman Wood Pigeon [@] [#]	<i>Columba palumboides</i>	1,2,3,4
4	Andaman Cuckoo-Dove [@] [#]	<i>Macropygia rufipennis</i>	1,2,3
5	Andaman Crow-Pheasant	<i>Centropus andamanensis</i>	1,2,3,4
6	Andaman Scops Owl [#]	<i>Otus balli</i>	1,3
7	Andaman Hawk-Owl [#] ^R [@]	<i>Ninox affinis</i>	1,3
8	Narcondam Hornbill ^X	<i>Aceros narcondami</i>	NR
9	Andaman Black Woodpecker [#]	<i>Dryocopus hodgei</i>	1,2,3,4
10	Andaman Drongo [#]	<i>Dicrurus andamanensis</i>	1,2,3,4
11	Andaman White-headed Myna [@]	<i>Sternus erythropygius</i>	1,2,3,4
12	Andaman Tree Pie [#]	<i>Dendrocitta bayleyi</i>	1,2,3,4
<u>Recently added Endemic Species</u> [according to Rasmussen & Anderton 2005]			
13	Andaman Teal ^R	<i>Anas albogularis</i>	1,2,3,4
14	Andaman Green Pigeon [@]	<i>Treron chloropterus</i>	1,2,3,4
15	Andaman Nightjar	<i>Caprimulgus andamanicus</i>	1,2,3
16	Andaman Cuckoo-shrike	<i>Coracina dobsoni</i>	1,2,3,4
17	Andaman Bulbul	<i>Pycnonotus fuscoflavescens</i>	1,2,3,4
18	Andaman Shama	<i>Copyschus albiventris</i>	1,2,3,4
19	Andaman Flowerpecker	<i>Dicaeum virescens</i>	1,2,3,4
20	Andaman Barn-owl	<i>Tyto deroepstorffi</i>	NR
21	Hume's Hawk-owl	<i>Ninox obscura</i>	NR

Note: ^X- Vulnerable, [#]- Near threatened, ^R- Rare, [@]- Occurring also in Nicobar; NR- Not recorded, 1- North, 2- Middle, 3- South and 4- Little Andamans.

3.3.2. Rare/vagrant birds

Present study across the habitats in different regions gives the sightings of rare and vagrant birds for further avifaunal conservation in Andaman Islands (**Table 3.6**).

Four rare species, detected during the study were Eastern Knot *Calidris tenuirostris*, Great Stone Plover *Esachus magnirostris*, Sooty Tern *Sterna fuscata nubilosa* and Nicobar Pigeon *Caloenus nicobarica* which are very little known to these Islands. Great Stone Plover and Nicobar Pigeon are recently classified as near-threatened (BirdLife International 2009) and are described in the *Chapter* six in detail (see *Chapter 6.4*) and the remaining are discussed below.

EASTERN KNOT *Calidris tenuirostris*:

Two sightings were made during the study period, both of a single bird in mangrove forest. The first was at Camp No.3 near Panighat jetty (12° 53' 160" N - 092° 52' 558" E), Mayabunder, North Andaman on 09th March 2004 and the second in the mangrove region at Mohanpur (12° 55' 921" N - 092° 50' 710" E), on 10th March 2004.

Species recorded for the second time

The present study documented some of the interesting species, which are recorded only once by Ali and Ripley (2001) and not listed after that by many other ornithological surveys conducted in these islands (**Table 3.6**).

EASTERN SAND PLOVER *Charadrius asiaticus veredus*

Three individuals were sighted in mangrove forest in Landfall Island sanctuary (13° 37' 40.6" N - 93° 01' 45.3" E), North Andaman on 30 August 2004 at 0930h. It breeds in Mongolia and North China and migrates through China and Japan and winters in the Sunda Islands, Celebes, Moluccas and Australia. The only known record is that of a single example (in winter plumage), of this vagrant bird collected in the Andaman Islands in May 1872, and no other records within our limits (Ali and Ripley 2001).

PIED CUCKOO-SHRIKE *Coracina nigra davisoni*

Two sightings were made during 2004, of single bird; the first was at coconut plantation, Dugong Creek (10° 48' 851" N - 92° 33' 655" E), Little Andaman a Tribal Reserve Protected area on 21st January 2004, and second at Ramkrishnapur dam (10° 42' 075" N - 92° 32' 728" E), Little Andaman, on 26th January 2004. Presumably one male specimen, *Lalage nigra*? subsp. bearing ZSI Regd. No. 28377, was collected by

Sherard, R.V. of the Zoological survey of the India, Port Blair, South Andaman, on 18 March 1952 (Das 1971/JBNHS 68: 460). This was the first authentic record of the occurrence of this species from the Andamans (Ali in Thomson 1964, pp. 556-559).

ASSAM GREAT REED WARBLER *Acrocephalus stentoreus amylae*

Three birds in two sightings were recorded from North Andaman, two individuals in the forest edges at the place named Chalis Ek, Pathilevel (13° 02' 649" N - 92° 59' 255" E) in Ram Nagar, on 16th April 2004, and one individual near mangrove creek at Yeratta (12° 27' 30.9" N - 92° 53' 43.6" E), Middle Andaman, on 17th October 2004. The only known record of this winter migrant from the Andamans was by Abdulali (JBNHS 61: 562) which was reported by Ali and Ripley (2001).

ARCTIC LEAF WARBLER *Phylloscopus borealis borealis*

Two sightings were made, of single bird; the first was in the littoral forest at Landfall Island sanctuary (13° 37' 43.2" N - 93° 01' 23.9" E), North Andaman on 30th August 2004, the second in the forest edges at the place named Beesfamilies (13° 29' 40.6" N - 92° 54' 50.2" E), North Andaman on 1st September 2004. There were two winter records of this species earlier from the Andaman Islands, (Ali and Ripley 2001).

WHITE-BROWED GROUND THRUSH *Zoothera sibirica sibirica*

Totally three sightings were made from different areas. Two individuals were sighted in semi-evergreen forest at Helicopter Island (12° 52' 789" N - 92° 45' 541" E), North Andaman, on 19th April 2004. Five individuals at four points in the littoral forest at North Reef Island sanctuary (13° 05' N - 92° 43' E), North Andaman, on 21st April 2004. A single record from disturbed area at New Circuit House (11° 40' N - 92° 43' E), Port Blair, on 21st October 2003. One record of this uncommon winter visitor from Andaman Islands (Ibid 2: 223) was reported by Ali and Ripley (2001).

BLYTH'S PIPIT *Anthus godlewskii*

Total nine individuals were recorded from two sightings. The first, eight individuals in the cultivation/field and forest edges near jetty, Havelock Island (12° 02' N - 92° 58' E) on 27th October 2003. The second, a single record in littoral forest at Biological Park (11° 30' 369" N - 92° 42' 212" E), Chidiyatapu, South Andaman, on 7th December 2003. A single record of this species was reported from the Andaman Islands by Ali and Ripley (2001).

New bird records

In the present avifaunal survey, conducted throughout the Andaman Islands (five major and 52 outer islands) during 2003-2004 and 2007-2008, a total of 10 bird species were found as new records, not recorded earlier from these Islands based on various ornithological studies conducted by Sankaran (1998), Vijayan (1999), Vijayan *et al.* (2000), Ali and Ripley (2001), Yahya and Zarri (2002). However, the status of these birds is not clearly understood (**Table 3.6**). They are as follows:

RED-FOOTED BOOBY *Sula sula rubripes*:

Three individuals were sighted foraging in the sea near the Henry Lawrence Island (12° 08' N - 93° 02' E), South Andaman, on 15th February 2004. The Red-footed Booby is known to breed on many tropical islands in the Indian Ocean. According to Jerdon (1864), occasionally seen in the Bay of Bengal, where Blyth later described it as 'common'. However, in the British Museum there is only a single specimen actually collected in the Bay of Bengal (Ali and Ripley 2001). This appears to be the first record of its occurrence in the Andaman Islands.

EASTERN GREY HERON *Ardea cinerea rectirostris*:

A single bird was sighted in the coastal backwater (10° 47' 16.6" N - 92° 24' 43.5" E) of Jackson Creek, Little Andaman on 18th March 2008 at 1700h. Resident bird in India, mainly breeds at vale of Kashmir and is not recorded from Andaman and Nicobar Islands. It is found in inland water-jeels, marshes, rivers, also tidal creeks, estuaries, mangrove swamps, coastal back waters, and rocky offshore islets. The extralimital distribution is in the Middle East, Burma, Thailand, Indochina, Malaysia, East Siberia, East China, Japan, Formosa and Hainan (Ali and Ripley 2001).

BLACK BITTERN *Ixobrychus flavicollis* (Least Concern; BLI 2009):

Three sightings were made during the study period. A single bird, first recorded in the littoral forest at Table (Excelsior) Island Sanctuary (13° 26' 0.5" N - 93° 05' 43.4" E), Ariel Bay, North Andaman, on 20th September 2004. Three individuals were sighted at the mangrove in Dhaninalla, Cuthbert Bay turtle sanctuary (12° 37' 57.2" N - 92° 57' 26.5" E), Middle Andaman, on 14th October 2004. A single bird was recorded in Moist deciduous forest in Porlob Island (10° 47' 16.6" N - 92° 24' 43.5" E), Middle Andaman, on 17th October 2004. The Black Bittern is known for its extralimital

distribution in Myanmar, Thailand, Malaysia, Indochina and Greater Sunda Island (Ali and Ripley 2001). This presumably is the first record of its occurrence in the Andaman Islands.

SOOTY TERN *Sterna fuscata nubilosa*:

A single bird was recorded at Cuthbert Bay turtle sanctuary beach (12° 37' 344" N - 092° 57' 513" E), Middle Andaman, on 7th March 2004 along with a foraging flock of Eastern Black-naped Tern. There is no record of occurrence of this bird from the Andaman and Nicobar Islands, but the extralimital records show 'Islands in the Indian Ocean (Mascarene, Seychelles) presumed that it may occur in the Islands of Bay of Bengal (Ali and Ripley 2001). This vagrant (storm-blown?) record of its occurrence in Andaman Islands may be the first record to this region.

MIGRATORY NIGHTJAR *Caprimulgus indicus indicus*

Four individuals of three sightings were made. The first, two individuals were recorded from the littoral forests of Redskin Island (11° 33' 084" N - 92° 35' 135" E; Mahatma Gandhi Marine National Park), South Andaman, on 26th February 2004. The second record was of a single bird in semi-evergreen forests at Anderson Island (12° 48' 184" N - 92° 41' 843" E), North Andaman, on 22nd April 2004 and the third sighting of a single bird from semi-evergreen forests at the place named Chalis Ek (13° 03' 045" N - 92° 59' 374" E) in Ram Nagar, North Andaman, on 16th April 2004. There is no previous record of its occurrence from Andaman and Nicobar Islands.

DAURIAN MYNA *Sturnus sturninus*

Two sightings were made of total nine individuals in the plantation area during the study period. The first, five individuals were sighted at Badabalu (11° 30' 229" N - 92° 42' 116" E), Chidiyatapu, South Andaman, on 14th December 2003. The second, four individuals were recorded at Dugong creek (10° 48' 661" N - 92° 32' 624" E; Tribal Reserve Protected Area), Little Andaman, on 21st January 2004. There are only two definite records of this aberrant straggler from within our limits: a specimen collected in Chitral (head of Turikho Valley, c. 3300 m) from a flock of 17 birds on 16th July 1902 (Fulton, JBNHS 16: 49), and another which flew on board ship in a squall in the open sea between Car Nicobar and Little Andaman Islands on 20th March (Hume, SF 2: 250, footnote) and also said to be an occasional winter visitor to the Nicobar; possibly also to the Andaman Islands (Ali and Ripley 2001).

OLIVE FLYCATCHER *Rhinomyias brunneata nicobarica*

Totally three sightings were made of six individuals from Andaman Islands as of its first record in this region. The first, three individuals were seen in the littoral forest at Reef Island Sanctuary (13° 30' 14.4" N - 92° 52' 24.2" E), North Andaman, on 27th August 2004. The second record of a single bird was seen in the littoral forest at Spike Island Sanctuary (12° 08' 13.7" N - 92° 48' 45.1" E; Jarawa Reserve Protected Area), Middle Andaman, on 23rd October 2004. The third record of two individuals was seen in the semi-evergreen forest at Talabaicha Island Sanctuary (12° 15' 38.8" N - 92° 44' 16.8" E; Jarawa Reserve Protected Area), Middle Andaman, on 23rd October 2004. So far known only as a common winter visitor to the Great and Little Nicobar Islands. Not known to occur north of Little Nicobar, but may be expected in the Andamans (see Butler, JBNHS 12: 401).

TICKELL'S BLUE FLYCATCHER *Muscicapa (Cyornis) tickelliae*

An individual was seen on a *Ficus* tree in moist deciduous/semi-evergreen forest near Sonapahar Reservoir, South Andaman (c. 11°42'-11°43' N; 92°36'-92°38' E) on 19 March 2004 at 0830 h. We observed it for c.12 minutes at a distance of 20 m while it foraged in the area. The blue body, orange-rufous throat and breast, prominent white belly, and the sharp 'tick tick' vocalization accompanied by tail-flicking were diagnostic (RajaMamannan and Vijayan 2009).

GREY-HEADED FLYCATCHER *Culicicapa ceylonensis*

An individual was observed perched on bushes in forest on 12 March 2004 at 0730h near Nayashar Reservoir, Silviculture Division, Sippighat, South Andaman (c. 11°34'-11°04' N; 92°40'-92°40' E). We watched it for c.25 minutes in poor weather and light conditions. Despite poor visibility, the prominent ashy grey on the head, throat and breast, and yellowish belly and rump were diagnostic of this species (RajaMamannan and Vijayan 2009).

BLUE-FRONTED ROBIN *Cinclidium frontale*

A male was sighted at close range in moist deciduous forest at Chidiyatapu, South Andaman (c. 11°30' N - 92°42' E) on 3rd and 4th December 2003. The long graduated tail lacking white, deep blue upperparts, deep slaty blue on the belly and whitish tail coverts were diagnostic (RajaMamannan and Vijayan 2009).

Table 3.6: Status and distribution of the rare (R) and vagrant (V) bird species recorded in Andaman Islands with Synopsis number (Syn. No) by Ali and Ripley (2001).

Syn. No.	Common name	Scientific name	Migratory Status	Region
<u>Rare</u>				
413	Eastern Knot	<i>Calidiris tenuirostris</i>	W	1
437	Great Stone Plover [#]	<i>Esachus magnirostris</i>	LM	1,3,4
544b	Nicobar Pigeon [#]	<i>Caloenus nicobarica</i>	R	1,4
<u>Re-discovered/Vagrant</u>				
377	Eastern Sand Plover	<i>Charadrius asiaticus veredus</i>	V	1
1079a	Pied Cuckoo-shrike	<i>Coracina nigra</i> ? subsp.	S?	4
1552	Assam Great Reed Warbler	<i>Acrocephalus stentoreus amya</i>	M?	1,2
1600	Arctic Leaf Warbler	<i>Phylloscopus bor. borealis</i>	W	1
1732	White-browed Ground Thrush	<i>Zoothera sibirica sibirica</i>	V	1,3
1863	Blyth's Pipit	<i>Anthus godlewskii</i>	V?	3
<u>New Records</u>				
24	Red-footed Booby	<i>Sula sula rubripes</i>	V	3
36	Eastern Grey Heron	<i>Ardea cinerea rectirostris</i>	V	4
58	Black Bittern	<i>Ixobrychus flavicollis</i>	V	1,2
474	Sooty Tern	<i>Sterna fuscata nubilosa</i>	V?	2
671	Migratory Nightjar	<i>Caprimulgus indicus indicus</i>	V	1,3
995	Daurian Myna	<i>Sturnus sturninus</i>	W	3,4
1402	Olive Flycatcher	<i>Rhinomyias brunneata nicobarica</i>	V?	1,2
1442	Tickell's Blue Flycatcher*	<i>Muscicapa tickelliae</i>	V	3
1449	Grey-headed Flycatcher*	<i>Culicicapa ceylonensis</i>	V	3
1682	Blue-fronted Robin*	<i>Cinclidium frontale</i>	V	3

Note: #-near threatened. W-winter visitor, LM-local migrant, R-resident, UC-uncommon, V-vagrant, S-straggler, M-migrant. Region of occurrence: 1-North, 2-Middle, 3-South and 4-Little Andaman. *-published (RajaMamannan and Vijayan 2009).

3.3.3. Habitat-wise status

The accumulation curve of bird species (resident) among the points from different habitats showed the highest number of bird species from littoral and lowest in degraded area. Evergreen and semi-evergreen forests were also harbouring high number of species. In each habitat, accumulation of the species was constant and stable after the 20th point. The present study maximum number of points was in littoral forests and minimum in degraded area. The major disturbed habitats of Forest edge, Plantation and Field scored minimum number of species (**Fig. 3.4**).

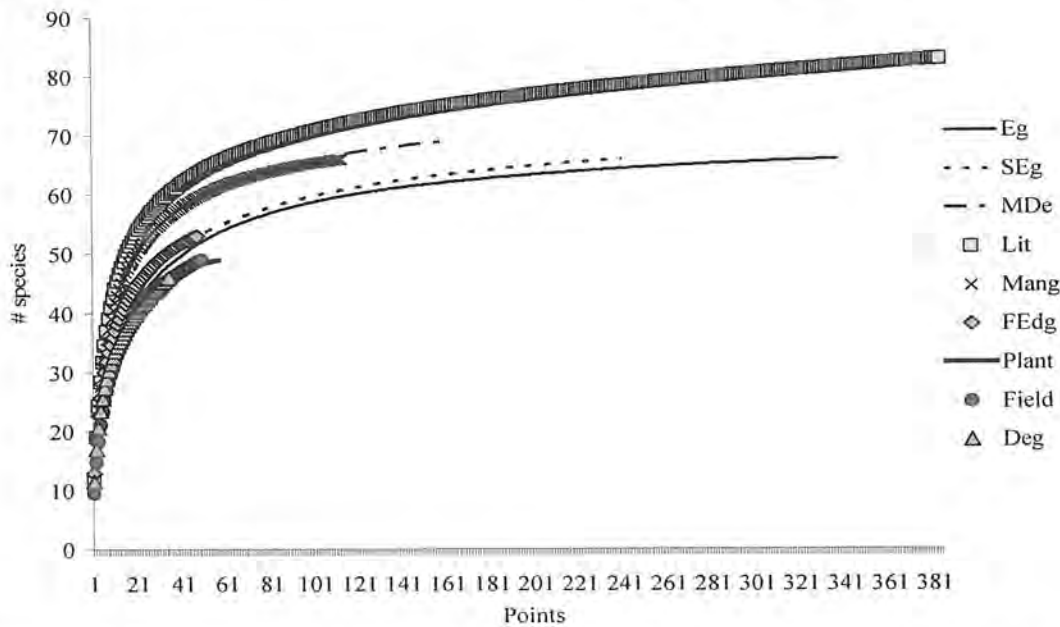


Figure 3.4: Species accumulation curve of birds (resident only) observed in different habitats (excluding wetlands and coast).

Among the total 26487 birds of 153 species, 23325 birds of 102 land/forest dwelling species and 3162 birds of 51 wetland/water species were recorded (**Table 3.7, 3.8, Annexure 3.1**). Apparently the natural forests, namely Littoral, Moist deciduous, Semi-evergreen, Evergreen and Mangrove harboured most land bird species and nevertheless maintained constant number of shared species between the habitats too (**Table 3.7, 3.8**, also see **Chapter: 4.3.4.** of shared species similarities). The highest number of species was recorded in the natural forests of Littoral forest (119) followed by Moist deciduous (90) and Mangrove (86). Though the area surveyed of mangrove was very low the number of species observed was high, whereas in disturbed habitats more number of species (65) was from Forest Edge and Plantation followed by Field area (62) (**Table 3.7, 3.8**).

Of the 56 endemics including subspecies, from natural forests totally 50 species each were recorded from Moist-deciduous and Littoral forests (Table 3.7, 3.8) followed by Semi-evergreen (47) and Evergreen (46), whereas in Disturbed habitats Plantation (47) harboured the maximum and minimum from Coastal (18). The Status of species endemics showed maximum in littoral (17) and minimum from the Coastal (4) region. Of the 16 endemics of forest birds 15 were recorded from Semi-evergreen, Moist deciduous and Littoral forests. However, the endemic species of Andaman Longtailed Nightjar *Caprimulgus andamanicus*, Andaman Hawk-owl *Ninox affinis*, and Andaman Cuckoo Dove *Macropygia rufipennis* were recorded from other habitats.

Table 3.7: The richness of forest/land and wetland/water birds observed in different habitats. (Habitat details see Table 3.2)

Habitat code		Forest/Land birds				Wetland/Water birds				Overall species richness (A+B)	Total endemic species observed
		Endemic birds (incl. subspecies)	Species endemic	Non-endemic sp.	Total (A)	Endemic birds (incl. subspecies)	Species endemic	Non-endemic sp.	Total (B)		
Natural forests	E	31	13	25	69	1	1	9	11	80	46
	SE	30	15	26	71	1	1	10	12	83	47
	MD	32	15	25	72	2	1	15	18	90	50
	L	31	15	34	80	2	2	35	39	119	50
	M	28	12	22	62	2	2	20	24	86	44
	FE	24	11	17	52	1	0	12	13	65	36
Other habitats	P	25	12	15	52	0	0	6	6	58	47
	F	21	9	19	49	0	0	13	13	62	30
	D	20	9	18	47	1	1	8	10	57	31
	W	13	8	15	36	0	1	17	18	54	31
	C	14	3	6	23	0	1	15	16	39	18
Total		35	16	51	102	3	2	46	51	153	56

The bird abundance in different habitats showed that Littoral forest harboured the maximum (7512) number of individuals and the minimum was in wetland (628). However, the natural forest of Evergreen (948) type showed more number of species endemics, followed by Semi-evergreen (770), Littoral (694) and Moist-deciduous (497) forest (Table 3.8).

Table 3.8: The abundance of forest/land and wetland/water birds observed in different habitats. (Habitat details see Table 3.2)

Habitat code	Forest/Land birds			Wetland/Water birds			Abundance		% endemic species
	Endemic birds (incl. subspecies)	Species endemic	Non-endemic species	Total (A)	Endemic birds (incl. subspecies)	Species endemic	Non-endemic species	Total (B)	
E	2915	948	550	4413	8	10	41	59	86.78
SE	2605	770	401	3776	1	18	32	51	88.69
MD	1847	497	301	2645	5	7	244	256	81.21
L	4687	694	1083	6464	21	147	880	1048	73.87
M	1176	209	459	1844	3	7	211	221	67.55
FE	669	109	256	1034	3	-	60	63	71.19
P	827	163	163	1153	-	-	24	24	84.11
F	416	79	323	818	-	-	66	66	56
D	368	56	250	674	1	1	91	93	55.54
W	159	76	146	381	-	139	108	247	59.55
C	53	6	64	123	-	450	584	1034	43.99
Total	15722	3607	3996	23325	42	779	2341	3162	76.08

Considering only forest or terrestrial birds among the habitats totally 24 species were observed as specialists. The trophic group of insectivore was found to have the maximum number of specialists (13), especially in littoral forests (6). Among the eleven habitats classified, only seven harboured the habitat specific species. Maximum 10 species was in littoral and minimum only one species in field and degraded (**Table 3.9**).

Table 3.9: Details of bird species observed (guild-wise) only in a particular habitat.

Habitat (code)	# species	Trophic group					
		Insectivore	Carnivore	Granivore	Nectarivore	Omnivore	Piscivore
Evergreen (E)	3	3	-	-	-	-	-
Semi-evergreen (SE)	2	2	-	-	-	-	-
Moist deciduous (MD)	5	1	1	-	1	2	-
Littoral (L)	10	6	-	1	-	1	2
Plantation (P)	2	-	-	-	-	2	-
Field (F)	1	1	-	-	-	-	-
Degraded area (D)	1	-	-	-	-	1	-
Total	24	13	1	1	1	6	2

3.3.4. Guild-wise and Migratory status

Total 16 orders comprising 153 species, in which 75 species were residents, 74 migrants, 2 vagrants and others are of unknown status were found. The order Passeriformes scored the maximum 32 residents, 20 migrants and 2 vagrants. In the trophic category insectivores formed the dominant group with 79 species and nectarivores the minimum followed by vegetarian mainly water birds under Anseriformes (4) and Gruiformes (1) (**Table 3.10**).

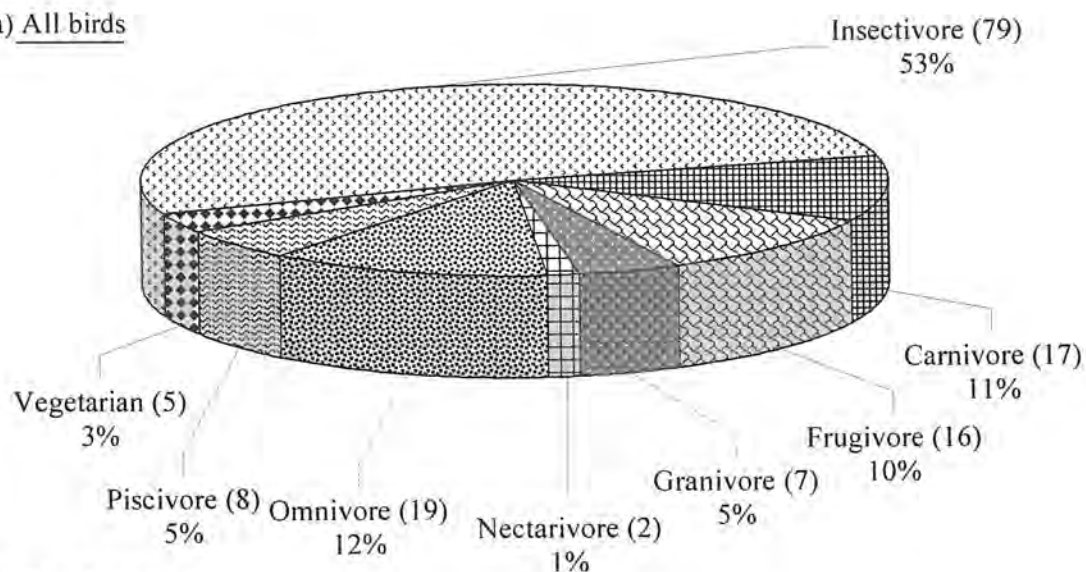
Overall resident and migratory bird species richness (excluding waders) showed the dominance of insectivore species (**Fig. 3.5**). The maximum of insectivore species was from littoral (34) and minimum of Nectarivore in all. Though the number of species was low in Frugivore (16) they were most abundant in all natural forests, especially

maximum in littoral 3092 (of 14 species) followed by Insectivore and Carnivore (**Fig. 3.6**) whereas in the coast Piscivore and Vegetarians were abundant.

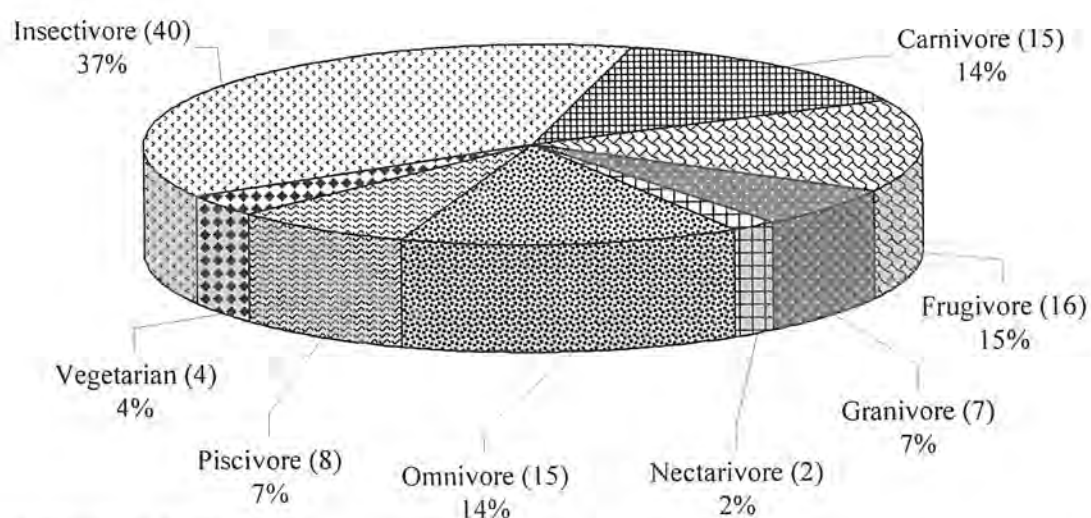
Table 3.10: Classification of the residential and trophic group-wise status of the avifauna recorded in Andaman islands.

Order	Species status			Total	Trophic group							
	Resident	Migrant	Vagrant		Insectivore (I)	Carnivore (C)	Frugivore (F)	Granivore (G)	Nectarivore (N)	Omnivore (O)	Piscivore (P)	Vegetarian (V)
Passeriformes	32	20	4	56	35	-	5	2	2	12	-	-
Charadriiformes	4	24	1	29	23	-	-	-	-	1	5	-
Coraciiformes	8	2	-	10	4	4	-	-	-	-	2	-
Ciconiiformes	1	8	-	9	1	7	-	-	-	-	1	-
Columbiformes	7	2	-	9	-	-	6	3	-	-	-	-
Cuculiformes	3	5	-	8	6	1	1	-	-	-	-	-
Falconiformes	6	-	-	6	-	5	-	-	-	1	-	-
Gruiformes	2	4	-	6	2	-	-	2	-	1	-	1
Anseriformes	1	3	-	4	-	-	-	-	-	-	-	4
Psittaciformes	3	1	-	4	-	-	4	-	-	-	-	-
Apodiformes	2	1	-	3	3	-	-	-	-	-	-	-
Caprimulgiformes	-	2	-	2	2	-	-	-	-	-	-	-
Galliformes	2	-	-	2	-	-	-	-	-	2	-	-
Pisciformes	2	-	-	2	2	-	-	-	-	-	-	-
Strigiformes	2	-	-	2	-	-	-	-	-	2	-	-
Pelecaniformes	-	1	-	1	1	-	-	-	-	-	-	-
Total	75	73	5	153	79	17	16	7	2	19	8	5

a) All birds



b) Resident birds



c) Migratory birds

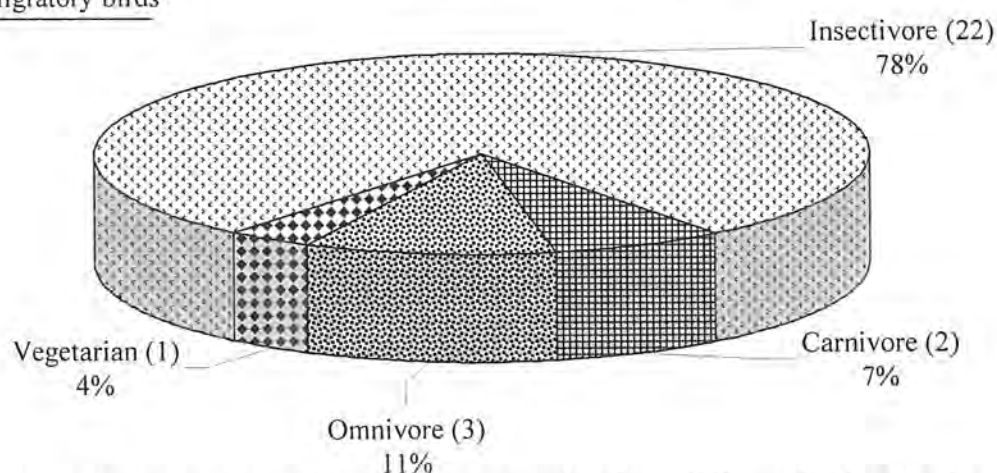


Figure 3.5: Guild structure of the avifauna recorded from different habitats in the Andaman Islands (number of species in the community in parenthesis).

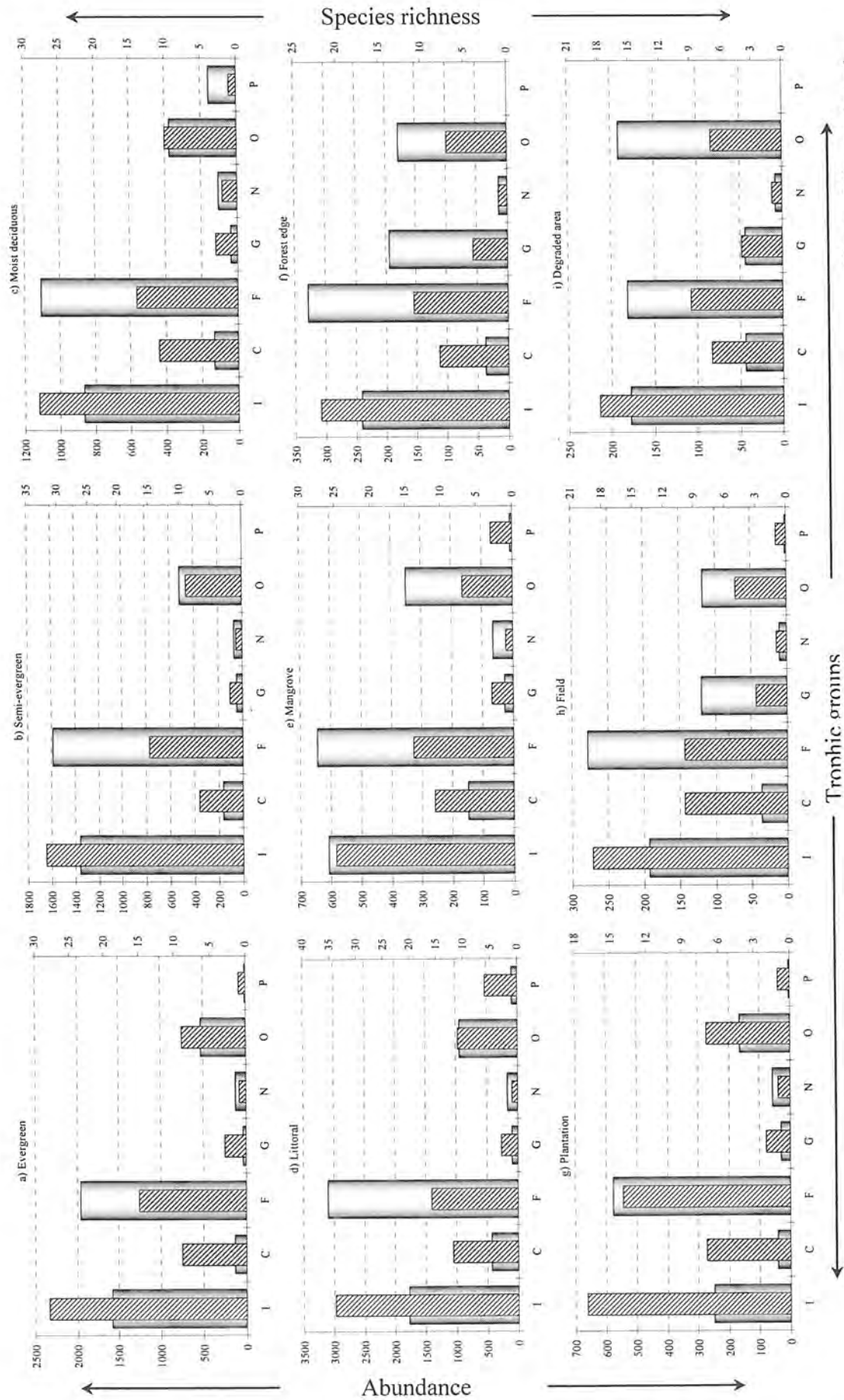


Figure 3.6: continued ...

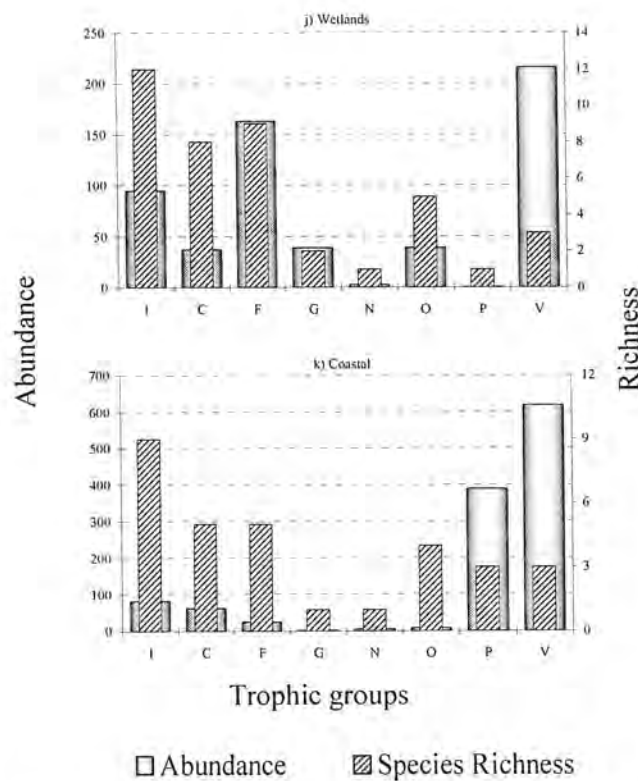


Figure 3.6: Guild structure: species richness and abundance of the resident bird species in the forested (a, b, c, d, e, f, g, h, i) and wetland habitats (j, k). (Guild /Trophic group abbreviation details in Table 3.10).

3.3.5. Systematic status

The total of 153 species observed in Andaman Islands belong to 36 families in 16 orders. Of these 16 families, Passeriformes (36.6%) represented the most number of species in the community followed by Charadriiformes (18.95%) and Coraciiformes (6.54%). Of 56 subspecies and 18 species endemics, Passeriformes had seven species and 25 subspecies endemics contributing to the maximum number of endemics followed by Coraciiformes (7). Families of Muscicapidae, Campephagidae, Alcedinidae, and Columbidae had five of subspecies endemics in the community (Table 3.11). In the phylogenetic classification a total of twenty orders of birds (Aves) in the world are classified under nine divisions (Cracraft 1981, Annexure 3.1). However, the phylogenetic relationship of birds recorded in the Andaman Islands by order (16) < family (36) < species (153) represents eight divisions with 16 orders except the division 2: order Palaeognathiformes, which is not related to one another in the bird community (e.g. Mayr and Amadon 1951, Wetmore 1960, Storer 1971) a reported by Cracraft (1981) (Table 3.11, Annexure 3.1).

Table 3.11: Systematic classification of birds recorded in Andaman Islands during the study period. (Phylogentic classification: Division of orders= I, III, IV, V, VI, VII, VIII, IX).

Order	# species (%)	Family	# species	# end. sp.	# sp. end.	# non-end.
1. Passeriformes ^{IX}	56 (36.60)	1. Muscicapidae	19	5	1	14
		2. Campephagidae	5	5	1	0
		3. Sturnidae	5	3	1	2
		4. Motacillidae	4	-	-	4
		5. Dicuridae	3	2	1	1
		6. Oriolidae	3	2	-	1
		7. Ploceidae	3	1	-	2
		8. Corvidae	2	1	1	1
		9. Hirundinidae	2	-	-	2
		10. Laniidae	2	-	-	2
		11. Nectariniidae	2	1	-	1
		12. Pycnonotidae	2	2	1	0
		13. Artamidae	1	1	-	0
		14. Dicaeidae	1	1	1	0
		15. Irenidae	1	-	-	1
		16. Zosteropidae	1	1	-	0
2. Charadriiformes ^V	29 (18.95)	17. Charadriidae	21	-	-	21
		18. Laridae	7	-	-	7
		19. Burhinidae	1	-	-	1
3. Coraciiformes ^{IX}	10 (6.54)	20. Alcedinidae	7	5	-	2
		21. Meropidae	2	1	-	1
		22. Coraciidae	1	1	-	0
4. Ciconiiformes ^{III}	9 (5.88)	23. Ardeidae	9	-	-	9
5. Columbiformes ^V	9 (5.88)	24. Columbidae	9	5	3	4
6. Cuculiformes ^{VII}	8 (5.23)	25. Cuculidae	8	2	1	6
7. Falconiformes ^{III}	6 (3.92)	26. Accipitridae	6	4	1	2
8. Gruiformes ^V	6 (3.92)	27. Rallidae	6	2	1	4
9. Anseriformes ^{IV}	4 (2.61)	28. Anatidae	4	1	1	3
10. Psittaciformes ^{VI}	4 (2.61)	29. Psittacidae	4	3	-	1
11. Apodiformes ^{VIII}	3 (1.96)	30. Apodidae	3	2	-	1
12. Caprimulgiformes ^{VIII}	2 (1.31)	31. Podargidae	2	1	1	1
13. Galliformes ^{IV}	2 (1.31)	32. Phasianidae	1	-	-	1
		33. Megapodiidae	1	-	-	1
14. Piciformes ^{IX}	2 (1.31)	34. Picidae	2	2	1	0
15. Strigiformes ^{III}	2 (1.31)	35. Strigidae	2	2	2	0
16. Pelecaniformes ^I	1 (0.65)	36. Sulidae	1	-	-	1
Total			153	56	18	97

3.4. DISCUSSION

The present study focused on the distributional overview of the birds of all regions in Andaman Islands, which although based on incomplete information, was intended to detect general patterns in the region's avifauna. Importantly the present work is intended to stimulate renewed attention to the region, especially by the ornithologists working on the island avifauna and by the workers employing new techniques such as molecular genetics, phylogenetic systematics, and geographic information systems. With the information available, however, it is possible to discuss the importance of the regions and habitats for the knowledge of Andaman Island birds and their conservation. The bird community study of the Andaman Islands in combination with extensive investigations has been done by Vijayan *et al.* (2005) by sampling each habitat and region, including most of the islands: North, Middle, South and Little Andaman. Some of the earlier studies like a review of the status of birds in Andaman and Nicobar Islands (Sankaran and Vijayan 1993) the exhaustive endemic bird studies by Sankaran (1998) and Vijayan (1999) and Vijayan *et al.* (2000) dealt with the status of the major bird species with special reference to the endemics. The few other studies dealt with bird species richness (Chandra and Rajan 1996, Davidar *et al.* 1997) with island area (Davidar *et al.* 1993, 1995), and habitat diversity in a few islands (Davidar *et al.* 2001).

The high species richness found in all regions is because of a variety of habitats and a large extent of natural forests with less disturbance. But increase in survey effort, especially in Middle Andaman might have increased the output. Although the accumulation curve has reached almost asymptotic richness of species still it showed possibilities of increase. Since the species richness provides a fundamental measure of community status in quantitative assessments of biological diversity, it is used in the development of ecological theory (MacArthur and Wilson 1967, Hubbell 2001) and in applied problems focused on the conservation of biodiversity (Vetaas and Grytnes 2002, Grytnes 2003).

It is very important to understand the patterns of distribution, diversity, and endemism (Odum 1996, Wilson and Comet 1996a, b, Cody 2001, Vetaas and Grytnes 2002, Grytnes 2003, Matlock and Edwards 2006) in the birds of Andaman Islands in 11 biotic regions or habitats with the acquired knowledge of the forest structure as suggested by Vijayan *et al.* (2005) for bird diversity conservation in these islands.

Many resemblances were apparent; species richness was concentrated in the natural habitats of Littoral, Mangrove, Moist-deciduous, Semi-evergreen and Evergreen forests, species endemic to the entire region were also found in all the natural habitats, but much less in the disturbed area.

The methods and measures used in this study are different and point count surveys in most of the islands are highly time dependent. The sampling was in point counts covering a total area of 429.26 ha, including 5 major and 52 outer islands where 1650 point stations were counted for bird study. A further problem could be the repeated counts in the points for birds with detailed quantitative observations of birds were from the major islands but not from most of the outer islands. Several species may be found to have a wider distribution in most of the outer islands, if covered more intensively.

Regional Status of avifauna

Avifauna of the Andaman Islands is unique in several ways, especially because of the geographic location and, avifaunal data suggests that most of the area all over the island may qualify as important endemic bird regions for conservation. During the study period one of the globally threatened and vulnerable Narcondam Hornbill *Aceros narcondami*, was not recorded as it is confined to the tiny island of Narcondam (area of <7 km²) which was not surveyed. Andaman Barn Owl *Tyto deroepstorffi* and Hume's Hawk Owl *Ninox obscura* were not recorded in any of the habitats as it needed wide range of nocturnal survey across the island habitats. Although present study recorded most of the endemic birds across the regions special effort should be devoted looking for nocturnal endemic birds (e.g. Andaman Scops Owl *Otus balli*, Andaman Hawk Owl *Ninox affinis*, Andaman Barn Owl *Tyto deroepstorffi* and Hume's Hawk Owl *Ninox obscura*) and some rare non-endemics (Great Stone Plover *Esachus magnirostris*, Nicobar Pigeon *Caloenus nicobarica*).

The bird species detected in Andaman Islands during the present study is 153 which represented 66.52% from the overall 237 bird species reported from Andaman and Nicobar Islands by various studies conducted by Sankaran (1998), Vijayan (1999), Vijayan *et al.* (2000), Yahya and Zarri (2002), RajaMamannan and Vijayan (2009). Although it is assumed that only 11.81% of 1295 birds from the Indian subcontinent (Inskipp *et al.* 1996) occur in the Andaman Islands, they are very rich in endemism consisting of 63 endemics including subspecies (Vijayan *et al.* 2000).

Rare and Vagrant birds

Records of the travellers from Hume (1873) and Kloss (1903) have the sightings and description of many birds in Andaman and Nicobar Islands. Several bird surveys conducted by Bombay Natural History Society and the Zoological Survey of India in the last few decades (Abdulali 1964, 1965, 1967a, 1967b, 1971, 1976, 1977, 1978; Das 1971, Dasgupta 1976, Ripley 1982, Ali and Ripley 2001) have documented the birds of these islands and compilation by Sankaran and Vijayan in 1993 listed 214 bird species and subspecies including 63 endemics in the Andaman Islands. An addition of 12 species was recorded during a study from 1994 to 1998 (Sankaran 1998, Vijayan 1999, Vijayan *et al.* 2000). Fairy Tern or Indian Ocean White Tern (*Gygis alba*) was later reported (Yahya and Zarri 2002) as a new record from Narcondam Island, Andaman Islands.

Andaman Islands have inimitable costal ecosystem, the platform for many waders and wetland birds which represent 51 species from the present study. Of the 153 avian forms recorded, 73 are not resident to the Andaman Islands. Since the publication of last complete list of birds of Andaman and Nicobar Islands (Sankaran and Vijayan 1993), an addition of ten birds which are new to the area, as well as a number of rare vagrants and passage migrants, have been noted in the islands, but have not been recorded in ornithological literature of the area. Hence, the total number of species and subspecies of birds recorded in Andaman Islands alone now stands at 237. These might have gone unrecorded for lack of extensive surveys in the right season of the year.

Species status and distribution of a total of twenty rare, secondly recorded and new birds from the Andaman Islands are discussed in the results by reviewing the available ornithological literature. Among the ten new birds, only three were confirmed literally such as Tickelle's Blue Flycatcher *Muscicapa (Cyornis) tickelliae*, Grey-headed Flycatcher *Culicicapa ceylonensis* and Blue-fronted Robin *Clinclidium frontale* (RajaMamannan and Vijayan 2009); perhaps the status of other rare, vagrant or passage migrants and winter visitors needs to be confirmed in these islands (RajaMamannan and Vijayan *under preparation*). Further, three new birds which were discussed pertinent to their closest observation from Southeast Asia to the Andamans obtained from available literature, others were discussed in the results with the closest point of the species range to the South Andamans, namely 1) Tickell's

Blue Flycatcher *Muscicapa (Cyornis) tickelliae*: was recorded in Burma (Myanmar; c.600 km), Malaysia (1100 km), Indonesia and Philippines (Ali and Ripley 2001) and also in Bangladesh (Clements 2000). 2) Grey-headed Flycatcher *Culicicapa ceylonensis*: Deignan (1947) reported this species from Sumatra (c.720 km) and Malaya (c.250 km) with the closest point of the species range to the south Andaman Islands. 3) Blue-fronted Robin *Cinclidium frontale*: The closest previous records of the species is c.1,600 km away, represented by a few isolated records from Assam, Mizoram and Tripura in north-east India (Blyth 1842, Anon. 1992, Redman 1992, Grimmett *et al.* 1998, Kazmierczak and Van Perlo 2000, Ali and Ripley 2001) and one male from Nagaland in February 2004 (Choudhury 2005).

Habitat-wise status

Andaman Islands are a site of high bird diversity especially in endemic species. Of the approximately 227 species of birds recorded in these Islands from several opportunistic surveys, the status of the resident birds needs confirmation (Sankaran and Vijayan 1993). The species accumulation curve showed the highest number in littoral forest, the reason for which might be that maximum points were covered here (see Fig. 3.4). The noticeable amount of forest birds was recorded from littoral (6464) followed by evergreen (4413) and semi-evergreen (3776) and therefore these natural forests are most important to maintain the diversity of birds in different islands. Other natural forests such as evergreen and semi-evergreen, although sampled in proportion to the availability (see also Fig. 3.1, 3.2) showed lower species richness mainly because of the difficulty of finding the species in dense vegetation as found in many other studies (Vijayan *et al.* 2005).

Andaman Islands are unique in having healthy populations of evergreen species considered uncommon or rare in other habitats (eg. Andaman Green Imperial Pigeon *Ducula aenea andamanica*, Andaman Red-whiskered Bulbul *Pycnonotus jocosus whistleri*). At the same time, some small population of the species with conservation status, 'Near Threatened' is also present (Andaman Wood Pigeon *Columba palumboides*, Andaman Cuckoo-Dove *Macropygia rufipennis andamanica*, Andaman Tree Pie *Dendrocitta bayleyi*). This is again dealt in detail in the **Chapter 6**.

Overall, the present study has shown the importance of mangrove and moist deciduous forest by hosting most forest or land birds in these islands. However, the

evergreen and semi-evergreen habitats also have given more input to the diverse island avifauna. This is because of most of the Islands are fringed by dense growth of mangroves (IIRS 2003) and most of the southern part of Middle Andaman and part of South Andaman is protected under *Jarawa Reserve Protected Areas* (JRPA's), notably the forest cover in the Andaman Islands showed more than one third of moist deciduous and one third shared by semi-evergreen and mangrove and the rest are in very less land cover (see **Chapter 2**). The present study has documented the absence of many forest and wetland birds from forest edges, plantation, field and degraded areas which indicates the effect of anthropogenic pressure on habitats in many islands. It is further presumed that the avian community diversity is related to vegetation complexity (e.g. MacArthur and MacArthur 1961, MacArthur 1964, Karr and Roth 1971, Wilson 1974, Roth 1976). This prompts the prediction that communities in similar habitats should be similar with respect to species richness and composition, population density, standing crop, community energy requirements, and feeding guilds (Roth 1976).

The generalist species among the habitats was constant. Though the maximum number of habitat specific species (specialists) were found only from littoral forest, most of the littoral forest had scattered distribution of smaller evergreen trees occurring with the fewer deciduous trees forming the dominant canopy. There are numerous shrubs and where the under growth is light, maritime grasses and surface creepers are conspicuous binding the sand, whereas in depressions, which are swampy usually with saline water, the tidal species are poorly developed with a dense under growth, if the water is fresh, tall grasses occur. Possibly this compound environment can harbour more specialists. Out of 24 specialist species 13 were insectivores and the littoral forest had the maximum of 10. Many of the *tsunami* devastated islands have lost their valuable habitats of littoral and mangrove forests and 85 to 95% of the shrubs under the littoral vegetation have vanished. This may adversely affect avifaunal richness in this habitat. Though the maximum effort or area was surveyed in the natural forests the disturbed forests also represented most number of species in the community. However, many of the species which were found from disturbed forests are shared with natural habitats due to nearness and their capacity of energy (food and shelter) available system (Scheiner and Rey-Benayas 1994, Hawksworth and Katlin-Arroyo 1995).

Guild-wise and migratory status

The most dominant orders Passeriformes and Charadriiformes had the majority of insectivore species. Though the number of species was high from the insectivores followed by omnivores, carnivores and frugivores, abundance was high for frugivores. Some of the studies from low elevation evergreen and dry deciduous habitats have highlighted the importance of floral impact on the bird diversity, correlation between vegetation and birds, mostly the frugivorous species (Corlett 1998). In India Vijayan (1975), Balasubramanian and Bole (1993), Ganesh (1996), Balasubramanian (1996), Jayson and Mathew (2003), and Datta and Rawat (2003) focused on bird-plant interactions in different parts of the country. The tree species, their diversity, density, and the vegetation complexity, and resource exploitation pattern have a direct impact on the wildlife (Willson 1974). Hence, the studies on the vegetation structure, phenology and abundance of flowers and fruits may give better understanding of bird ecology (MacArthur and MacArthur 1961).

The vastness of Andaman and Nicobar Islands and the variety of avifauna it contains overwhelm any ornithologist with colours, fascination and patterns. Contrary to superficial appearances, this diversified archipelago is a complex mosaic of islands of varying sizes which vary from isolated forests with more or less same vegetation. The avifauna of these islands represents a snap shot of endemism in the Southeast Asia region and the biogeographic value of these islands. This diversity takes these island avifaunal communities one by one and delves back into their distribution to explain why and how they may have diversified in different habitat as they have and thus the reason why the community is there.

Systematic status

It is remarkable that, with the possible exception of several avifaunal studies from Andaman and Nicobar Islands, there has been no comprehensive attempt to present phylogenetic classification of the higher avian taxa. The present avian classifications to the extent that they are based on overall (phonetic) similarity or on elevating morphologically distinct taxa to ranks higher than those of their close relatives, where the twenty orders were classified in to nine divisions and the families of each order were arranged into taxa seem best to express their relationships phylogenetically (Cracraft 1981). According to the view of Cracraft (1981) most avian orders (say, of

Mayr and Amadon 1951, or of Wetmore 1960) are monophyletic, but that most hierarchical arrangements of taxa within orders are not. The reasons for this are not difficult to identify (Cracraft 1972, 1980): it has resulted from the attempts of avian systematists to cluster taxa on the basis of overall (or weighted) similarity and to bestow high rank on taxa that are morphologically divergent compared to their closest relatives. More specifically, systematists have not partitioned similarity into its primitive and derived components and clustered using only the latter (Cracraft 1981). The present study may add information for development of the phylogenetic classifications, based on the avian history of these islands.

3.5. SUMMARY

- A total of 153 species with 56 endemics including subspecies was recorded.
- Birds were counted at 1650 points in 254 locations covering various habitats. More sampling efforts from South Andaman (873 point count stations in 116 sites) resulted in maximum percentage of species of 82.53 followed by North Andaman (455 points from 76 sites) 71.90, Little Andaman (200 points in 33 sites) 62.75 and Middle Andaman (122 points in 29 sites) 52.29.
- The percentage of endemic species recorded was the highest in North Andaman (92.86) followed by South (91.07), Little (80.36) and Middle (78.57) Andaman.
- Overall, the study showed that mangrove and moist deciduous habitats harboured most of the forest or land birds in these islands. However, the evergreen and semi-evergreen habitats also have given more input to the diversity of island avifauna.
- Twenty rare or vagrant species were recorded of which 10 were new to Andaman Islands. About 50% of birds recorded were resident; 53% of birds were insectivores. Passeriform birds dominated the area (37%).
- The generalist species among the habitats was constant. The maximum number of habitat specific species (specialists) was found only from littoral forest (10). Among the 24 specialists species 13 were insectivores and the littoral had the maximum of 6.

CHAPTER FOUR

STRUCTURE OF BIRD COMMUNITIES

4.1. INTRODUCTION

In recent decades, most of the studies on bird communities have been conducted in temperate forests (eg. Holmes *et al.* 1986, Wiens 1989a, Thiollay 1994, Robinson *et al.* 2000, Cody 2001, Wesolowski 2002) and relatively less in tropical forests (eg. Johnsingh and Josua 1994, Chettri *et al.* 2001, Jayson and Mathew 2002, Laiolo 2003, Vijayan and Gokula 2006, Blake 2007). Indian subcontinent is known for high bird species diversity and richness and whose species taxonomy, distribution and their general characteristics are well documented in India (Jerdon 1862–1964, Ali and Ripley 1983, 2001). However, very little is known about bird community structure and their dynamics in India (Daniels 1989, Khan *et al.* 1993, Johnsingh and Joshua 1994, Shafiq *et al.* 1997).

Often the tropical communities have questioned whether assemblages of birds are organized by species interactions and have begun to show that diverse factors influence the distribution and abundance of species and hence community structure (Holmes *et al.* 1986). The studies on tropical communities by Wallace (1878), MacArthur *et al.* (1966), Ricklefs (1990) state that they are often broadly categorized as being similar to one another because of high diversity and large numbers of rare species. Recently, however, a growing appreciation for the highly patchy nature of organismal distributions in the tropics has suggested that nearby local communities may differ considerably (Diamond 1980, Campbell 1994, Tuomisto *et al.* 1995). The bird species richness, diversity and community composition vary within and between habitats (Wiens 1989a, Johnsingh and Joshua 1994, Cody 2001, Sultana *et al.* 2007). For instance community diversity can be examined by noting the number of species within a single habitat of known area (alpha-diversity), the changes in species composition along a series of habitats (beta-diversity), or the total species richness of a large geographic region (gamma-diversity; Whittaker 1960, 1972). The diversity of breeding birds in a community is closely related to the structure of the vegetation

(MacArthur and MacArthur 1961, MacArthur *et al.* 1962, 1966, Tramer 1969, Karr and Roth 1971, Roth 1976). Hence, evaluating the bird community is an important tool in biodiversity conservation (Kremen 1992, Shafiq *et al.* 1997). Further determinations of bird population in different habitats are central to understanding the community structure and niche relationships (Chettri *et al.* 2001).

The single most important forest type is tropical lowland moist forest with about 70% of threatened forest birds (BirdLife International 2001); 93 % of all avian extinctions since AD 1600 have been of island species, and most endangered avian taxa are island endemics (King 1981). The species with restricted distributional ranges have more chances of becoming endangered or extinct (Lee *et al.* 2005). Although the theory of Island biogeography (MacArthur and Wilson 1967) has been used in general for planning of nature reserves, there is no substitute for a study on the ecology of the species or the community whose conservation is intended (Begon *et al.* 1990). The island ecosystems are being severely threatened because of increasing demands on resources in the islands. Currently over 11% of all bird species in the world, and about 12% in Asia are threatened with extinction and the majority of these are found in tropical forests and islands (Collar *et al.* 1994, Stattersfield *et al.* 1998, Mountfort 1988, Rosenzweig and Clark 1994, BirdLife International 2000, 2001). Since 1600, 103 of the 116 known bird extinctions have occurred on islands (Gaston and Blackburn 1995).

Sankaran and Vijayan's (1993) ornithological work in the Andaman and Nicobar Islands is the most exhaustive to date. In addition, only a few more recent extensive survey reports in Andaman Islands are available (eg. Vijayan 1993, 1996, Vijayan *et al.* 2000, 2005). The present study has added three more species to the list (RajaMamannan and Vijayan 2009). Although bird taxonomy, distribution and their general habitats have been documented (Jerdon 1862-1964, Ali and Ripley 1983, 2001) no attempts are made for bird community studies of Andaman and Nicobar Islands in detail. Hence, the present chapter deals with the following objectives:

- Understand the community structure of birds in different habitats and
- Assess the species distribution and rarity of species along habitat gradients.

4.2. METHODS

4.2.1. Bird Survey

Variable distance point survey method was followed for assessing the bird species richness and abundance (for details see *Chapter 3.2.1. Bird Survey*).

4.2.2. Estimating Species Richness

The major approaches to estimate species richness from the samples were: i) fitting parametric models of relative abundance (log normal distribution), and using the shape of the species abundance to deduce the total species richness, ii) non-parametric estimators and iii) extrapolation of species accumulation or species-area curves (Magurran 2004). However, the non-parametric estimates considered only the forest/land birds and not waders/migrants as the methods precluded adequate counts of them.

Non-parametric methods

Non-parametric methods for estimating the number of species in a community, sampling by individuals are reviewed, in the case that one individual is observed or encountered at a time and classified as to species identity. This concern leads to the non-parametric approaches, which avoids making assumptions about species discovery rates, especially a species accumulation curve was used where the graph of cumulative number of observed species as a function of some measures of sampling effort (Colwell *et al.* 2004). The *individual-based*, which the species are randomly and sequentially recorded one after another within the sampling area and *sample-based* where the survey area is subdivided into smaller sampling units (such as quadrats) and the total number of species is accumulated as a result of successively sampling additional quadrats (Gotelli and Colwell 2001). The non-parametric estimators of species richness were computed in EstimateS by (Colwell 2004) (**Table 4.1**). All richness estimators refer to the kind of nonparametric methods used to estimate species richness as asymptote value of a fitted species accumulation curve obtained from the software used for computing of EstimateS (Colwell 2004, available at <http://purl.oclc.org/estimates>).

The estimators are homologous in that richness is estimated from the preponderance of infrequently occurring species in each sample, i.e. the higher the proportional

Table 4.1: Characteristics of the species richness non-parametric estimators used.

Richness Estimators	Description	Reference
ACE= (Abundance-based Coverage Estimator)	Abundance-based coverage estimator. It is a modification of the Chao & Lee (1992) estimators based on the ratio between rare (less than 10) and common species.	Chao & Lee (1992); Chao <i>et al.</i> (2000); Chazdon <i>et al.</i> (1998) in Colwell (2004)
ICE= (Incidence-based Coverage Estimator)	incidence of the species in each sample	Lee & Chao (1994); Chao <i>et al.</i> (2000); Chazdon <i>et al.</i> (1998) in Colwell (2004)
Chao1= Abundance-based estimator	Abundance-based estimator based on the number of rare species in a sample, i.e., represented by less than 3 individuals.	Chao (1984) in Colwell (2004)
Chao2= (Incidence-based estimator)	Incidence-based estimator. Takes into account the distribution of species amongst samples, i.e., the number of species that occur in only 1 sample ('rare species') and the number of species that occur in exactly 2 samples.	Chao (1984, 1987); Colwell (2004)
Jackknife1 (First-order Jackknife)	First-order Jackknife. Is based on the species occurring only in a single sample.	Burnham & Overton (1979); Heltshe & Forrester (1983) in Colwell (2004)
Jackknife2= (Second-order Jackknife)	Second-order Jackknife. Is based on the species occurring in only 1 sample as well as in the number that occur in exactly 2 samples.	Smith & van Belle (1984) in Colwell (2004)
Bootstrap	incidence of the species in each sample	Smith & van Belle (1984) in Colwell (2004)

abundance of rare species, the greater the probability of encountering more new species with increased sampling effort. The method for determining the best estimator involves visually estimating whether a plot of the estimated number of species for each successively accumulated sampling unit reaches a horizontal asymptote and reduces bias, following which conclusions are drawn regarding the adequacy of the size of the data set and the performance of the estimator, sampling, or a census, is essentially complete if all species are observed “multiple” times or “not a rare” (Colwell and Coddington 1995). It is essential to note that richness estimators do not extrapolate beyond the last sample to estimate richness at an asymptote (Soberon and Llorente 1993). Instead, richness estimators predict richness, including species not discovered in the sample, from the proportional abundances of species within the total sample (Soberon and Llorente 1993, Colwell 2005).

4.2.3. *Species distribution pattern*

In the present study two parametric methods of relative abundance with the greatest potential for estimating species richness are the log normal and log series distributions (Magurran 2004, Henderson and Seaby 2007) has been analysed. To know the rarity of the bird species among the population along habitats, truncated log normal distribution and *Goodness of fit test* was performed.

The k-dominance plot was used to find the cumulative proportion abundance against the log species rank. Chi-square tests were used to determine the patchiness of the species in the given population or bird community (i.e. whether the birds are distributed randomly throughout the samples, aggregated, or uniformly distributed) with *Biodiversity Pro* software (McAleece *et al.* 1997).

4.2.4. *Species Diversity, Equitability and Dominance*

Samples from eleven habitats of the Andaman Islands were scrutinized and computed in the statistical package of *Species Richness and Diversity* (Henderson and Seaby 2007) for bird species diversity (Shanon-Weaver- H'), richness and evenness. The Randomization test (Solow 1993) for significant difference in above diversity between two samples was performed by the statistical package of *Species Richness and Diversity* re-samples 10,000 times from a distribution of species abundances produced by a summation of the two samples. This Randomization test is supported by *Equitability-J* or evenness and compares the observed Shannon-Weaver- H' index

against the distribution of individuals between the observed species, which would maximize diversity.

4.2.5. *Classic Similarity indices*

The Classic Jaccard index, the Classic Sørensen incidence-based (qualitative, presence/absence) index, and the Bray-Curtis index (= "Sørensen quantitative" index) Magurran (1998, 2004) are computed with EstimateS to ascertain the shared species similarity between the habitats. Further Chao's Abundance-based Jaccard and Sørensen indices are performed based on the probability that two randomly chosen individuals, one from each of two samples (quadrats, sites, habitats, collections, etc.), both belong to species shared by both samples (but not necessarily to the same shared species). This approach has been shown to reduce substantially the negative bias that undermines the usefulness of traditional similarity indices, especially with incomplete sampling of rich communities (Chao *et al.* 2005).

4.3. RESULTS

4.3.1. Estimating species richness

A total of 154 bird species were found across the different habitats (see also Chapter Three: 3.3.2), but the resident species alone were used in species estimators. The number of resident bird species observed at a single point across the different habitat varied from 66 to 83 (Table 4.2). There was significant variation in the observed number of species among the point in the habitats (ANOVA, $F_{8, 1418}=189.1$, $p<0.01$). The observed resident bird species richness (cumulative number of species) from different habitats showed the highest in Littoral (83) and lowest in Degraded area (46) (Table 4.2). The number of unseen and missing species in the community, species richness from estimators of Chao1 & 2, Jackknife1 & 2 showed the highest number in Littoral (ranged between 10.97 and 60.5) and lowest in Plantation (ranged between 1.6 and 3.93) and standard deviation of the entire population was also calculated. The estimated species tended to be higher than the observed species richness in all habitats (Table 4.2).

Table 4.2: The observed and estimated bird (resident) species richness recorded in different habitats of Andaman Islands with the computed standard deviation (SD) which represents the entire population.

Habitat	Bird abundance	Species observed	Species Richness estimators			
			Chao 1 ± SD	Chao 2 ± SD	Jackknife 1 ± SD	Jackknife 2 ± SD
E	4369	66	67.60 ± 5.03	67.60 ± 4.65	69.99 ± 7.25	69.01 ± 6.67
SE	3749	66	70.50 ± 6.47	70.50 ± 5.92	71.98 ± 8.26	73.98 ± 8.12
MD	2767	69	73.50 ± 6.58	73.50 ± 6.15	74.96 ± 9.55	76.96 ± 9.42
L	6577	83	143.50 ± 19.07	143.50 ± 18.84	93.97 ± 9.96	103.92 ± 11.29
M	1854	66	68.08 ± 6.63	67.79 ± 5.25	70.96 ± 9.68	69.05 ± 9.67
FE	992	53	55.72 ± 5.88	55.45 ± 8.61	59.85 ± 10.31	57.18 ± 11.27
P	1123	49	50.60 ± 3.67	50.60 ± 4.44	52.93 ± 7.45	52.05 ± 8.30
F	755	49	53.05 ± 7.81	53.05 ± 6.31	57.82 ± 10.88	57.06 ± 11.89
D	646	46	56.08 ± 7.48	60.40 ± 9.41	57.66 ± 10.57	64.40 ± 13.23
Total	22832	104				

Habitat details: E=Evergreen, SE=Semi-evergreen, MD=Moist deciduous, L=Littoral, M=Mangrove, FE=Forest edges, P=Plantation, F=Field, D=Degraded.

The performances of six non-parametric estimators of species richness made for an empirical data set among the habitats produced the smoothed curves which include the rarefaction curve, a statistical expectation of the corresponding accumulation curves, assessed the homogeneity of the samples in all habitats and exclude Chao1 and Chao2, which very much depended on the sample order (**Fig. 4.1a, b, c**).

The estimated number of unseen or missing species in the bird community of Andaman Islands is portrayed in **Figure 4.1a, b, c**. Although the different species richness estimators, namely Chao1 & 2, and Jackknife1 & 2 curves approached plateau which shows the completeness of the sampling except some of the habitats, which showed the asymptote curves with respect to any one of the estimators.

The estimated species richness is constrained by the sampling effort taken in different habitats and in almost all habitats most of the species were encountered in early sampling and the addition of new species was slower. In all habitats estimates from Chao1 & 2 showed the low species richness than Jackknife1 & 2 except in Littoral forests (**Table 4.3**).

Table 4.3: Details of the effort (Point counts) and estimated number of unseen or missing species differences between various species estimators among the habitats in the Andaman Islands (see also **Table 4.2**).

Habitat	# Points surveyed	Species richness estimators	
		Chao	Jackknife
1. <i>Evergreen</i> (E)	338	1.60	3.99
2. <i>Semi-evergreen</i> (SE)	241	4.50	7.98
3. <i>Moist deciduous</i> (MD)	159	1.70	7.96
4. <i>Littoral</i> (L)	384	60.50	10.97 & 20.92
5. <i>Mangrove</i> (M)	114	2.08	4.96
6. <i>Forest edge</i> (FE)	48	2.45	6.85
7. <i>Plantation</i> (P)	58	1.60	3.93
8. <i>Field</i> (F)	50	4.05	8.82
9. <i>Degraded area</i> (D)	35	10.08 & 14.40	18.40
Total	1427		

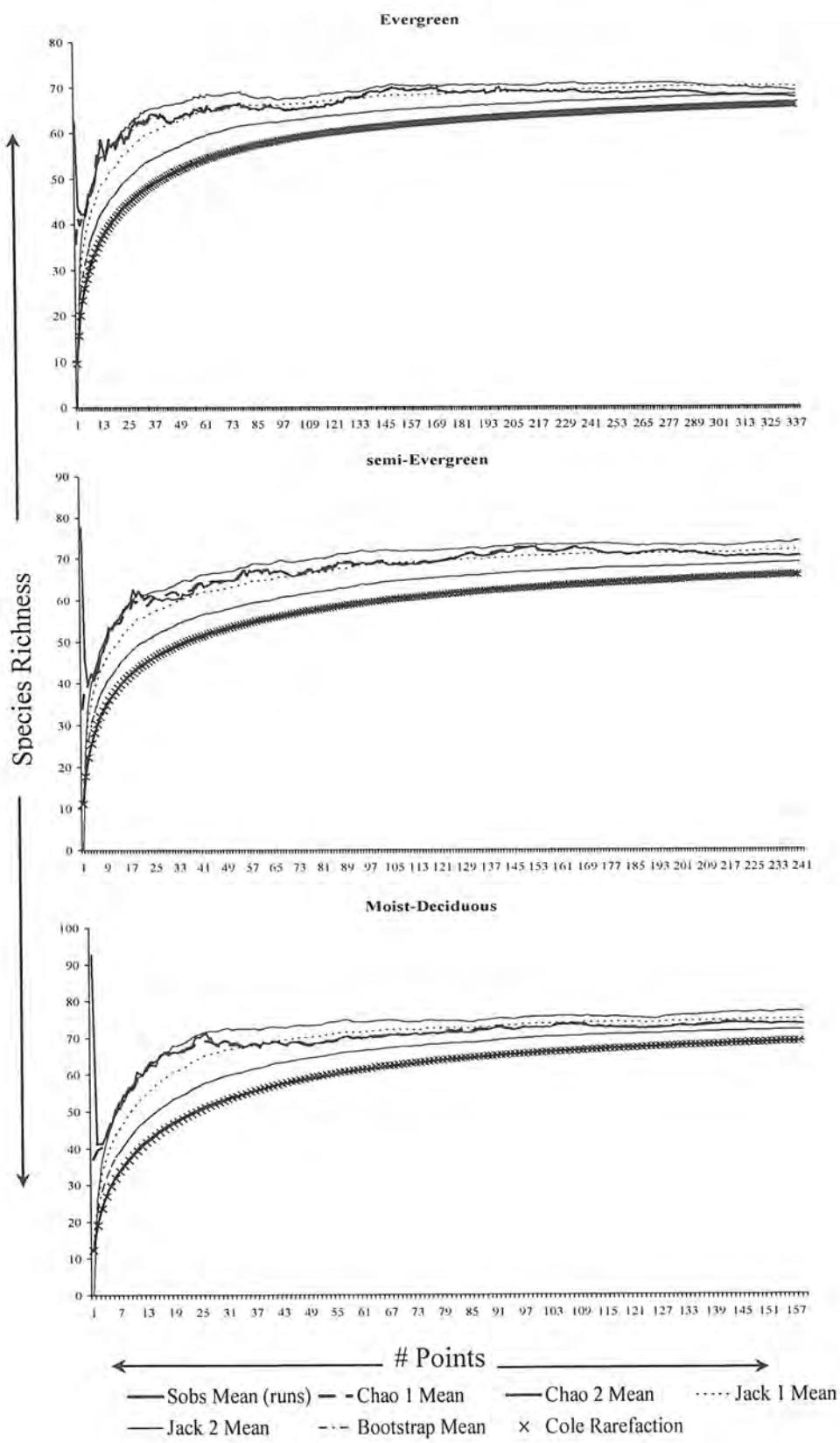


Figure 4.1a: Performance of six non-parametric estimators of species richness for an empirical data set of different habitats in Andaman Islands.

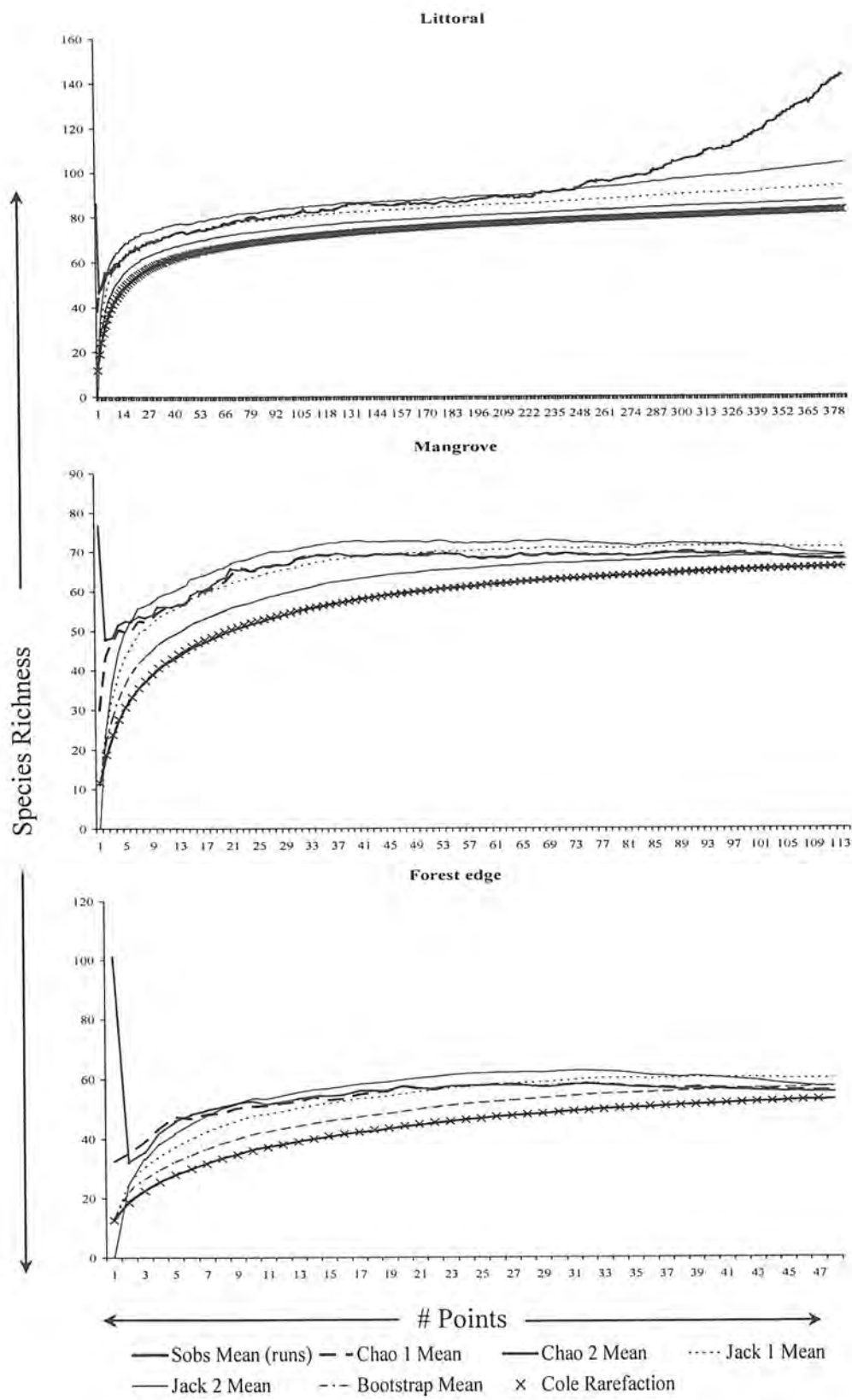


Figure 4.1b: Performance of six non-parametric estimators of species richness for an empirical data set of different habitats in Andaman Islands.

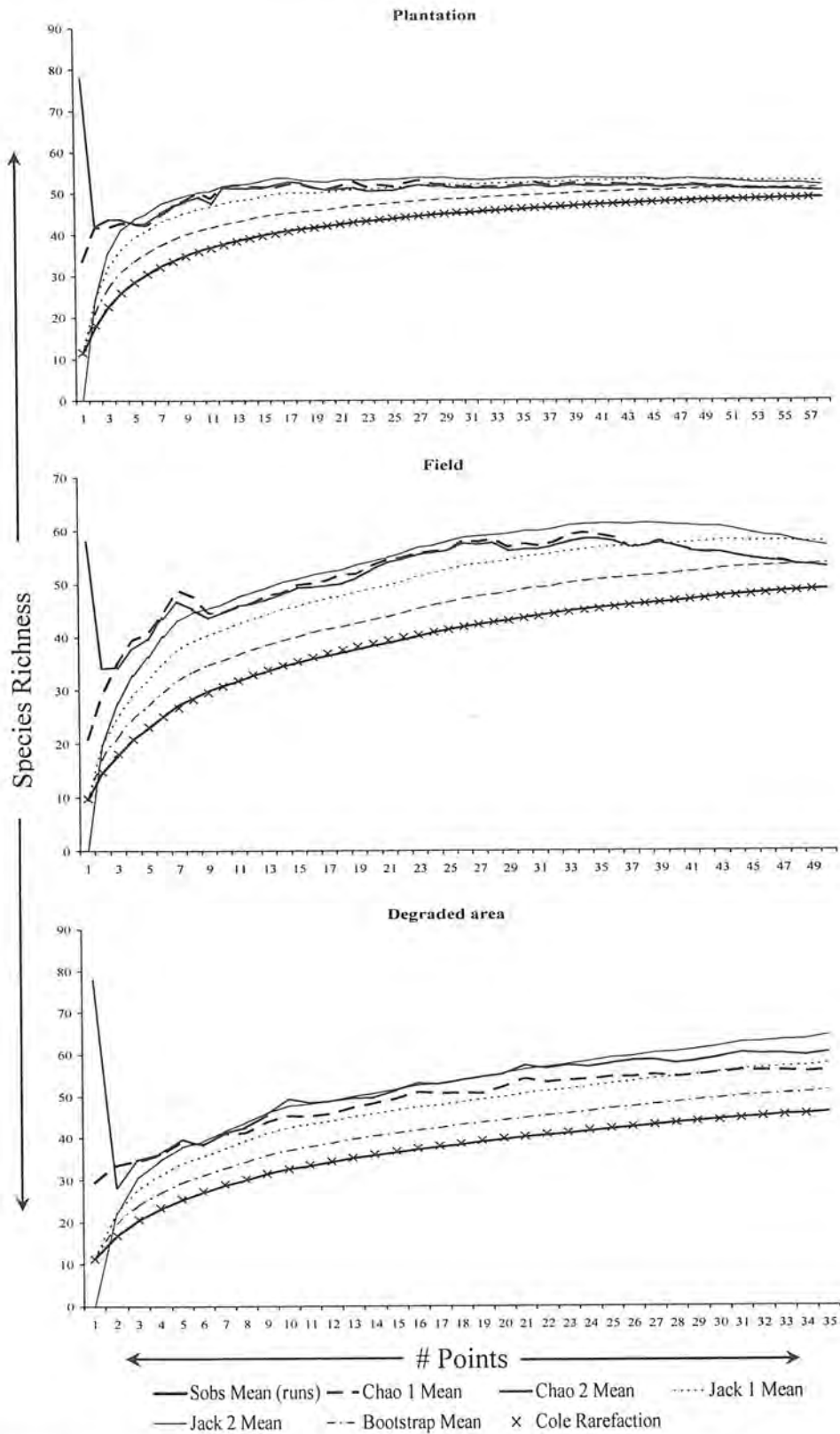


Figure 4.1c: Performance of six non-parametric estimators of species richness for an empirical data set of different habitats in Andaman Islands.

4.3.2. Species distribution pattern

a) Abundance model of the species

Although the data set did not fit geometric and log series models it did fit a truncated log normal distribution, where individuals per species are divided into eleven geometric classes, I=2.5, II=4.5, III=8.5, IV=16.5, V=32.5, VI=64.5, VII=128.5, VIII=256.5, IX=512.5, X=1024.5, XI=2048.5 (Fig. 4.2, 4.3, Annexure 4.1). The results of observed and predicted number of species among the community, species behind the Veil line (the species number missing from the samples), and the lambda diversity statistic: of the estimated species, number divided by the standard deviation was obtained (Table 4.4).

The frequency of all bird species (resident and migrant) observed and predicted number of species from the samples was compared using Chi-square (χ^2) goodness of fit test. The observed and predicted number of species among the habitats showed perfect match in all habitats (Table 4.4).

Table 4.4: Log normal model fit and Chi-square value (χ^2), a comparison between the observed and predicted frequency of species abundance classes in different habitats, Andaman Islands (see habitat details in Table 4.3).

Habitat	# observed species	# predicted species in Community	Species behind the Veil Line	Lambda, Diversity Statistic	Goodness of fit test		
					χ^2	Calculated p-value	Degree of freedom
E	80	83.79	3.79	101.17	14.30	0.07	8
SE	83	88.40	5.40	105.80	9.82	0.28	8
MD	90	95.95	5.95	124.30	6.87	0.44	7
L	119	125.25	6.25	145.53	7.10	0.63	9
M	86	89.19	3.19	132.00	3.68	0.82	7
FE	65	68.96	3.96	104.67	5.77	0.45	6
P	58	59.82	1.82	95.83	5.18	0.52	6
F	62	69.39	7.39	97.93	4.11	0.53	5
D	57	63.79	6.79	89.77	2.81	0.73	5
W	54	63.94	9.94	87.94	2.64	0.76	5
C	39	53.73	14.73	56.15	6.50	0.26	5

Rare species scores

The estimated rare species among the habitats based on the abundance classes was maximum in Field/agriculture practice land (26) and minimum in evergreen (13). Frequency of the number of species in various abundance classes from the community was high in littoral followed by moist deciduous, semi-evergreen and evergreen (**Fig. 4.2, 4.3, Annexure 4.1**). There were two species found with upper bound of abundance of 2048.5 in littoral and 1024.5 in each evergreen and semi-evergreen (**Fig. 4.2**). There was no observed species in the abundance class 32.5 from the coastal habitat (**Fig. 4.3**).

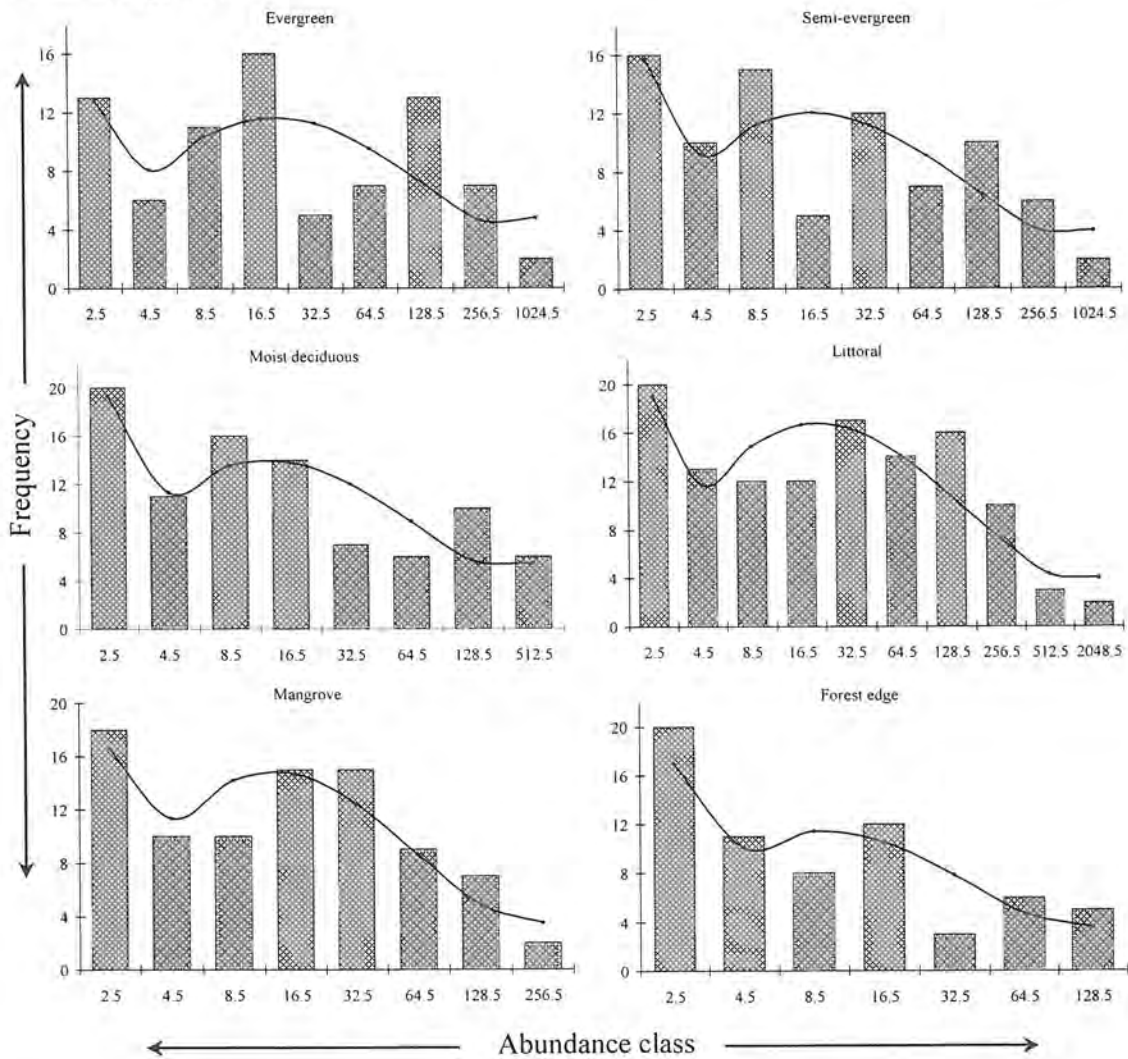


Figure 4.2: Truncated log-normal distribution of birds in the natural forests in Andaman Islands; a plot of observed (as a histogram) and expected (as a line) species frequency distributions arranged by species abundance class (Henderson and Seaby 2001).

Compared with other forested land, the moderate species abundance was observed in plantation and forest edges, while in the most disturbed habitats of field and degraded areas it was minimum (Fig. 4.3).

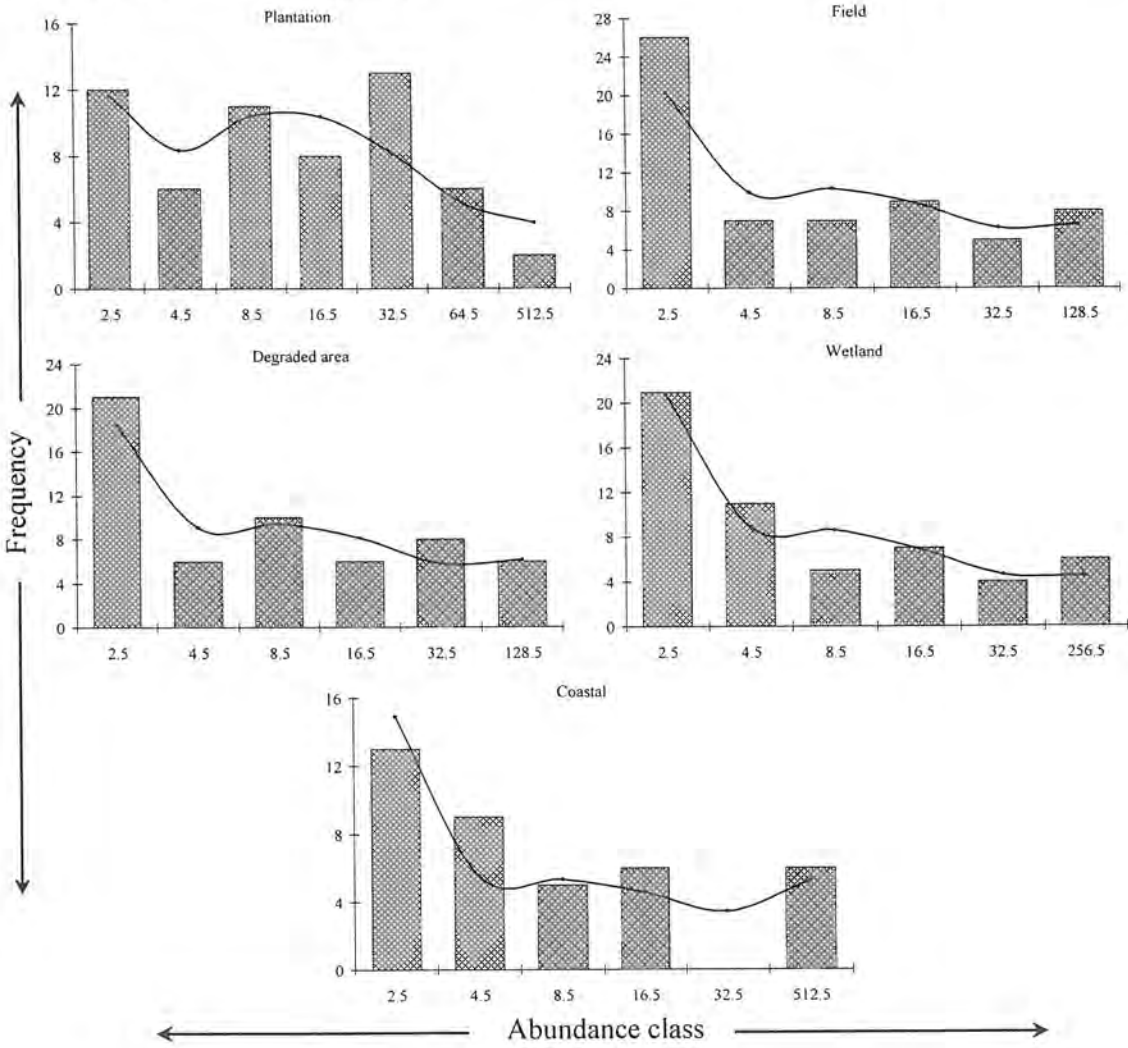


Figure 4.3: Truncated log-normal distribution of birds in the disturbed habitats in Andaman Islands; a plot of observed (as a histogram) and expected (as a line) species frequency distributions arranged by species abundance class (Henderson and Seaby 2001).

b) Distribution of forest/land birds

The other way of presenting species abundance data is rank format K-dominance plot (Lambshead *et al.* 1983, Tóthmérész 1995), where the percentage cumulative abundance (y-axis) in relation to the species rank or log species rank (x-axis) is used. Under this plotting method, curves that are more elevated present the less diverse

assemblages (Magurran 2004). In the present study K-dominance curves were constructed based on number of birds observed across the eleven habitat types. In which the species rank was plotted where it illustrates the bottom curve (Littoral) as of highest diversity, while the uppermost curve (Coastal) represented the lowest diversity, among the habitats (Fig. 4.4).

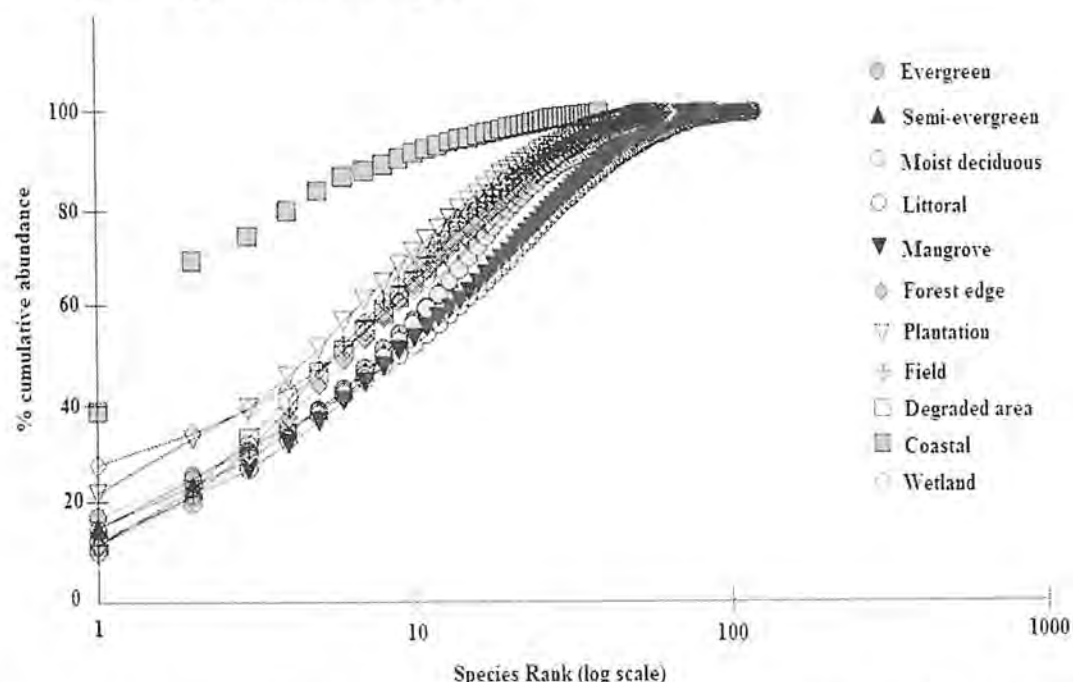


Figure 4.4: The K-dominance plot when the abundance of species is plotted against log of species rank for each class.

c) Patchiness of the bird community

The distribution of bird species across the habitat and region was examined; chi-square test was performed to know the patchiness of the individuals in which 120 of 153 birds were collectively distributed in all habitats the rest had randomly patchy distribution in the bird community of the Andaman Islands (Annexure 4.2).

4.3.3. Species diversity

Shannon-Weaver H' diversity index denotes that the Littoral (3.69) supported greater diversity among all, followed by Mangrove (3.66), Moist-deciduous (3.53), Semi-evergreen (3.43) and Evergreen (3.40). The species diversity (H') decreased from forest/land to water birds reaching the minimum in the coastal area. The widely used Fisher's- α , index provided high diversity of species in Littoral (20.09) followed by Mangroves (18.15) Field (15.21), Forest edges (15.14), Semi-evergreen (14.97),

Degraded (14.25) and Wetlands (14.17). Randomisation tests showed the pairs of samples of E=SE; L=M; F=D have the same diversity at 5% Level, whereas MD, FE, P, W and Coastal region did not have similar diversity (**Table 4.5**).

Table 4.5: Avifaunal diversity and equitability of different habitats in Andaman Islands.

Habitat	Shannon- H'	Equitability- J	Fisher's- α
1) <i>Evergreen</i> (E)	3.40 [@]	0.676 [@]	13.85
2) <i>Semi-evergreen</i> (SE)	3.43 [@]	0.681 [@]	14.97
3) <i>Moist deciduous</i> (MD)	3.53	0.702	17.63
4) <i>Littoral</i> (L)	3.69 [@]	0.734 [@]	20.09
5) <i>Mangrove</i> (M)	3.66 [@]	0.728 [@]	18.15
6) <i>Forest edge</i> (FE)	3.34	0.664	15.14
7) <i>Plantation</i> (P)	3.14	0.625	12.81
8) <i>Field</i> (F)	3.25 [@]	0.646 [@]	15.21
9) <i>Degraded area</i> (D)	3.24 [@]	0.645 [@]	14.25
10) <i>Wetland</i> (W)	3.05	0.606	14.17
11) <i>Coastal</i> (C)	1.94	0.385	7.80

Note: [@] = a simulation result of the samples has same diversity at 5% level.

4.3.4. Shared species and similarities between the habitats

Total number of shared species between the habitats was calculated (**Table 4.6**). The highest number of shared species (81) was found between the natural moist deciduous forests and littoral as well as mangrove and littoral followed by semi-evergreen and littoral (74) and littoral and evergreen (73).

Jaccard similarity

Among the habitats, Jaccard similarity indices shared the maximum value of 0.7 between evergreen and semi-evergreen forests, whereas the minimum was 0.25 between evergreen and coastal. The values diminished between natural forests and disturbed habitats (**Table 4.6**).

Table 4.6: Estimated species similarity matrix of birds between different habitats of Andaman Islands (Jaccard similarity indices are to the left; number of species shared are to the right; total number of species observed in each habitat is in diagonal) (see habitat details in **Table 4.5**).

Habitat	E	SE	MD	L	M	FE	P	F	D	W	C
EG	80	67	69	73	64	53	50	50	43	36	24
SE	0.70	83	67	74	61	52	50	49	48	38	25
MD	0.68	0.63	90	81	71	53	49	50	46	40	30
L	0.58	0.58	0.63	119	81	61	54	57	51	49	37
M	0.63	0.56	0.68	0.65	86	55	49	52	47	43	34
FE	0.58	0.54	0.52	0.50	0.57	65	41	45	42	35	23
P	0.57	0.55	0.49	0.44	0.52	0.50	58	42	36	30	23
F	0.54	0.51	0.49	0.46	0.54	0.55	0.54	62	38	36	21
D	0.46	0.52	0.46	0.41	0.49	0.53	0.46	0.47	57	32	22
W	0.37	0.38	0.38	0.40	0.44	0.42	0.37	0.45	0.41	54	24
C	0.25	0.26	0.30	0.31	0.37	0.28	0.31	0.26	0.30	0.35	39

In the present study, cluster analysis was performed based on presence/absence of avifauna in different habitats to understand the similarity of the species distribution (which includes migrants and waders) (**Fig. 4.5**).

The dendrogram showed two major clusters at 40% grouping, the five natural habitats of evergreen to littoral as one and the other of four disturbed forests of degraded area to forest edge. Among the natural habitats, Evergreen and Semi-evergreen showed close relation, so also Moist deciduous and Mangrove to which Littoral was associated. The coastal habitat stood separately while wetland showed very little association with the other two groups (**Fig. 4.5**).

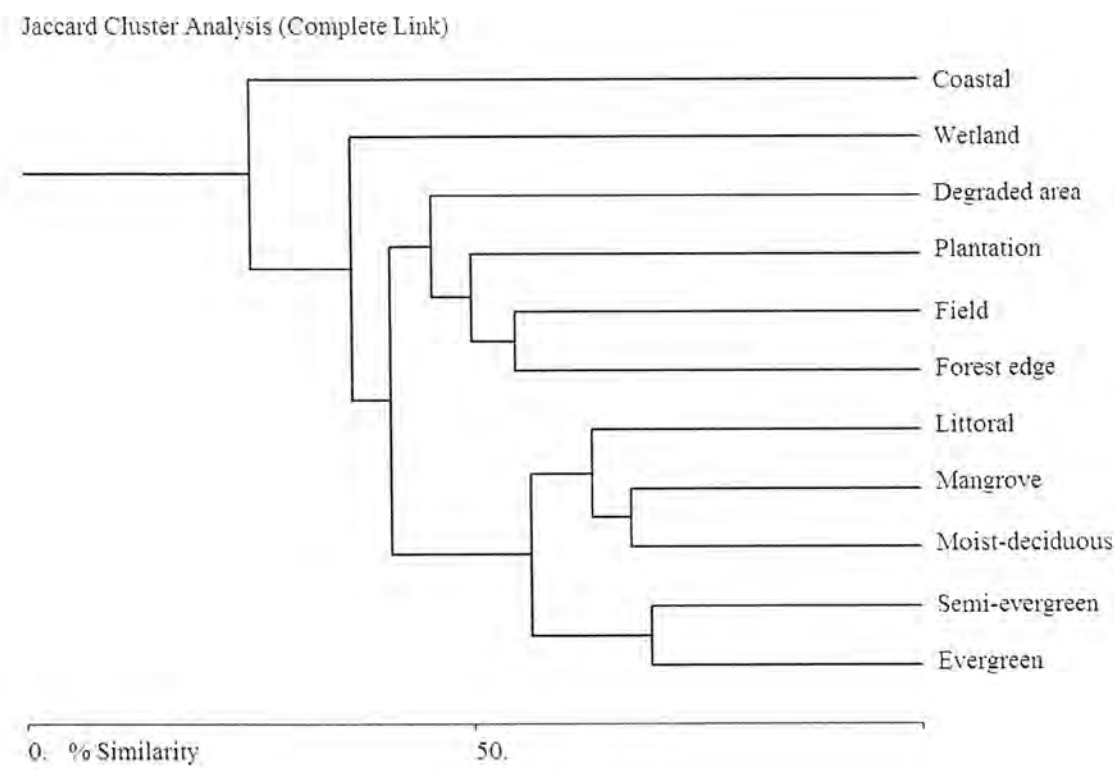


Figure 4.5: Cluster analysis of birds on presence/absence data using Jaccard index of similarity and complete linkage clustering. The samples are labelled according to the habitat from which they were recorded.

Sørensen’s similarities

The greatest difference among bird assemblages and habitat, according to Sørensen’s indices (qualitative= C_S & quantitative= C_N), was found between evergreen forest and coastal habitat. However, the proportionate value of Sørensen’s qualitative indices (C_S) exceeding 0.8 indicates the high similarity of communities between Evergreen-Semi-evergreen, Evergreen-Moist deciduous and Moist deciduous-Mangrove, while for Sørensen’s quantitative indices (C_N) only Evergreen and Semi-evergreen indicates the high similarity among the others, whereas Semi-evergreen-Moist deciduous and Mangrove-Moist deciduous showed low values (Table 4.7).

In favor to the Sørensen’s quantitative indices (C_N) dendrogram of Bray-curtis cluster showed the similarities of the avifaunal distribution among different habitats, where the option of divide by overall abundance in the community was used for standardization (Fig. 4.6).

Table 4.7: Shared Species estimations, classic similarity indices, of birds between different habitats computed by EstimateS vs.8 [Classic Sørensen incidence-based (qualitative) sample similarity indices (CS) are to the left; Bray-Curtis (=Sørensen quantitative) sample similarity indices (CN) are to the right; total number of species observed in each habitat is in diagonal].

Habitat	E	SE	MD	L	M	FE	P	F	D	W	C
E	80	0.81	0.65	0.62	0.49	0.27	0.38	0.22	0.19	0.12	0.03
SE	0.82	83	0.74	0.60	0.53	0.32	0.45	0.25	0.22	0.15	0.03
MD	0.81	0.77	90	0.53	0.65	0.40	0.53	0.32	0.28	0.18	0.12
L	0.73	0.73	0.78	119	0.40	0.22	0.27	0.18	0.16	0.13	0.11
M	0.77	0.72	0.81	0.79	86	0.52	0.60	0.43	0.44	0.25	0.12
FE	0.73	0.70	0.68	0.66	0.73	65	0.55	0.63	0.52	0.33	0.06
P	0.72	0.71	0.66	0.61	0.68	0.67	58	0.47	0.45	0.31	0.06
F	0.70	0.68	0.66	0.63	0.70	0.71	0.70	62	0.56	0.36	0.06
D	0.63	0.69	0.63	0.58	0.66	0.69	0.63	0.64	57	0.29	0.14
W	0.54	0.55	0.56	0.57	0.61	0.59	0.54	0.62	0.58	54	0.23
C	0.40	0.41	0.47	0.47	0.54	0.44	0.47	0.42	0.46	0.52	39

Habitat details: E=Evergreen, SE=Semi-evergreen, MD=Moist deciduous, L=Littoral, M=Mangrove, FE=Forest edges, P=Plantation, F=Field, D=Degraded.

In the dendrogram at approximately 18% similarity level, two major regions of the species assemblage were divided, the southern habitats from Evergreen to Littoral and mangrove to degraded forests. The northern one habitat of coastal (at approximate of 3% Level) and the other Wetland are separated, although the disturbed habitats formed a cluster at the level of 24%. However, the tropical rain forests of evergreen and semi-evergreen are most similar with moist deciduous and littoral (Fig. 4.6).

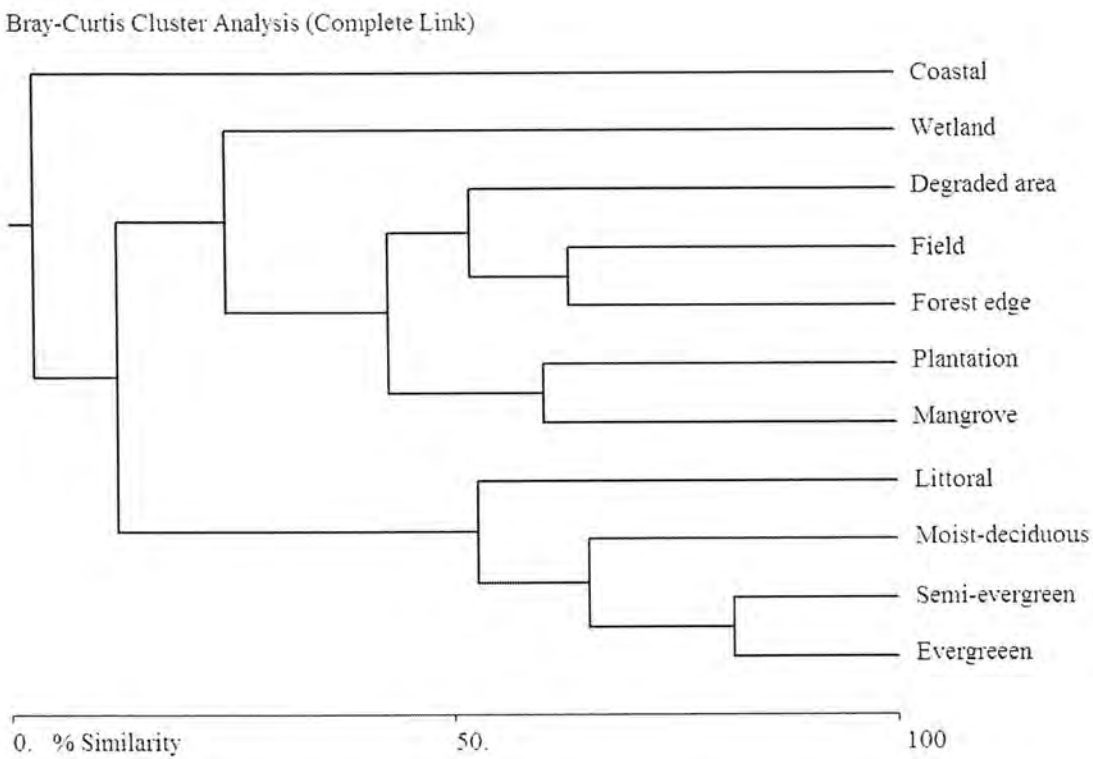


Figure 4.6: Cluster analysis of birds between different habitats, computed by Estimate-S vs.8 on divide by overall abundance option using Bray-curtis complete linkage clustering. The samples are labelled according to the habitat from which they were recorded (for abbreviations see Table 4.7: Sørensen quantitative estimator).

4.4. DISCUSSION

An important problem in ecology and conservation is the estimation of species richness (diversity) of a habitat or region. Species richness is the most commonly used biodiversity indicator (Gaston 1996) for conservation (e.g. Conroy and Noon 1996, Kerr 1997, vanJaarsveld *et al.* 1998) and ecological research (e.g. Brown *et al.* 2001). The information on bird species richness (diversity) derived from the present study may be useful for detecting trends, impacts, or recovery of the Andaman Islands ecosystem, for selection and management of nature preserves, and for basic understanding of biophysical factors controlling the bird species numbers. Ideally, complete inventories provide a full count of species. Unfortunately, full inventories are rarely available. In their place, samples or surveys usually provide the best available data. A sample of species is not analogous to a sample of biomass or leaf-area, however. Simple means of richness over samples (e.g. Jones *et al.* 2000) ignore the strong dependence of species richness on sampling effort or organism abundance. Pooling species across samples has the same shortcoming.

Moreover, differences in the characteristics of biological assemblages produce differences in sampling effectiveness (Hortal *et al.* 2006). Thus, when the same sampling effort with standardized techniques is carried out in different areas and/or community types, sampling success may not be always the same, leading to important biases in the total species richness inventoried at each site (Hortal *et al.* 2006). Due to this, studies involving comparisons of species richness among different areas, sites or communities need to use extrapolation or rarefaction techniques to 'standardize' richness data (see Palmer 1991, Soberón and Llorente 1993, Colwell and Coddington 1994, Gotelli and Colwell 2001, Walther and Martin 2001, Walther and Moore 2005).

Hence, the present study used the methodologies for this task such as: Non-parametric estimators which used the species-abundance and/or occurrence relationships throughout the samples to estimate total number of species (e.g. Sørensen *et al.* 2002, Rosenzweig *et al.* 2003, Shen *et al.* 2003), *Fitting species-abundance distributions*, where parametric models are adjusted to the distribution of the relative abundances of the species, and are then used to extrapolate the number of still unknown species (May 1975, Colwell and Coddington 1994) and *Species accumulation curves*, where the parameters of several asymptotic equations are adjusted to describe the

relationship between sampling effort and sampling success (i.e. the number of species added to the checklist by each sample). Total richness is extrapolated as the number of species that would be found with a hypothetical infinite sampling effort (see, e.g. Soberón and Llorente 1993, Hortal *et al.* 2004).

Species richness

The basic extrapolation problem is that from collective sample data the present study is focused to estimate the number of species in each habitat that would be found in a complete survey. In order to get accurate value out of species richness estimators (Walther and Martin 2001, O'Dea and Whittaker 2007) five estimators from EstimateS (Colwell 2002) were performed. Of 104 resident/non-migrants species, among the bird community used for species richness estimation resulted in the completeness of sampling (Colwell and Coddington 1994) by means of species accumulation curves (i.e. the estimated total species richness) which perfectly approached asymptote across the region/habitats in Andaman Islands (see **Chapter Five: 5.4.1**). The species accumulation curves, a descriptive model has been found to yield an excellent fit to most large samples from heterogeneous communities (Gray 1981). May (1975), however, has argued that this model is merely descriptive and has no biological meaning.

Since the estimated number of unseen/missing species was found minimum in all habitats except littoral forests (10.97, 20.92 & 60.05) by *Chao* and *Jackknife* orders, and the above estimators showed relatively less deviation compared to the others, these are considered as efficient estimators (Walther and Moore 2005). Though, the littoral forests scored maximum number of point counts (384), species richness and abundance the estimated unseen/missing species is high due to more number of shared species was found, with natural forests and disturbed habitats. Thus, heavily influenced to *Chao* and *Jackknife* species richness estimators, in terms of singletons and doubletons of the species observed in littoral forests (see also **Table 4.6**). However, *chao1* & 2, the Presence/Absence species estimator matrix and shared birds (β -diversity) between habitats listed was showed less number of forest birds presence in littoral. In addition, the curves indicated that most of the species were detected in early samplings followed by a few additions later. This most commonly reported community measure of species richness also correlated with productivity (e.g. Currie

1991, Wright *et al.* 1993, Fraser and Currie 1996) and habitat heterogeneity (Kerr and Packer 1997) at large spatial scales (Fredrik and Svensson 2001).

Species distribution pattern

Present data of bird abundance in different habitats was fitted into truncated lognormal distribution model among the four (geometric series, logarithmic series, lognormal distribution and MacArthur's broken stick model). If many independent factors are involved in determining the community structure, species abundance follows lognormal distribution (John 1986, Krebs 1989). Where the assemblages of species did not fit into a log normal model but fitted with the log series distributions which showed a 'hollow curve'. In other words, comparatively a few species are common and large numbers of species are rare (or infrequently recorded). Additionally, the model class is always the singletons no matter how large the sample (Colwell and Coddington 1994, 1995). The estimate of species richness is always non-asymptotic; hence, the number of estimated species will increase as the number of individuals (N) increases (Magurran 2004).

The observed lognormal abundance distribution pattern of birds in Andaman Islands exhibits the equilibrium in natural habitats (undisturbed) and disturbed habitats (such as plantation, forest edge, field and degraded area) irrespectively. The lognormal distribution is usually better model for original data (Limpert *et al.* 2001). The present study showed very few rare and common species in arrangement of species with moderate abundance (Magurran 1988, Krebs 1989, Wiens 1989b) and the model fits well, where the community is at equilibrium or free from disturbance (Wiens 1989b). In recent studies from tropical forest bird communities in India and away on the lognormal distribution pattern (Terborgh *et al.* 1990, Jayson and Mathew 2000) which displayed by biological communities comprising many species especially birds (Magurran 1988, Wiens 1989b, Tokeshi 1999) were stated.

Diversities and similarities

The various diversity indices showed greater diversity in all natural and disturbed habitats by means of species richness and abundance. In short, the natural habitats of Evergreen=Semi-evergreen, Littoral=Mangrove and Field=Degraded area was scored the same diversity at 5% significant level by randomization test because of more species similarity (Henderson and Seaby 2001). However, at the community level, the

ecological interpretation of patterns in species richness and traditional diversity indices (Shannon-weaver H' , etc.) is inconsistent. Moreover, the possible values of H' at any given number of species, has constraints in many cases dictate a strong, positive correlation between species richness and H' (and other similar, abundance-weighted indices) (Austin 1999, Fredrik and Svensson 2001).

The Sorensen similarity indices were analyzed to find similarity of bird communities between habitats. The highest species similarity among the bird assemblages was found in natural forests (between evergreen and semi-evergreen followed by evergreen and moist deciduous forests) rather than disturbed habitats. The greatest difference was found between evergreen and coastal habitats. This is not unexpected because the samples showed most of the forest dwelling birds are dependent on the natural forests rather than disturbed habitats.

Similarities of birds between habitats are related to habitat quality (Nakwa *et al.* 2008) and the bird habitats had relationships to forests with high structural complexity offer diverse microhabitats for foraging, nesting opportunities and reduced predation (Parish 1995, Kornan 2000, Whelan 2001, Lee and Rotenberry 2005). If the threats or disturbance occur in the habitats that are less similar to one another habitat, birds can not survive, as no suitable alternative habitats are present (Walson and Round 1992). For example, when either evergreen or semi-evergreen forest is disturbed, birds migrate between the two habitats instead of migrating to different habitats (Nakwa *et al.* 2008).

The present study has been over viewed with the major perspectives by locally of relationship between the number of species and the internal structure of the habitat. Nevertheless, the structural complexity of the habitat and disturbance mechanisms, along with competition process, would explain the abundance of species (e.g. Huston 1994, Andrén 1994, Parish *et al.* 1995, Burel and Baudry 1995, Baz and Boyero 1995, Grossi *et al.* 1995, Berg 1997, Edenius and Sjöberg 1997, Estrada and Estrada 1997, Miller *et al.* 1997). However, one central objective of ecology is to study the factors affecting the distribution of biodiversity (Andrewartha 1961, Shmida and Wilson 1985, Lubchenco *et al.* 1991, Huston 1994). At the global or biogeographical point of view, the most widely accepted theory is that the main factor affecting diversity is the energy available to the system (Wright 1983, Scheiner and Rey-Benayas 1994, Hawksworth and Katlin-Arroyo 1995, Kerr and Packer 1997). The disturbance and

habitat alterations of natural forests in Andaman Islands did not appear to have a negative impact on breeding birds. In fact, based on the relative abundance and diversity of bird species, the disturbed habitats of plantation, field and degraded area appeared to enhance both the richness and diversity of the bird community. In general, disturbed forests/habitats through logging, regeneration and encroachments created a diversity of habitats, found in rich but not more abundant bird community.

Bird communities that inhabit natural habitats appear to be remarkably similar between regions in the Andaman Islands. In general, these communities were very diverse and often contained bird species that were unique to disturbed habitats. Compared to disturbed habitats, diversity and abundance in natural habitats was substantially higher. Within natural habitats, abundance and diversity were consistently highest in littoral forest.

4.5. SUMMARY

- The completeness of sampling by observed species from the region/habitat was examined.
- To avoid the bias of samplings in the region different extrapolating methods, for species richness and accumulation pattern using EstimateS: Chao1, Chao2, Jackknife1, Jackknife2, Bootstrap, Cole, Abundance-based Coverage Estimator or ACE and Incidence-based Coverage Estimator or ICE were tested on the empirical data set.
- The estimated species richness across the habitats and region in Andaman Islands were perfectly approached asymptote in terms of the species richness accumulation curve against the effort (point count), which indicates the completeness of the sampling.
- Distribution of individual species among the population in the community was performed. The species abundance was followed lognormal distribution pattern, in which the determination of bird community structure is involved various independent factors. The model exhibits the equilibrium in natural habitats (undisturbed) rather than disturbed habitats of Plantation, Forest edge, Field and Degraded area.
- The results showed very few rare and common species in arrangement of species with moderate abundance in bird community of the Andaman Islands and

lognormal distribution model fits well, where the community is at equilibrium or free from disturbance was observed.

- Samples from eleven habitats of the Andaman Islands were scrutinized and computed for bird species diversity, richness and evenness. The various diversity indices showed greater diversity in all natural and disturbed habitats by means of species Richness and abundance at 5% significant level.
- However, Sorensen similarity indices were analyzed to find similarity of bird communities between forest types. The highest similarity index was found in both evergreen and semi-evergreen followed by evergreen and moist deciduous forest rather than disturbed habitats.
- The greatest difference among the bird assemblages and habitat was found between evergreen and coastal habitats, which are obvious. This is not unexpected because the samples showed most of the forest dwelling birds are dependent to the natural forests rather than disturbed habitats.
- The disturbance and habitat alterations of natural forests in Andaman Islands did not appear to have a negative impact on breeding birds. In general, disturbed forests/habitats through logging, regeneration and encroachments created a diversity of habitats, found in rich but not more abundant bird community. Compared to disturbed habitats, diversity and abundance in natural habitats was substantially higher. Within natural habitats, abundance and diversity were consistently highest in littoral forest.

CHAPTER FIVE

BIOGEOGRAPHY OF AVIFAUNA OF ANDAMAN ISLANDS

5.1. INTRODUCTION

Biogeography is traditionally the history and geography of the animals (zoogeography) and plants (phytogeography); and the study of the ecology and evolution of living things. The historical biogeography explores the long-term evolution of life and the influence of continental drift, global climatic change, and other large-scale environmental factors (Huggett 2004). Archipelagoes, be they composed of islands at sea, are theoretical and the empirical challenges to ecological research (Halia 1990). Biodiversity is most commonly taken to be synonymous with the species richness of an ecosystem. Islands are species poor for their size but rich in forms found nowhere else, i.e. endemic to that island or archipelago. It is in this sense that certain islands warrant the description 'biodiversity hot-spots' (Whittaker 1998).

Hitherto, the total number of living species on the planet is not yet known to within an order of magnitude (Groombridge 1992) and, it is difficult to provide a quantitative measure of the relative contribution of islands to global biodiversity. Yet, for particular taxa there are sufficient data to demonstrate that, taken collectively, islands contribute disproportionately for their area to global species total (Whittaker 1998). Island biogeography is consisting of two patterns as: the species-area curve (Begon *et al.* 1990) and the dynamics of island colonization (Simberloff and Wilson 1969).

In general, Islands are relatively small body of landmass surrounded entirely by water. Depending on their origin they may be classified as either continental or oceanic. Continental islands are created by rise in sea level where only the summits of coastal highlands remain above the water; or by the sea breaking through an isthmus or peninsula and cutting the land from the mainland. The key distinctions of islands were summed up by Wallace (1902). Continental (self) islands are more varied geologically, containing both ancient and recent stratified rocks, they are rarely remote from a continent and always contain some land mammals and amphibians as well as representative of the other classes and orders in considerable variety. The history is clearly important in distinguishing the oceanic from the continental. A few are difficult to be distinguished. This is exemplified by the avifauna of the

Philippines, which is intermediate in character between oceanic and continental island type (Diamond and Gilpin 1983).

The formation of Andaman and Nicobar Islands is a result of tectonic process followed by the uplift of the Himalayas and the Arakan Yomas of Mynamar (Gee 1927, Chibbers 1934, Rodolfo 1969, Das 1999). The Himalayas are the result of the shock of collision between two continental plates and the Andaman and Nicobar Islands were created from the subduction of the Indian Ocean oceanic crust under the Asian plates. When the Indian plate collided with the Asian plate during the Tertiary period, the uplifting of the sea floor and accumulation of debris created this chain of islands, which lie parallel to the fault line (oceanic trench) further west. The island chain probably acquired its present structure in the early Tertiary period, around 25 million years ago. Later upheavals of the sea floor during the Miocene epoch resulted in the formation of several of the archipelagos. These true oceanic islands were formed from the sedimentary and volcanic material from the oceanic floor and geologically are the part of a continent and therefore close to it and are known as land bridge islands (Gee 1927, Chibbers 1934, Rodolfo 1969, Das 1999, Davidar *et al.* 2001, Andrews and Sankaran 2002).

Andaman and Nicobar Islands are purely oceanic in origin and the closest they came to the continent was during the Pleistocene glaciation, when the sea level sometimes receded over 150m. It was probably during this period that maximum dispersal of species to these islands occurred, where the geological processes such as uplifting of the ocean floor in the Tertiary period and climatic variations which caused the drop in sea levels during the Pleistocene epoch. Due to the geological history of these oceanic islands, the flora and fauna were much richer than the other oceanic islands (Gadgil 1997, Das 1999, Davidar *et al.* 2001, Andrews and Sankaran 2002). However, the long isolation from the adjoining landmass of these islands caused their high species endemism and are known as one of the third most significant area for biodiversity in India, the first two being the Western Ghats and the Eastern Himalayas, especially as there are 144 species of flowering plants and 75 species of land snails that do not occur anywhere else in the world (Gadgil 1997).

These islands constitute globally important biodiversity hotspots because of their very high endemism in all taxa, particularly in reptiles, plants, fish and corals. These two

groups of islands form two endemic bird areas in the world as Andaman Islands EBA-125 and Nicobar Islands EBA-126 (Stattersfield *et al.* 1998).

The biota of the Andaman is closely related to that of Burma and the Malay Peninsula, and that of the Nicobars to Sumatra (Davidar *et al.* 2001, Das 1999, Gadgil 1997). Vegetation is usually more abundant, as seeds are carried from remote lands by wind, water currents and birds. Though plants have greater powers of dispersal than most animal groups, it is not uncommon to find even large trees with tiny restricted distributions within these island groups (Andrews and Sankaran 2002). For the avifauna, there are indications that the Burmese element was predominant, and that the Nicobars have an impoverished subset of the Andamanese avifauna, rather than a distinct Nicobarese avifauna (Davidar *et al.* 2001). While the herpetofauna of the Andamans is considered to have Indo-Chinese affinities which is being a subset of the Rakhine (Arakan) Yomas of Burma, the Nicobars has Indo-Malayan affinities, which is established largely through waif (=homeless child) dispersal across the Great Channel from Sumatra (Das 1999, Andrews 2001).

A biogeographical realm or ecozone is a biogeographical and ecological land classification system of the world first formally proposed by Udvardy (1975) for conservation purposes. Arguably, biomes are better suited for conservational purposes. The boundaries of an ecozone are often the result of plate tectonics as a region is biologically isolated for a long period leading to unique fauna and flora. The biogeography values of the Andaman Islands, coming under the Indomalaya Ecozone (Udvardy 1975) mostly differ from the closest and large landmass of Burma and Malaysia.

Southeast Asia's geographical distribution of biodiversity

Indo-Malayan region is one of the richest bird species areas in the world. Data on bird fauna in Southeast Asia, as well as New Guinea, was taken from documented field guides. A total of 88 families (with 479 genera and 1718 species) of resident breeding birds were collated (migrant species excluded). This accounts for about 17.6% of the total number of bird species in the world, making this region one of the richest bird species regions in the world.

The evolutionary processes leading to the development of new species, their extinction, immigration and emigration may be influenced by both historical and

contemporary mechanisms. For instance, falling sea levels and climate change during the last glacial period (about 18,000 to 10,000 years before present) had developed a savanna-like habitat in the "exposed" land area that connects the current landmasses in Sundaland (the Malay Peninsula, Sumatra, Java and Borneo). Such massive changes are predicted to have played a key role in influencing faunal composition and geographic distribution of species in the Southeast Asia region (Rahman 2007).

The current pattern of bird fauna distribution is predicted to fit the proposed landbridges or dispersal routes that appear due to the physical splitting of once continuous area by the processes of continental drift and changes in sea levels during the Last Glacial Maximum (LGM). The comparison of the patterns of bird species distribution in the Wallacea, Sunda and Sahul Shelf (the subregions and island of Thailand, Peninsular Malaysia, Sumatra, Borneo, Java, Bali, Lombok, Sulawesi, the Philippines and New Guinea) was made by Rahman (2007). Analysis of species similarity among the 10 subregions/island in the study supports the model of biogeographic divergence based on historical changes in sea levels. At each of the three subgroups, the distribution of land and water birds revealed a major transition line that fitted with the glacial model.

New Guinea and the Philippines showed little species resemblance with the rest of the subregions/islands (Rahman 2007). This finding agrees with the geographic position of New Guinea lying on the continental shelf of Australia and sharing much of its fauna with that island-continent. The Philippines, on the other hand, was never joined to the Sunda Shelf's islands and mainland Asia during the last glacial period, because of the presence of deep water channels (>200m deep) that separate Philippines from the region. Even when sea level was predicted to have dropped as much as 160 m during the glacial periods, that still failed to connect the Philippines (except Palawan) archipelago with Borneo and the rest of the region.

These findings suggest that bird species diversification took place across a range of glacial stages, with ancient diversification between families taking place at a time of lower sea level. Diversification within families occurs at a time when Sumatra moved away from mainland Asia to form a group with Borneo and the diversification within species related closely to mainland Asia. The pattern of distribution suggests that the descendant that crossed over from mainland Asia or remained in Sumatra during the glacial and inter-glacial period may have perished and become extinct, especially

those families that have few species, and shows vulnerability to environmental changes and human intervention (Rahman 2007).

While the findings support the glacial model of Southeast Asia's geographical distribution of biodiversity over space and time, it does not agree with the proposed faunal boundaries of Wallace's line that separates the zoogeographical regions of Asia and Australasia; the finding does not point to the major faunal transition between Bali and Lombok as well as between Borneo and Sulawesi. Instead, their findings at family level agree with Mayr's line which cuts at the west of Lombok, allowing Lombok to be grouped with Java and Bali. The bird species composition in Bali shows more resemblance to Java and Borneo while Lombok shares more of its genera and species with Sulawesi; and the bird compositions of Borneo and Sulawesi have little resemblance even at the family level even though the two islands are separated by a 50 km wide Straits of Makasar.

Indomalaya ecozones

The Indomalaya Ecozone or Oriental Region, one of the eight ecozones in the world with the area of 7.5 million km² (Udvardy 1975), extends across most of the South and Southeast Asia and in to the southern parts of East Asia and well known for its greater affinities towards flora and fauna. Mostly covered by the tropical and subtropical evergreen forests, with moist deciduous forests predominant in much of India and parts of Southeast Asia (example the dominant tree species of *Dipterocarpus*) these Indomalaya ecozones revealed most affinities of the flora and fauna. The avifauna of Andaman and Nicobar Islands are mainly typical of the Indomalaya ecozones, with genus, species affinities to the mainland India to the west, Myanmar to the northeast, Thailand, Laos, Cambodia, Vietnam to the east and the Malay archipelago, the group of 20,000 islands in the world's largest archipelago by area, includes the countries Malaysia, Indonesia, Philippines, Singapore, East Timor and most of the Papua Guinea, to the southeast.

The pioneering study was carried out by Sclater (1858) about the major avifaunal regions of the world in which he included an 'Indian' region comprising India, Ceylon, Burma, Indochina and Malaysia, as well as Andaman and Nicobar islands. And Walden (1873) stated '...the most resemblance of avifauna with southern India'. By contrast, ornithologically, Andamans' closest affinities were to Burma, whereas

those of the Nicobars were to Malaya (Elwes 1873, Blanford 1901). According to Mani (1974) the Andamans are characterized by their improvised Burmese fauna and the Nicobar Islands have essentially Sumatran fauna. The recent biogeographic analysis dealt by Ripley and Beehler (1989) reported that the sharing of breeding avifauna between Southeast Asia and southern India was maximum towards southwestern Burma (78%) followed by Malaysia (72%), Sumatra (64%) and south India (62%).

Research objectives

Main objective of this research is to contribute a better knowledge of the avifauna of different islands in Andamans, and to elucidate the underlying environmental factors and implications for avifaunal distribution. More specifically, the aims of this chapter are:

- Estimate the species richness from the data set (region-wise) for their completeness,
- Determine the zoogeographical distributions of forest/land birds and
- Describe subset of the bird species distributed in different islands

5.2. METHODS

5.2.1. Estimating Species Richness

i) Species accumulation curve

Species-accumulation curves were generated from cumulative bird species richness (BSR) values, calculated from the count data to ascertain whether the samples per habitat were sufficient to detect most species that were on each site/region. Only forest/land birds were considered. Waders and migrants were excluded, as the methods precluded adequate counts of them.

ii) Non-parametric methods

For species richness and accumulation pattern in the region using EstimateS: Chao1, Chao2, Jackknife1, Jackknife2, Bootstrap, Cole, Abundance-based Coverage Estimator or ACE and Incidence-based Coverage Estimator or ICE were tested on the empirical data set from along regions in Andaman Islands (see **Table 4.1**) in which Chao, Jackknife and Bootstrap are explained in **Chapter Four** (see 4.2.2.-II).

5.2.2. Classification of the study area

i) Geographical

Bird survey was carried out in outer (islands lying separated from main islands) and major islands of Andaman in which four major islands, namely North, Middle, South (including Rutland island) and Little Andaman and, 52 outer islands (36 protected and 16 unprotected) have been covered. The 52 outer islands are classified under four categories, depending on the size as very small (0.32-0.58 km²), small (1.42-1.61 km²), medium (4.92-9.51 km²), and large (11.1-29.48 km²) (see Table 5.7, Annexure 5.2). The islands having the area above 133 km² are considered as major islands (Fig. 5.1. to 5.4).

ii) Biogeographical

Due to the unique nature of scattered islands, covering a small area, they have been divided into a total of 11 biogeographic subdivisions (Rodgers and Panwar 1988) under two distinct zones as follows:

a) 9A: Andaman Islands (with Barren and Norcondam Islands)

The island group has by far larger land area, totalling 6,408 km²; most of the land mass is that of "Great Andaman", which consists of five islands separated by creeks namely North, Middle, and South Andaman, Baratang, and Rutland Island. Little Andaman is some distance to the south (Fig. 5.1. to 5.4). For conservation planning several subdivisions including eight biogeographic regions of Andaman islands are recognised, namely 1) North, 2) Middle, 3) South, Baratang and Rutland, 4) Little, 5) Ritchie's Archipelago (geologically recent with calcium rich soils), 6) Off-shore volcanic islands, 7) East Coast and 8) West Coast.

b) 9B: Nicobar Islands

The Nicobar group is much smaller, with only 24 islands and has three subdivisions namely 1) North Group: Car Nicobar and Batimalv, 2) Teressa, Tilongchong, Camorta, Nancowry and other small islands and 3) Little Nicobar and Great Nicobar.

Further, the Andaman and Nicobar Islands are differentiated by their ecological separation and island species composition (Andrews and Sankaran 2002).

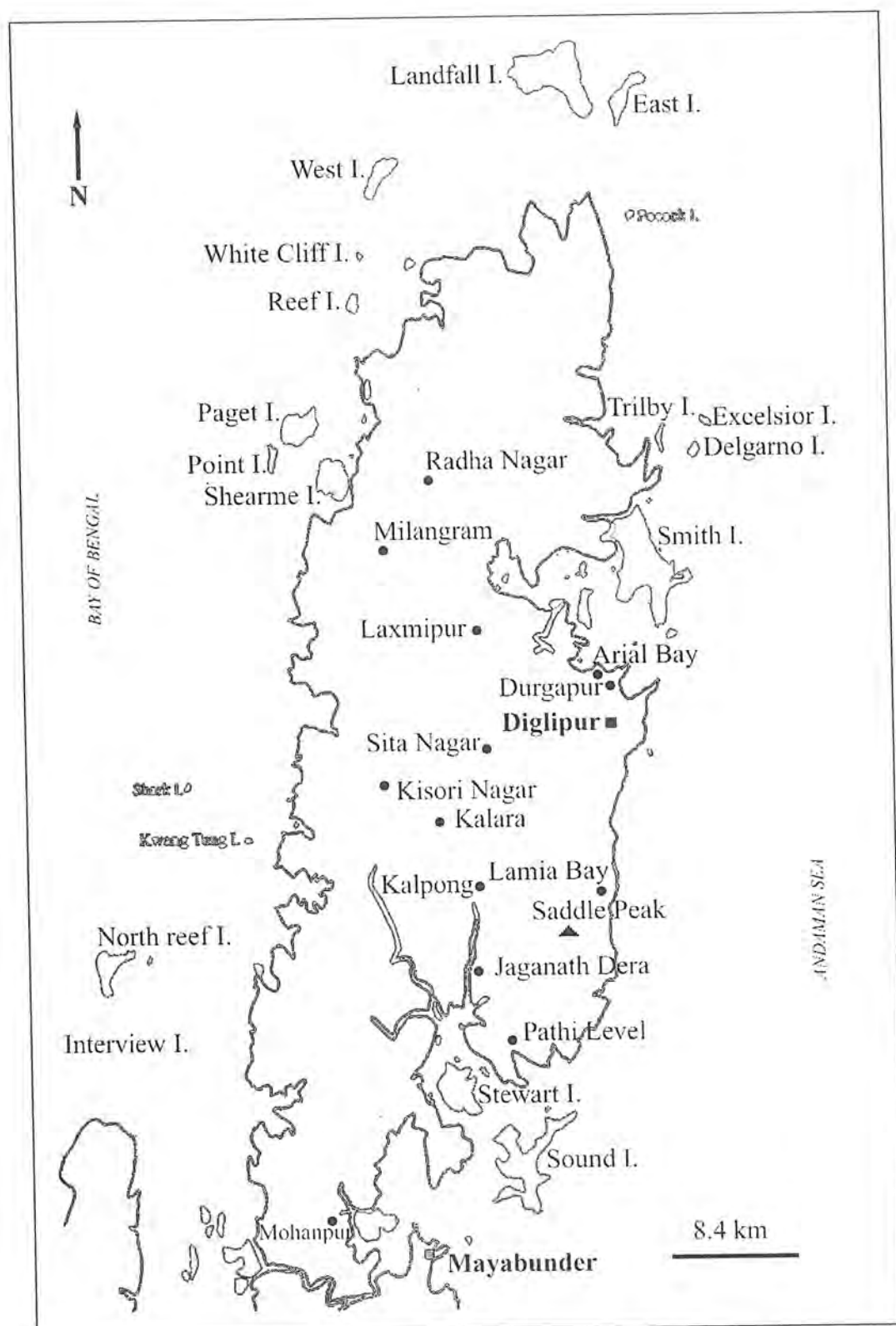


Figure 5.1: The outer islands and other locations surveyed from the North Andaman biogeographic region in Andaman Islands.

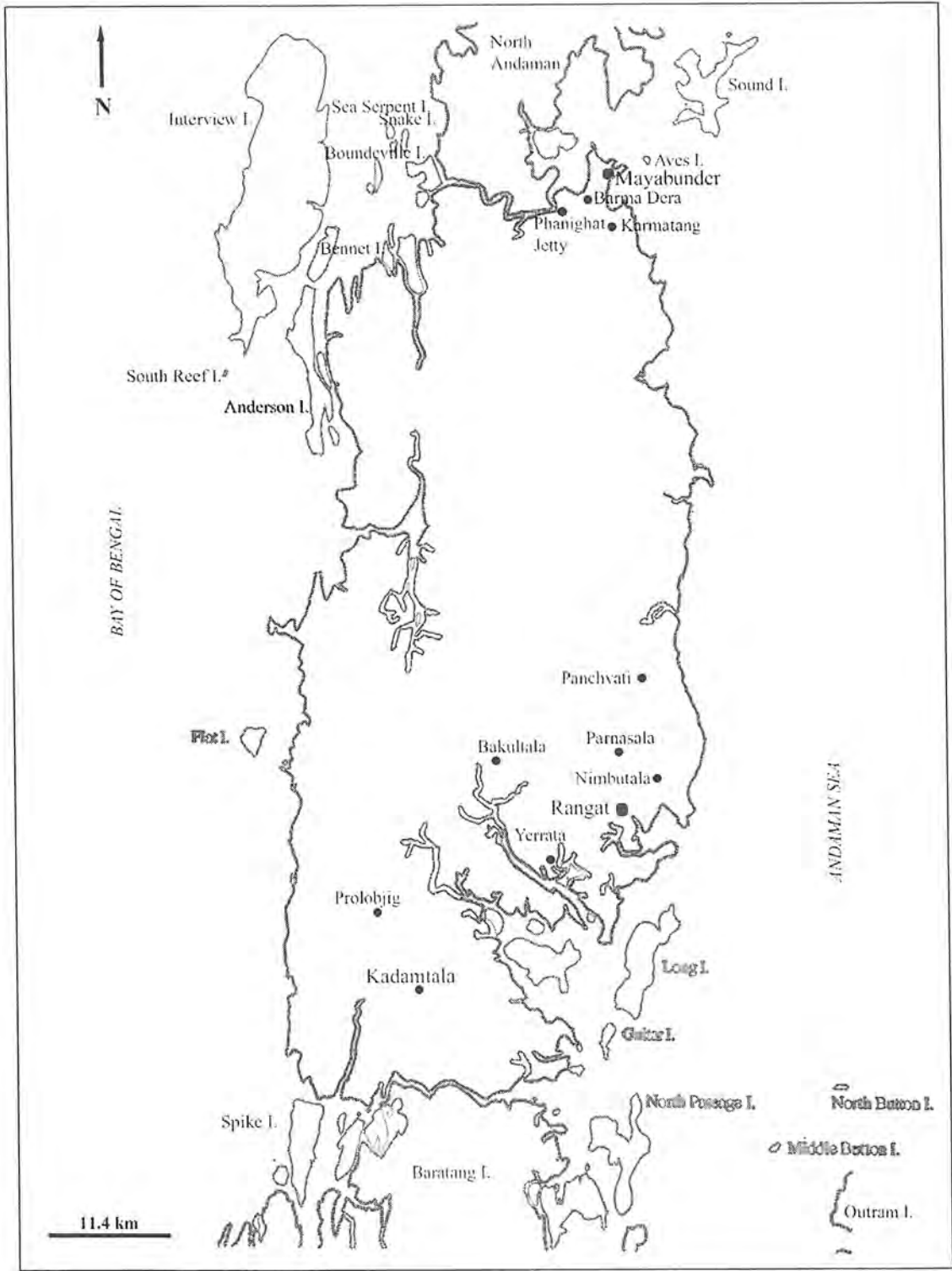


Figure 5.2: The outer islands and other locations surveyed from the Middle Andaman biogeographic region in Andaman Islands.

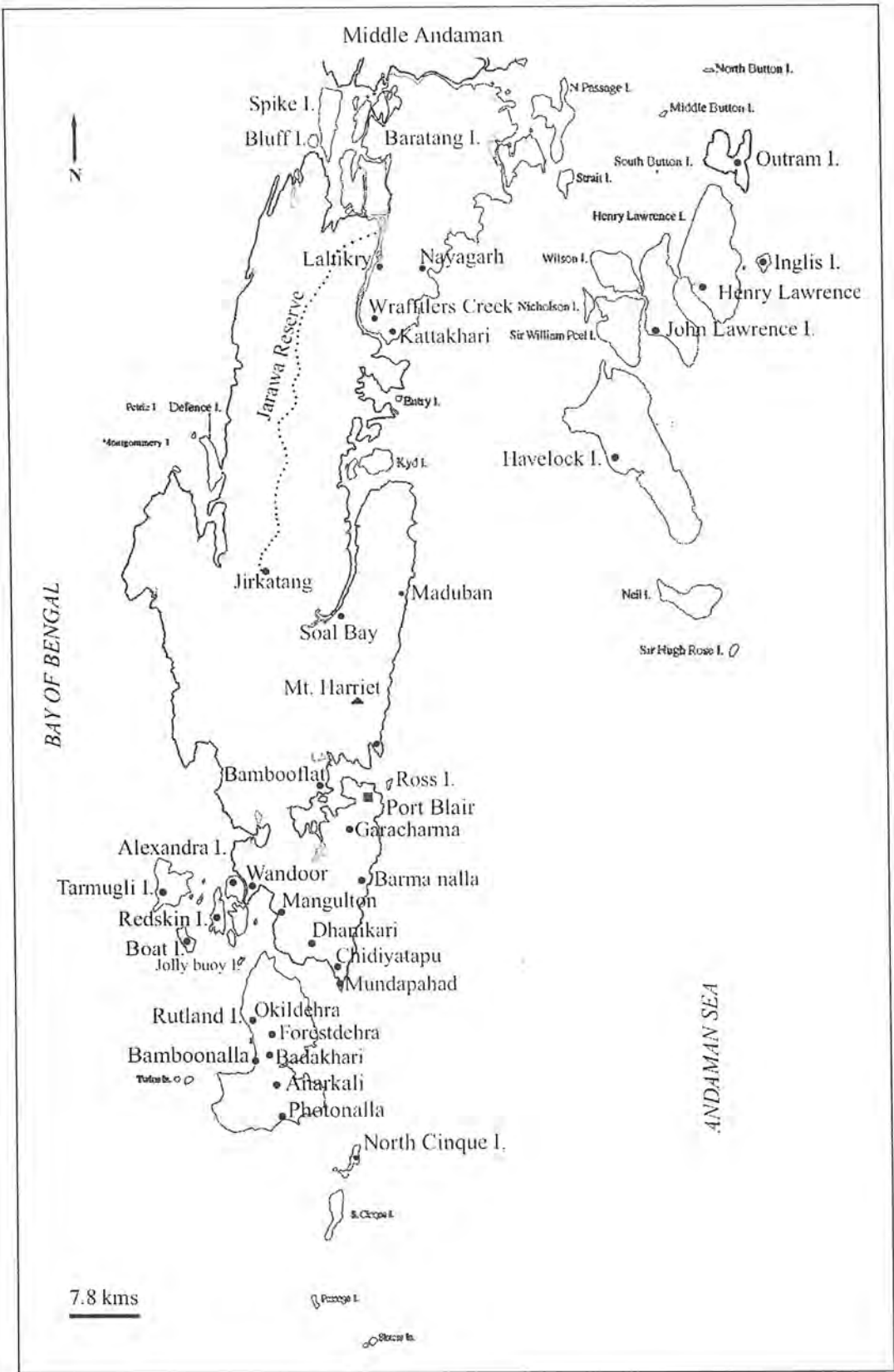


Figure 5.3: The outer islands and other locations surveyed from the South Andaman biogeographic region in Andaman Islands.

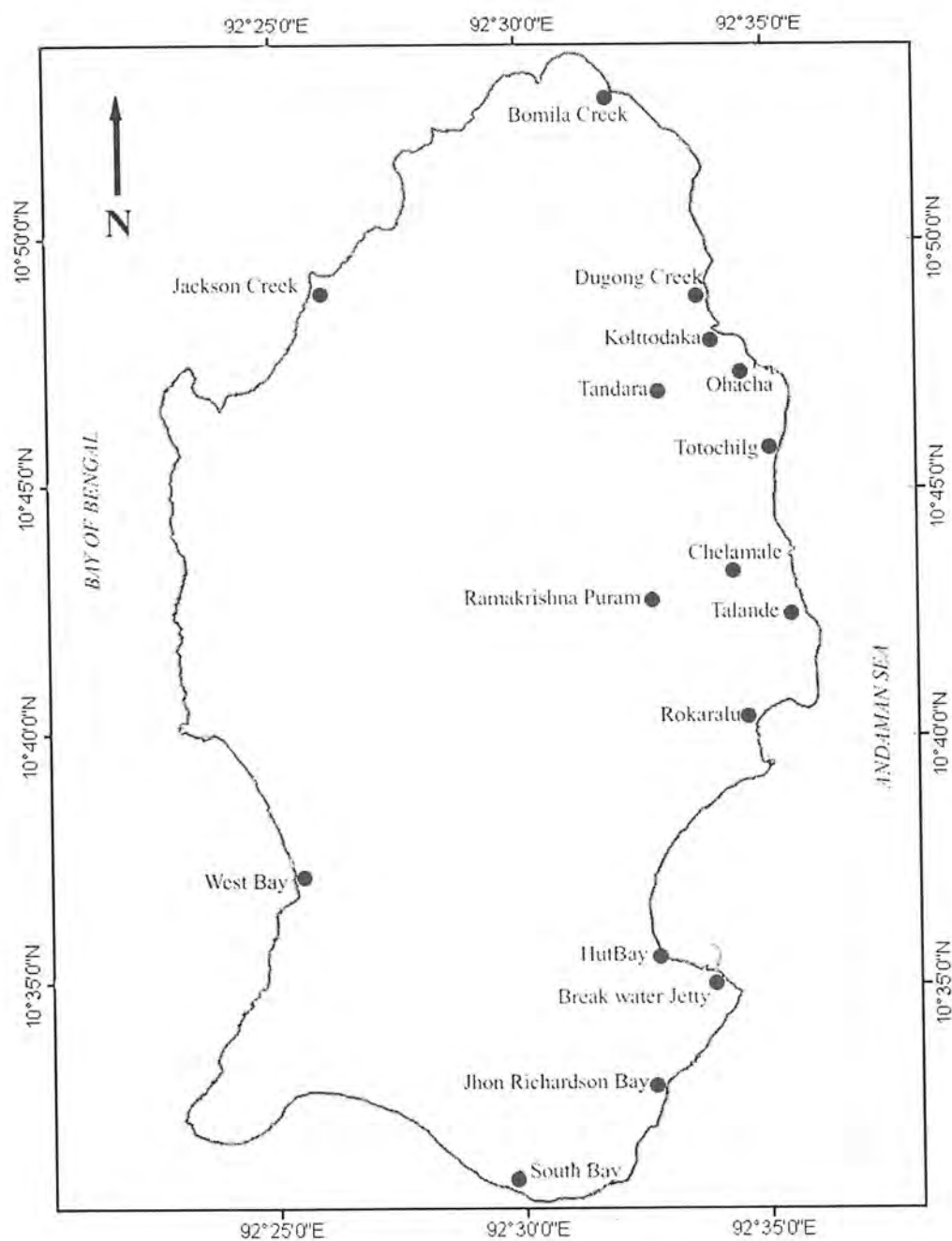


Figure 5.4: The locations surveyed from the Little Andaman biogeographic region in Andaman Islands.

5.2.3. Pattern of biogeography

To examine the pattern of biogeography of avifauna in the Andaman Islands, sampled bird data during the study period from total of 52 outer islands consisting of 36 Protected (Wildlife Sanctuaries and National Park territories) and 16 unprotected islands in Andamans has been taken for consideration (*Annexure 5.2*). On each island, birds were surveyed by a combination of visual observation and song identification. Species list, for all protected and un-protected islands, land/fresh water birds of resident and migratory status in eleven habitats were compiled (*Annexure 3.1*). The model applied here postulates that the number of species on an island is determined by the dynamic equilibrium opposing rates of immigration and extinction, which are influenced in part by island size and isolation. Further, to know the distribution pattern and ornithobiogeography the presence/absence data of bird species from different islands were scrutinized as follows.

i) *Nestedness*

To measure Nestedness of resident and migratory birds in Andaman Islands Nestedness Temperature Calculator (Atmar and Patterson 1995), a windows-based program created specifically to analyze nested patterns of island biotas was used. This program analyses presence/absence matrices of species distribution, where the islands are rows and species are columns (Atmar and Patterson 1993). Nestedness is assessed as 'temperature', ranging from 0-100°. A temperature close to 0° is very nested and one that is near 100° is decidedly not nested. A z-score was used to determine the probability that the 'temperatures' obtained from 1000 computer-generated simulations were different from the Nestedness actually evident in the Andaman Islands.

A program which considered the "nested subsets," where the species in smaller biotas comprise a proper subset of those in richer assemblages, was used (*Fig. 5.5*). The pattern is thought to result from the predictable sequence of species undergoing extinction from fragments: species that need vast areas to sustain minimum viable populations will go extinct quickly from each of the patches, while less needy species will find sufficient resources on a larger proportion of fragments. For Nestedness calculator presence-absence data of the species from different islands was used providing a risk assessment of the extinction probability of the various species' populations isolated on the islands of fragmented habitat.

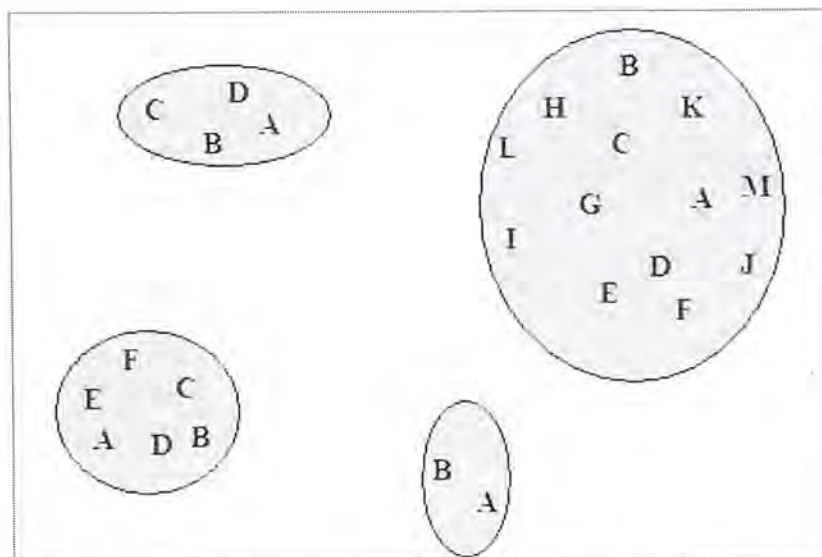


Figure 5.5: Schematic representation of nested archipelago. Species (denoted by letters) in the smaller islands are subsets of the larger ones. In a non-nested archipelago, each island may share a percentage of species with species-rich sites, but does not have an entire subset of the larger islands (Patterson 1987).

All physical observations are a mixture of signal and noise and nestedness is no different. The continuum that exists between the extremes of perfect nestedness and complete randomness can be described in the simplest of thermodynamic terms. A perfectly ordered system (perfectly nested), absent of all randomness, may be described as maximally "cold" (0°). Similarly, a system absent of all order may be labelled as maximally "hot" (100°). A presence-absence matrix that contains both a degree of nestedness order and randomness will register an "intermediate temperature" between these two end-points.

ii) *Ornithobiogeography*

An intertwined network of individuals, populations and interacting systems of the plant and animal world exist within the biosphere; it is essential to understand and view their systematic way of distribution in various approaches such as taxonomically, ecologically, phylogenetically and biogeographically. Present study undertook the task to develop ornithobiogeography based on similarities and differences in the occurrence of bird species recorded from the Andaman Islands within the group of islands and between mainlands of Southeast Asia and India for their conservation concern. Besides that, classification of the islands surveyed during

the present study based on the area was performed and the closest distance between the landmass was documented.

a) *Species area relationship*

In the 52 outer islands surveyed for bird study, following four variables were considered in the prediction of the number of bird species which are geographically distributed: area of the island, distance from the major Islands (includes North, Middle and South Andaman), distance to the large islands or the region of Southeast Asia and latitude. Further the approximate distance of the closest landmass from different region of Andaman Islands to Southeast Asia was obtained from www.googleearth.com.

b) *Source of data: status of avifauna and distance (from closest landmass)*

To compare the species affinity and dissimilarity with Southeast Asia and mainland India checklist of birds were obtained from the literature such as Check list of the birds of Southeast Asia (includes Myanmar [Burma], Vietnam, Thailand, Malaysia, Indonesia, Laos, Cambodia, Philippines and Papua Guinea) (source: <http://www.birdlist.org>) and Birds of the World-a Checklist (Clements 2000). According to Cook (1974) the distance effect can be illustrated by expressing the number of species on an island plotted against distance to the larger islands or the closest land mass (mainland) (Nores 1995). The updating and compilation of the species and subspecies was carried out by reference to major distributional and taxonomic works on India and Southeast Asia.

Myanmar (Burma)

Burma, officially known by Union of Myanmar (total area of 678,500 km²), is a large country in mainland Southeast Asia or Indochina, and is situated in the northeast of Andaman Islands, which has a total of 1,930 km of contiguous coastline along the Bay of Bengal and Andaman Sea to the southwest and south. It is bounded by Laos and Thailand to the southeast. The closest landmass or forest cover to the Andaman Islands has been considered to know the avifaunal distribution pattern between the regions such as a) Little Coco Island, Myanmar (13°58' N - 93°13' E), b) Kangyaing, Ayeyarwady Division (15°58' N - 94°14' E), c) Bogiyiwa, Tanintharyi Division (14°43' N - 97°50' E), d) Bailey Island, Tanintharyi Division (12°07' N - 97°43' E) (Table 5.1).

Thailand

Thailand lies in the middle of Southeast Asia and to the west of Andaman Islands covering about 5,13,000 sq.km. The closest landmass to the Little Andaman is Lankaen (10°31' N - 92°30' E), Thai Mueang, Phang Nga (**Table 5.1**).

Table 5.1: The list of the closest geographical distance (in km) from Andaman Islands to the nearest landmass in Southeast Asia. (Source: Google Earth 2009).

Locations in Andaman Islands (Co-ordinates)	Distance of nearest locations (in km)				
	to Myanmar				to Thailand
	a	b	c	d	
<u>Towards Northeast</u>					
1. Landfall Island, North Andaman (13°40' N - 93°01' E)	40	286	532		
2. East Island, North Andaman (13°39' N - 93°03' E)	39	285	528		
3. North mainland (13°34' N - 93°01' E)	48	295	534		
<u>Towards East</u>					
4. Inglis Island, South Andaman (12°08' N - 93°07' E)				505	
<u>Towards Southeast</u>					
5. South Bay, Little Andaman (10°31' N - 92°30' E)					660

Note: a) Little Coco Island, b) Kangyaing, Ayeyarwady Division, c) Bogiyiwa, Tanintharyi Division, d) Bailey Island, Tanintharyi Division.

Philippines

Philippines, the other geologically unique region of Southeast Asia consists of approximately 7000 islands, containing multiple centers of endemism (Mittermeier *et al.* 1998, Steppan *et al.* 2003).

5.3. RESULTS

5.3.1. Estimating species richness

Species accumulation curve with 95% confidence interval, as a function of occurrence (sample based rarefaction curve) for pooled data of North, Middle, South and Little Andaman has approached an asymptote and reached a plateau. After the initial (from 20th point) steep rise till end of the points sampled, the graph has almost flattened. It indicated addition of only a few species with additional sampling from major islands. Since the sample based rarefaction curve (darker line) is not above the observed richness, which is merged together indicates that enough sampling was done to detect most of the birds from total 1593 points across the 11 habitats surveyed in Andaman Islands (**Fig 5.6**).

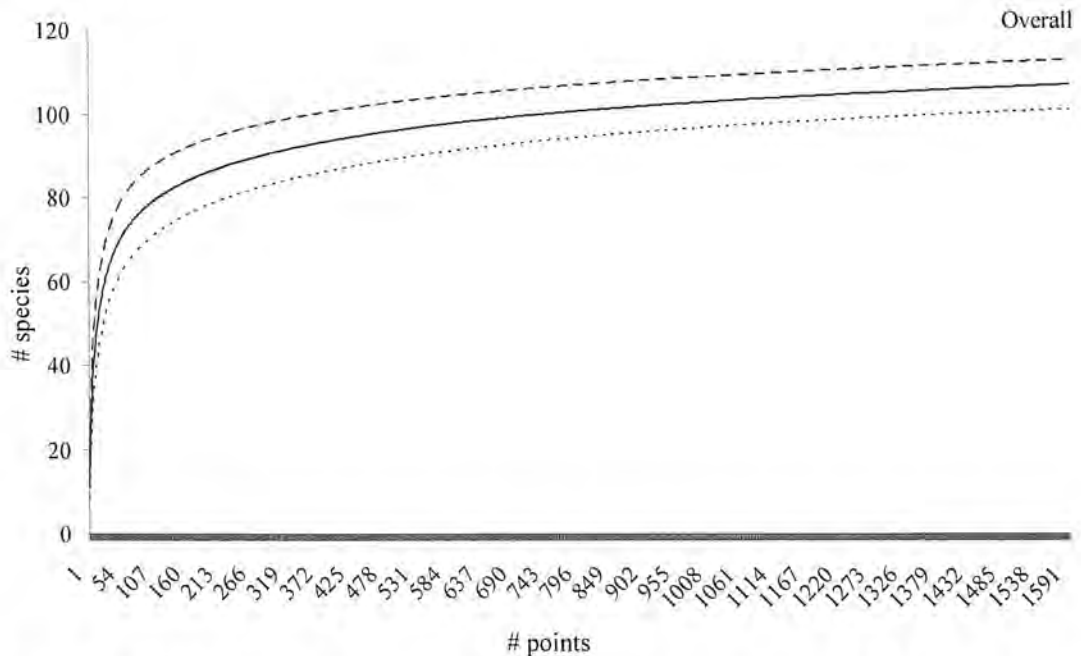


Figure 5.6: Sample based rarefaction curve (darker line) with 95% confidence intervals of upper and lower bounds (irregular lines) in the Andaman Islands.

The region-wise species accumulation curves also approached their asymptote and reached plateau (**Fig. 5.7**). Though the North (437), South (849) and Little (188) Andamans' sample based rarefaction curves indicated addition of only a few species, Middle Andaman (119) showed possibility of addition of more species by additional sampling effort.

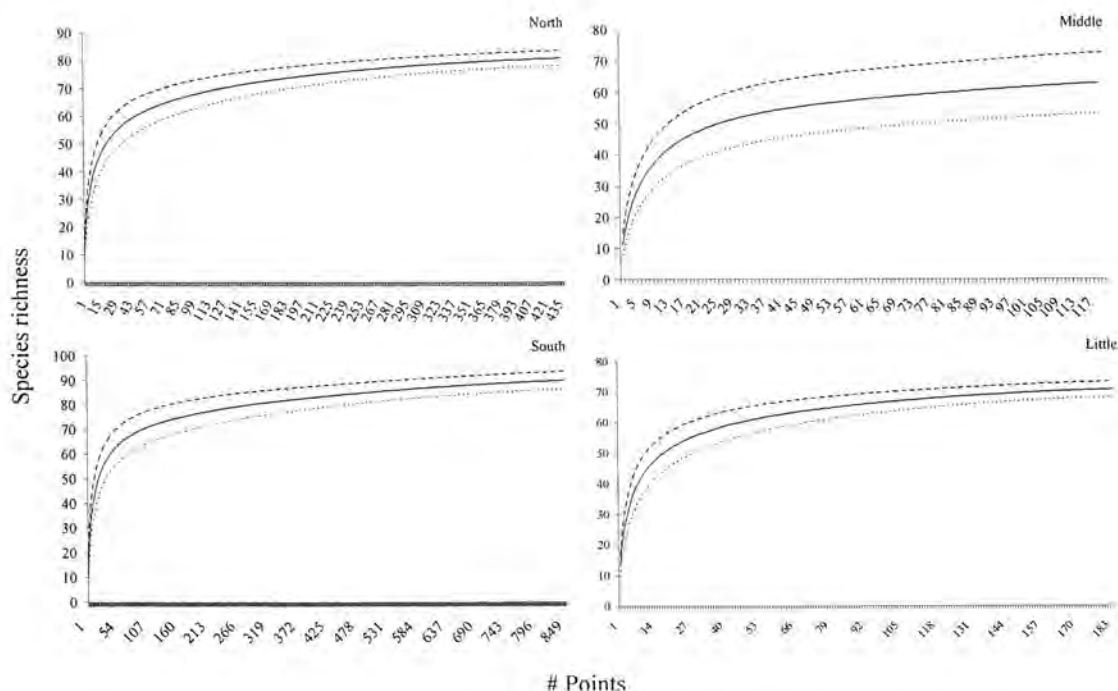


Figure 5.7: Sample based rarefaction curve with 95% confidence intervals of upper and lower bounds in different regions of Andaman Islands.

Further, considering only resident bird species in Andaman Islands non-parametric species estimators were used on the empirical data set collected from different regions. Together 107 resident birds were observed in the Andaman Islands from 1593 point stations and the pooled data set was analyzed for their estimated value (**Table 5.2, Fig 5.8**), in which the species accumulation curves for the pooled data has approached the asymptote and reached a plateau across the region. The lower curve in each panel (the species accumulation curve) plots the observed number of species, which is strongly (negatively) biased estimator of species richness as a function of the pooled samples for the avifaunal diversity study of Andaman Islands, and the upper curve in each graph as the estimated total species richness based on successively larger number of samples from the data set, which have reduced the bias.

The results from incidence based estimator-ICE (species in each samples) showed less number of unseen/missing estimated species among the bird community followed by abundance-based estimator (based on the ratio between rare/less than 10 and common species) and Jackknife orders (the species occur in 1 and exactly 2 samples). Notably in Middle Andaman Chao1 & 2 estimators showed the missing species higher than the others (**Table 5.3, Fig. 5.8**). For all curves, each point is the mean of 100 estimates based on 100 randomization of sample accumulation order (**Fig. 5.8**).

Table 5.2: The observed and estimated bird (resident) species richness recorded in different regions of the Andaman Islands with computed standard deviation (SD) which represents the entire population.

Region	Bird abundance	Species observed	Species richness estimators			
			Chao 1 ± SD	Chao 2 ± SD	Jackknife 1 ± SD	Jackknife 2 ± SD
North	6544	81	83.00 ± 7.82	83.00 ± 7.54	86.99 ± 9.32	84.02 ± 8.67
Middle	1789	63	103.50 ± 12.56	103.50 ± 12.07	71.92 ± 9.19	79.80 ± 10.51
South	12275	90	93.56 ± 9.39	93.56 ± 9.28	97.99 ± 9.63	97.00 ± 9.37
Little	4009	71	72.79 ± 6.50	72.79 ± 6.16	75.97 ± 8.60	74.03 ± 8.49
Overall	24617	107	117.13 ± 9.94	117.83 ± 9.82	115.99 ± 10.14	120.99 ± 9.91

Table 5.3: The effort (Point counts) and estimated number of unseen or missing species differences by various species estimators in different regions of the Andaman Islands.

Region	No. of points surveyed	Species richness estimators				
		ACE	ICE	Chao1 & 2	Jackknife 1	Jackknife 2
North	437	3.89	3.74	2.00	5.99	3.02
Middle	119	5.53	5.15	40.5	8.92	16.80
South	849	7.67	7.54	3.56	7.99	7.00
Little	188	3.06	2.90	1.79	4.97	3.03
Overall	1593	6.83	6.73	10.13	8.99	13.99

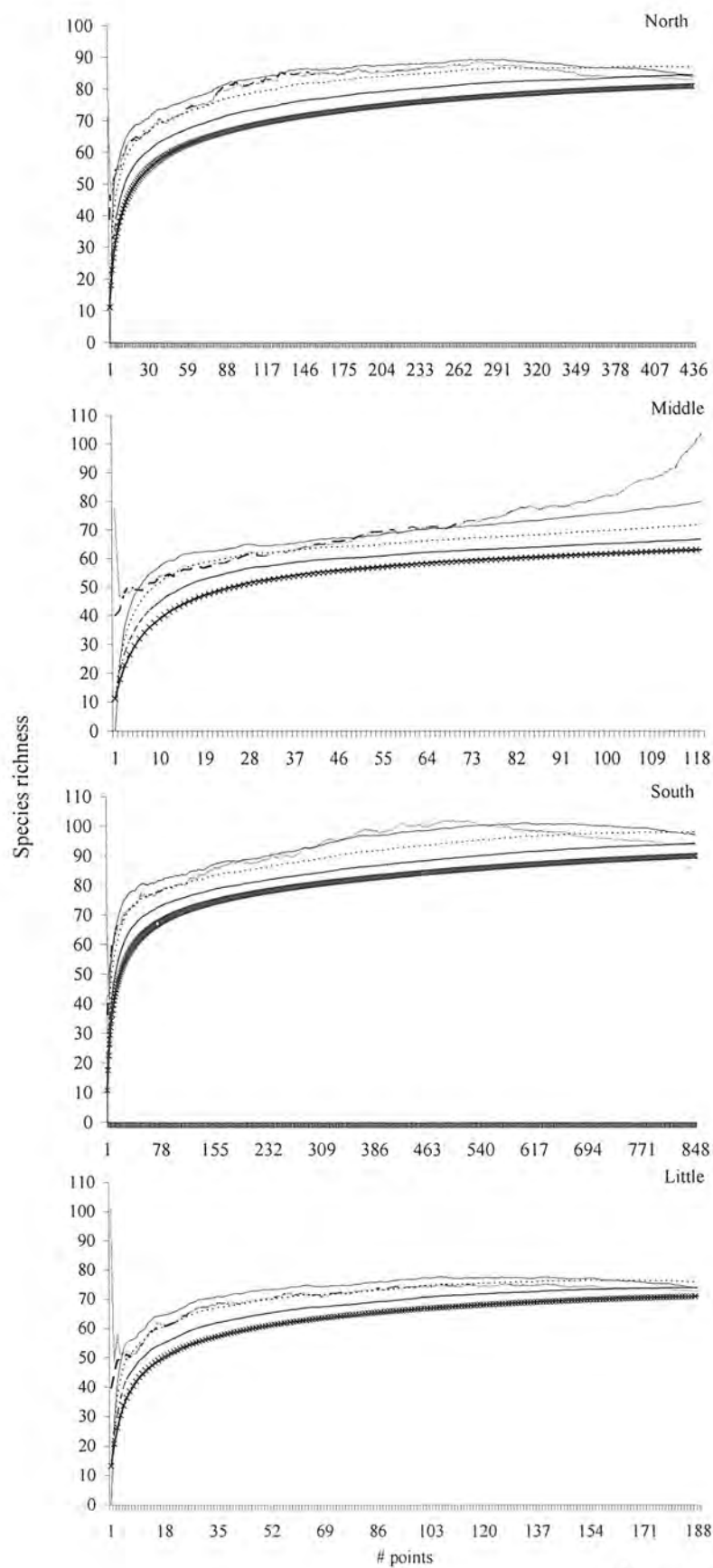


Figure 5.8. *continued.*

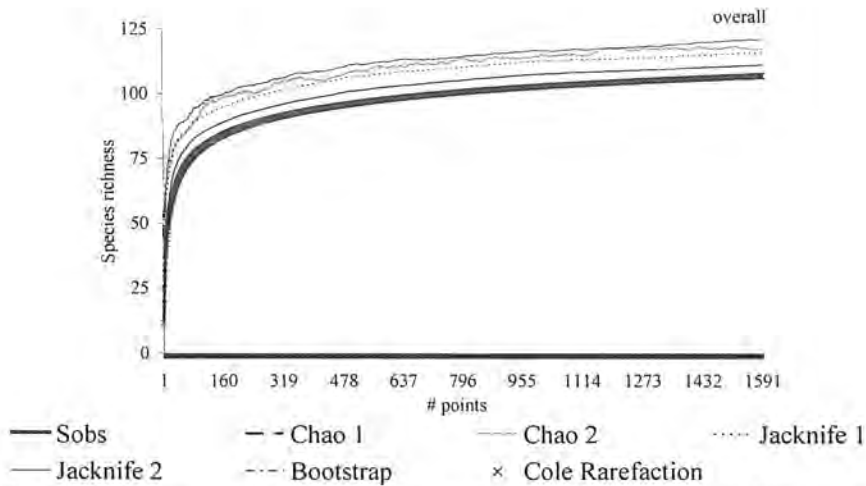


Figure 5.8: Performance of six non-parametric estimators of species richness for an empirical data set of different regions in Andaman Islands.

5.3.2. Nestedness

Species of 52 islands ranged from 7 to 39 and the composition of ranges was highly nested ($T=19.78^\circ$, $p<<0.0001$) (Fig. 5.9). If all species contributed equally to the nestedness of Islands of Andaman, then each would contribute equally to the temperature of the archipelago (Fig. 5.9c). Unusually strongly nested and non-nested species stand out from this expected pattern as particularly short (say, very few, or 10°) or especially long (say, ten expected, or 52°) bars. The species that fall in the middle of these extremes present ambiguities that cannot be fully explored. With this categorization to species scores resulted in 30 species out of 95 that are strongly nested (Annexure 5.1) and five species are distinctively idiosyncratic (Fig. 5.9c) and 23 are generally confined to the 14 islands richest in species (Fig. 5.9b).

Bird communities showed highly significant nested subset pattern, with observed $T = 19.78^\circ\text{C}$ ($P=9.15\text{e-}64$, matrix fill 18.6%). The T -values derived from 1000 randomized matrices were much higher (mean $T = 60.7^\circ\text{C}\pm 2.04$) (Fig 5.9d). As the high temperature suggests, however, there was much noise in the maximally packed matrix attributable to idiosyncratic species. The number of idiosyncratic species was low (5), constituting 5.3% of total species number (95) in sampled stream sites. This indicates that a strongly ordered pattern of distribution exists among the bird community in Andaman Islands. Species that exhibited a nested pattern are divided into two main groups as their probability of state occupancy:

- i) 21 species nested at 10-20% and below probability of state occupancy in the matrix, includes three near-threatened species marked by stars (Andaman Black

Woodpecker *Dryocopus hodgei*, Andaman White-breasted Kingfisher *Halcyon smyrnensis saturator*, Andaman White-breasted Waterhen *Amaurornis phoenicurus insularis*, Andaman Hill Myna *Gracula religiosa andamanensis*, Forest Wagtail *Motacilla indica*, Andaman Little Green Heron *Butorides striatus spodiogaster*, Brown-throated Spinetail Swift *Chaetura gigantea indica*, Andaman Chestnut-headed Bee eater *Merops leschenaulti andamanensis*, Burmese Red Turtle-Dove *Streptopelia tranquebarica humilis*, Large Sand Plover *Charadrius leschenaultia*, Great Stone Plover *Esacus magnirostris magnirostris**, Andaman Green Imperial Pigeon *Ducula aenea andamanica*, Andaman Wood Pigeon *Columba palumboides**, Grey Wagtail *Motacilla cinerea cinerea*, Brown Flycatcher *Muscicapa latirostris*, Eastern Black-naped Tern *Sterna sumatrana sumatrana*, Mangrove Whistler *Pachycephala grisola*, Small Andaman Drongo *Dicrurus andamanensis andamanensis**, Eastern Small Minivet *Pericrocotus cinnamomeus vivideus*, Large Andaman Parakeet *Psittacula eupatria magnirostris*, Andaman Blue-eared Kingfisher *Alcedo meninting rufigaster*).

ii) nine were strongly nested between 50-100% probability of state occupancy in the matrix (Andaman Magpie Robin *Copsychus saularis andamanensis*, Indian Drongo-Cuckoo *Surniculus lugubris dicruroides*, Eastern Reef Heron *Egretta sacra*, Andaman Crow-Pheasant *Centropus (sinensis) andamanensis*, Andaman Spotted-breasted Pied Woodpecker *Picoides macei andamanensis*, Black-capped Kingfisher *Halcyon pileata*, Himalayan Cuckoo *Cuculus saturatus saturatus*, Olive Flycatcher *Rhinomyias brunneata nicobarica*, Small Cuckoo *Cuculus poliocephalus poliocephalus*) (Fig. 5.9a, Annexure 5.1).

Roughly a five of 95 species in this archipelago exhibited pronounced idiosyncratic distributions (Andaman Red-breasted Parakeet *Psittacula alexandri abbotti*, Eastern Jungle Crow *Corvus macrorhynchus levaillantii*, Common Redshank *Tringa totanus totanus*, Migratory Nightjar *Caprimulgus indicus indicus*, Curlew-Sandpiper *Calidris ferruginea*) (Fig. 5.9a,c) with the highest species richness which occurred in ten major Islands, namely Tarmugli, Cinque, Point, Reef, Smith Island, Redskin, Landfall, Table (Excelsior), Alexandra, Bluff (Fig. 5.9b, Annexure 5.1 & 5.2).

With regard to the islands, the most distinctively nested were Redskin, Table (Excelsior), Bluff, Thorn Hill, Table (Dalgarne), Stewart, Anderson, West, Ox, Trilby and Bennette, whereas the species poor islands like Brush, Boat, East, South Reef, Helicopter, Avis, Oyster-1, Oyster-2, Mayo and Oliver supported relatively

idiosyncratic avifauna in the bird community (Fig. 5.9b, Annexure 5.2). Results of this analysis showed the level of observed nestedness was still highly significant ($p<0.0001$), but the temperature increased up to 52° (Fig. 5.9c).

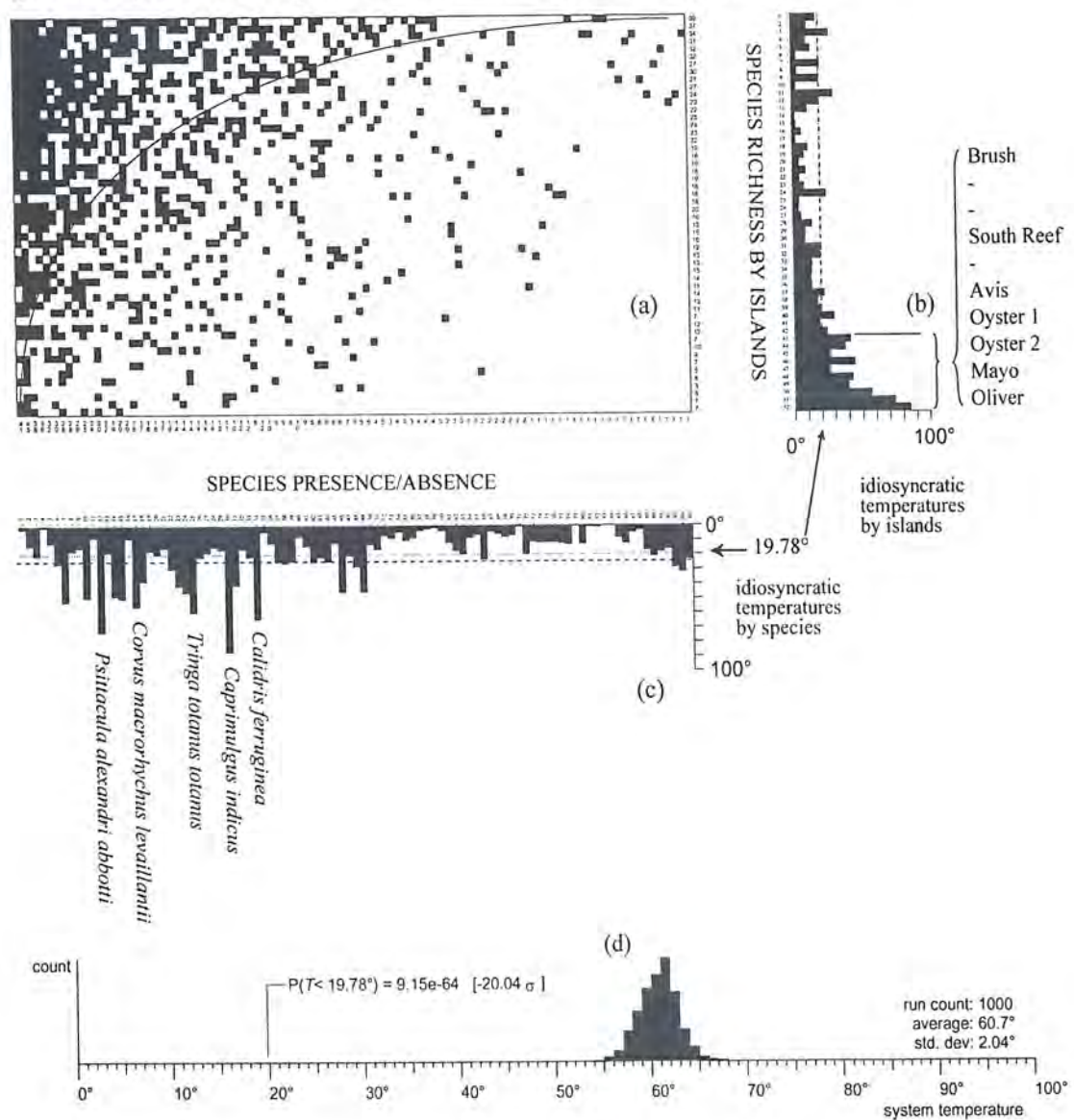


Figure 5.9: Nested subset patterns of avifauna in Andaman Islands. (a) Packed matrix showing distribution of species (columns) and species richness by islands (rows). Species presence in each island is depicted by a darkened square. (b) Nested and idiosyncratic islands portrayed here are ordered with corresponding species richness shown in (a). (c) Idiosyncratic species are listed here, whereas nested species are indicated in Annexure 5.1 either grouping of species follows the presence/absence in the islands and therefore resulting ‘temperatures’ directly follow the species-island pattern shown in (a). (d) Test statistic demonstrates the highly significant nestedness pattern ($P=9.15 \times 10^{-64}$) with a temperature’ of 19.78° .

5.3.3. Ornithobiogeographic affinities

i) Towards mainland of Southeast Asia and India

The total of 153 bird species recorded during the study period (*Annexure 3.2*) were used for its ornithobiogeographic affinities. The results showed total by 54 species (35.3%) shared with Nicobar Islands. The number of species shared with Southeast Asia is 136 (88.9%) consisting of 43 (31.6%) endemic (occurring as separate subspecies) and 93 (68.4%) non-endemic species. While compared with mainland India totally 129 (84.3%) species are common consisting of 37 (28.7%) endemics (as separate subspecies) and 92 (71.3%) non-endemic species. Together, Southeast Asia and mainland India had 124 (81%) common at species level. In subspecies level the comparison showed only 63 (41.2%) shared with India, 42 (27.5%) with Southeast Asia and 34 (22.2%) common to both (*Table 5.4, 5.5, Fig. 5.10, 5.11*).

Table 5.4: Details of the species and subspecies level affinities and dissimilarity of the avifauna recorded from the Andaman Islands towards nearest landmasses.

Region	Species level		Subspecies level	
	Affinity	Dissimilarity	Affinity	Dissimilarity
Southeast Asia (SE)	136	17	42	111
Mainland India	129	24	63	90
SE Asia & India	124	29	34	119

The total number of observed (153) bird species and subspecies coming under 98 genera were classified according to the affinity with Southeast Asia and mainland India and their species contributions (a= number of genera with only one species, b= two species, c= three species, d= four species and e= five species) (*Table 5.5*).

Among the 153 species recorded there are a) 64 species in 64 genera, b) 42 species in 21 genera, c) 21 species in 7 genera, d) 16 species in 4 genera and e) 10 species in two genera and categories of a & b have more affinities among regions, Southeast Asia and mainland India. In which out of 136 species (consist of 43 endemics and 93 non-endemics) having affinity with Southeast Asia, 129 species (consist of 37 endemics and 92 non-endemics) affinity with mainland India, and 124 species (consist of 36 endemics, 88 non-endemics) affinity with together Southeast Asia and mainland India, was found. No subspecies affinity was found with Southeast Asia and mainland India together (*Table 5.5*).

Table 5.5: Discriminate list of avifauna recorded in Andaman Islands and their affinities and dissimilarities to the nearest landmasses.

Category (G×S)	Southeast Asia (SE)				mainland India				SE Asia & India			
	species		subspecies		species		subspecies		species		subspecies	
	A	D	A	D	A	D	A	D	A	D	A	D
a (64×1=64)	53	11	21	43	53	11	24	40	49	15	15	49
b (21×2=42)	39	3	11	31	35	7	19	23	35	7	10	32
c (7×3=21)	18	3	2	19	16	5	6	15	15	6	2	19
d (4×4=16)	16	0	4	12	16	0	6	10	16	0	4	12
e (2×5=10)	10	0	4	6	9	1	8	2	9	1	3	7
Total (153)	136	17	42	111	129	24	63	90	124	29	34	119
(%)	88.9	11.1	27.5	72.5	84.3	15.7	41.2	58.8	81	19	22.2	77.8
Endemic	43	1	4	40	37	7	2	42	36	8	0	44
Non-endemic	93	4	38	59	92	5	61	36	88	9	34	63

Note: G = number of Genera, S=number of species, A=Affinities, D=Dissimilarities.

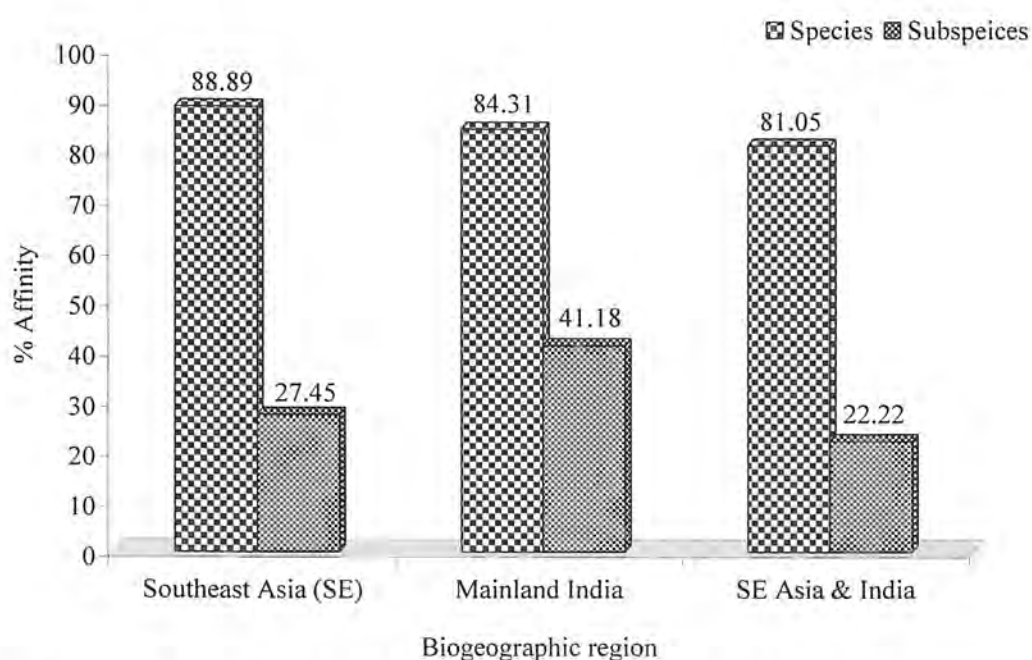


Figure 5.10: The calculated total percentage of avifauna affinity in Andaman Islands towards Southeast Asia, Mainland India and together (see also **Table 5.5**).

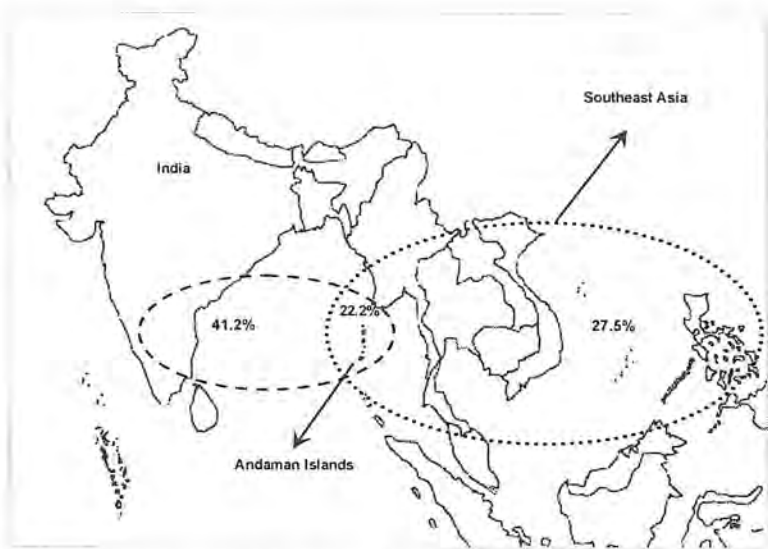


Figure 5.11: Schematic presentation of avifaunal affinities of the Andaman Islands. Percentages are proportion of the insular breeding and non-breeding subspecies shared with the sources areas.

ii) *Systematic affinities*

The systematic affinity against 153 species recorded from Andaman Islands which belongs to 36 families of 16 orders was analyzed. The first five taxa that are best represented in the archipelago are Plovers (21 species), Flycatchers (19 species), Herons, Egrets and Bitterns (9 species), Gulls & Terns (7 species) and cuckoos (7 species). The dominant families were Charadriidae and Muscicapidae and most of these were common to Mainland India and Southeast Asia (**Table 5.6**).

Table 5.6: Most abundant families of birds and their affinities in Andaman Islands.

S. No	Family	Southeast Asia (SE)				Mainland India				SE Asia & India			
		Species		Sub-sp.		Species		Sub-sp.		Species		Sub-sp.	
		A	D	A	D	A	D	A	D	A	D	A	D
1	Charadriidae	21	0	6	15	21	0	10	11	21	0	6	15
2	Muscicapidae	19	0	5	14	17	2	8	11	17	2	4	15
3	Ardeidae	8	1	4	5	8	1	5	4	7	2	3	6
4	Laridae	7	0	3	4	7	0	6	1	7	0	3	4
5	Cuculidae	7	1	5	3	7	1	6	2	7	1	4	4
6	Alcedinidae	7	0	1	6	7	0	1	6	7	0	1	6

Note: A = Affinities, D = Dissimilarities.

5.3.4. Biogeographic distribution of birds in the outer islands

The islands surveyed were categorized from 0.32 to 29.48 km² (Table 5.7).

Table 5.7: Classification of islands surveyed based on the area and biogeographic region of Andaman Islands.

Category	Size class (in km ²)	Biogeographic divisions			Total
		North	Middle	South	
a. <u>In protected list</u>					
i. Islands under Sanctuary					
a) Very small	0.32 - 0.58	17	1		18
b) Small	1.42 - 1.61	6		1	7
c) Medium	4.92 - 9.51	4		1	5
d) Large	11.10 - 29.48	1		1	2
ii. Islands under National Park					
b) Small	1.42 - 1.61			2	2
c) Medium	4.92 - 9.51			2	2
Sub total		28	1	7	36
b. <u>In unprotected list</u>					
a) Very small	0.32 - 0.58	5		1	6
b) Small	1.42 - 1.61	1		1	2
c) Medium	4.92 - 9.51	1	1		2
d) Large	11.10 - 29.48	4		2	6
Sub total		11	1	4	16
Grand total		39	2	11	52

Species area relationship

Based on the area and vegetation structure available in all major and outer islands surveyed in the Andaman Islands, from the empirical data set bird species richness and abundance were scrutinized. Overall the bird abundance was high in littoral habitat in various classes of islands such as very small (703), small (939), medium (1012) and very large (4514) islands excluding large island, where the evergreen habitat harboured more number of birds (560). Species richness in different size classes of islands showed that the littoral forest harboured more number of species than others. Species richness was very low in mangrove, plantation and coastal areas ranging from 6 to 28 in all size classes of islands except very large islands (Fig. 5.12). Bird diversity was high, ranged from 3.03 to 3.64 in all habitats in very large islands

except in the coastal (0.77). Diversity was found low across all habitats in very small islands (Table 5.8).

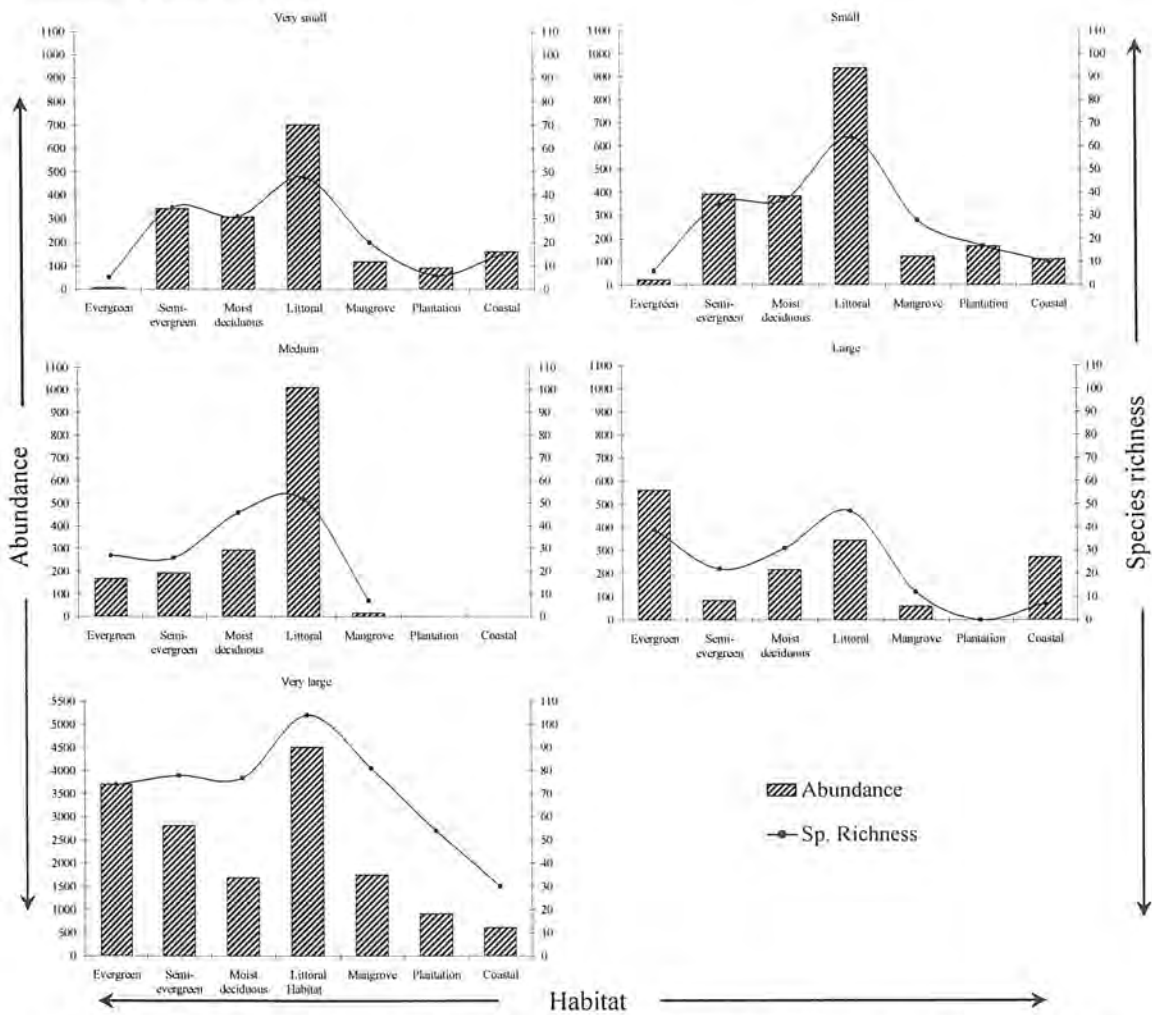


Figure 5.12: The observed bird species abundance and richness in different habitats based on the island area classification.

Table 5.8: The observed bird species diversity in different habitats based on the island area classification.

Island size class	Evergreen	Semi-evergreen	Moist-deciduous	Littoral	Mangrove	Plantation	Forest edges	Field	Degraded	Wetlands	Coastal
Very small	1.55	2.94	2.05	3.03	2.28	0.98					2.20
Small	1.01	2.98	2.98	3.32	2.97	1.72					1.44
Medium	2.52	2.41	3.24	3.17	1.84						
Large	2.87	2.79	2.92	3.36	1.99						0.77
Very Large	3.39	3.39	3.43	3.64	3.55	3.25	3.32	3.22	3.23	2.99	1.27

5.4. DISCUSSION

Estimating species richness

Totally 1650 points across the 11 habitats surveyed in Andaman Islands sampling five major and 52 outer islands were analyzed for the function of species occurrence. The sample based rarefaction curves showed completeness of the sampling in the regional level. Although it showed the variation of sampling effort in the biogeographical regions of the Andaman Islands (North, Middle, South and Little) the observed and estimated bird species was comfortable, by means of less number of estimated unseen and missing species from various species richness estimators. The quantitative estimators of chao 1 & 2 worked out from the empirical data set from respective regions gives the presence-absence data of species found in one sample and two (Chao 1984) separately in order to invent habitat sustainability of the species for conservation management. The results obtained showed high affinity between expected and observed species in North, South and Little Andaman except Middle where incise of Jackknife 1 & 2 estimator showed minimum bias. Most of the other estimators showed less variances which are considered as efficient estimators (Walther and Moore 2005). The results showed the need for more sampling in Middle Andaman for better species estimation among the region.

Nestedness

Nestedness, the expected pattern for species assemblages of the Andaman islands exhibits total 30 species are strongly nested and five (Andaman Red-breasted Parakeet *Psittacula alexandri abbotti*, Eastern Jungle Crow *Corvus macrorhynchus levaillantii*, Common Redshank *Tringa totanus totanus*, Migratory Nightjar *Caprimulgus indicus indicus*, Curlew-Sandpiper *Calidris ferruginea*) are distinctively idiosyncratic and 23 are generally confined to the 14 islands richest in species (see *Annexure 5.1*). Nestedness represents the degree to which species assemblages are proper subsets of larger assemblages. Where highly nested assemblages are characterized by a high number of species conforming to nested subset pattern and a low number of species, which depart from nested pattern, that is, idiosyncratic species (e.g. Soininen 2008). However, results showed that the degree of nestedness was highly significant in these data, bird communities in Andaman Islands were characterized by low number of idiosyncratic species.

Speciation is largely driven by allopatry i.e. geographical separation, of which islands are ideal examples. There is also a relationship between island size and size of the biota (Koh *et al.* 2002). Furthermore, the Southeast Asian region features unique ecological processes, such as the strong synchrony of fruiting of trees (mast events) from the Dipterocarpaceae, which has major implications for forest ecology and conservation (Curran *et al.* 1999).

Ornithobiogeographic affinities

The geographical and biogeographical classification of the Andaman Islands has been performed in the present study to acquire knowledge about the avifaunal distribution among and between nearest landmasses, Southeast Asia and mainland India. The results showed distinct nature of avifauna in the Andaman Islands with that of the Nicobar Islands and the affinity with Southeast Asia and India, but more with the former. A biogeographic analysis of avifauna in Andaman and Nicobar Islands on 104 breeding species by Ripley and Beehler (1989) has demonstrated their affinities together with the Andaman and Nicobar Islands. Since these islands groups are closest to that of Southeast Asia and far away from mainland of India by distance the bird species distribution among and between the islands are liable. The impoverished nature of breeding avifauna was attributed to the isolated nature of these islands. Especially, the Nicobar Islands have been isolated by permanent water barriers from the Andaman Islands and thus had less affinity of bird species. The importance of gaps in deciding the capability of colonization of species and determining the species relations have been discussed by Grubb and Doherty (1999). They showed that larger species are able to move between patches and colonize. Abundance of smaller species such as warblers are poorer in these islands (Thiollay 1997) and is probably because of this effect.

The major path of the colonization of the islands took place along a single route from southwestern Burma, via series of overwater barriers that acted as filters (Ripley and Beehler 1989). The model is developed by compilation of bird distribution data from the region of Southeast Asia and mainland India. In which the island breeding species, total of 153 bird species recorded from the present study that occur in only two of the possible source regions include the mainlands of Southeast Asia and India was analyzed. Where, the Southeast Asia, closest landmass to the Andaman Islands claimed more similarities in species and subspecies level. While the systematic

affinities amongst the region are from Charadriidae and Muscicapidae, known for their wide distribution/migration are the dominant as well as reinforced high similarity of species among the bird community in the Andaman Islands.

Biogeographic distribution of birds in the outer islands

The quantitative approach on bird community in outer islands, in different size classes in different habitats showed abundance and species richness to be high in the littoral habitat excluding larger islands, where the evergreen habitat harboured more number of birds (560). Since the less area of mangrove, plantation and coastal region was covered from the 52 outer islands, due to high and low tide movements, the species richness detected was very low. The species richness does not depend solely either on area or habitats but on both of them. In many studies it has been implied or established that area and habitat diversity are inter-connected (Power 1972, Kitchener *et al.* 1980a, b, Reed 1981, Rafe *et al.* 1985, Newmark 1986, Kohn and Walsh 1994, Williamson 1988, Ricklefs and Lovette 1999) and thus habitat hypothesis and area *per se* hypothesis may not be mutually exclusive (Newmark 1986, Kohn and Walsh 1994, Rosenzweig 1995, Ricklefs and Lovette 1999). In at least three different works, there has been not only a quantitative approach of the effects of island area and habitat diversity on islands' species richness but also of the degree of their interconnection. Kohn and Walsh (1994) used path analysis with correlated causes (Sokal and Rohlf 1981) in order to assess quantitatively the direct and indirect effects of habitats and island size on species richness. They managed to calculate the direct effects of area and habitat diversity on species richness, respectively, but also the indirect effects of area through habitats (Triantis *et al.* 2003).

The species diversity and richness in different size classes showed that very small islands had minimum number of birds and less diversity, except littoral forests than the others. The maximum bird diversity and richness was observed from very large islands across all habitats. As MacArthur and Wilson (1967) and many others have observed (Wiens 1962, Niering 1963, Whitehead and Jones 1969, Woodroffe 1986, Dunn and Loehle 1988, Lomolino 2000, Lomolino and Weiser 2001), species richness may be uncorrelated with island area for relatively small islands. This phenomenon is known as the small island effect. The main feature of small island effect is that an increase of species number along with the increase of area in small islands is not observed. On small islands, habitat characteristics, occasional disturbances, isolation

and intraspecific interactions are likely to determine how many species have the ability to maintain populations (Losos 1996, Whittaker 1998, Lomolino 2000, Lomolino and Weiser 2001).

5.5. SUMMARY

- In order to know the insular biogeography of the bird community in the Andaman Islands the Nestedness pattern was studied considering the “nested subsets” where the species in smaller biotas comprise a proper subset of those in richer assemblages.
- The Nestedness would assess a ‘temperature’, ranged between 0 and 100° where the temperature close to 0° is very nested and one that is near 100° is decidedly not nested.
- Further, the pattern will execute results from the predictable sequences of species undergoing extinction from fragments: where the species that need vast areas to sustain minimum viable populations would go extinct quickly from each of the patches, notoriously the less needy species would find sufficient resources on a larger proportion of fragments.
- In Nestedness calculator the presence/absence matrix of species distribution in 52 outer islands from the Andaman was analysed where the islands were arranged in rows and species in columns. The species ranged from 7 to 39 among 52 islands in the matrix the composition of these ranges is highly nested ($T=19.78^\circ$, $p < 0.0001$) which indicates a strongly ordered pattern of bird species distributions in the Andaman Islands.
- The categorisation of species with scores resulted in 30 out of 95 species strongly nested, five distinctively idiosyncratic and 23 are generally confined to the 14 islands, which are richest in species.
- Species that exhibited a nested pattern were divided into two main groups as their probability of state occupancy: i) 21 of 95 species were nested at 10-20% and below probability of state occupancy in the matrix, includes three near-threatened species and ii) nine of 95 were strongly nested between 50-100% probability of state occupancy in the matrix.
- Roughly, a five of 95 species in this archipelago exhibited pronounced idiosyncratic distributions. With regard to islands, the most distinctively nested were the Redskin, Table (Excelsior), Bluff, Thorn Hill, Table (Dalgarne), Stewart,

Anderson, West, Ox, Trilby and Benette, whereas the species poor islands Brush, Boat, East, South Reef, Helicopter, Avis, Oyster 1, Oyster 2, Mayo, Oliver supported relatively idiosyncratic avifauna. Results of this analysis showed that the level of observed nestedness was still highly significant ($p < 0.0001$), but the temperature increased to 52°.

- For ornithobiogeographic affinities of the Andaman Islands the total of 153 species belonging to 36 families of 16 orders recorded during the study period was used. The species similarity in terms of occurrence amongst the mainland's of Southeast Asia and India was examined.
- Andaman avifauna showed closer affinity towards Southeast Asia than Mainland India as well in the case of endemics at the species level too.
- Based on the area and different vegetation structure available in all major and outer islands in the Andaman Islands, from the empirical data set bird species richness and abundance were scrutinised.
- Overall the bird abundance was observed high in littoral habitat in various classes of islands such as very small, small, medium and very large islands excluding large island, where the evergreen habitat harboured more number of birds.

CHAPTER SIX

INSULAR BIOLOGY OF ENDEMIC AND THREATENED BIRDS WITH SPECIAL ATTENTION TO ANDAMAN TEAL AND POST-TSUNAMI EFFECTS ON ITS COASTAL HABITATS

6.1. INTRODUCTION

Despite their remarkable flying abilities, most birds are limited, as are other animals, to specific areas called ranges; very few can have cosmopolitan ranges. Most of the oceanic islands birds have highly restricted ranges for which the major factor is geographical barriers; stretches of open water may limit the ranges of land species (Pettingill 1985). Each continent has its own fauna with certain forms that are endemic, or indigenous, meaning that they are native to or restricted to the area and reside nowhere else. The Oriental region has perhaps 1,500 species among some 83 families only one of which is endemic. All the other families are shared with one or more of the neighbouring regions (Pettingill 1985).

However, the most attention has been focused on community-wide density compensation of the summed population density of individuals of all species on islands [is] equal to the summed mainland density as a result of niche expansions and higher abundances of island species compensating for the absence of many mainland species (MacArthur *et al.* 1972). Island density may also be greater if the island species are generally smaller than their mainland counterparts, so that a larger number of individuals will result in the same community biomass (MacArthur *et al.* 1972, Emlen 1979, Emlen *et al.* 1986, Blondel 1985a).

The predictions of the competition theory says that populations of a species should occur in areas or habitats lacking one or more competing species, should exhibit ecological release relative to populations occupying similar situations where the competing species are present (MacArthur *et al.* 1972, Pianka 1981). Though the populations change to use some portion of the resources or niche space made available by the absence of the other species, a new state of integration and balance is achieved within the avifauna (Keast 1970). Nevertheless, population densities may be

higher in the absence of putative competitors, leading to density compensation in populations or in entire guilds or communities (MacArthur *et al.* 1972). The niche breadth of the population may increase with respect to habitat, elevation, foraging, or diet, either through the expansion of the niche space of individuals or through an increased diversity of individuals within the population (Roughgarden 1979).

The mega earthquake and *tsunami* of December 2004 created havoc on the coastal areas in the Andaman Islands. Due to tilt in the land, the southernmost Nicobar Islands were sunk by about 1.6m and northernmost Andaman Islands have been lifted up about 1.2m causing seawater inundation of inland freshwater bodies, destruction of marshes and creeks and soil erosion etc. (Sankaran 2005, Jayaraj and Andrews 2005). Most of the coastal wetlands in the Andaman Islands have been affected. However, specific habitats and locations of occurrence of the Andaman Teal were not given attention and it was essential to understand the magnitude of the impact of *tsunami* on their habitat and population in the coastal wetlands.

6.2. BACKGROUND

The current scenario of our planet is that 40% of the arable land has suffered long-term damage. Every year 13 million hectares of forest disappear due to anthropogenic activities, forest fire etc, and one mammal in four, one bird in eight, one amphibian in three are threatened with extinction. Species are dying at a rhythm 1000 times faster than the natural rate. Three quarters of the fishing grounds are exhausted, depleted or in dangerous decline. The average temperature of the last 15 years has been the highest ever recorded. The ice cap is 40% thinner than 40 years ago. There may be at least 200 million climate refugees by 2050 (www.goodplanet.org).

Worldwide total of 16,119 species are threatened with extinction, but this may be a gross underestimate because fewer than 3% of the world's 1.9 million described species have been assessed by the Red List, Animals: 7,725 species, Plants and lichens: 8,394. In major species groups, the percentage of threatened species ranges between 12% and 52% (Table 6.1, IUCN 2007); 99% of the threatened species are at risk from Anthropogenic activities (accounted for all) and, habitat loss and degradation are the leading threats for birds, for about 86% of all threatened birds, followed by others, introductions of alien species, over-exploitation (resource extraction, hunting and pets) and human induced climate change (IUCN 2007, BirdLife International 2009).

Table 6.1: Details of the threatened species in the world.

Group	within group
Birds	12% or 1 in 8
Mammals	23% or 1 in 4
Amphibians	32% or 1 in 3
Turtles and tortoises	approximately 42%
Conifers	25% or 1 in 4
Cycads (an ancient group of plants)	52%

Source: IUCN Species Survival Commission, 2007.

Most threatened species are in the tropics, especially on mountains and on islands, noticeably the vast majority of extinctions since 1500 AD have occurred on oceanic islands and over the last 20 years, roughly 50% of extinctions occurred on continents. Since 1994 the number of bird species threatened with global extinction has risen to 12%. Red List Indices for birds and amphibians show that the status of both has declined steadily since the 1980s, for birds 30% are threatened by over-exploitation and invasive alien species which are impacting 67% of threatened birds on islands (IUCN 2008). In the latest assessment done by BirdLife International (2008) (the official IUCN Red List Authority for birds, and therefore coordinates the categorisation and documentation for all bird species on the IUCN Red List), 1,226 species are considered threatened with extinction. This represents 12% of the total of 9,856 living bird species in the world. Of the threatened species, 190 are considered Critically Endangered and are therefore at extremely high risk of extinction in the wild. In, India, of the 1,228 species, around 73 are threatened and 55 near threatened (Fig. 6.1, 6.2).

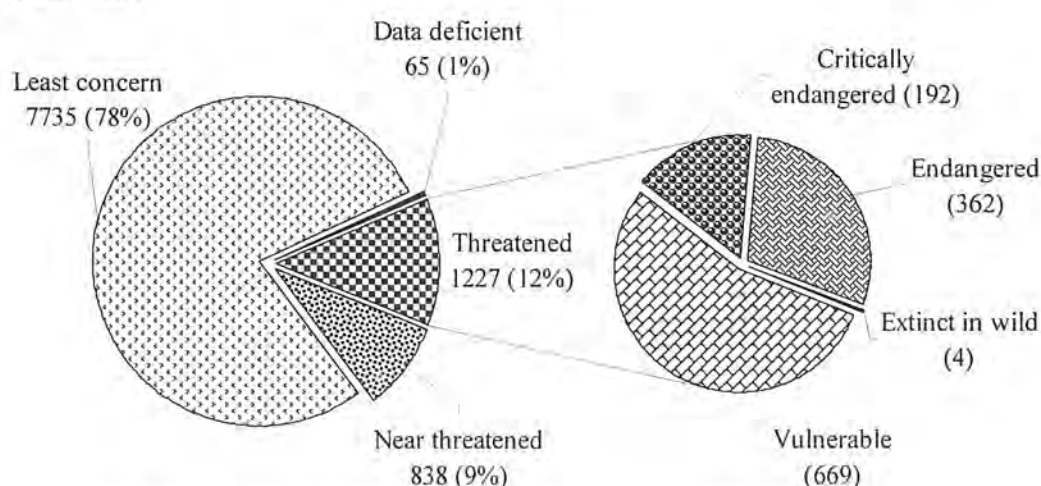


Figure 6.1: Status of the number of Red listed birds in the world.

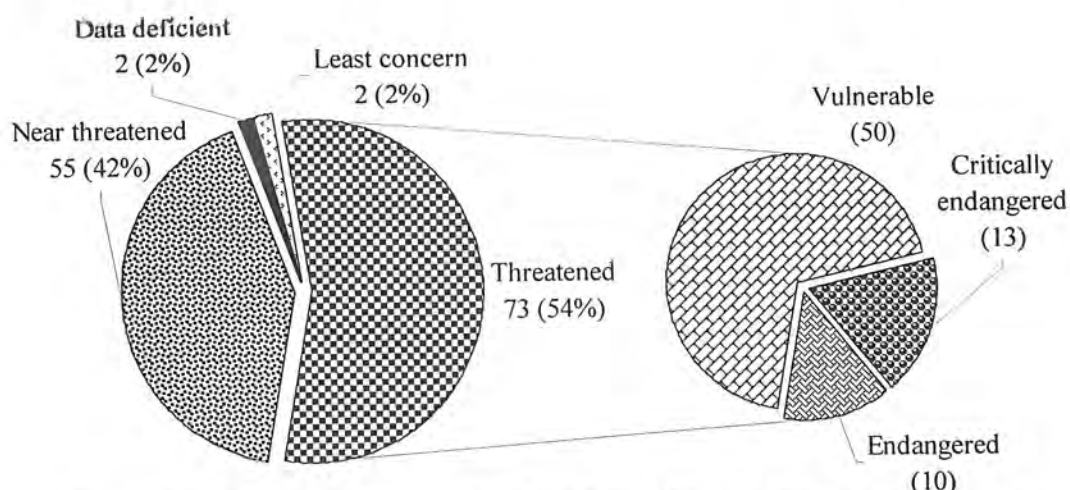


Figure 6.2: Status of the number of Red listed birds in Indian subcontinent.

6.2.1. Indo-Burma biodiversity hotspot

The tropical rain forest of Andaman Islands comes under the Biodiversity hotspot in Indo-Burma region (Biodiversity Hotspots 2007), which encompasses more than 2,373,000 km² of tropical Asia stretching from India to Vietnam (Plate 6.1). This hotspot is also known for its incredible bird diversity, holding almost 1,300 different bird species, including the threatened Narcondam Hornbill *Aceros narcondami*, White-eared Night-heron *Gorsachius magnificus*, the Grey-crowned Crocias *Crocias langbianis*, and the Orange-necked Partridge *Arborophila davidi* (BirdLife International 2004).



Plate 6.1: Map of the Indo-Burma biodiversity Hotspot (Source: Conservation International).

Endemism in the region

Endemism of the Southeast Asia, the nearest landmasses to the Andaman Islands was documented. Myanmar (Burma) has a total of 1062 birds of which six are endemic, two introduced, 10 rare or accidental, one extirpated and 51 globally threatened species. While in Thailand, of about 982 species, there are three endemic, one introduced, 45 rare or accidental, seven extirpated (Robson 2004) and 49 globally threatened species (Table 6.2, Birdlife International 2007).

The other region of Southeast Asia, which are the closest landmasses to Andaman Islands, namely Laos, Cambodia, Malaysia and Philippines are well known for high endemism in avifauna and their vulnerability. Though the number of birds are less than in Malaysia and Laos, the number of globally threatened species in Philippines is high which might be due to their diversified island structure, the environmental changes and human intervention. The colonization of newly formed oceanic islands, followed by genetic differentiation and long-term persistence has resulted in the extraordinarily high species richness and endemism of the Philippines (Steppan *et al.* 2003) (Table 6.2).

Table 6.2: The list of birds documented from the closest landmasses in Southeast Asia to Andaman Islands.

Region	Total area (in sq. km)	Total No. of species	Endemic	Introduced	Rare/ accidental	Globally threatened
Myanmar	676,578	1062	6	2	10+1	51
Thailand	513,120	982	3	1	45+7	49
Laos	236,800	701	-	2	8	25
Cambodia	181,035	553	-	2	-	25
Malaysia	329,847	781	10	3	10	45
Philippines	300,000	612	194	3	52	67

6.2.2. Uniqueness of Andaman Islands biodiversity

Andaman Islands, which fall within the Indo-Burma biodiversity hotspot form one of the 218 endemic bird areas (EBA 125) in the world with 12 endemic bird species (Birdlife International 2008) of which two are threatened and 10 near-threatened, in addition two near-threatened species are non-endemics (Birdlife International 2009).

The biological diversity in Andaman Islands has resulted from the interaction of topography, past climate changes, soil characteristics, and the hotspot's patterns of seasonal rainfall. From the collective information total of 6408 km² 87.84% area are protected and the region contains high endemism in flora and fauna (**Table 6.3**).

Table 6.3: Vital Signs of flora and fauna of the Andaman and Nicobar Islands.

Region	area (in km ²)	of plant sp No.. (n=246)		No. of bird species						
		Endemic	Rare	Total spp.	Exclusive spp.	Threatened	Vulnerable	Near threatened	Data deficient	Least concern
<u>Within hotspot</u>										
Andaman Islands	6408	66	48	216	126	16	1	12	-	3
<u>Outside the hotspot</u>										
Nicobar Islands	1841	48	18	144	56	5	3	1	1	-

Source: Dept. Environment & Forests, A&N Islands, Sankaran and Vijayan 1993, Birdlife International 2009.

Endemism of the Islands

Of special note while discussing the ecological profile of these islands is the high level of endemism. Overall, 9% of the fauna is endemic. In birds, 40.2% of the 246 species and subspecies are endemic. In mammals, 61.5% of the 55 species are endemic (**Table 6.4**). The Andaman and Nicobar Islands support a significant diversity of reptile and amphibians with a high level of endemism. Currently seven amphibians and 16 reptile species are endemic to the Andamans and two amphibians and 15 reptiles are endemic to the Nicobars (Das 1994, Andrews and Whittaker 1998, Das 1999, Andrews 2001, Andrews and Sankaran 2002).

Representing 700 genera and 2500 species belonging to 140 families, about 14% of the angiosperm species are endemic to the islands (**Table 6.4**). Among the non-endemic angiosperms about 40% are not found in mainland India, but have only extra-Indian distribution in South East Asia (Rao 1996). The butterfly diversity and endemism is also very high, of the 214 species and 236 subspecies in 116 genera, over 50% are endemic (Khatri 1993).

Table 6.4: Status of endemism: Flora and Fauna of Andaman & Nicobar Islands.

Group	No. of sp./ subspecies	No. of Endemics	% Endemics
<u>Flora</u>			
Plants	2500	350	14.0
<u>Terrestrial Fauna</u>			
Mammalia	55	32	61.5
Aves	246	99	40.2
Reptilia	76	24	31.6
Amphibia	18	3	16.7
Mollusca	110	77	70.0
Arachnida	94	38	40.4
Hemiptera	146	22	15.0
Diptera	214	24	11.2
Coleoptera	878	92	10.5
Lepidoptera	426	52	12.2
Isoptera	40	19	47.5
Odonata	36	4	11.1
Annelida	30	9	30.0
Total	2369	495	20.9 average
<u>Marine Fauna</u>			
Mammalia	7	-	-
Reptilia	12	-	-
Pisces	1200	2	0.2
Echinodermata	350	4	0.4
Mollusca	1000	18	1.9
Crustacea	600	6	1.0
Polychaeta	184	4	2.2
Anthozoa	326	2	0.6
Porifera	72	-	-
Micofauna	490	102	21.0
Total	4241	138	0.11 average

Source: Souvenir (1883-2008), Dept. Environment & Forests, A&N Islands.

This endemism is due to the isolation from mainland Asia (Das 1999). Thus, considering the size and area of the islands, loss of habitat leading to extinctions will have far greater consequences in terms of the loss of genetic diversity than

comparable areas elsewhere. A rough calculation using island biogeography theory indicates that with the area of forest down to 86% of what it used to be; about 4.5% of species may have been lost (Jayaraj and Andrews 2005).

Threatened species of the Islands

Generally the distribution pattern supports the extralimital range to most of the birds using the terms defined under 'Area covered'. Only a few species occurred in oriental region and most are restricted to the Andaman and Nicobar Islands. The existing data was used to get island-wise information on the population and density of the endemic and threatened birds.

Over 9.13% of avifauna (21 of 230+species) of Andaman and Nicobar islands are of great conservation concern, considered globally threatened (categorised as Endangered or Vulnerable, threatened or Data Deficient and near threatened) following the IUCN (2007) Red List criteria. Andaman Teal, threatened subspecies (Green 1996) also has been considered as a full species (Rasmussen and Anderton 2005). These birds will be the next to go extinct (due to a number of different threat factors), and thus it is our collective responsibility to focus on their conservation. There is not much study and very little awareness or understanding of these island threatened birds and this can inhibit the species conservation efforts locally.

6.3. MATERIALS AND METHODS

6.3.1. Endemic and Red listed species

The recent list gives 21 full species endemics only in Andamans (Rasmussen and Anderton 2005). Relying on information from Ali and Ripley (2001), Inskipp *et al.* (1996), Grimmet *et al.* (1998) and Kazmierczak and VanPerlo (2000), Sankaran and Vijayan (1993), Vijayan *et al.* (2000), Yahya and Zarri (2002), Vijayan *et al.* (2005, 2006), Rasmussen and Anderton (2005) and all endemic/non-endemic threatened species account from BirdLife International (2009) details on status and distribution of the endemic and threatened species are documented.

6.3.2. Methods adopted

The present study assessed the distribution, and density of near threatened birds which includes 10 indigenous, resident species (9 land birds + one water bird, the Andaman Banded Crane) and 2 non-endemic the Great Stone Plover, locally migrant and Nicobar Pigeon, widely distributed small island specialist. Nevertheless, among the

three least concern species from Andaman Islands the Andaman Teal, endemic and only threatened species among the 48 Anatidae recorded in India and recently denoted as least concern species by BirdLife International (2009) was studied in detail with their population and habitat assessment in terms of post-*tsunami* impacts on the coastal wetlands.

i) Avifaunal Density

The knowledge on the size or density of a population of birds from Andaman Islands is potentially a very valuable piece of information and is essential for the further studies on avian population biology, community ecology, and conservation in this region. Many techniques exist for acquiring estimates or relative indices of bird population sizes (Ralph and Scott 1981, Verner 1985). For the estimation of the size and trend of islands forest bird population, variable circular-plot (VCP) method (Ramsey and Scott 1979, 1981, Reynolds *et al.* 1980, DeSante 1981, 1986, Scott *et al.* 1986) was used. The method was used in all stations covering all major vegetation types along transect. It is also known as variable area surveys or point transects (Buckland *et al.* 1993). From a fixed 10min sampling period and 200m intervals between the stations, each bird seen or heard was counted particularly those birds which were actively using the study area and the birds flying overhead (Reynolds *et al.* 1980). The straight-line distance from the station center to the birds was estimated. The birds that were flushed while approaching the station were counted and their distance from the station center was estimated. The raw data consisted a list of birds, observed with individuals and their estimated distance from the station centre (Reynolds *et al.* 1980, Skirvin 1981).

The estimation of density (bird/m²) for each species the bird abundance vs distance, within the concentric bands (minimum 0 to 10m and maximum 50 to 60m width) was plotted. The calculated area for 10m concentric bands are as follows: 0-10m = 314m², 10-20 = 943m², 20-30m = 1570m², 30-40m = 2200m², 40-50m = 2827m², 50-60m = 3456m². Further the population density (birds/km²) for each species in region/habitat-wise was then estimated by summing the densities (both the number of individuals and the areas were summed). Since greater than one station was used, the estimated bird densities for all stations was divided by total number of stations, to provide an estimate of density for the species as a whole for the region (Reynolds *et al.* 1980, Skirvin 1981).

ii) *Habitat assessment*

The habitat assessment was conducted in the Andaman Islands (10° 30' to 13° 41' N and 92° 12' to 93° 57' E) through a rapid survey during non-monsoon period (from December 2007 to May 2008) in select wetlands, inland and coastal covering 14 sites (**Fig. 6.1**) to know the status of the Andaman Teal, by using total count method (Bibby *et al.* 2000). The study sites covered wetlands of inland and coast in North, South and Little Andaman (Andrews and Sankaran 2002). Some of the teal habitats (Kadamtala Reservoir, Constance Bay (Plover corner) and Sonapahar Reservoir) under Jarawa Reserve Protected Area were not surveyed due to poor weather conditions and permit problem.

Based on the habitat information gathered from select coastal wetlands, the major Andaman Teal habitats in Andaman Islands which were drastically affected by major earthquake of 2004 that occurred in Indian Ocean followed by *tsunami* were studied. Qualitative assessment of damages was looked at: a) whether the marshes and wetlands were functioning or destroyed and dried up and, b) whether the vegetation in to nallas and tidal creeks was green or scorched and vanished.

Numbers of the Andaman Teal counted from select wetlands surveyed during 2007-2008 post-*tsunami* study were compared with those recorded earlier before *tsunami* during 1995 to 1998 and 2003-2004 (Vijayan 1996, Vijayan *et al.* 2006) to assess the impact of *tsunami* on their population.

Importantly the satellite imageries of 2003 for the Andaman Islands (Vijayan *et al.* 2005) and from the Global Land Cover Facility at the University of Maryland the paths such as North-Middle, South-Little and Little Andaman (<http://glcf.umiacs.umd.edu>) was used to determine pre-*tsunami* status. The aerial views of post-*tsunami* images of select areas from Google earth were also used for qualitative assessment of damages on the wetlands. From the visual interpretation of field conditions and imageries, the damages observed in the major coastal wetlands of the Andaman Teal habitats were categorised into five levels as:

Category 1: The habitats with massive damages were the fresh water swamps completely dried due to the draining caused by the upheaval of North Andaman, and vast amount of vegetation had been destroyed.

- Category 2:* The habitats with heavy damage. These too were the major feeding grounds of teals which have been submerged to an average depth of 0.9-1m in the east coast of South Andaman.
- Category 3:* The habitats with moderate damages. These were the badly affected freshwater wetlands and marshes, permanently turned to saline or brackish and had immense amount of deceased vegetation due to the closure of the mouth of nallas and creeks by the formation of sand bund.
- Category 4:* The habitats with mild damages were the areas with minor impacts on coastal wetlands and the roosting places flooded by *tsunami* waves.
- Category 5:* The habitats without any damages were the inland wetlands not affected by *tsunami*.

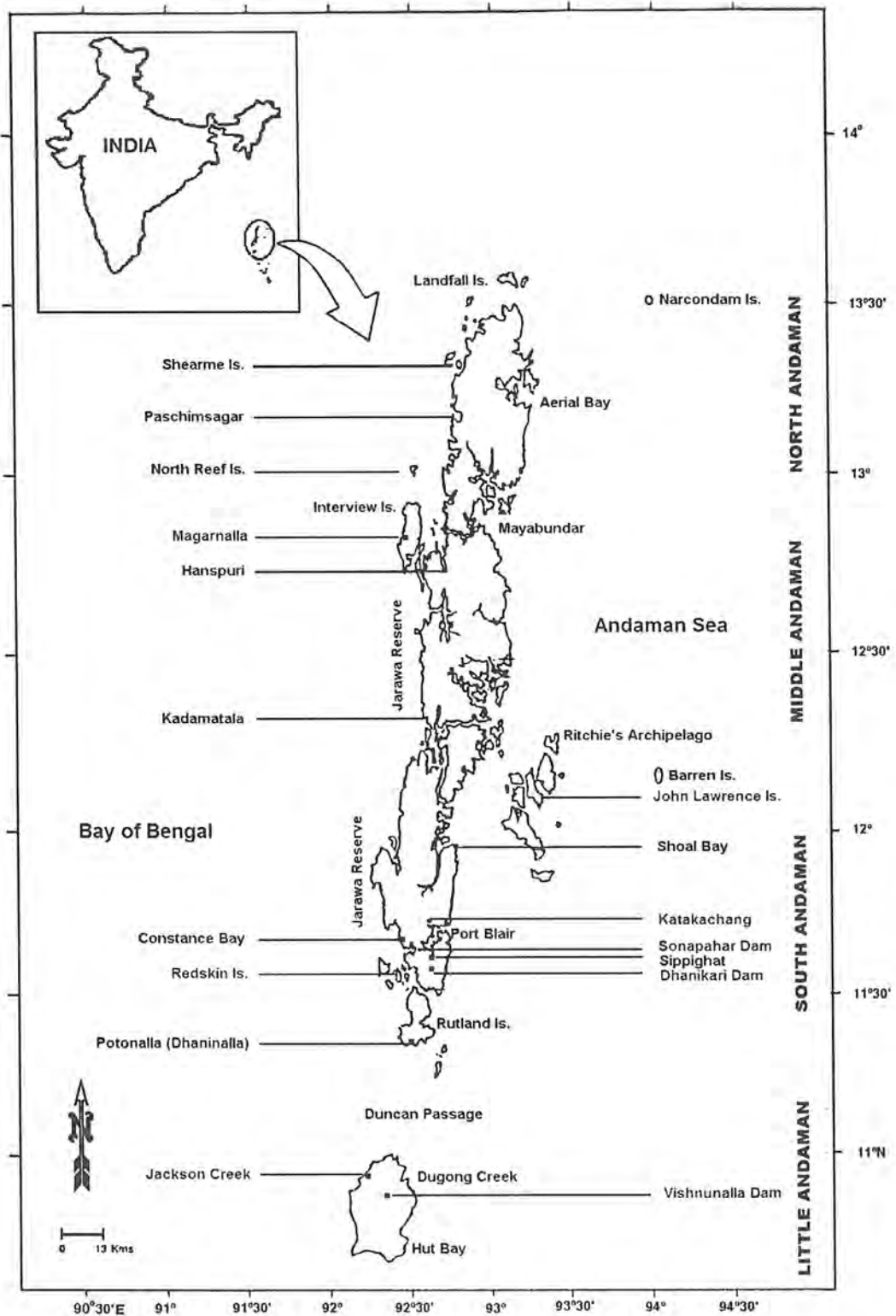


Figure 6.3: The major sites of inland and coastal wetland habitats of the Andaman Teal surveyed during 2007-2008.

6.4. RESULTS

Among the birds recorded from the Andaman Islands globally threatened species are listed below (**Table 6.5**).

Table 6.5: List of globally threatened species of Andaman Islands.

S. No.	Common name (Authority)	Scientific name	Family name (groups)
<u>Vulnerable</u>			
1	Narcondam Hornbill (Hume 1873)	<i>Aceros narcondami</i>	Bucerotidae (Hornbills)
<u>Near Threatened</u> (endemics)			
2	Andaman Serpent Eagle (Blyth 1863)	<i>Spilornis elgini</i>	Accipitridae (Osprey, Kites, Hawks & Eagles)
3	Andaman Crake (Blyth 1863)	<i>Rallina canningi</i>	Rallidae (Rails, Crakes & allies)
4	Andaman Wood Pigeon (Hume 1873)	<i>Columba palumboides</i>	Columbidae (Doves & Pigeons)
5	Andaman Cuckoo-dove (Blyth 1846)	<i>Macropygia rufipennis</i>	
6	Andaman Scops Owl (Hume 1873)	<i>Otus balli</i>	
7	Andaman Hawk Owl (Beavan 1867)	<i>Ninox affinis</i>	Strigidae (Owls)
8	Andaman Woodpecker (Blyth 1860)	<i>Dryocopus hodgei</i>	Picidae (Woodpeckers)
9	Andaman Drongo (Beavan 1867)	<i>Dicrurus andamanensis</i>	Dicruridae (Drongos)
10	Andaman Treepie (Blyth 1863)	<i>Dendrocitta bayleyi</i>	Corvidae (Crows & Jays)
11	Long-tailed Parakeet (Boddaert 1783)/Andaman Redcheeked Parakeet*	<i>Psittacula longicauda</i> <i>tyleri</i>	Psittacidae (Parrots)
<u>Near Threatened</u> (non-endemics)			
12	Beach Thick-knee ^x (Wagler 1829)	<i>Esacus</i> spp.	Burhinidae (Thick-knees)
13	Nicobar Pigeon ^x (Linnaeus 1758)	<i>Caloenas nicobarica</i>	Columbidae (Doves & Pigeons)
<u>Least Concern</u>			
14	Sunda Teal* (Müller 1842) or Andaman Teal	<i>Anas gibberifrons</i> <i>albogularis</i>	Anatidae (Ducks, Geese & Swans)

Note: * = subspecies endemics, ^x = non-endemic. Source: Birdlife International 2009.

6.4.1. *Endemic and Red listed species account*

A short account of one threatened, 12 near threatened and one of least concern, but rare species is given below.

a) *Globally endangered species:* Narcondam Hornbill *Aceros narcondami*

This is one among the threatened, endemic and rare species, being confined to the small isolated Island of Narcondam (6.82 km²) in Andaman and Nicobar Islands, which has not yet been studied in detail. Among the nine species of hornbills from India three are endemics, namely the Malabar Grey Hornbill *Ocyeros griseus* which is endemic to the Western Ghats, the Indian Grey Hornbill *Ocyeros birostris* having wider distribution over peninsular India and the Narcondam hornbill *Aceros narcondami*, which is endemic to the Narcondam island, the tiny extinct volcano in the Andaman Sea. The Narcondam Hornbill shows the greatest degree of endemism of any of India's avifauna, and ranks amongst the top few species that have small ranges worldwide (Sankaran 2000). The hornbills occur mostly in the evergreen forests and may be indicators of habitat quality (Snow 1981, Leighton 1982, Kalina 1988).

The Narcondam Hornbill, also known as the Narcondam Wreathed Hornbill on account of the rings on its casque that resemble a wreath, was first described by Hume in 1873. There are nine documented visits by biologists to the island (Prian 1893, Osmaston 1906, Baker 1927, Abdulali 1971, 1976, Hussain 1984, Sankaran 1997, Yahya 2002); all except the last two were with the primary objective of collecting species. In 1998, population of Narcondam Hornbill was estimated at 295-320 birds and stable, including an estimated 68-85 breeding pairs, while during fieldwork in 2000 the population was estimated to be 432 individuals (Yahya and Zarri 2002); these figures may indicate that the number of mature individuals is fewer than 250 (Kinnaird and O'Brein 2007).

Further, Narcondam hornbill has been uplisted to Endangered by BirdLife International 2009 due to its suggested small population (fewer than 250 mature individuals) and possible threats of hunting and habitat degradation. This species was not observed during this study since the Narcondam Island could not be covered due to its remoteness and various other reasons.

b) Near Threatened (Endemic species)**1. Andaman Dark-serpent Eagle *Spilornis elgini* (ADSE):**

Among 82 species of Accipitridae from the oriental region this resident and restricted range species to the Andaman Islands was recorded widely in North (35), Middle (8), South (48) and Little (9) Andaman and overall 100 individuals by 78 detections (**Table 6.6**). These forest dwellers mostly occurred in the open forests and forest clearings. The estimated population was around 1000 (BirdLife International 2009).

2. Andaman (Banded) Crake *Rallina canningi* (ABC):

Among 34 species of Rallidae from the oriental region, this resident, endemic species is widely distributed in North (16), Middle (7), South (13) and Little (2) Andaman Islands. In the present baseline avifaunal survey, overall 38 individuals with 18 detections of Andaman Crake were recorded (**Table 6.6**). Notably, first record of two individuals of this species from Little Andaman was obtained. The bird mainly inhabits the forest, forest edges, marshes near to the wetlands (inland and coastal), mangrove creeks and lagoons; favours of dense vegetation including tangled thickets of rattan and pandanus (Ali and Ripley 2001) and the present study showed presence of the Andaman Crake is from wet forests of evergreen, semi-evergreen and moist deciduous forest also from littoral and mangrove (**Table 6.6**).

Further, detailed study on status and ecology of the Andaman Crake carried out by Vijayan and Ezhilarasi (2007) was recorded a total of 253 birds from 2001 points under 255 sites/localities (majority of them are unprotected areas) with the encounter rate of 0.13 birds/point. Compared to outer islands the high number of Crake was recorded from major islands (0.16 bird/point). Since the moist-deciduous forest is occurred in most of the islands encounter rate of Andaman Crake is also increased with increasing of island size which was statistically significant (Ezhilarasi 2009).

Andaman Crake was classified as Data deficient by BirdLife International (2001) but reclassified as near threatened recently due to data which revealed that it was not uncommon in suitable habitat (BirdLife International 2008). Although this species has a very small range in major and outer Islands, the population size is

moderate and the major threats of heavy trapping and habitat degradation was documented (Vijayan and Ezhilarasi 2007). The estimated population by BirdLife International 2009 was within 10,000 to 25,000 with the range of 4,500 km².

3. Andaman Wood Pigeon *Columba palumboides* (AWP):

Totally 107 Columbidae species were found in the oriental region in which this uncommon endemic species was recorded throughout the Andaman and Nicobar Islands and appears to rely on dense forest. In the present study total of 116 individuals from 67 detections in North (29), Middle (7), South (59) and Little (21) Andaman were found (Table 6.6). This small range species population has declined due to heavy hunting and logging in recent decades. It is therefore classified as Near Threatened (BirdLife International 2009).

4. Andaman Cuckoo-dove *Macropygia rufipennis* (ACD):

This endemic species (*rufipennis*) has been treated by White and Bruce (1986) as part of superspecies with *amboinensis* (Brown Cuckoo Dove), but Goodwin (1967), suggested not to link *rufipennis* with any other form although it has drawn similarities with *M. magna* (Dusky Cuckoo Dove) and *M. phasianella* (Brown Cuckoo Dove). It is the only Cuckoo Dove found in Andaman and Nicobar Islands; prefers dense broadleaved and also semi-evergreen forests. Total 24 individuals, from 19 detections maximum of 22 in South and one in both North and Middle were found (Table 6.6). This poorly known species faces threats of anthropogenic activities and habitat degradation. The regular monitoring to know the population trends and necessary investigation to assess the tolerance of degraded forests and the extent of hunting by local residents is proposed by BirdLife International (2009).

5. Andaman Scops Owl *Otus balli* (ASO):

This restricted range species (Marshall and King 1988) is one among the 63 species of the family strigidae in the Oriental region endemic to the Andaman Islands, easily found in nature, inhabits the forest edges and agricultural lands around the human settlements. During the present extensive study only 24 individuals, 12 each in North and South Andaman were recorded (Table 6.6) from only 8 detections due to the inadequate night-time survey, since the nocturnal habits of species. The unknown population of the Andaman Scops Owl was

common in the early twentieth century. The major threats to this species are forest loss due to the developmental activities and small scale agricultural practises (BirdLife International 2009).

6. Andaman Hawk Owl *Ninox affinis* (AHO):

This strigidae species is restricted to the Andaman & Nicobar Islands, mainly inhabits mangrove forests, lightly wooded areas, plantations, forest clearings and near the settlements, apparently hawking insects at dusk. Total 5 individuals were observed in three detections, 4 in North and one in South Anadaman (**Table 6.6**). The major threats denoted are the consequent pressure from agriculture, grazing and logging. Although its tolerance of degraded habitats gives cause for optimism, the species may be declining as human populations on the islands increase. BirdLife International (2009) proposed wide range of research and monitoring of this small range species to assess its conservation needs.

7. Andaman Black Woodpecker *Dryocopus hodgei* (ABWP):

The endemic and near threatened species is one of the 61 species of Picidae in the Oriental region, which occurred mainly in lowlands forests such as evergreen, semi-evergreen and moist deciduous. During the present study total 325 individuals from 225 detections across the regions maximum 145 in South and minimum of 24 in Middle Andaman were recorded (**Table 6.6**). This common species is now under pressure from agriculture, grazing and logging (BirdLife International 2009). A detailed study is needed on the habitats to show precisely the habitat requirements, tolerance of secondary habitats and response to fragmentation of this near threatened species.

8. Small Andaman Drongo *Dicrurus andamanensis* (SAD):

Among 51 Dicrurinae from the Oriental region the Andaman Drongo is endemic found in the Andaman (India) and Coco Islands (Myanmar) (BirdLife International 2009). It is a common resident of forests. The present study was found total 272 individuals by 151 detections across the region maximum in South (147) and minimum (12) from Middle Andaman (**Table 6.6**). This small range forest dweller is under pressure due to the heavy development activities, habitat alterations and fragmentations, grazing and logging.

9. Andaman Tree Pie *Dendrocitta bayleyi* (ATP):

Of the 125 Corvinae from the Oriental region, this is one of the endemic and near threatened species to the Andaman Islands. The species inhabits mainly evergreen forests and other lowland forests and frequently found in a pair and flocks (up to 20) occasionally in mixed flocks in woody forests. Of the 100 individuals by 58 detections in the present study maximum 65 in South and minimum 5 from Middle Andaman were recorded (Table 6.6). The population decline of the species may be caused by the developmental pressure in the Islands and habitat loss (BirdLife International 2009).

10. Longtailed or Andaman Redcheeked Parakeet *Psittacula longicauda* (ARCP):

The species, known as Andaman Red-cheeked Parakeet (ARCP), abundant in Andaman and Nicobar Islands (India) is one among the 64 Psittacidae from the Oriental region. This subspecies endemic also occurs in Coco islands, (Myanmar), peninsular Thailand, Sabah, Sarawak and Peninsular Malaysia, Singapore, Kalimantan (including the Natuna Islands), Sumatra (including the Riau Islands), Indonesia and Brunei (widespread). Since, it is assumed to have experienced moderately rapid declines it is consequently considered Near Threatened. It is not considered more threatened because it can use human modified habitats (BirdLife International 2009). The species mainly inhabits coastal and many types of lowland forests including mangroves, Oil-palm plantations (Little Andaman), coconut groves and preferably forest edges. Most often it is gregarious and flocks of large number, thousands and above was reported from Nicobar Islands. Totally 834 individuals by 260 detections, across the regions maximum of 495 in South and minimum of 59 in Little Andaman Islands were recorded (Table 6.6). The loss of habitat, especially deforestation in many of the lowland forests is the major threat to this species. Population is unknown, movements poorly understood, being abundant in a locality for a period, then absent for years (BirdLife International 2009).

c) *Near Threatened (Non-Endemic species)*

11. Beach Thick-knee or Great Stone Plover *Esacus magnirostris* (GSP):

The Beach Thick-knee is known as Great Stone Plover (GSP), largest species of thick-knees/stone curlews (53-57cm in length) (Sibley and Monroe 1990, 1993).

Generally pairs may be found on most beaches within its ranges, especially beaches associated with estuaries and mangroves and it lays a single egg in a scrape in the sand at the landward edge of the beach, often using the same area repeatedly. The Beach Thick-knee forages mainly in the inter-tidal zone on crustaceans and other invertebrates (Garnett and Crowley 2000).

During the present extensive study, which includes five major (covering most of its disturbed and undisturbed beaches) and 52 outer islands in Andaman Islands totally 27 individuals by 12 detections maximum 19 in North and minimum one in Little Andaman were recorded. Since the area of sandy beaches found less from the Middle Andaman surveyed there is no individual of the species was found (Table 6.6).

The Beach Thick-knee's population-6000 and range-2,140,000 km² were estimated by BirdLife International (2009). Their distribution is widespread around coasts from Andaman Islands, India, Mergui Archipelago, Myanmar, islands off peninsular Thailand, and Peninsular Malaysia through Indonesia, Brunei, the Philippines, Papua New Guinea, the Solomon Islands, Vanuatu, New Caledonia (to France) and Australia. Since it has a small population and no more threat is found to this population, the species qualifies under near threatened (BirdLife International 2009).

12. Nicobar Pigeon *Caloenus nicobarica* (NP):

This small island specialist, is limited and most abundant on the smallest, least disturbed islands, is distributed in south east Asian islands wide Andaman and Nicobar, India, Mergui archipelago (Myeik Kyunzu), Myanmar, Islands off south-west peninsular Thailand, Islands around peninsular Malaysia, Islands of southern Cambodia and Vietnam, Islands around Sumatra, Wallacea and Papua, Indonesia, many islands in the Philippines, Islands in Papua New Guinea and throughout the Solomon Islands. During the present study total 4 individuals, each two in North and Little Andaman Islands; no other previous records literally from Little Andaman were found. The unknown population of Nicobar Pigeon is classified as near threatened due to heavy hunting pressure for food and the pet trade (BirdLife International 2009).

d) Least concern (Endemic species)

At the species level justification given by BirdLife International (2009) stated that two endemic species (subspecies level) the Andaman Teal *Anas gibberifrons albogularis* and Chestnut-headed Bee-eater *Merops leschenaulti andamanensis* have extremely large range at species level, and hence does not approach the thresholds for Vulnerable or near threatened and hence, these are evaluated as Least Concern by BirdLife International (2009). The above species accounts are as follows:

1. Andaman Teal *Anas (gibberifrons) albogularis* (AT):

The Andaman Teal *Anas gibberifrons albogularis*, is a subspecies endemic recently claimed a full species endemic as *Anas albogularis* by Rasmussen and Anderton (2005) and the only threatened species among the 48 Anatidae recorded in India (World Conservation Union 1994) under the Wildlife (Protection) Act 1972; inhabiting inland or coastal wetlands, freshwater streams, ponds, swamps and brackish water swamps, tidal creeks or estuaries (Ali and Ripley 2001, Vijayan 1996) is rare and has recently declined in its distribution in nature (BirdLife International 2005, Vijayan *et al.* 2006). The Andaman Teal has required a special attention as the island endemics have greater chances of extinction (Brooks *et al.* 1997, Castellatta *et al.* 2000, Riley 2002). The present extensive bird survey total 741 individuals by 21 detections across the region maximum of 681 individuals from South and minimum 3 from Little Andaman Islands were recorded (Table 6.6). Further post-tsunami effects on the coastal habitats of Andaman Teal were studied for their habitat utilization and given under section 6.4.5. The total population of, resident in Andaman group of Islands was estimated between 500-1000 in Andaman Islands and Coco Island (Wetlands International 2002) and 500-600 in Andaman Islands (Vijayan 1996, Vijayan *et al.* 2006). It has been changing continually, over time as a result of the natural ecological changes and anthropogenic activities (Vijayan 2006).

6.4.2. Distribution of endemic and Red listed species

Total abundance of 1869 threatened bird species from the Andaman Islands was analysed. In region-wise maximum of 1014 in South and minimum 150 from Little Andaman were observed (Table 6.6). The habitat-wise observations showed more number of threatened species has been harboured by natural forests, namely evergreen, littoral, semi-evergreen and moist-deciduous rather than others (Table

6.7). Noticeably, among the threatened birds the Andaman Redcheeked Parakeet *Psittacula longicauda tytleri* were recorded with high number (834) followed by Andaman Woodpecker *Dryocopus hodgei* (325).

Table 6.6: Region-wise distribution and abundance of the threatened species in Andaman Islands (number of points birds detected in parenthesis).

Common & Scientific name	North	Middle	South	Little	Total
<u>Near Threatened (endemic)</u>					
1. Andaman Dark-serpent Eagle <i>Spilornis elgini</i>	35 (31)	8 (6)	48 (38)	9 (9)	100 (78)
2. Andaman Crake <i>Rallina canningi</i>	16 (5)	7 (2)	13 (10)	2 (1)	38 (18)
3. Andaman Wood Pigeon <i>Columba palumboides</i>	29 (18)	7 (6)	59 (35)	21 (10)	116 (67)
4. Andaman Cuckoo-dove <i>Macropygia rufipennis</i>	1 (1)	1 (1)	22 (17)	(0)	24 (19)
5. Andaman Scops Owl <i>Otus balli</i>	12 (2)	(0)	12 (6)	(0)	24 (8)
6. Andaman Hawk Owl <i>Ninox affinis</i>	4 (2)	(0)	1 (1)	(0)	5 (3)
7. Andaman Woodpecker <i>Dryocopus hodgei</i>	88 (65)	24 (20)	145 (117)	68 (49)	325 (225)
8. Andaman Drongo <i>Dicrurus andamanensis</i>	56 (38)	12 (9)	147 (85)	57 (25)	272 (151)
9. Andaman Treepie <i>Dendrocitta bayleyi</i>	11 (6)	5 (4)	65 (43)	19 (6)	100 (58)
10. Andaman Redcheeked Parakeet <i>Psittacula longicauda tytleri</i>	194 (74)	86 (28)	495 (177)	59 (18)	834 (260)
<u>Near Threatened (non-endemic)</u>					
11. Beach Thick-knee <i>Esacus magnirostris</i>	19 (8)	(0)	7 (3)	1 (1)	27 (12)
12. Nicobar Pigeon <i>Caloenas nicobarica</i>	2 (2)	(0)	(0)	2 (2)	4 (4)
Total	467	150	1014	238	1869
<u>Least Concern (locally near threatened)</u>					
13. Andaman Teal <i>Anas (gibberifrons) albogularis</i>	32 (12)	23 (9)	55 (21)	7 (5)	117 (46)

Table 6.7: Habitat-wise distribution and abundance of the threatened species in Andaman Islands (number of points detected in parenthesis).

Species code	Evergreen	Semi-evergreen	Moist deciduous	Littoral	Mangrove	Forest edges	Plantation	Field	Degraded	Wetlands	Coastal	Total
1. ADSE	12 (11)	21 (19)	9 (8)	22 (19)	13 (9)	6 (5)	5 (4)	3 (2)	8 (6)	1 (1)	(0)	100 (78)
2. ABC	10 (4)	18 (10)	7 (1)	1 (1)	2 (2)	(0)	(0)	(0)	(0)	(0)	(0)	38 (18)
3. AWP	44 (25)	17 (12)	9 (7)	29 (14)	10 (6)	1 (1)	(0)	(0)	1 (1)	4 (2)	1 (1)	116 (67)
4. ACD	14 (11)	7 (5)	1 (1)	(0)	(0)	(0)	1 (1)	1 (1)	(0)	(0)	(0)	24 (19)
5. ASO	(0)	6 (3)	10 (1)	8 (4)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	24 (8)
6. AHO	(0)	4 (2)	(0)	1 (1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	5 (3)
7. ABWP	107 (83)	90 (66)	32 (26)	52 (39)	15 (13)	6 (5)	6 (5)	8 (5)	(0)	9 (6)	(0)	225 (151)
8. SAD	109 (58)	60 (44)	27 (15)	37 (21)	16 (7)	3 (2)	8 (6)	(0)	2 (1)	9 (2)	1 (1)	151 (111)
9. ATP	47 (26)	17 (13)	13 (9)	13 (5)	5 (2)	2 (1)	2 (2)	(0)	1 (1)	(0)	(0)	100 (58)
10. ARCP	190 (83)	112 (46)	95 (41)	236 (68)	37 (13)	33 (10)	15 (7)	76 (15)	32 (10)	7 (2)	1 (1)	260 (181)
11. GSP	(0)	1 (1)	(0)	17 (7)	(0)	(0)	(0)	(0)	(0)	(0)	9 (4)	27 (12)
12. NP	1 (1)	1 (1)	(0)	1 (1)	(0)	(0)	1 (1)	(0)	(0)	(0)	(0)	4 (4)
13. AT	(0)	(0)	(0)	146 (9)	5 (2)	(0)	(0)	(0)	1 (1)	139 (8)	450 (1)	741 (21)

6.4.3. Estimating density: in region

Considering 1650 point counts totally 144 bird species were counted, which actively used the study area and did not count birds flying overhead unless they actively used the area. Overall the estimated bird species density (birds/km²) in the Andaman Islands was ranged between >0.05 and <133.7, where the occurrence of 58 species to all four regions, 16 from three regions, 31 from two regions and 39 in one region (*Annexure 6.1*). The region-wise lowest and highest densities are given below:

- a) North Andaman: from the total of 455 points bird density of this region between >0.19 and <173.86 was observed. The lowest density of 0.19 with nine species namely Indian Pond Heron or Paddybird *Ardeola grayii grayii*, Cattle Egret *Bubulcus ibis coromandus*, Black Bittern *Ixobrychus flavicollis flavicollis*, Bartailed Godwit *Limosa lapponica lapponica*, Wood or Spotted Sandpiper *Tringa glareola*, Andaman Cukoo-Dove *Macropygia rufipennis andamanica*, Small Cuckoo *Cuculus poliocephalus poliocephalus*, Black Headed Oriole *Oriolus xanthornus andamanensis*, Crowbilled Drongo *Dicrurus annectans* and highest 173.86 of Andaman Red whiskered Bulbul *Pycnonotus jocosus whistleri* followed by Andaman Green Imperial Pigeon *Ducula aenea andamanica* (71.1), Eastern Blacknaped Tern *Sterna sumatrana sumatrana* (62.74) were found.
- b) Middle Andaman: covering 122 points during the study period from this region bird density between >0.72 and <131.13 was observed. Total thirteen species with the lowest density of 0.72 namely Andaman crested Hawk-Eagle *Spizaetus cirrhatus andamanensis*, Little Stint *Calidris minuta*, Eastern broadbilled Sandpiper *Limicola falcinellus sibirica*, Sooty Tern *Sterna fuscata nubilosa*, Andaman Cukoo-Dove *Macropygia rufipennis andamanica*, Indian Small Blue Kingfisher *Alcedo atthis bengalensis*, Andaman Blue-eared Kingfisher *Alcedo meninting rufigaster*, Andaman Storkbilled Kingfisher *Pelargopsis capensis osmastoni*, Andaman Broadbilled Roller *Eurystomus orientalis gigas*, Swallow *Hirundo rustica gutturalis*, Philippine Shrike *Lanius cristatus lucionensis*, Assam Great Reed Warbler *Acrocephalus stentoreus amya*, Eastern Greenish Leaf Warbler *Phylloscopus trochiloides trochiloides* and highest of Andaman Red-whiskered Bulbul *Pycnonotus jocosus whistleri* (131.13) followed by Eastern Blacknaped Tern *Sterna sumatrana sumatrana* (118.81), Andaman Green Imperial Pigeon *Ducula aenea andamanica* (87.66) were observed.

- c) South Andaman: over 873 points covered from this region bird density between >0.1 and <137.79 was estimated. Total eleven species with the lowest density of 0.1 (such as Indian Purple Moorhen *Porphyrio porphyrio poliocephalus*, Terek Sandpiper or Avocet-Sandpiper *Xenus cinereus*, Violet Cuckoo *Chalcites xanthorhynchus xanthorhynchus*, Andaman (Brown) Hawk-Owl *Ninox affinis affinis*, Whitebreasted Swallow-Shrike *Artamus leucorhynchus humei*, Tickell's Redbreasted Blue Flycatcher *Muscicapa tickelliae tickelliae*, Greyheaded Flycatcher *Culicicapa ceylonensis calochrysea*, Dusky Leaf Warbler *Phylloscopus fuscatus weigoldi*, Bluefronted Robin *Cinclidium frontale frontale*, Whitebrowed Ground Thrush *Zoothera sibirica sibirica*, Little Spiderhunter *Arachnothera longirostris longirostris*) and highest of 137.79 (Andaman Green Imperial Pigeon *Ducula aenea andamanica*) followed by 110.15 (Andaman Red-whiskered Bulbul *Pycnonotus jocosus whistleri*) was estimated.
- d) Little Andaman: total 200 points from this region bird densities were estimated between >0.44 and <146.72 . Overall total eleven species with the lowest density of 0.44 such as Chinese Pond Heron *Ardeola bacchus*, (Eastern) Baillon's Crake *Porzana pusilla pusilla*, Swinhoe's Snipe *Gallinago megala*, Common or Fantail Snipe *Gallinago gallinago gallinago*, Longtoed Stint *Calidris subminuta*, Great Stone Plover *Esacus magnirostris magnirostris*, Small Cuckoo *Cuculus poliocephalus poliocephalus*, Andaman Ruddy Kingfisher *Halcyon coramanda mizorhina*, Philippine Shrike *Lanius cristatus lucionensis*, Andaman Palefooted Bush Warbler *Cettia pallidipes osmastoni*, Siberian Dusky Leaf Warbler *Phylloscopus fuscatus fuscatus* and highest density of 146.72 (Andaman Red-whiskered Bulbul *Pycnonotus jocosus whistleri*) followed by 121.09 (Andaman Red-breasted Parakeet *Psittacula alexandri abbotti*) and 92.36 (Andaman Green Imperial Pigeon *Ducula aenea andamanica*).

Importantly density of the twelve near-threatened species (BirdLife International 2009) and one least concern species among the three was observed. Among the near-threatened species the bird densities were estimated between >0.21 and <20.78 and regional-wise minimum and maximum density ranged as given below. However density of the Andaman Teal *Anas albogularis*, one of the least concern species among the three from Andaman Islands total 38.09 in which maximum of 66.11 in South and minimum of 1.33 from Little Andaman was estimated (Table 6.8).

a) North Andaman: 0.19 (Andaman Cuckoo Dove *Macropygia rufipennis andamanica*) to 21.76 (Andaman Red-cheeked Parakeet *Psittacula longicauda tytleri*), b) Middle Andaman: 0.72 (Andaman Cuckoo Dove *Macropygia rufipennis andamanica*) to 26.08 (Andaman Red-cheeked Parakeet *Psittacula longicauda tytleri*), c) South Andaman: 0.1 (Andaman [Brown] Hawk-Owl *Ninox affinis affinis*) to 20.86 (Andaman Red-cheeked Parakeet *Psittacula longicauda tytleri*), d) Little Andaman: 0.44 (Great stone Plover *Esacus magnirostris magnirostris*) to 28.28 (Andaman Woodpecker *Dryocopus hodgei*).

Table 6.8: Estimated density (birds/km²) of red listed endemic and non-endemic birds in different regions of Andaman Islands (number of point counts in parenthesis).

Common name (species code)	North (455)	Middle (122)	South (873)	Little (200)	Overall (1650)
<u>Near Threatened</u>					
1. Andaman Dark-serpent Eagle (ADSE)	5.63	5.07	2.94	3.09	3.86
2. Andaman Crake (ABC)	3.11	5.07	1.32	0.88	2.04
3. Andaman Wood Pigeon (AWP)	4.47	1.45	4.86	3.54	4.34
4. Andaman Cuckoo Dove (ACD)	0.19	0.72	1.62	-	0.96
5. Andaman Scops Owl (ASO)	2.33	-	1.21	-	1.29
6. Andaman Hawk Owl (AHO)	0.58	-	0.1	-	0.21
7. Andaman Black Woodpecker (ABWP)	16.51	13.77	14.17	28.28	16.5
8. Small Andaman Drongo (SAD)	8.74	4.35	13.67	22.54	12.7
9. Andaman Treepie (ATP)	2.14	3.62	6.28	7.07	5.04
10. Andaman Red-cheeked or Long-tailed Parakeet (ARCP)	21.76	26.08	20.86	15.03	20.78
11. Great Stone Plover (GSP)	3.69	-	0.71	0.44	1.45
12. Nicobar Pigeon (NP)	0.39	-	-	0.88	0.21
<u>Least Concern</u>					
13. Andaman Teal (AT)	7.38	12.32	66.11	1.33	38.09

6.4.4. Estimating density: in habitats

Although, densities of the birds actively using the area in different habitats has not given any considerable values the near threatened species from the natural forests observed are taken for examination. The other disturbed (filed and degraded forests) and wetland (inland and coastal) habitats were not examined due to poor distribution of these species (Table 6.9). Considerable amount of density of most the species from evergreen, semi-evergreen, moist-deciduous and littoral forests was estimated except Andaman Red-cheeked Parakeet *Psittacula longicauda tytleri*, where the highest number of density (34.27) among this group from forest edges. The lowest density of 0.19 of Andaman Banded Crake *Rallina canningi* and Andaman [Brown] Hawk-Owl *Ninox affinis affinis* was estimated from the littoral forests (Table 6.9).

Table 6.9: Habitat-wise estimated density (birds/km²) of near threatened birds in Andaman Islands (total number of point counts in parenthesis).

Species code	Evergreen (384)	Semi-evergreen (259)	Moist deciduous (170)	Littoral (471)	Mangrove (123)	Forest edges (49)	Plantation (69)	Overall (1650)
ADSE	1.84	5.80	4.16	2.63	8.62	7.22	5.12	3.86
ABC	2.30	6.14	3.64	0.19	1.44	-	-	2.04
AWP	7.37	5.12	3.12	3.57	5.03	1.80	-	4.34
ACD	2.30	2.05	0.52	-	-	-	1.28	0.96
ASO	-	2.05	5.20	1.50	-	-	-	1.29
AHO	-	1.02	-	0.19	-	-	-	0.21
ABWP	23.71	30.03	15.08	9.38	10.78	3.61	5.12	16.5
SAD	22.56	18.77	10.92	5.44	10.06	5.41	7.69	12.7
ATP	10.82	4.78	6.76	1.88	3.59	3.61	2.56	5.04
ARCP	23.02	20.82	23.40	18.39	12.93	34.27	6.40	20.78
NP	0.23	0.34	-	0.19	-	-	1.28	0.21

6.4.5. *Post-tsunami habitat assessments in select wetlands*

The earthquake and *tsunami* have changed most of the coastal wetlands in Andaman Islands; the worst affected habitats include the mouths of creeks, rivers and fresh water bodies. However, the Andaman Teal inhabited different types of wetlands, inland and coastal. The present survey on select coastal wetlands where the habitat change occurred due to *tsunami* was studied (Plate 6.2, 6.3). The qualitative assessment of the damages (Plate 6.4, 6.5) on survey sites is given in Table 6.10 and on the major sites is explained below:

Site 1- North Reef Island (13° 04' 38.9" N - 92° 42' 14.2" E): The upheaval of land in the North Andaman has changed the fresh water swamps in North Reef Island. The northern freshwater marsh was completely dry and there was no fresh water anywhere on the island (Plates 6.1a, b, 6.2a). These drastic changes have caused the loss of habitat for teals. However, a few teals were observed in a small pond.

Site 2- Magarnalla (12° 52' 02.2" N - 92° 39' 15.7" E): Due to the upheaval of land in the western coast of Interview Island there was no sea water entering into this marsh and hence was dry except for a small pool (Plates 6.1c, d, 6.2b).

Site 3- John Lawrence: The major Teal habitat in this Island was filled with sand and dry due to the *tsunami* waves resulting in the loss of habitat.

Site 4- Kadakachang (11° 43' 22.5" N - 92° 41' 9.24" E): The mangrove creek and marshes (Plates 6.1e, f, 6.2c) have been destroyed completely and submerged under sea water above 0.5 m which has changed the habitat.

Site 5- Sippighat (11° 36' 36.1" N - 92° 41' 07.0" E): This major feeding ground of the Teals (Plates 6.1g, h, 6.2e) was drastically affected with the increase in the depth of sea water and fallen logs of mangroves. The mangrove and lagoon with reeds at this site have been destroyed completely resulting in habitat loss.

Site 6- Potonalla (11° 21' 17.0" N - 92° 37' 34.8" E): The wetland adjacent to the coast in Rutland Island (Plate 6.2d) was damaged heavily by waves.

Site 7- Jackson creek (10° 46' 49.5" N - 92° 23' 50.7" E): The high waves brought in sand which built up a new beach and blocked the mouth of northern coastal wetland adjacent to this creek which resulted in no sea water entering inside and probably damaging the vegetation drastically.

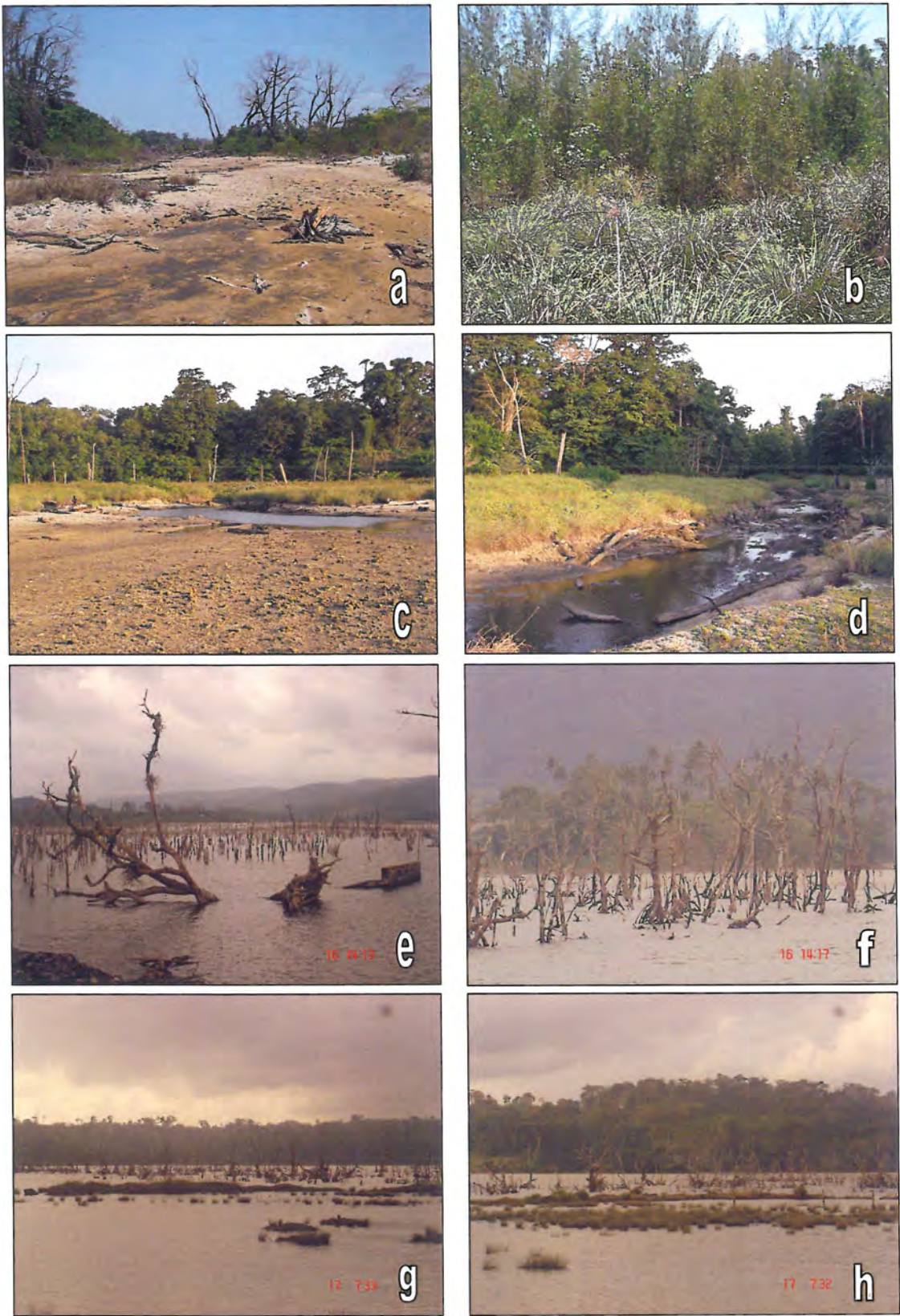


Plate 6.2: The Andaman Teal habitat change/loss in the major coastal wetlands, Andaman Islands. a & b) fresh water swamps, Badak Tikiri, North Reef Island, c & d) Magarnallah, Interview Island e & f) Mangrove creeks in Kadakatchang and g & h) Sippighat in South Andaman (see results for details).



Plate 6.3: Aerial view of tsunami affected coastal wetlands: a) Badak tikiri, North reef Island, b) Magarnallah, Interview Island, c) Katakatchang, Port Blair, d) Potonallah, Rutland Island, and e) Sippighat.



Plate 6.4: The Andaman Teal in the inland wetlands



Plate 6.5: The Andaman Teal in the coastal wetlands.

Number of the Andaman Teal

A total of 99 individuals of the Andaman Teal were recorded from 14 sites surveyed in the three major island groups; the maximum of 73 birds were counted from North Andaman, whereas no birds were found in Little Andaman including some inland wetlands. During the survey among eight coastal wetlands from Little and South Andaman no birds were found except in Sippighat (11), South Andaman (Table 6.10).

Table 6.10: Status of the Andaman Teal *Anas albogularis* and qualitative assessment of damage to the select wetlands, Andaman Islands during 2007-08.

S. No	Name of the place	No. of Teals counted	Damage level
<u>North Andaman</u>			
1	Water hole-II, Interview Island * (IW)	26	5
2	Magarnalla, Interview Island*	24	2
3	North Reef Island *	23	1
<u>South Andaman</u>			
4	John Lawrence Island	0	1
5	Potonalla (Dhaninalla), Rutland Island	0	2
6	Redskin Island	0	4
7	Dhanikari reservoir (IW)	15	5
8	Sippighat	11	2
9	Kadakatchang*	0	2
<u>Little Andaman*</u>			
10	At km-6	0	2
11	At km-2	0	2
12	Jackson creek	0	3
13	Vishnunalla dam (IW)	0	5
14	Ramakrishnapur dam (IW)	0	5
Total		99	

Note: * = Important Bird Areas (Islam & Rahmani 2004), IW= Inland wetland, 1,2,3,4 & 5= categories for damage levels (see details under section 6.3.2-II pp-144-145).

Sightings of the Andaman Teal from select coastal wetlands were compared with that of the earlier records which showed absence of birds in many of the sites (Pre-*tsunami*=136, Post-*tsunami*=58). Significant numbers were found only in North Reef Island (23) and Magarnalla (24) in North Andaman. The pre-*tsunami* survey during 1995-1998 had recorded 386 birds at 6 sites and 136 in 2003-2004 while it was only 58 in the corresponding sites surveyed during the present study (**Table 6.11**).

Table 6.11: The pre-*tsunami* and post-*tsunami* comparison of Andaman Teal population in select major wetlands in Andaman Islands.

Major coastal habitats	Pre- <i>tsunami</i>		Post- <i>tsunami</i>
	1995-98	2003-04	2007-08
North Reef Island *	33	26	23
Magarnalla, Interview Island*	-	0	24
Potonalla, Rutland Island	230	110	0
Sippighat	4	0	11
John Lawrence Island	107	0	0
Kadakatchang	6	0	0
Jackson creek	6	0	0
Total	386	136	58

* Protected area (Wildlife Sanctuary)

6.5. DISCUSSION

Endemics and threatened species

The comparison of endemic species recorded from the Indo-Burma biodiversity hotspot the Andaman Islands, offshore islands of the above hotspot have more endemic species than Burma and Thailand, the mainlands of Southeast Asia. Although the less number of endemic species accounted from Burma and Thailand (Robson 2004) number of globally threatened bird species is high rather than the Andaman Islands (Birdlife International 2007). The reason behind is chronic anthropogenic activities, habitat loss and degradation followed by others, introductions of alien species, over-exploitation (resource extraction, hunting and pets) and human induced climate change (IUCN 2007, BirdLife International 2009). However the number of bird species threatened with global extinction has risen to 12% since 1994. Nevertheless, due to the over-exploitation 30% of birds are threatened and invasive alien species which are impacting 67% of threatened birds on islands were also accounted (IUCN 2007).

The present study recorded 12 near threatened species from the Andaman Islands consisting of 10 endemics and two non-endemics. There was no survey of Narcondam Hornbill *Aceros narcondami*, the only vulnerable species from the Andaman Islands (BirdLife International 2009). Since it inhabits only tiny and isolated Narcondam Island, the tiny extinct volcano in the Andaman Sea more than 150 km from mainland Burma, and 125 km from North Andaman the bird survey was not conducted in this island. However the special attention for documentation of this species has been given. Though the Andaman Teal *Anas gibberifrons albogularis* is listed as least concern species by BirdLife International (2009) still its being the only threatened species among the 48 Anatidae recorded in India (World Conservation Union 1994) under the Wildlife (Protection) Act 1972 and recently claimed a full species endemic as *Anas albogularis* by Rasmussen and Anderton (2005) was also taken for consideration.

The region-wise distribution more number of threatened birds were observed from South (1014) followed by North (467) Andaman Islands and the habitat-wise observations showed more number of threatened species has been harboured by natural forests, namely evergreen, littoral, semi-evergreen and moist-deciduous rather than others. Notecably among the threatened birds the Andaman Redcheeked Parakeet

Psittacula longicauda tytleri, majorly frugivore were recorded with high number (834) followed by Andaman Woodpecker *Dryocopus hodgei* (325), the insectvore. Results showed that the validity of natural forests and its role on niche breadth of the population, it may increase with respect to habitat, elevation, foraging, or diet (Roughgarden 1979).

Avifaunal density

Among 153 bird species recorded during the present study from North, Middle, South and Little Andaman Islands total of 144 species which actively used the study area has been taken for density estimation. Considering region-wise estimated density (birds/km²) total 58 species occurring in all four regions had the density estimated between >0.75 and <133.7 followed by 16 species observed in total three different regions with the density between >0.48 and <26.94, 31 species found in total two regions with the density between >0.11 and <15.8 and total 39 species present in any of one region with the density between >0.05 and <3.54. Based on the estimated density (birds/km²) of each species from the community ranking has been made for their conservation concern. Totally 46 species with highest density ranged between >10.14 and <173.86, and the rest of 98 species with lowest density between >0.1 and <9.42 was estimated across the region (**Annexure 6.1**).

Among the 46 species classified under the highest densities in the community the Common Myna *Acridotheres tristis*, one of the exotic land bird to these island groups and the species is on IUCN's list of "The hundred worst invasive species" (ISSG 2002) in the world had the density of 27.03 (24th place among the region) from South Andaman Island. The other exotic species of House Sparrow *Passer domesticus* (the species need clearance under the Wildlife [Protection] Act, 1972 in India for control measures to be implemented) extensively found from South and Little Andaman had the density of 13.26 (33rd place among the region) in Little Andaman. Importantly both the exotic species were detected from the forest edges and degraded areas (human habitation) (**Annexure 6.1**).

The bird density has to be an inverse function of the size of forest islands, which clearly confirms the outstanding effect of an edge (Oelke 1966). Haila *et al.* (1980) report that the edge effect at 50m increases bird densities by about 20% in southwestern Finland. It is natural, however, that the effect of a forest edge on the bird

population density ought not to remain constant, but should vary for numerous reasons (Helle and Helle 1982). The forest edges are difficult to classify because of their very high variability. The 'breadth' of the edge effect for specific forest bird species depends both on the habitat and the bird species, the latter being based e.g., on different minimal area requirements of different species (Forman *et al.* 1976). When the size of a forest is 0.2 hectares or less, the whole forest should be considered an edge habitat (Galli *et al.* 1976). However Terborgh *et al.* (1997) stated the bird densities on islands <0.79 ha in area can be normalized to 1 ha. Several bird species have been known to prefer edges between open ground and forest with young vegetation (see also Whitcomb *et al.* 1981, Odum 1996) and this seems to be characteristic of passerines in general (Galli *et al.* 1976).

The region-wise estimated bird density of redlisted/threatened birds in Andaman Islands the land bird of Andaman Black Woodpecker *Dryocopus hodgei* had the highest density (28.28) from Little Andaman followed by Andaman Red-cheeked Parakeet *Psittacula longicauda tytleri* (26.08) in Middle Andaman, where less disturbance (since most of them comes under Jarawa Reserve Protected area) was noticed. Considering Andaman Teal *Anas albogularis* a water bird, locally threatened and the least concern species (BirdLife International 2009) had the highest density (66.11) where in the Constance Bay (a Jarawa Reserve Protected area), South Andaman had about 410 individuals (Viajayn *et al.* 2006). Their abundance varied because of their local movement.

Among the region out of 144 species accounted for the density estimation maximum of 115 were found in South Andaman followed by North (100), Little (90) and Middle (76). The distribution pattern of birds and their abundance, in the region in Andaman Islands has been related to the rate of disturbance. For example based on the comparison of estimated bird density (birds/km²) from the above regions South Andaman had more number of species (44 sp.) not only with high density or HD also total 71 species with low density or LD followed by North (HD-43 sp., LD-57 sp.), Little (HD-42 sp., LD-48) and Middle (HD-39 sp., LD-37sp.) (*Annexure 6.1*). The high bird density in South Andaman is mainly because of more extant of moist forests and more protected forests (see *Chapter 7-* in *Table 7.2*). This documents the significance of protection and reducing disturbance for the conservation of birds and biodiversity.

In the habitat wise density estimation out of 144 species, maximum number of species was found from the natural forests, namely Littoral (107) followed by Moist deciduous (82), Mangrove (81), Evergreen (74), Semi-evergreen (72), forest edges (53). Whereas, in the disturbed habitats, the Plantation (57), Field (50) and degraded area (49) scored less number of species, which indicates poor distribution of avifauna in the community. However, the species occurrence in vegetation structure total 23 birds were found in nine types of forested and disturbed habitats with the estimated density ranging between >3.86 and <133.7 . Nevertheless, the Andaman Red-whiskered Bulbul *Pycnonotus jocosus whistleri* had the highest density of 406.06 in the plantation area followed by the Andaman Whitebacked Munia *Lonchura striata fumigate* (193.01) in the forest edge, Andaman Green Imperial Pigeon *Ducula aenea andamanica* (171.65) from semi-evergreen. The bird community diversifies with the structural complexity of the habitats. The strength of any edge effect depends on the heterogeneity of the ecotone, the number of bird species increasing markedly with increasing horizontal structural complexity in the vegetation (Pianka 1974). The vertical complexity of the vegetation (measured in terms of 'foliage height diversity') has the same effect (MacArthur and MacArthur 1961). According to Hohtola (1978) the edge heterogeneity in urban habitats increases bird species diversity, but Haila *et al.* (1980) did not find any clear differences in diversity between edge and central forest habitats.

Habitat assessment

The present study covered most of the Teal habitats during 2003-2004 (pre-*tsunami*) and 2007-2008 (post-*tsunami*) to know their distribution pattern in the Andaman Islands. The post-*tsunami* survey documented most of the wetlands, mainly Teal habitats situated along the coastal region in Andaman Islands damaged by strong and high *tsunami* waves on 26th December 2004. Overall habitat change/loss due to the upheaval of land, loading of sand by the waves, increase in depth level and enduring salinity in different parts of the Islands was also documented. This *tsunami* has brought in drastic changes in the water and vegetation in the habitats. The Teal prefers sparse vegetation at depths of 20-50cm for feeding (Vijayan 2006), the vegetation is strongly correlated with depth and salinity (Ntiamoa-Baidu *et al.* 1998, Vijayan 2006); these factors are identified as most important in the selection of habitat by waterfowl (Cody 1985, Colwell and Taft 2000, Isola *et al.* 2000). The loss or changes

in the habitat might be the reason for decreasing Andaman Teal population in select coastal wetlands, in comparison with the earlier surveys (Vijayan *et al.* 2006). Though the habitat had changed, Andaman Teals were observed in the small pools at North reef Island (23) and Magarnalla (24) in Interview Island, but in none of the other sites neither inland nor coastal wetlands which might be due to the drastic changes in their feeding and breeding grounds. In addition, some of them might have moved between the wetlands, inland or coastal during the survey.

The habitat loss is the most important factor affecting 73% of these globally threatened taxa (Green 1996). Worldwide, there are 1025 bird species (Collar and Andrew 1988) and 82% of endangered bird species (Temple 1986) were significantly threatened by habitat loss and many studies have shown that habitat change can have considerable effect on the numbers of individuals using site (Sutherland 1998). The present study revealed predominance of the habitat destruction in the coastal wetlands including the major Teal habitats due to tsunami. The changes in detection of Andaman Teal from select wetlands observed may be because the area of their foraging or breeding habitats have been changed. However, besides the population decline due to the anthropogenic activities, such major natural disasters may cause the local extinction of the Andaman Teal or the population.

6.5. SUMMARY

- For the study of insular biology of the avifauna in Andaman Islands importance has been given to the endemic and threatened birds. To acquire knowledge on avian population biology, community ecology and the island birds conservation, the size or density of the population was estimated, by using variable circular-plot (VCP) method.
- The method was used in all stations covering all major vegetation types along transect. From a fixed 10 minute, sampling period each bird seen or heard was counted at 200m intervals between the stations particularly those birds which actively used the study area.
- Population density for each species in the habitat (birds/km²) was then estimated by summing the densities inside of the inflection point (both the number of individuals and the areas was summed). Since greater than one station was used, the estimated density from all stations was divided by total number of stations, to provide an estimated density for the habitat as a whole.

- Totally 144 bird species were counted, which actively used the study area. And the region-wise density was estimated with the observed bird population across the habitats, in which the occurrence of 58 species were common to all four regions, 16 from three regions, 31 from two regions and 39 were recorded only in one region.
- The bird density (bird/km²) of Andaman Islands ranged between >0.05 and <133.7, importantly density of twelve near-threatened birds from Andaman Islands was observed, by both regional and habitat-wise.
- A rapid survey was carried out for habitat assessment in the select wetlands (inland and coastal) of the Andaman Islands, during non-monsoon period (from December 2007 to May 2008) covering 14 sites and to know the status of the Andaman Teal by using total count method.
- Habitat information was gathered on the major Andaman Teal habitats, which were drastically affected by major earthquake in 2004 in Indian Ocean followed by *tsunami*. Qualitative assessment of damages of select coastal wetlands was also made.
- Total by 99 individuals of the Andaman Teal were recorded from 14 sites surveyed and among 3 major island groups, maximum of 73 birds were counted from North Andaman, whereas no birds were found in Little Andaman including some inland wetlands. Among the eight coastal wetlands from Little and South Andaman no birds were found except at Sippighat (11) in South Andaman.

CHAPTER SEVEN

CONCLUSION: CONSERVATION PRIORITIES AND IMPLICATIONS

7.1. BACKGROUND

Given the urgency of the biodiversity crisis, much effort has been invested in establishing conservation priorities. Most of this has addressed broad regional priorities (Myers *et al.* 2000), with increasing efforts to set site-scale targets for actual conservation implementation (Eken *et al.* 2004). According to Brooks (2006) the Southeast Asian Biodiversity in Crisis is overviewed and structured along a similar state–pressure–response framework as **Fig. 7.1**. A cursory examination of immediately available biodiversity data sets (number of endemic mammals, birds and amphibians by Baillie *et al.* 2004), threat (mean human footprint index by Sanderson *et al.* 2002) and response (percentage of land area protected by Chape *et al.* 2003) is informative (**Fig. 7.1**). Whereas Latin America, as popularly expected, is the most biodiverse continent, the high threat and paucity of current investment provide a compelling argument that Southeast Asia is at least as high a continental conservation priority (Sodhi and Brook 2006).

Given this context, biodiversity and conservation in the continent are long overdue for a comprehensive review. With a short survey of global rates, causes and environmental effects of deforestation, Sodhi and Brook (2006) focused heavily on the geological and climatological drivers of Southeast Asian biodiversity followed by a shorter assessment of contemporary ecological process includes *dipterocarp* mashing and of co-evolution of wild cattle with human impacts on Asian seasonal forests. However, the continental conservation priorities were framed with published work from the region on the impacts of deforestation are covered, surveying effects across plants, invertebrates, herptiles, birds and mammals (**Fig. 7.1**) and the threats from fire, hunting, trade, invasive species, climate change and disease (Sodhi and Brook 2006).

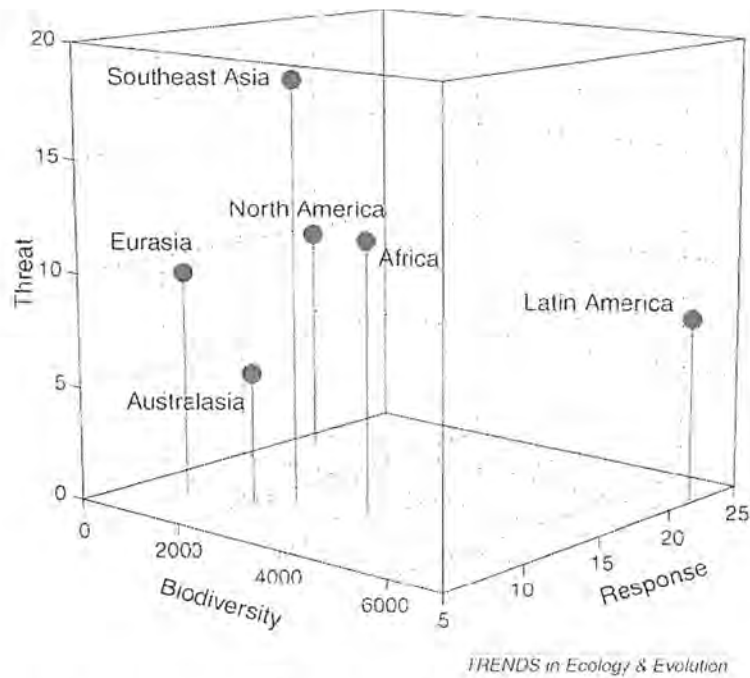


Figure 7.1: Continental conservation priorities, based on biodiversity (number of endemic mammals, birds and amphibians; Baillie *et al.* 2004), threat (mean human footprint index; Sanderson *et al.* 2002) and conservation response (percentage of land area protected; Chape *et al.* 2003).

Why biodiversity conservation is an urgent need of these islands?

Today, the total area of 6,408 square kilometres of the Andaman Islands has a population of more than 356,000 and about 85 per cent of it is covered by forest. From 1788, attempts to explore and colonize the islands were met with resistance from the tribal people, who were the sole occupants of the large territory, identified by various dialect groups. The situation changed from 1858, when the British finally set up control of the islands and Andaman islanders experienced a major decline in their number in relation to an increasing number of non-tribal settlers (Pandya 2007). However, the Andaman islanders oscillating between coast and forest also posed a major problem for the expanding colonial administration and its control of space which had the major impact on the biodiversity conservation in these islands in one way.

A recommended conservation responses, from proximate tactics (environmental education, establishment of new protected areas and better management of existing ones, and improving logging practices) to long-term policy actions (improving

administration collaboration, balancing livelihoods and conservation, and enhancing biological research) to the Andaman and Nicobar Islands is urgent.

7.2. CONSERVATION CONCERNS

7.2.1. Identification and prioritization of important sites using criteria of birds

Biodiversity prioritization has been done in various regions and ecosystems using various parameters (Spellerberg 1992, Prasad *et al.* 1998, Myers *et al.* 2000, Singh *et al.* 2000, Vijayan *et al.* 2005) to help in planning the conservation strategies. In this study the number of bird species and individuals in total and of different status are given ratings as explained under methods. The total ratings obtained for a locality was pooled and rating per unit area was calculated. Such analyses showed a combination of habitats in a locality with the presence of evergreen, semi-evergreen, moist deciduous and littoral forests had high ratings. Areas with dense forest cover and less disturbance had more rare endemics and thus needs special attention. The landscape ecology studies following IIRS (2003) and Vijayan *et al.* (2005) has generated Disturbance Index and Biological Richness maps which are depicted in the maps (Plate 7.1 to 7.4). The Biological Richness results for the Andaman Islands showed (Table 7.1) Little Andaman having as much as a third of the area as very high priority locality followed by South Andamans. In contrast, the North and Middle Andaman have only 11 and 10 percent of the area respectively.

Table 7.1: The estimated biological richness in ha.(%) from different regions in Andaman Islands.

Class	North	Middle	South	Little
Low	23,558.17 (16.6)	12,810.53 (08.4)	18,646.79 (09.4)	5,641.46 (08.1)
Moderate	34,953.75 (24.6)	16,167.86 (10.6)	55,678.81 (27.9)	8,675.31 (12.5)
High	68,145.24 (47.9)	108,075.23 (70.7)	90,509.47 (45.4)	32,404.49 (46.8)
Very high	15,636.04 (11.0)	15,722.15 (10.3)	34,689.77 (17.4)	22,569.06 (32.6)
Total	142,293.20	152,775.76	199,524.84	69,290.32

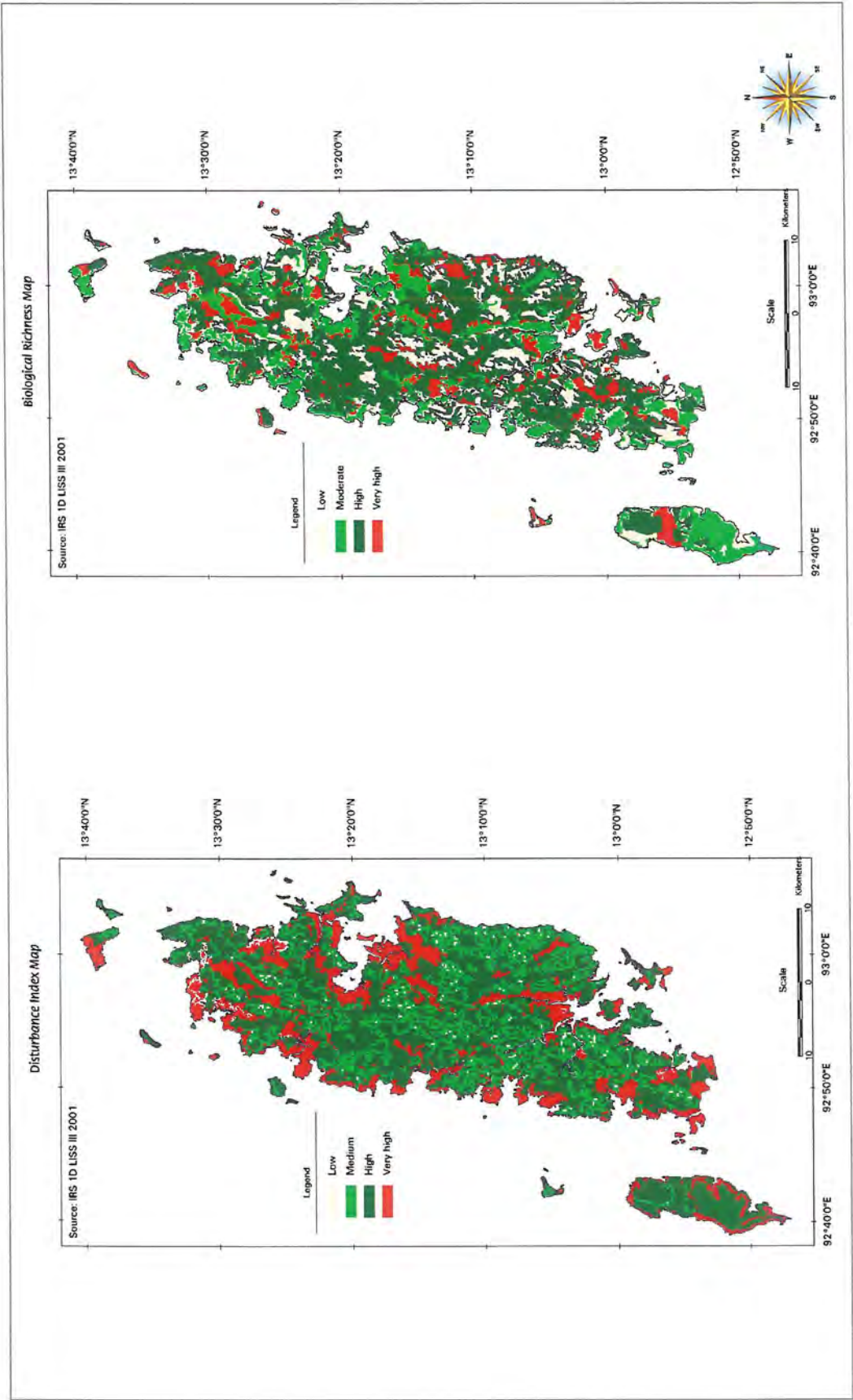


Plate 7.1: The assessment of site prioritization in North Andaman islands.

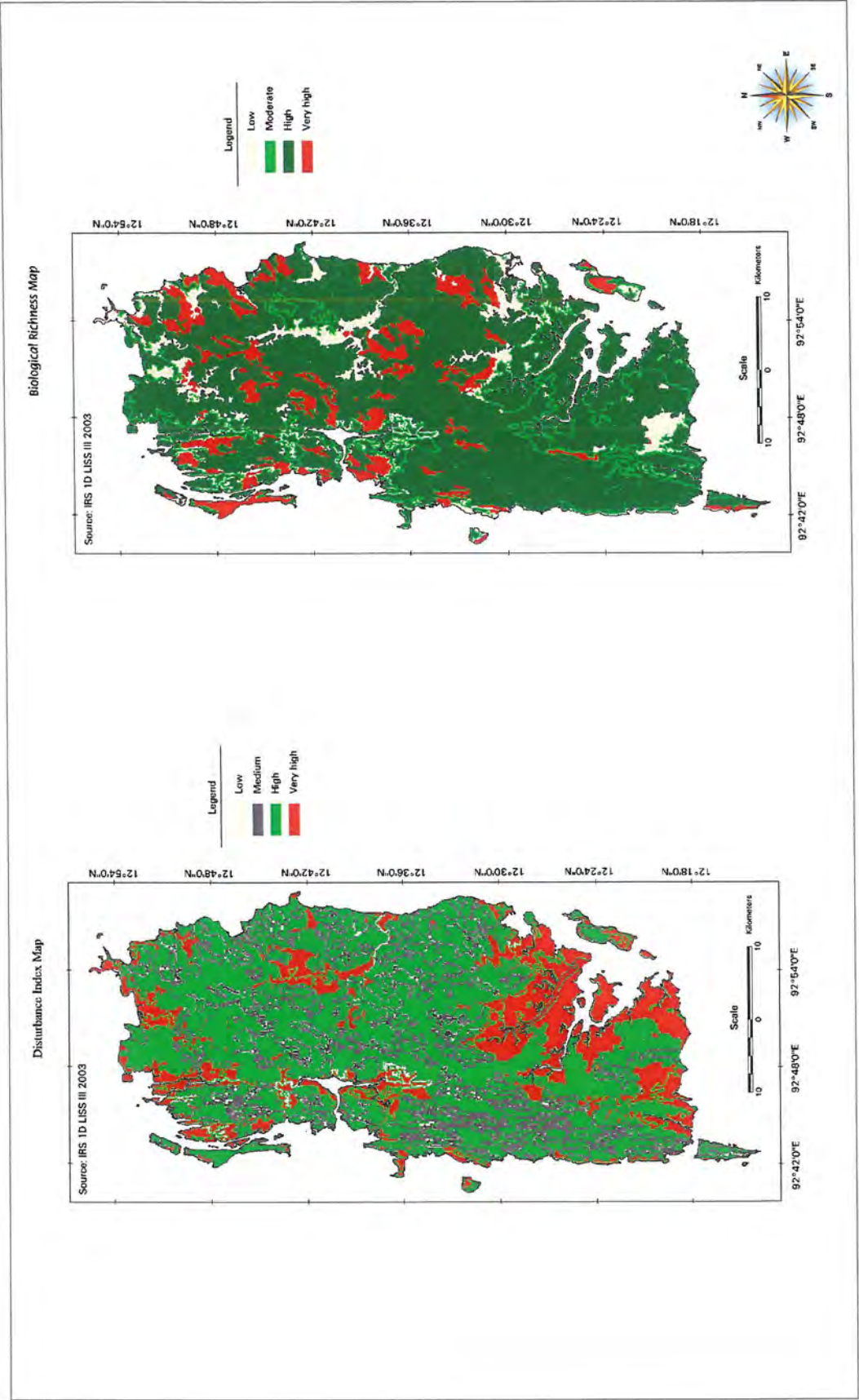


Plate 7.2: The assessment of site prioritization in Middle Andaman islands.

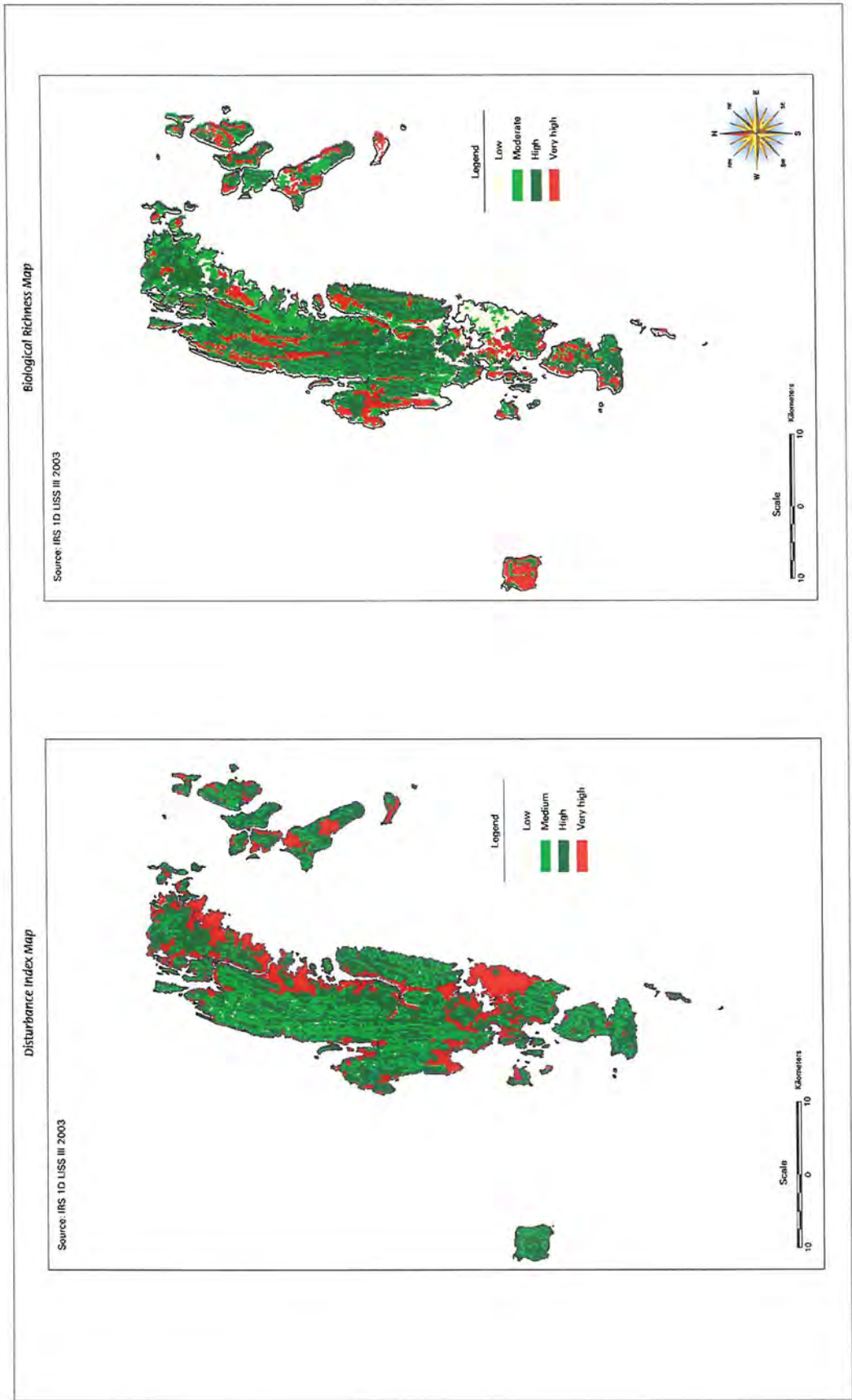


Plate 7.3: The assessment of site prioritization in South Andaman islands.

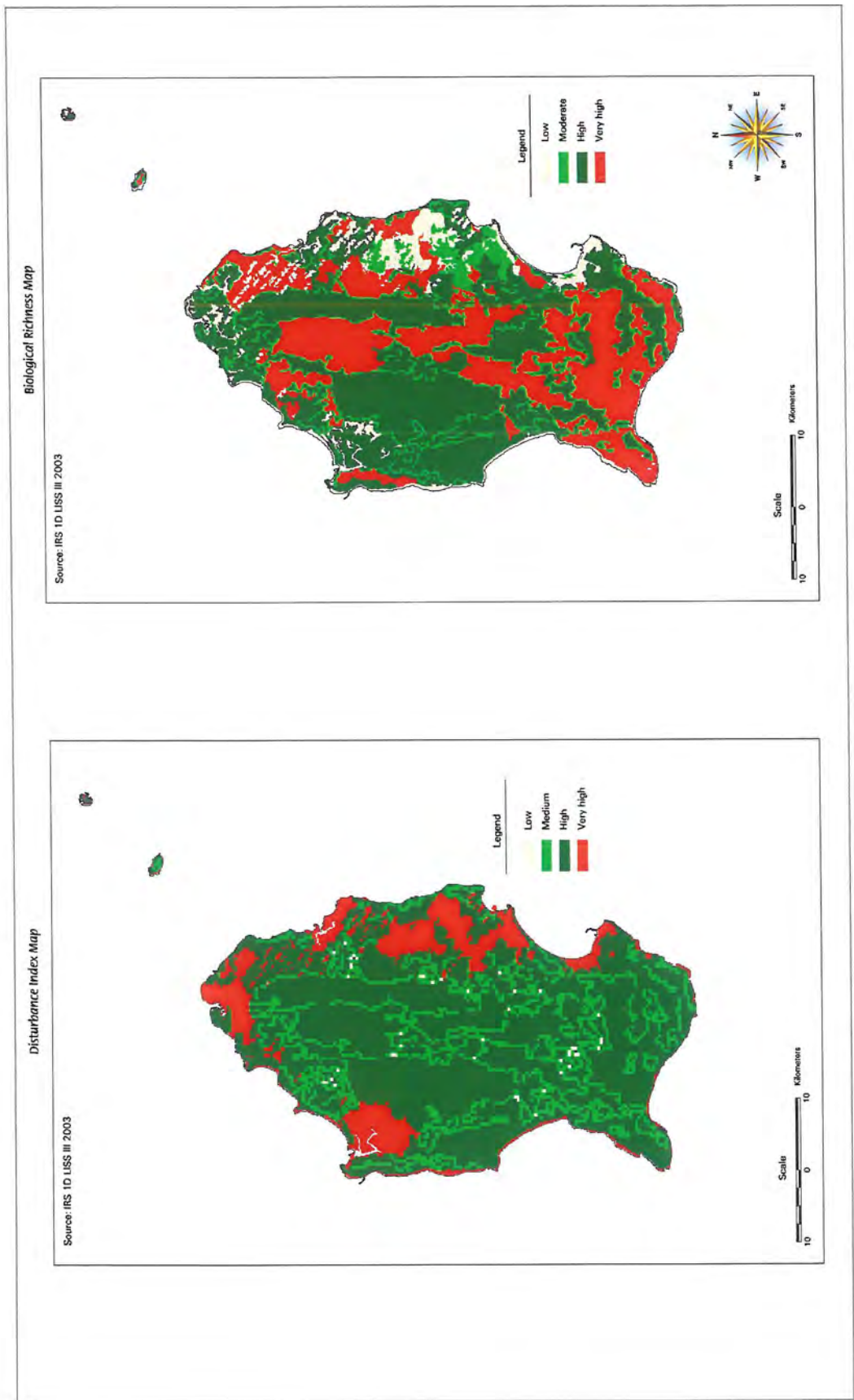


Plate 7.4: The assessment of site prioritization in Little Andaman islands.

7.2.2. Conservation Problems and Prospects

In the development of an effective conservation programme for natural habitats, one of the first steps is the compilation of an inventory of the most important forest and wetland sites. The reported decline in the dense forest cover by FSI (1999, 2003, 2009) is of great concern, mainly because it was attributed to encroachment which is more in North Andaman. The same reason can be attributed to more areas having low biological richness. In Middle Andaman also partly it is due to the disturbances as well as less extent of evergreen/semi-evergreen forests. Importance of dense forests for biological diversity and abundance of endemic and threatened species was shown in other studies in Andamans (Thiollay 1997, Yoganand and Davidar 2000, Davidar *et al.* 2001) in Singapore (Castellatta *et al.* 2000) and in the Hawaiian Islands (Scott *et al.* 1986).

However, measures are taken to stop commercial timber operations and illegal encroachments and to remove the recent ones which will go a long way in the conservation of biodiversity in these islands which have still considerable extent of less disturbed pristine habitats compared to the mainland of India. Formerly subsistence agriculture in small areas and extensive hunter-gatherer utilization of the forested areas were present. These activities yielded to extensive agriculture and intensive commercial exploitation of forests.

Disturbances and threats: The population problem has been identified as one of the root causes for habitat changes and other related problems with the development of the area (Saldanha 1989, Pande *et al.* 1991, Davidar *et al.* 1995, Vijayan 1996, 2009, Sankaran 1997). The human populations of the Andaman and Nicobar Islands have undergone a ten fold increase between 1911 and 1981 (Singh 1981) mainly because of the settlers from the mainland India while the native tribes have only declined in number and they generally do not cause much impact on the natural habitats (Sankaran 1995, Daniels 1997, Vijayan *et al.* 2000).

Andrews *et al.* (2006) reported that the rapid increase in population in past years has exerted tremendous pressure in the land. Various attempts have been made to estimate the carrying capacity of the islands. All previous estimates have not indicated any figure more than three lakhs as the maximum carrying capacity. Research based on methodology developed by Food and Agriculture Organization (FAO) has calculated

that at the present level of technology, the islands can support a population of about 2,50,000 (Ghosh 1994). The study has warned that increasing land under agriculture to increase the domestic output, will only worsen land-man ratios, strain carrying capacity further and increase dependence on supplies from mainland and on the government budget. The population has already exceeded the carrying capacity and the results are visible in terms of the increased encroachments of forest and revenue lands (Andrews *et al.* 2006).

Habitat loss and degradation have affected all the threatened birds of Asia mainly because 80% are forest species, especially of lowland tropical forests; 30% have very restricted range of distribution as in the islands (BridLife International 2001, Riley 2002) where habitat changes affect the species much more than in the mainland. Considering the size and area of the islands, loss of habitat leading to extinctions will have far greater consequences in terms of the loss of genetic diversity than comparable areas elsewhere. A rough calculation using island biogeography theory indicates that with forest down to 86% of what it used to be, about 4.5% of species may have been lost (Jayaraj and Andrews 2005).

The degradation of the littoral habitats are due to encroachments, unregulated and illicit harvesting of coastal sand and lack of regeneration in the formerly cleared mangrove areas (Sirur 1999). Settlement also resulted in the loss of most of the lowland evergreen forest, and small freshwater riverine habitats, which include most of the Andaman Teal and crocodile nesting habitats in Andamans (Andrews and Whitaker 1994, Vijayan 1996, Andrews 1999, 2000, 2001). These flat lands close to freshwater streams were thought to be the most suited for agriculture and were preferentially cleared.

There is, currently, very little of the lowland forest type left in the Andamans except in Protected Areas and in the Jarawa Reserve along the west coast of south and middle Andaman Islands (Jayaraj and Andrews 2005). Even at the time of settlement, the estimate of land available for allotment for the purpose of cultivation, was not more than 373 km² (Andrews *et al.* 2006). Even in the early years of colonization, experts have opined that the land in Andaman and Nicobar Islands is not suitable for agricultural settlement and agriculture based enterprises and that the economy must be based on forestry and forest products, if damage to the environment is to be avoided (McVean 1976).

The immense potential of the forests for renewable resource utilization has been largely ignored in a rush to exploit the standing timber for powerhouse, matchwood and plywood factories. Timber has been the main resource exploited in these islands (Saldanha 1989); indirect losses due to the logging operations are also not negligible (Daniels 1997). Since the 1970s, a vast expansion of the logging has been done as in 15% of the forest area 85% of the area is intact in the Tribal Reserves, National Parks and Sanctuaries. Expansion of plantations converting the coastal forests has been identified as a threat to the endangered species in the Andaman and Nicobar islands (Sankaran 1997, Stattersfield *et al.* 1998, Vijayan 1996, 2009, Vijayan *et al.* 2000).

Increased immigration has led to increasing agricultural activity. Such activity leads to encroachments, resulting in soil loss, loss of productivity and damage to coral reefs (Jayaraj and Andrews 2005). The agricultural practices adopted by the settlers are also not suitable to the area (Daniels 1997). About 4000 ha of forestland is under encroachment. This has caused fragmentation of the forests and disturbance to the flora and fauna in these Islands (Jayaraj and Andrews 2005). However, there is hope in the future with stopping of commercial forestry (logging) operations and removal of encroachments.

Hunting or poaching: is yet another major problem in these islands threatening the birds and animals, especially the endemic birds (Chandra and Rajan 1996, Sankaran 1998, Vijayan 1995, 1996, 2009). Unrestricted persecution of Estuarine Crocodiles by local people in the past has greatly reduced their numbers. Choudhury and Bustard (1980) recorded 97% destruction of crocodile nests in the 1977 nesting season, almost entirely as a result of egg-robbing by settlers and 17% of the nest-guarding females were killed in that year alone. Poaching occurs even in protected areas (Chandra and Rajan 1996), mostly because of the inadequate facilities with the Forest Department and lack of awareness in the local communities (Vijayan 1996). The foreign poachers are more dangerous (Sankaran 1995, 1997, Das 1996, Daniels 1997, Vijayan *et al.* 2005), but is being planned to be tackled with coordination between various departments in these islands.

Introduced species: Several examples of introduced species causing extinction or rarity of endemic species in island ecosystems are present (Recher and Clark 1974, Atkinson 1989, Olson 1989, Carew-Reid 1990, Baker 1991). Many of the invasive and noxious species to the Andaman and Nicobar Islands having been witnessed as the culprits in

adverse environmental problems (Table 7.2). They also cause economic damage. Yet, the research done on these species is negligible (Ali 2003). Introduced mammals, including man as a predator, account for 74% of avian extinctions in New Zealand since AD 1840 (Atkinson 1989). The introduction of dogs, cats and civets in the Andaman and Nicobar Islands can have identical consequences. Dogs and cats would cause problem for the rare Andaman Crake (Stattersfield *et al.* 1998, Vijayan and Ezhilarasi 2007, Ezhilarasi 2009). Birds such as the Common Myna *Acridotheres tristis* and House Sparrow *Passer domesticus* may replace local species as the Andaman Red-whiskered Bulbul introduced into North Nicobar forming threat to the Nicobar Bulbul (Sankaran 1998, BirdLife International 2001).

Table 7.2: List of exotics recorded from the Andaman Islands. (*- indicates that the species is on IUCN's list of "The hundred worst invasive species" (ISSG 2002), @- indicates that the species need clearance under the Wildlife Protection Act, 1972 for control measures to be implemented).

S.No.	Scientific name	English name	Type
1	<i>Eichhornia crassipes</i> *	Water Hyacinth	aquatic plant
2	<i>Lantana camara</i>	Largeleaf Lantana	land plant
3	<i>Leucaena leucocephala</i> *	Ipilipil, Subabul	land plant
4	? <i>Opuntia stricta</i>	Cactus, Erect Pricklypear	land plant
5	? <i>Parthenium hysterophorus</i>	Congress Grass	land plant
6	<i>Achatina fulica</i> *	Giant African Snail	land invertebrate
7	<i>Lissemys punctata</i> @	Flapshell Turtle	aquatic reptile
8	<i>Acridotheres tristis</i> *	Common Myna	land bird
9	<i>Passer domesticus</i> @	House Sparrow	land bird
10	<i>Funambulus pennanti</i> * @	Five Striped Palm Squirrel	arboreal mammal
11	<i>Bos taurus</i>	Cattle	land mammal
12	<i>Axis axis</i> @	Spotted Deer, Chital	land mammal
13	<i>Canis familiaris</i>	Domestic Dog, Feral Dog	land mammal
14	<i>Capra hircus</i> *	Goat	land mammal
15	<i>Elephas maximus</i> @	Elephant	land mammal
16	<i>Felis catus</i> *	Domestic Cat, House Cat	land mammal
17	<i>Muntiacus muntjak</i> @	Barking Deer	land mammal
18	<i>Mus musculus</i> *	Field Mouse, House Mouse	land mammal
19	<i>Rattus norvegicus</i>	Brown Rat, Norway Rat	land mammal
20	<i>Rattus rattus</i> *	Black Rat	land mammal

Protected areas: The Andaman Islands have 99 protected areas covering 1059.42 km² which is 16.44% of the total geographical area (Table 7.3). The situation here is much better than many other places and is above the minimum requirement; 10% of the area is the minimum suggested for protecting biodiversity (Dobson *et al.* 1997).

Table 7.3: Status of Protected Areas (PAs) of different region in the Andaman Islands.

Particulars			North	Middle	South	Total
Sanctuary (size class of islands)	Very Small	No.	40	11	3	54
		Area	12.74	3.75	1.73	18.22
		Mean	0.32	0.34	0.58	0.34
	Small	No.	9	4	2	15
		Area	14.53	5.67	2.85	23.05
		Mean	1.61	1.42	1.43	1.54
	Medium	No.	14	3	1	18
		Area	85.50	14.75	9.51	109.76
		Mean	6.11	4.92	9.51	6.10
	Large	No.	1	2	0	3
		Area	29.48	22.2	0.00	51.68
		Mean	29.48	11.10	0.00	17.23
	Very Large	No.	1	0	1	2
		Area	133.00	0.00	106.00	239.00
		Mean	133.00	0.00	106.00	119.50
	Sub-total	No.	65	20	7	92
		Area	275.25	46.37	120.09	441.71
		Mean	4.23	2.32	17.16	4.80
	National Park	No.	1	3	3	7
		Area	32.54	0.91	584.26	617.71
		Mean	32.54	0.30	194.75	88.24
	Grand Total	No.	66	23	10	99
		Area	307.79	47.28	704.35	1059.42
		Mean	4.66	4.42	70.44	10.70
Area	Totally covered	in km ²	1348.00	1070.00	3990.00	6408
	Protected	in %	22.83	4.42	17.65	16.44

Source: Andrews *et al.* 2006.

At present 69.58% of the forest area (4,989.90 km²) is totally protected in the form of Tribal Reserves, National Parks and Sanctuaries, and further in the form of mangrove conservation working circle, and protection working circle even within the area covered by working plans. 30.41% of the forest area (2,180.79 km²) was set aside for forestry operations involving felling and regeneration and till 2002 only 15.49% of the forest area (1,110.52 km²) had been regenerated under the Andaman Canopy System. The future operation for timber extraction, solely for meeting the local requirements, shall remain confined to this area of 1,110.52 km² already extracted and regenerated, in terms of the recent order of the Supreme Court. The rest of the forest area will remain completely protected (Andrews *et al.* 2006).

Global warming and sea level rise: The current global issues regarding the environment and biodiversity conservation such as global warming and sea level rise are applicable to the Andaman and Nicobar islands. With respect to the coral reefs of this region, the rise in temperature has probably caused large scale mortality as reported by Soundarrajan of CARI. *Ocean Temperature:* various mathematical models predict global warming over the next century that will resulting in a rise in ocean temperature of 1-3°C (Boesch *et al.* 2000). However these projections are not without their critics and an alternate viewpoint is that the "greenhouse effect" of increased atmospheric CO₂ and other gases will result in global cooling. Therefore, projections of coral bleaching in response to continued warming of the earth's oceans must be viewed within this uncertain context, although the global warming scenario appears to be becoming more rigorous and accepted as models are refined (Barnett *et al.* 2001, Levitus *et al.* 2001).

Small island nations such as Tuvalu and some of the Solomon Islands-where sea level rise is submerging low-lying land and saltwater is inundating vital groundwater reserves. Sea-level rise will affect coastal regions throughout the world, causing flooding, erosion, and saltwater intrusion into aquifers and freshwater habitats (<http://www.panda.org/climate/glaciers>). Average global sea level rose by 1-2 mm per year during the 1900s and is projected to continue rising, with an estimated contribution of 0.2-0.4 mm per year from melting glaciers. Various consequences of global warming such as melting of sea ice, volume expansion due to temperature increase in the ocean, etc. can contribute to global sea level rise (Unnikrishnan *et al.* 2006).

The sea level rise is also a result of global warming which could have serious impacts on the coastal species, especially the brackish or fresh water ponds that are preferred by the Andaman Teal. The ingress of seawater into such areas as in the North Reef and Little Andaman could increase the salinity of water and thereby change the flora and fauna. Impact on the abundance of plankton and invertebrates, which form food of the Andaman Teal, could not be documented. Detailed investigations and regular monitoring in these islands are required for assessing these phenomena.

Natural causes: Many of the endemics are threatened by the natural limited distribution and rarity (Davidar *et al.* 1995) and low productivity. Occurrence in very specific habitats becomes a threat, especially when such habitats are damaged by natural disasters such as tsunami. Receding of water would affect the coastal wetlands and littoral forest.

7.2.3. Purpose

The purpose of the present study is to:

- provide information for local communities to discuss threatened and endemic bird issues within their locality,
- provide a link between the department of Environment and Forests, Andaman and Nicobar Islands Administration and the community in relation to threatened, endemic bird issues and for two-way information exchange,
- urge communities to become involved in the management of the threatened/endemic birds conservation which is very important to protect their natural resources, and
- provide a forum via which members of the community may have input into the management and be aware of threatened and endemic birds within their region.

7.2.4. Implications

The major anticipated implications for threatened, endemic bird conservation in the Andaman Islands may be comprised of representatives of community groups from within the effected communities such as:

- Community Associations
- Neighbourhood/Rural/School Watch Groups
- School Management Committees
- Environmental Groups

7.3. CONCLUSION

7.3.1. *Major findings and proposal*

Species distribution: The obvious results from the opportunistic bird survey conducted (present study) from the Andaman Islands concluded that the natural forests have more potential for sheltering birds than the disturbed/degraded vegetations, especially for endemic birds of the islands (see **Table 3.8 & 3.9**). Hence, the proposed mapping of occurrence or relative abundance of bird populations are of great importance not only for highlighting the strongholds of particular species and through change maps allow areas of significant changes to be identified, but they also allow information such as this to be made accessible to a much wider audience than would normally be possible. However, whilst the collection of survey data for producing maps of occurrence or relative abundance of bird populations of this type requires a huge effort, it is rarely possible to survey more than a small proportion of a species range. Nevertheless advances in the application of geostatistics over the past ten years have improved the estimation and precision of predicting occurrence or relative abundance at non-surveyed sites and so allow the potential for producing reliable maps over the area of interest. Further, we examine the influence of species-specific traits such as habitat specialism, flocking behaviour and detectability on the reliability of species-specific predictions and the extent to which landscape data or additional survey data can be used to improve our predictions.

Possible changes in land use: Increasing external pressure on the islands is likely to result in further degradation of the remaining terrestrial ecosystems with concomitant damage to the mangrove forest, coral reefs and fisheries. The islands have been designated as a "specially backward" region where industry can claim general financial concessions in order to establish itself.

Protection of mangrove forests

Economic and social values: Under proper management, the terrestrial and mangrove forests of the Andaman and Nicobar Islands would be capable of supporting a major forestry industry on a sustainable basis. The mangrove forests are breeding and nursery grounds for many commercially important fishes and crustaceans, and are thus of crucial importance in maintaining the region's fisheries. The mangrove forest also provides valuable coastal protection from cyclonic storms. Many of the islands are of great scenic beauty and have tremendous potential for tourism.

Proposed area for protection

In the major island groups, protected area is good in the North and South Andaman (18-23%), but very less in the Middle Andaman, only 4% (see **Table 7.2**). The Jarawa Reserve also protected, infact has more protection than even sanctuaries and National Parks. If they are also included, area will increase. Some of the major mangrove forests and the moist deciduous and semi-evergreen forests nearby Rangat may be declared as protected area, especially as the habitat of the rare endemic Andaman Crake. Although North and South Andaman regions have a good network of protected areas, some of the crucial habitats of the endangered Andaman Teal are not covered (see **Table 7.2**). Hence, a few specific localities were recommended to be protected as sanctuaries or conservation areas such as Dhaninala in Rutland in South Andaman, Hanspuri and Mohanpur in North Andaman, Jackson creek in Little Andaman. Some of these are already proposed (Vijayan 1996, 2009, Vijayan *et al.* 2000, 2005, 2006) and being considered for detailed examination by the Department of Environment and Forests, Andaman and Nicobar Islands administration and Wildlife Board. However, it is imminent that such conservation actions have to be implemented at the earliest, or else these areas will be lost; some of the areas suggested to be protected as in Sippighat and Bimlitan in SA are already converted to habitations and the marshes at Kadakachang to coconut plantations.

7.3.2. Recommendations

The present study suggests the following major recommendations to the Department of Environment and forests, Andaman and Nicobar Islands administration based on the observations from prioritization of important sites and outcome of the bird studies.

1. The crucial habitats of the endangered Andaman Teal, namely Dhaninala in Rutland and Constance Bay in SA, Hanspuri and Mohanpur in NA, Jackson creek in LA should be protected as sanctuaries or conservation areas as suggested earlier (Vijayan *et al.* 2000, 2005, 2006).
2. Some of the major mangrove forests and the moist deciduous and semi-evergreen forests in Middle Andaman may be declared as Protected Areas, especially as the habitat of the rare endemic Andaman Crake.

3. Detailed studies on the rare endemics, namely the Andaman Cuckoo-Dove, Andaman Hawk-Owl and Andaman Teal have to be taken up on priority to assess their status and understand the ecological requirements.
4. Habitat restoration studies in all major habitats need to be taken up for climate related adaptation strategies.
5. Further settlement by the mainlanders should be stopped and areas from where the encroachments are evicted should be restored with natural species.
6. Detailed investigations and regular monitoring are required for assessing the impact of climate change and sea level rise on these islands.
7. Hunting and poaching, although illegal, are frequent and should be tackled seriously with the involvement of various agencies.
8. The impact of invasive/ introduced species on the endemic flora and fauna should be studied and management actions adopted.
9. The land cover is an important determinant of the habitat of the endangered, endemic bird species and hence, it is essential to have large scale maps (1: 2500 or higher) for effective understanding of the conservation needs.
10. A proper monitoring system needs to be put in place using temporal satellite data along with the GIS information on human influences on the habitat.
11. The present study addressed only Andaman group of islands. Nicobar Islands also need such an assessment.
12. In view of the *tsunami* impacts, the impacted habitats need to be surveyed and monitored for avian biodiversity along with other key taxa.
13. An integrated approach among the various governmental agencies should be adopted for planning conservation and development.
14. Environmental Awareness programmes should be executed more systematically and intensively.

7.3.3. Conservation actions

Protected Areas (PA):

A proposal is being considered by the WildLife Board of the Andaman and Nicobar Islands for restructuring the PA network in these islands.

Awareness Programme:

As per the results obtained and recommendations given from the existing project various lectures were given by me to the selected school children all over the Andaman Islands through ongoing project of DNA Club, Andamans (Dept. of Biotechnology Nature resource Awareness) (Table 7.4).

Table 7.4: Details of awareness activity on the natural resources of the Andaman Islands to the schools/college students during the study period, between 2003 and 2008.

S. No.	School/Region	Topic of the lecture given
1.	Govt. Model Senior Secondary School, Mayabunder, North Andaman. (03/01/2008).	Natural resources in Andaman and Nicobar Islands
2.	Kendriya Vidyalaya No.1, Port Blair, South Andaman. (09/01/2008).	Biodiversity of the Andaman Islands
4.	Govt. Senior Secondary School, Diglipur, North Andaman. (25/01/2008).	Endemic Birds of the Andaman Islands and their conservation
5.	Govt. Senior Secondary School, Diglipur, North Andaman. (24/01/2008).	Biodiversity of Andaman Islands
6.	Govt. Senior Secondary School, Diglipur, North Andaman. (25/01/2008).	Protected areas in Andaman Islands
7.	Govt. Model Senior Secondary School, Hutbay, Little Andaman. (5/02/2008).	Protected Forests in Andaman Islands

Several other programmes are being conducted by CPR Foundation, Chennai, Sálím Ali Cente for Ornithology and natural History (SACON), Coimbatore, Andaman and Nicobar Environmental Team (ANET), Port Blair and the Departments of Forests, Wildlife, Education and Biotechnology of the Andaman and Nicobar Islands.



Plate 7.1: Natural resource Awareness activities in Andaman Islands. a,b,c,d,e,f) lectures on the local Bio-resources and Protected Areas, Andaman Islands, g) field trip to Limestone caves, Nayadera, Baratang, Middle Andaman, h) Nature trial at Mt. Harriet National Park, South Andaman.

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ANNEXURE

Annexure 2.1: Chronostratigraphic divisions of the Andaman and Nicobar Islands Late Cenozoic.

Stage	Lithology	Epoch/Age in Million year (M.Y)
<u>Nicobar Series</u>		
Shompenian	Shell lime stone	Pleistocene (1.95 M.Y and younger)*
Taipian	Silty mudstone, Lime stone	Late Pliocene (3 to 1.95 M.Y)
Sawarian	Mudstone, Lime stone, Silty mudstone	Earley Pliocene (5 to 3 M.Y)
<u>Archipelago Series</u>		
Neilian	Mudstone, Lime stone, Silty mudstone	Late Miocene (10 to 5 M.Y)
Havelockian	Mudstone, Silty mudstone, Limestone	-do-
Ongeian	Mudstone, Limestone	Middle Miocene
Inglisian	Creamish yellow Calcerous Chack and Mari	-do-
Jaravaian	Creamish yellow Calcerous Chack and Limestone	Early Miocene (22.5 to 16 M.Y)
Andamanian	Grey sandy Limestone, White siliceous chak and silt	-do-

* Absolute time relationship determined by calibrating Neogene Planktonic foraminiferal datum levels with radiometric dates. Source: Srinivasan (1986).

Annexure 2.2: The month/year wise average Temperature, Humidity and Rainfall recorded in Andaman & Nicobar Islands.

▼ Month/Year ►	2003	2004	2005	2006	2007	Mean
a) <u>Temperature</u> (°C)						
January	26.10	27.40	26.95	26.40	26.35	26.64
February	27.05	26.50	26.95	27.70	26.85	27.01
March	27.80	27.50	28.40	27.10	26.80	27.52
April	28.30	29.25	29.50	28.10	28.95	28.82
May	28.45	27.45	28.35	27.25	27.58	27.816
June	27.65	27.00	27.00	26.75	27.50	27.18
July	26.25	26.75	22.45	27.45	27.25	26.03
August	26.90	26.95	27.05	27.00	26.95	26.97
September	26.80	26.85	26.50	23.50	26.30	25.99
October	26.90	27.20	27.00	26.85	26.80	26.95
November	28.10	27.90	27.15	27.80	27.00	27.59
December	27.15	27.30	26.70	26.75	26.70	26.92
b) <u>Relative Humidity</u> (at 08.30 h)						
January	72.00	71.00	69.60	70.10	72.00	70.94
February	72.00	69.00	68.40	71.60	67.00	69.6
March	70.00	67.00	69.40	70.10	65.00	68.3
April	68.00	66.00	67.80	67.90	69.00	67.74
May	77.00	83.00	76.80	78.00	83.00	79.56
June	82.00	84.00	85.20	89.00	84.00	84.84
July	89.00	83.00	83.80	85.00	84.00	84.96
August	84.00	84.00	82.20	84.00	86.00	84.04
September	84.00	83.00	84.90	90.00	87.00	85.78
October	82.00	80.00	82.40	83.00	85.00	82.48
November	72.00	75.00	78.90	75.00	79.00	75.98
December	69.00	65.00	79.00	71.00	72.00	71.2

contd...

▼ Month/Year ►	2003	2004	2005	2006	2007	Mean
c) <u>Mean Rainfall</u> (mm)						
January	49.92	40.20	19.43	20.85	6.10	27.30
February	25.67	104.30	0.00	20.98	2.31	30.65
March	102.70	60.08	30.50	66.26	16.50	55.21
April	18.10	49.00	50.20	195.46	54.85	73.52
May	282.55	472.10	227.25	366.68	372.35	344.19
June	158.80	391.73	449.83	370.20	386.18	351.35
July	460.45	301.73	323.20	173.56	360.50	323.89
August	308.50	291.94	283.30	225.11	415.70	304.91
September	329.30	296.61	402.30	525.90	458.40	402.50
October	349.50	222.94	299.11	416.90	244.50	306.59
November	183.90	169.31	306.90	81.70	254.86	199.33
December	214.20	36.67	322.43	74.93	93.01	148.25
Total	2483.59	2436.61	2714.45	2538.53	2665.26	-
d) <u>Mean wind speed</u> (km/Hrs)						
January	5.3	7.0	5.8	5.8	9.5	-
February	5.2	4.5	4.2	4.9	8.2	-
March	4.7	2.8	4.2	2.4	5.1	-
April	3.7	4.3	3.9	3.7	5.0	-
May	11.2	8.9	6.8	8.4	11.4	-
June	11.5	11.3	7.9	9.0	9.2	-
July	9.7	10.2	9.8	14.2	16.0	-
August	11.1	12.1	7.1	13.7	13.4	-
September	7.9	6.0	7.0	7.5	10.5	-
October	4.2	5.5	2.7	7.8	8.5	-
November	5.3	5.5	3.4	8.8	8.2	-
December	6.7	6.6	7.3	9.9	9.7	-
Average	7.2	7.0	5.8	8.0	9.5	-

Source: Meteorological Statistics of A&N Islands 2007, AN DE & St.

Annexure 2.3: Vegetation-wise check list of plant species recorded in Andaman Islands during study period (2003-2008).

S.No	Scientific name	Vernacular name
<u>Principal Evergreen species</u>		
1	<i>Dipterocarpus grandiflorus</i>	Lambapathi Gurjan
2	<i>Dipterocarpus pilosus</i>	
3	<i>Dipterocarpus alatus</i>	
4	<i>Xanthophyllum andamanicum</i>	Letphew
5	<i>Pterocymbium tinctorium</i>	Jungli Papita *
6	<i>Albizia lebbek</i>	Koko *
7	<i>Artocarpus chaplasha</i>	Taung penne *
8	<i>Tetrameles nudiflora</i>	
9	<i>Lagerstroemia hypoleuca</i>	Pyinma *
10	<i>Dillenia pentagyna</i>	
11	<i>Pometia pinnata</i>	Chitkandu *
12	<i>Dinochloa scandens</i>	Bel Bamboo
13	<i>Dinochloa andamanica</i> (climbing bamboo)	
14	<i>Scindapsus officinalis</i>	Hathi Bel
15	<i>Ficus sagittata</i>	Pepal Bel
16	<i>Calamus andamanicus</i> (cane)	Mota Bet
17	<i>Calamus longisetus</i> (cane)	Jungli Bet
18	<i>calamus palustris</i> (cane)	Malai Bet
19	<i>Calamus viminalis</i> (cane)	Rassi Bet
20	<i>Daemonorops kurzianus</i>	Sanga Bet
21	<i>Aglaia andamanica</i>	Letauk *
22	<i>Alstonia kursii</i>	Chatium *
23	<i>Diospyros oocarpa</i>	Marblewood *
24	<i>Eugenia Jambulana</i>	Jamun *
25	<i>Ficus benjamina</i>	Gular or Bargad *
26	<i>Ficus retusa</i>	Bargad *
27	<i>Murraya exotica</i>	Satinwood *
28	<i>Pandanus andamanensis</i>	Kasam or Keora *
29	<i>Sageraea elliptica</i>	Chooi *
30	<i>Combretum</i> spp.	

<u>Principal Deciduous species</u>		
31	<i>Terminalia bialata</i>	White Chuglum *
32	<i>Terminalia mannii</i>	Black Chuglum *
33	<i>Terminalia catappa</i>	Badam *
34	<i>Terminalia procera</i>	White Bombwe
35	<i>Tetrameles nudiflora</i>	Thitpok *
36	<i>Bombax insigne</i>	Didu *
37	<i>Pterocarpus dalbergioides</i>	Padauk *
38	<i>Adenanthera pavonina</i>	Ywegui *
39	<i>Ailanthus kurzi</i>	Ailanthus *
40	<i>Albizia procera</i>	Siris *
41	<i>Anthocephalus cadamba</i>	Kadam *
42	<i>Artocarpus lakoocha</i>	Lacooch *
43	<i>Berrya ammonilla</i>	Trincomale wood *
44	<i>Chukrasia tabularis</i>	Agil or Chukrasia *
45	<i>Dipterocarpus incanus</i>	Garjan *
46	<i>Pajanelia longifolia</i>	Jhingum *
47	<i>Parishia insignis</i>	Lal Dhup
48	<i>Planchonia valida</i>	Red Bombwe *
49	<i>Vitex</i> spp.	
50	<i>Magnifera</i> spp.	Jungli Amm *
51	<i>Lannea coromandelica</i>	Nabbe
52	<i>Semecarpus prainii</i>	Jungli Kaju
53	<i>Semecarpus kurzii</i>	Bhelwa
54	<i>Entada phaseolides</i> (climbers)	
<u>Littoral species</u>		
55	<i>Manilkara littoralis</i>	Khari Mahua *
56	<i>Pongamia pinnata</i>	Karanj
57	<i>Pongamia glabra</i>	Karanj *
58	<i>Morinda citriflora</i>	
59	<i>Calophyllum inophyllum</i>	Poon *
60	<i>Barringtonia asiatica</i>	Dotta
61	<i>Thespesia populnea</i>	Khari kapas
62	<i>Pandanus tectorius</i>	
63	<i>Caesalpinia bonducella</i> (creeper)	Kath karanj *

64	<i>Crinum asiaticum</i>	
65	<i>Cycas rumphii</i>	
66	<i>Cynometra ramiflora</i>	
67	<i>Dedonaea viscosa</i>	
68	<i>Ganophyllum falcatum</i>	Jungli Neem *
69	<i>Hibiscus tiliaceus</i>	Safed Chilkaa *
70	<i>Ipomea pes-caprae</i> (creeper)	
	<u>Mangrove species</u>	
71	<i>Rhizophora mucronata</i>	
72	<i>Rhizophora apiculata</i>	
73	<i>Rhizophora candelaria</i>	
74	<i>Rhizophora conjugata</i>	
75	<i>Bruguiera gymnorrhiza</i>	
76	<i>Bruguiera parviflora</i>	
77	<i>Xylocarpus moluccensis</i>	
78	<i>Avicennia officinalis</i>	
79	<i>Ceriops tagal</i>	
80	<i>Kandelia candel</i>	
81	<i>Sonneratia caseolaris</i>	
82	<i>Excoecaria agallocha</i>	
83	<i>Heritiera littoralis</i>	Sundri *

* indicates some major commercial tree species in Andaman Islands.

Annexure 3.1: Phylogentic classification of birds (Aves) in the world (Cracraft 1981).

Orders	Division
Sphenisciformes, Gaviiformes (including grebes), Procellariiformes, and Pelecaniformes	1
Palaeognathiformes	2
Ciconiiformes and Falconiformes (including owls)	3
Anseriformes and Galliformes	4
Gruiformes, Charadriiformes and Columbiformes	5
Psittaciformes	6
Cuculiformes	7
Caprimulgiformes and Apodiformes	8
Piciformes, Coliiformes Coraciiformes and Passeriformes	9

Annexure 3.2: The checklist of birds observed during the study period (2003-2008) in Andaman Islands.

S. No	Synopsis No. (in Ali & Ripley 2001)	Species code	Vernacular name	Scientific name	Conservation Status	Migratory Status
Pelecaniformes						
Sulidae						
1	24	RFB0	Redfooted Booby	<i>Sula sula rubripes</i>	NU	W
Ciconiiformes						
Ardeidae						
2	39	LGH	Andaman Little Green Heron	<i>Butorides striatus spodiogaster</i>	NU	R
3	42	IPH	Indian Pond Heron or Paddybird	<i>Ardeola grayii grayii</i>	C	LM
4	43	CPH	Chinese Pond Heron	<i>Ardeola bacchus</i>	NU	LM
5	44	CE	Cattle Egret	<i>Bubulcus ibis coromandus</i>	C	LM
6	45	LE	Larger Egret or Great White Heron	<i>Ardea alba alba</i>	R	WS
7	49	LiE	Little Egret	<i>Egretta garzetta garzetta</i>	C	LM
8	51	ERH	Eastern Reef Heron	<i>Egretta sacra</i>	C	LM
9	56	CnBit	Chestnut Bittern	<i>Ixobrychus cinnamomeus</i>	UN	LM
10	58	BBit*	Black Bittern	<i>Ixobrychus flavicollis flavicollis</i>	NC	PM/LM
Anseriformes						
Anatidae						
11	88	LWT	Lesser Whistling Teal or Tree Duck	<i>Dendrocygna javanica</i>	C	LM

12	94	CT	Common Teal	<i>Anas crecca crecca</i>	C	W
13	96	AT	Andaman Teal	<i>Anas albogularis</i>	R	ED/R
14	97	SBDu	Spotbill Duck	<i>Anas poecilorhyncha poecilorhyncha</i>		
Falconiformes						
Accipitridae						
15	128a	ABCB	Andaman Blackcrested Baza	<i>Aviceda leuphotes andamanica</i>	R	R
16	133	PK	Pariah Kite	<i>Milvus migrans govinda</i>	C	R
17	162	ACHE	Andaman crested Hawk-Eagle	<i>Spizaetus cirrhatus andamanensis</i>	RED	R
18	173	WBSE	Whitebellied Sea Eagle	<i>Haliaeetus leucogaster</i>	NU	R
19	200	APSE	Andaman Pale Serpant Eagle	<i>Spilornis cheela davisoni</i>	NC	R
20	202a	ADSE	Andaman Dark Serpent Eagle	<i>Spilornis elgini</i>	NU/ED	ED/R
Galliformes						
Phasianidae						
21	246	SIGP	South Indian Grey Partridge	<i>Francolinus pondicerianus pondicerianus</i>	UN	R
Megapodiidae						
22	311	IPF	Indian Peafowl	<i>Pavo cristatus</i>	IN	R
Gruiformes						
Rallidae						
23	333	ABC	Andaman Banded Crane	<i>Rallina canningi</i>	C	ED
24	337	BC	(Eastern) Baillon's Crane	<i>Porzana pusilla pusilla</i>	C	PM
25	345	AWBWH	Andaman Whitebreasted Waterhen	<i>Amaurornis phoenicurus insularis</i>	C	R
26	346	WaC	Kora or Watercock	<i>Gallirex cinerea cinerea</i>	UN	LM
27	347	IMH	Indian Moorhen	<i>Gallinula chloropus indica</i>	NU	PM

28	349	IPM	Indian Purple Moorhen	<i>Porphyrrio porphyrio poliocephalus</i>	UN	LM
Charadriiformes						
Charadriidae (sub family-Charadriinae)						
29	371	GP	Blackbellied or Grey Plover	<i>Pluvialis squatarola</i>	UN	W
30	374	LSP	Large Sand Plover	<i>Charadrius leschenaultii</i>	NC	W
31	377	ESP	Eastern Sand Plover	<i>Charadrius asiaticus veredus</i>	UN	V
32	381	KP	Kentish Plover	<i>Charadrius alexandrinus alexandrinus</i>	NC	PM
33	384	LesSP	Pamirs Lesser Sand Plover	<i>Charadrius mongolus atrifrons</i>	VC	PM
sub family-Scolopacinae						
34	385	W	Whimbrel	<i>Numenius phaeopus phaeopus</i>	UN	W
35	387	Cur	Curlew	<i>Numenius arquata arquata</i>	UN	W
36	391	BtGw	Bartailed Godwit	<i>Limosa lapponica lapponica</i>	UN	W
37	393/394	CRS	Common Redshank	<i>Tringa totanus totanus</i>	C	PM
38	396	GS	Greenshank	<i>Tringa nebularia</i>	UN	W
39	398	WSP	Wood or Spotted Sandpiper	<i>Tringa glareola</i>	UN	W
40	400	TerSP	Terek Sandpiper or Avocet-Sandpiper	<i>Xenus cinereus</i>	UN	W
41	401	CSP	Common Sandpiper	<i>Actitis hypoleucos</i>	UN	PM
42	402	TSt	Turnstone	<i>Arenaria interpres interpres</i>	UN	W
43	407	SwSn	Swinhoe's Snipe	<i>Gallinago megala</i>	NC	W
44	409	CS	Common or Fantail Snipe	<i>Gallinago gallinago gallinago</i>	VC	PM
45	413	EKnot	Eastern Knot	<i>Calidris tenuirostris</i>	UN	W
46	416	LS	Little Stint	<i>Calidris minuta</i>	UN	W
47	418	LtS	Longtoed Stint	<i>Calidris subminuta</i>	VC	W

48	422	CuSP	Curlw-Sandpiper	<i>Calidris ferruginea</i>	C	W
49	425	BBSP	Eastern broadbilled Sandpiper	<i>Limicola falcinellus sibirica</i>	V	W
50	437	GSP	Burhinidae Great stone Plover	<i>Esacus maguirostris maguirostris</i>	R	LM
51	459	WWBT	Laridae Whitewinged Black Tern	<i>Chlidonias leucopterus</i>	R	W
52	461	JGBT	Javan Gullbilled Tern	<i>Gelocheidon nilotica affinis</i>	UN	R
53	468	EBNT	Eastern Blacknaped Tern	<i>Sterna sumatrana sumatrana</i>	C	LM
54	474	ST	Sooty Tern	<i>Sterna fuscata nubilosa</i>	C	R
55	475	LitT	Little Tern or Ternlet	<i>Sterna albifrons albifrons</i>	UN	LM
56	478	LaCT	Red Sea Large Crested Tern	<i>Sterna bergii velox</i>	R	R
57	479	ILCT	Indian Lesser Crested Tern	<i>Sterna bengalensis bengalensis</i>	C	R
58	500	APP	Columbiformes Columbidae Andaman Pompadour Pigeon	<i>Treron pompadora chloroptera</i>	C	ED
59	508a	AGIP	Andaman Green Imperial Pigeon*	<i>Ducula aenea andamanica</i>	C	ED
60	509	PIP	Pied Imperial Pigeon	<i>Ducula bicolor</i>	C	R
61	516	BRP	Blue Rock Pigeon	<i>Columba livia neglecta</i>	C	LM
62	525	AWP	Andaman Wood Pigeon	<i>Columba palumboides</i>	NC	ED
63	527a	ACD	Andaman Cukoo-Dove	<i>Macropygia rufipennis andamanica</i>	NC	ED
64	536	BRTD	Burmese Red Turtle-Dove	<i>Streptopelia tranquebarica humilis</i>	NC	LM
65	544	AED	Andaman Emerald Dove	<i>Chalcophaps indica maxima</i>	C	ED
66	544b	NP	Nicobar Pigeon	<i>Caloenas nicobarica nicobarica</i>	NC	R

Psittaciformes						
Psittacidae						
67	548	LAP	Large Andaman Parakeet	<i>Psittacula eupatria magnirostris</i>	C	ED
68	552	ARBP	Andaman Redbreasted Parakeet	<i>Psittacula alexandri abbotti</i>	C	ED
69	555	ARCP	Andaman Redcheeked Parakeet	<i>Psittacula longicauda tyleri</i>	VC	ED
70	566/ 567	IL	Indian Lorikeet	<i>Loriculus vernalis</i>	NC	LM
Cuculiformes						
Cuculidae						
71	576	ICu	Indian Cuckoo	<i>Cuculus micropterus micropterus</i>	NC	LM
72	578	Cuc	Cuckoo	<i>Cuculus canorus canorus</i>	NC	PM
73	580	HC	Himalayan Cuckoo	<i>Cuculus saturatus saturatus</i>	NC	PAM
74	581	SCu	Small Cuckoo	<i>Cuculus poliocephalus poliocephalus</i>	NC	LM
75	587	VCu	Violet Cuckoo	<i>Chalcites xanthorhynchus xanthorhynchus</i>	NC	LM
76	588	IDC	Indian Drango-Cuckoo	<i>Surniculus lugubris dicruroides</i>	NC	R
77	592	AK	Andaman Koel	<i>Eudynamys scolopacea dolosa</i>	NU	R
78	603	ACP	Andaman Crow-Pheasant	<i>Centropus (sinensis) andamanensis</i>	C	ED
Strigiformes						
Strigidae (sub family-Striginae)						
79	618a	ASO	Andaman Scops Owl	<i>Otus balli</i>	R	ED
80	646	AHO	Andaman (Brown) Hawk-Owl	<i>Ninox affinis affinis</i>	R	ED
Caprimulgiformes						
Podargidae						
81	671	MNJ	Migratory Nightjar	<i>Caprimulgus indicus indicus</i>	NU	LM

82	675	ALTNJ	Longtailed Nightjar	<i>Caprimulgus macrurus albonotatus</i>	NU	PM
			Apodiformes			
			Apodidae (sub family-Apodinae)			
			Andaman Greyrumped (or Edible-nest) Swiftlet			
83	686	AGRS		<i>Collocalia fuciphaga inexpectata</i>	C	R
84	687	WBS	Whitebellied Swiftlet	<i>Collocalia esculenta affinis</i>	C	R
85	691	BTSS	Brownthroated Spinetail Swift	<i>Chaetura gigantea indica</i>	NU	LM
			Coraciiformes			
			Alcedinidae			
86	723	ISBKF	Indian Small Blue Kingfisher	<i>Alcedo atthis bengalensis</i>	C	R
87	726a	ABEKF	Andaman Blue-eared Kingfisher	<i>Alcedo meninting rufigaster</i>	VR	R
88	731	ASBKF	Andaman Storkbilled Kingfisher	<i>Pelargopsis capensis osmastoni</i>	C	R
89	734	ARKF	Andaman Ruddy Kingfisher	<i>Halcyon coramanda mizorhina</i>	UN	R
90	738	AWBKF	Andaman Whitebreasted Kingfisher	<i>Halcyon smyrnensis saturator</i>	VC	R
91	739	BCKF	Blackcapped Kingfisher	<i>Halcyon pileata</i>	NC	LM
92	742	AWCKF	Andaman Whitecollared Kingfisher	<i>Halcyon chloris davisoni</i>	C	R
			Meropidae			
93	745	ACHBE	Andaman chestnutheaded Bee-eater	<i>Merops leschenaulti andamanensis</i>	C	R
94	748	BTBE	Bluetailed Bee-eater	<i>Merops philippinus philippinus</i>	NU	LM
			Coraciidae			
95	762	ABBR	Andaman Broadbilled Roller	<i>Eurystomus orientalis gigas</i>	NU	R
			Piciformes			
			Picidae (sub family-Picinae)			

96	831	ABWP	Andaman Black Woodpecker	<i>Dryocopus hodgei</i>	C	ED
97	846	ASBPWP	Andaman Spottedbreasted Pied W.P.	<i>Picoides macei andamanensis</i>	C	R
Passeriformes						
Hirundinidae						
98	917	Sw	Swallow	<i>Hirundo rustica gutturalis</i>	NU	LM
99	920	JHS	Javan House (Pacific) Swallow	<i>Hirundo tahitica javanica</i>	NU	R
Laniidae						
100	949	BS	Brown Shrike	<i>Lanius cristatus cristatus</i>	NC	W
101	950	PS	Philippine Shrike	<i>Lanius cristatus lucionensis</i>	NC	W
Oriolidae						
102	952	GO	Golden Oriole	<i>Oriolus oriolus oriolus</i>		V
103	956	ABNO	Andaman Blacknaped Oriole	<i>Oriolus chinensis andamanensis</i>	C	ED
104	958/959	BHO	Blackheaded Oriole	<i>Oriolus xanthornus andamanensis</i>	NC	ED?
Dicruridae						
105	970	CBD	Crowbilled Drongo	<i>Dicrurus annectans</i>	NC	R?
106	975	SAD	Small Andaman Drongo	<i>Dicrurus andamanensis andamanensis</i>	C	ED
107	980	ARTD	Andaman Racket-tailed Drongo	<i>Dicrurus paradiseus olivaceus</i>	C	ED
Artamidae						
108	983	WBSS	Whitebreasted Swallow-Shrike	<i>Artamus leucorhynchus humei</i>	NU	ED
Sturnidae						
109	986	AGS	Andaman Glossy Stare	<i>Aplonis panayensis tyleri</i>	C	LM
110	990	AWHM	Andaman Whiteheaded Myna	<i>Sturnus erythropygus andamanensis</i>	VC	R/ED
111	995	DM	Daurian Myna	<i>Sturnus sturninus</i>	O	W

112	1006	IM	Common Myna	<i>Acridotheres tristis tristis</i>	VC	R
113	1018	AHM	Andaman Hill Myna	<i>Gracula religiosa andamanensis</i>	C	R/ED
Corvidae						
114	1040	ATP	Andaman Tree Pie	<i>Dendrocitta bayleyi</i>	NU	ED
115	1055	EJC	Eastern Jungle Crow	<i>Corvus macrorhynchus levaillantii</i>	R	LM
Campephagidae						
116	1075	ALCS	Andaman Large Cuckoo-Shrike	<i>Coracina novaehollandiae andamana</i>	C	R
117	1076	BCS	Barred Cuckoo-Shrike	<i>Coracina striata dobsoni</i>	R	R
118	1079a	NPCuS	Pied Cuckoo-Shrike	<i>Coracinanigra davisoni</i>	R	R
119	1080a	ASM	Andaman Scarlet Minivet	<i>Pericrocotus flammeus andamanensis</i>	C	R
120	1095/1092	ESM	Eastern Small Minivet	<i>Pericrocotus cinnamomeus vivideus</i>	NC	R
Irenidae						
121	1109/1110	FBB	Fairy Bluebird	<i>Irena puella puella</i>	NU	LM
Pycnonotidae						
122	1113	ABHB	Andaman Blackheaded Bulbul	<i>Pycnonotus atriceps fuscoflavescens</i>	C	R
123	1122	ARWB	Andaman Red-whiskered Bulbul	<i>Pycnonotus jocosus whistleri</i>	C	R
Muscicapidae (subfamily-Muscicapinae)						
124	1402	OFC	Olive Flycatcher	<i>Rhinomyias brunneata nicobarica</i>	NU?	W
125	1407	BFC	Brown Flycatcher	<i>Muscicapa latirostris</i>	C	R
126	1442	TBFC*	Tickell's Redbreasted Blue Flycatcher	<i>Muscicapa tickelliae tickelliae</i>	NC	LM
127	1448	GHFC*	Greyheaded Flycatcher	<i>Culicicapa ceylonensis calochrysea</i>	NC	SM/R
128	1467	ABNM	Andaman Blacknaped Monarch	<i>Monarcha azurea tyleri</i>	C	R
Subfamily-Pachycephalinae						

129	1470	MW	Mangrove Whistler	<i>Pachycephala grisola</i>	C	R
Subfamily-Sylviinae						
130	1475	APFBW	Andaman Palefooted Bush Warbler	<i>Cettia pallidipes osmastonii</i>	C	R
131	1552	AsGReWar	Assam Great Reed Warbler	<i>Acrocephalus stentoreus anyae</i>	NC	PLM
132	1556	Bl.RWar	Blyth's Reed Warbler	<i>Acrocephalus dumetorum</i>	VC	W
133	1584	DLW	Dusky Leaf Warbler	<i>Phylloscopus fuscatus weigoldi</i>	NC	W
134	1586	SiDuW	Siberian Dusky Leaf Warbler	<i>Phylloscopus fuscatus fuscatus</i>	C	W
135	1600	AW	Arctic Leaf Warbler	<i>Phylloscopus borealis borealis</i>	C	R
136	1601	LBLW	Largebilled Leaf Warbler	<i>Phylloscopus magnirostris</i>	C	SM
137	1604	EGLW	Eastern Greenish Leaf Warbler	<i>Phylloscopus trochiloides trochiloides</i>	VC	SM
Subfamily-Turdinae						
138	1664	AMR	Andaman Magpie-Robin	<i>Copsychus saularis andamanensis</i>	C	R
139	1668	AS	Andaman Shama	<i>Copsychus malabaricus albiventris</i>	C	R
140	1682	BFR*	Bluefronted Robin	<i>Cinclidium frontale frontale</i>	NC	R?
141	1732	WBG	Whitebrowed Ground Thrush	<i>Zoothera sibirica sibirica</i>	NC	W
142	1735	AGT	Andaman Ground Thrush	<i>Zoothera citrina andamanensis</i>	C	R
Motacillidae						
143	1863	BPipit	Blyth's Pipit	<i>Anthus godlewskii</i>	NC	W
144	1874	FW	Forest Wagtail	<i>Motacilla indica</i>	C	W
145	1875	YW	Yellow Wagtail	<i>Motacilla flava thunbergi</i>	C	W
146	1884	GW	Grey Wagtail	<i>Motacilla cinerea cinerea</i>	C	WSM
Dicaeidae						
147	1903	AFP	Andaman Flowerpecker	<i>Dicaeum concolor virescens</i>	C	R

Nectariniidae					
148	1913	AOBS	Andaman Olivebacked Sunbird	<i>Nectarinia jugularis andamanica</i>	VC R
149	1931	LSH	Little Spiderhunter	<i>Arachnothera longirostris longirostris</i>	NC R
Zosteropidae					
150	1936	NWE	Nicobar White-Eye	<i>Zosterops palpebrosa nicobarica</i>	C R
Ploceidae (subfamily-Passerinae)					
151	1938	IHS	Indian House Sparrow	<i>Passer domesticus indicus</i>	VC LM
152	1941	TrSp	Tree Sparrow	<i>Passer montanus dilutus</i>	NC R
Subfamily-Estrildinae					
153	1969	AWBM	Andaman Whitebacked Munia	<i>Lonchura striata fumigata</i>	C R

Note: Bold letters in species code are endemics. *-Indicates new bird records in Andaman Islands (RajaMamannan and Vijayan 2009).

Code	Abbreviations	Code	Abbreviations
C	Common	SM	Summer Migrant
ED	Endemic	SM/R	Summer Migrant or Resident
LM	Local Migrant	UN	Unknown
NC	Not Common	V	Vagrant
NU	Not uncommon	VC	Very Common
O	Occasional	VR	Very Rare
PAM	Passage Migrant	W	Winter Visitor
PLM	Partially Local Migrant	WS	Winter Straggler
PM/LM	Partial Migrant or Resident subject to local movements	WSM	Winter Summer Migrant
R	Resident	WV	Winter Vagrant
RED	Rare and Endemic	IN	Introduced species

Annexure 4.1: Truncated log normal distribution matrix of observed (O) and expected (Ex) species abundance of the species in different habitats.

Upper Bound	Evergreen		Semi-evergreen		Moist deciduous		Littoral		Mangrove		Forest edges		Plantation		Field		Degraded		Wetland		Coastal	
	O	Ex	O	Ex	O	Ex	O	Ex	O	Ex	O	Ex	O	Ex	O	Ex	O	Ex	O	Ex	O	Ex
2.5	13	12.79	16	15.73	20	19.33	20	19.08	18	16.54	20	16.93	12	11.64	26	20.22	21	18.52	21	20.71	13	14.92
4.5	6	8.07	10	9.2	11	11.31	13	11.7	10	11.32	11	10.06	6	8.34	7	9.89	6	9.06	11	8.84	9	5.51
8.5	11	10.35	15	11.28	16	13.52	12	14.88	10	14.2	8	11.41	11	10.39	7	10.27	10	9.43	5	8.56	5	5.33
16.5	16	11.56	5	12.04	14	13.8	12	16.63	15	14.66	12	10.5	8	10.36	9	8.81	6	8.11	7	6.87	6	4.54
32.5	5	11.24	12	11.2	7	12	17	16.32	15	12.39	3	7.81	13	8.19	5	6.25	8	5.77	4	4.59	0	3.45
64.5	7	9.54	7	9.09	6	8.92	14	14.1	9	8.57	6	4.7	6	5.13	-	-	-	-	-	-	-	-
128.5	13	7.07	10	6.46	10	5.68	16	10.74	7	4.85	5	3.58	-	-	8	6.56	6	6.11	-	-	-	-
256.5	7	4.58	6	4.03	-	-	10	7.24	2	3.47	-	-	-	-	-	-	-	-	6	4.44	-	-
512.5	-	-	-	-	6	5.43	3	4.31	-	-	-	-	2	3.95	-	-	-	-	-	-	6	5.26
1024.5	2	4.79	2	3.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2048.5	-	-	-	-	-	-	2	4.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Annexure 4.2: Chi-squared test to demonstrate the measure of patchiness in species populations of the bird community in Andaman Islands.

Common name		Mean	Chi-sq (χ^2); d.f. 10	p-value
<u>Aggregated</u>				
1.	Red-footed Booby	0.2727	30.00	0.000917
2.	Indian Pond Heron or Paddy bird	2.3636	47.62	1.10E-06
3.	Cattle Egret	1.7273	38.32	4.11E-05
4.	Larger Egret or Great White Heron	7.0909	107.03	0
5.	Little Egret	6.2727	215.57	0
6.	Eastern Reef Heron	20.9091	546.41	0
7.	Lesser Whistling Teal or Tree Duck	6.9091	638.42	0
8.	Common Teal	2.7273	85.13	0
9.	Andaman Teal	67.3636	2868.71	0
10.	Spotbill Duck	0.9091	100.00	0
11.	Andaman Crested Hawk-Eagle	4.0909	139.56	0
12.	White-bellied Sea Eagle	9.7273	222.69	0
13.	Andaman Dark Serpent Eagle	9.0909	59.94	0
14.	Indain Peafowl	0.3636	40.00	2.16E-05
15.	Andaman Banded Crake	3.4545	100.37	0
16.	Andaman White-breasted Waterhen	3.2727	81.33	0
17.	Kora or Watercock	1.1818	74.15	0
18.	Indian Moorhen	1.1818	26.77	0.002933
19.	Black-bellied or Grey Plover	2.7273	80.00	0
20.	Large Sand Plover	5.1818	548.39	0
21.	Eastern Sand Plover	0.2727	30.00	0.000917
22.	Kentish Plover	25.2727	716.99	0
23.	Pamirs Lesser Sand Plover	0.8182	41.11	1.41E-05
24.	Whimbrel	14.3636	952.86	0
25.	Curlew	14.6364	548.53	0

26. Bartailed Godwit	0.2727	30.00	0.000917
27. Common Redshank	13.9091	528.78	0
28. Greenshank	4.1818	417.91	0
29. Wood or Spotted Sandpiper	0.7273	60.75	0
30. Terek Sandpiper or Avocet Sandpiper	0.8182	41.11	1.41E-05
31. Common Sandpiper	11.2727	323.81	0
32. Common or Fantail Snipe	0.5455	27.00	0.002702
33. Little Stint	1.7273	150.63	0
34. Longtoed Stint	0.7273	25.00	0.005459
35. Curlew Sandpiper	0.9091	23.00	0.010845
36. Eastern broad-billed Sandpiper	2.5455	82.79	0
37. Great Stone Plover	2.4545	124.15	0
38. Javan Gull-billed Tern	8.1818	404.02	0
39. Eastern Blacknaped Tern	54.4545	2287.76	0
40. Little Tern or Ternlet	0.8182	41.11	1.41E-05
41. Red Sea Large Crested Tern	1.3636	150.00	0
42. Indian Lesser Crested Tern	1.8182	113.10	0
43. Andaman Pompadour Pigeon	31.1818	459.81	0
44. Andaman Green Imperial Pigeon	277.8182	5067.00	0
45. Pied Imperial Pigeon	14.5455	940.00	0
46. Blue Rock Pigeon	1.0909	33.83	0.000223
47. Andaman Wood Pigeon	10.5455	193.71	0
48. Andaman Cukoo Dove	2.1818	89.67	0
49. Burmese Red Turtle Dove	38.2727	248.38	0
50. Andaman Emerald Dove	7.4545	116.27	0
51. Large Andaman Parakeet	7.8182	117.37	0
52. Andaman Red-breasted Parakeet	87.6364	809.37	0
53. Andaman Red-cheeked Parakeet	75.8182	786.96	0
54. Indian Lorikeet	65.0909	753.18	0
55. Indian Cuckoo	1.3636	57.60	0
56. Himalayan Cuckoo	8.2727	169.01	0
57. Small Cuckoo	0.3636	40.00	2.16E-05

58. Indian Drango Cuckoo	7.7273	432.00	0
59. Andaman Koel	5	92.00	0
60. Andaman Crow Pheasant	42.5455	433.58	0
61. Andaman Scops Owl	2.1818	67.67	0
62. Andaman (Brown) Hawk-Owl	0.4545	32.40	0.00038
63. Longtailed Nightjar	0.8182	55.78	0
64. Andaman Grey-rumped Swiftlet	3	78.00	0
65. White-bellied Swiftlet	154.1818	1246.42	0
66. (Large) Brown-throated Spinetail Swift	14.9091	279.76	0
67. Andaman Blue-eared Kingfisher	0.4545	32.40	0.00038
68. Andaman Stork-billed Kingfisher	6.0909	69.10	0
69. Andaman ruddy Kingfisher	0.7273	30.50	0.000764
70. Andaman white-breasted Kingfisher	11.0909	110.80	0
71. Black-capped Kingfisher	6.6364	263.78	0
72. Andaman White-collared Kingfisher	5.6364	98.39	0
73. Andaman chestnut-headed Bee eater	10.6364	122.09	0
74. Bluetailed Bee eater	4.4545	97.59	0
75. Andaman Broadbilled Roller	1.1818	33.54	0.000249
76. Andaman Black Woodpecker	29.6364	480.44	0
77. Andaman Spotted-breasted Pied W.P.	6.3636	124.23	0
78. Swallow	6.7273	121.62	0
79. Javan House(Pacific) Swallow	11.4545	371.62	0
80. Brown Shrike	12.2727	97.14	0
81. Golden Oriole	2.1818	31.00	0.000636
82. Andaman Black-naped Oriole	48.6364	746.82	0
83. Crow-billed Drongo	4.1818	85.04	0
84. Small Andaman Drongo	24.7273	455.70	0
85. Andaman Racket-tailed Drongo	55.3636	770.80	0
86. White-breasted Swallow-Shrike	10.7273	212.75	0
87. Andaman Glossy Stare	64.9091	448.24	0
88. White-headed Myna	34.9091	179.35	0
89. Daurian Myna	0.8182	90.00	0

90. Common Myna	36	424.22	0
91. Andaman Hill Myna	33.7273	289.27	0
92. Andaman Tree Pie	9.0909	215.70	0
93. Eastern Jungle Crow	25.9091	330.96	0
94. Andaman Large Cuckoo Shrike	5.5455	49.90	5.00E-07
95. Barred Cuckoo Shrike	0.4545	23.60	0.008844
96. Andaman Scarlet Minivet	38.2727	643.81	0
97. Eastern Small Minivet	81.5455	886.70	0
98. Fairy Bluebird	27.3636	645.99	0
99. Andaman Black-headed Bulbul	6.1818	53.00	1.00E-07
100. Andaman Red-Whiskered Bulbul	243.7273	1965.85	0
101. Olive Flycatcher	0.5455	30.67	0.000719
102. Brown Flycatcher	2.5455	106.36	0
103. Andaman Black-naped Monarch	44.7273	838.87	0
104. Mangrove Whistler	9.5455	287.12	0
105. Andaman Pale-footed Bush Warbler	1.0909	33.83	0.000223
106. Largebilled Leaf Warbler	0.3636	40.00	2.16E-05
107. Eastern Greenish Leaf Warbler	3.6364	46.90	1.50E-06
108. Andaman Magpie-Robin	27.5455	224.82	0
109. Andaman Shama	63.0909	903.47	0
110. White-browed Ground Thrush	0.7273	33.25	0.000277
111. Andaman Ground Thrush	5.2727	157.83	0
112. Blyth's Pipit	0.8182	31.33	0.000563
113. Forest Wagtail	6.8182	100.85	0
114. Grey Wagtail	16.6364	134.80	0
115. Andaman Flowerpecker	55.8182	772.75	0
116. Andaman Olive-backed Sunbird	56.4545	525.71	0
117. Nicobar White-Eye	34.8182	1676.58	0
118. Indian House Sparrow	2.9091	227.19	0
119. Tree Sparrow	3.6364	400.00	0
120. Andaman White-backed Munia	16.7273	634.18	0

<u>Random</u>			
121. Andaman Little Green Heron	0.2727	15.33	0.119736
122. Chinese Pond Heron	0.2727	15.33	0.119736
123. Chestnut Bittern	0.4545	14.80	0.138836
124. Black Bittern	0.4545	19.20	0.037665
125. Andaman Black-crested Baza	0.3636	18.00	0.054689
126. Pariah Kite	0.0909	10.00	0.440749
127. Andaman Pale Serpant Eagle	0.0909	10.00	0.440749
128. South Indian Grey Partridge	0.1818	20.00	0.029201
129. (Eastern) Baillon's Crake	0.0909	10.00	0.440749
130. Indian Purple Moorhen	0.0909	10.00	0.440749
131. Turnstone	0.5455	16.00	0.099077
132. Swinhoe's Snipe	0.0909	10.00	0.440749
133. Eastern Knot	0.1818	20.00	0.029201
134. White-winged Black Tern	0.0909	10.00	0.440749
135. Sooty Tern	0.0909	10.00	0.440749
136. Nicobar Pigeon	0.3636	7.00	0.72671
137. Cuckoo	0.1818	20.00	0.029201
138. Violet Cuckoo	0.0909	10.00	0.440749
139. Migratory Nightjar	0.3636	18.00	0.054689
140. Indian Small Blue Kingfisher	0.0909	10.00	0.440749
141. Philipine Shrike	1.2727	11.14	0.346251
142. Black Headed Oriole	0.0909	10.00	0.440749
143. Pied Cuckoo-Shrike	0.1818	9.00	0.532849
144. Tickell's Red-breasted Blue Flycatcher	0.0909	10.00	0.440749
145. Greyheaded Flycatcher	0.0909	10.00	0.440749
146. Assam Great Reed Warbler	0.2727	15.33	0.119736
147. Blyth's Reed Warbler	0.1818	9.00	0.532849
148. Dusky Leaf Warbler	0.0909	10.00	0.440749
149. Siberian Dusky Leaf Warbler	0.0909	10.00	0.440749
150. Arctic Leaf Warbler	0.1818	9.00	0.532849
151. Blue-fronted Robin	0.0909	10.00	0.440749
152. Yellow Wagtail	0.1818	20.00	0.029201
153. Little Spiderhunter	0.0909	10.00	0.440749

Annexure 5.1: The resident/migratory birds largely confined to the outer Islands in Andaman arranged from left to right in the column order presented in **Figure 5.9a** (nested species are denoted by ‘n’ and idiosyncratic species with an ‘i’). Species of conservation concern- near threatened species (BirdLife International 2009) are marked with * in the table and see migratory details in *Annexure 3.2*.

Column Position	Species	Migratory Status	Degree of Nestedness
1	Andaman Magpie-Robin <i>Copsychus saularis andamanensis</i>	R	n
2	Andaman Racket-tailed Drongo <i>Dicrurus paradiseus otiosus</i>	ED	-
3	Andaman Flowerpecker <i>Dicaeum concolor virescens</i>	R	-
4	Indian Drongo-Cuckoo <i>Surniculus lugubris dicruroides</i>	R	n
5	Andaman crested Hawk-Eagle <i>Spizaetus cirrhatus andamanensis</i>	R	-
6	Andaman Blacknaped Monarch <i>Monarcha azurea tyleri</i>	R	-
7	Longtailed Nightjar <i>Caprimulgus macrurus albonotatus</i>	PM	-
8	Whitebellied Swiftlet <i>Collocalia esculenta affinis</i>	R	-
9	Andaman Redcheeked Parakeet <i>Psittacula longicauda tyleri</i> *	ED	-
10	Arctic Leaf Warbler <i>Phylloscopus borealis borealis</i>	R	-
11	Eastern Reef Heron <i>Egretta sacra</i>	LM	n
12	Andaman Redbreasted Parakeet <i>Psittacula alexandri abbotti</i>	ED	i
13	Eastern Greenish Leaf Warbler <i>Phylloscopus trochiloides trochiloides</i>	SM	-
14	Eastern broadbilled Sandpiper <i>Limicola falcinellus sibirica</i>	W	-
15	Andaman Olivebacked Sunbird <i>Nectarinia jugularis andamanica</i>	R	-
16	Andaman Crow-Pheasant <i>Centropus (sinensis) andamanensis</i>	R	n
17	Eastern Jungle Crow <i>Corvus macrorhynchus levaillantii</i>	LM	i
18	Common Sandpiper <i>Actitis hypoleucos</i>	PM	-
19	Andaman Blacknaped Oriole <i>Oriolus chinensis andamanensis</i>	ED	-
20	Javan House(Pacific) Swallow <i>Hirundo tahitica javanica</i>	R	-
21	Whitebrowed Ground Thrush <i>Zoothera sibirica sibirica</i>	W	-
22	Andaman Red-Whiskered Bulbul <i>Pycnonotus jocosus whistleri</i>	R	-
23	Andaman Pompadour Pigeon <i>Treron pompadora chloroptera</i>	ED	-
24	Andaman Emerald Dove <i>Chalcophaps indica maxima</i>	ED	-
25	Common Redshank <i>Tringa totanus totanus</i>	PM	i
26	Andaman Ground Thrush <i>Zootheacitrina andamanensis</i>	R	-
27	Nicobar Pigeon <i>Caloenas nicobarica nicobarica</i> *	ED	-

28	Andaman Whitecollared Kingfisher <i>Halcyon chloris davisoni</i>	R	-
29	Redfooted Booby <i>Sula sula rubripes</i>	W	-
30	Migratory Nightjar <i>Caprimulgus indicus indicus</i>	LM	i
31	Andaman Koel <i>Eudynamys scolopacea dolosa</i>	R	-
32	Eastern Sand Plover <i>Charadrius asiaticus veredus</i>	V	-
33	Andaman Glossy Stare <i>Aplonis panayensis tyleri</i>	LM	-
34	Curlew-Sandpiper <i>Calidris ferruginea</i>	W	i
35	Andaman Spottedbreasted Pied WoodPecker <i>Picoides macei andamanensis</i>	R	n
36	Greenshank <i>Tringa nebularia</i>	W	-
37	Andaman Storkbilled Kingfisher <i>Pelargopsis capensis osmastoni</i>	R	-
38	Red Sea Large Crested Tern <i>Sterna bergii velox</i>	R	-
39	Crowbilled Drongo <i>Dicrurus annectans</i>	R	-
40	Blackcapped Kingfisher <i>Halcyon pileata</i>	LM	n
41	Andaman Shama <i>Copsychus malabaricus albiventris</i>	R	-
42	Whiteheaded Myna <i>Sturnus erythropygius andamanensis</i>	R	-
43	Whitebellied Sea Eagle <i>Haliaeetus leucogaster</i>	R	-
44	Andaman Greyrumped Swiftlet <i>Collocalia fuciphaga inexpectata</i>	R	-
45	Fairy Bluebird <i>Irena puella puella</i>	LM	-
46	Indian Lorikeet <i>Loriculus vernalis</i>	LM	-
47	Turnstone <i>Arenaria interpres interpres</i>	W	-
48	Bartailed Godwit <i>Limosa lapponica lapponica</i>	W	-
49	Indain Peafowl <i>Pavo cristatus</i>	R	-
50	Andaman Dark Serpent Eagle <i>Spilornis elgini</i> *	R	-
51	Black Bittern <i>Ixobrychus flavicollis flavicollis</i>	PM	-
52	Andaman Black Woodpecker <i>Dryocopus hodgei</i> *	R	n
53	Andaman whitebreasted Kingfisher <i>Halcyon smyrnensis saturator</i>	R	n
54	Andaman Whitebreasted Waterhen <i>Amaurornis phoenicurus insularis</i>	R	n
55	Nicobar White-Eye <i>Zosterops palpebrosa nicobarica</i>	R	-
56	Andaman Hill Myna <i>Gracula religiosa andamanensis</i>	R	n
57	Forest Wagtail <i>Motacilla indica</i>	W	n
58	Andaman Little Green Heron <i>Butorides striatus spodiogaster</i>	R	n
59	(Large) Brownthroated Spinetail Swift <i>Chaetura gigantea indica</i>	LM	n
60	Andaman Chestnut-headed Bee eater <i>Merops leschenaulti andamanensis</i>	R	n

61	Terek Sandpiper or Avocet-Sandpiper <i>Xenus cinereus</i>	W	-
62	Andaman Large Cuckoo-Shrike <i>Coracina novaehollandiae andamana</i>	R	-
63	Indian Lesser Crested Tern <i>Sterna bengalensis bengalensis</i>	R	-
64	Burmese Red Turtle-Dove <i>Streptopelia tranquebarica humilils</i>	LM	n
65	Large Sand Plover <i>Charadrius leschenaultii</i>	W	n
66	Whimbrel <i>Numenius phaeopus phaeopus</i>	W	-
67	Great stone Plover <i>Esacus magnirostris magnirostris</i> *	LM	n
68	Andaman Green Imperial Pigeon <i>Ducula aenea andamanica</i>	C	n
69	Andaman Wood Pigeon <i>Columba palumboides</i> *	ED	n
70	Grey Wagtail <i>Motacilla cinerea cinerea</i>	WSM	n
71	Brown Flycatcher <i>Muscicapa latirostris</i>	R	n
72	Curlew <i>Numenius arquata arquata</i>	WV	-
73	Javan Gullbilled Tern <i>Gelochelidon nilotica affinis</i>	R	-
74	Blackbellied or Grey Plover <i>Pluvialis squatarola</i>	W	-
75	Pariah Kite <i>Milvus migrans govinda</i>	R	-
76	Andaman Banded Crake <i>Rallina canningi</i> *	R	-
77	Indian Moorhen <i>Gallinula chloropus indica</i>	PM	-
78	Swallow <i>Hirundo rustica gutturalis</i>	LM	-
79	Himalayan Cuckoo <i>Cuculus saturatus saturatus</i>	PAM	n
80	Eastern Blacknaped Tern <i>Sterna sumatrana sumatrana</i>	LM	n
81	Mangrove Whistler <i>Pachycephala grisola</i>	R	n
82	Small Andaman Drongo <i>Dicrurus andamanensis andamanensis</i> *	ED	n
83	Olive Flycatcher <i>Rhinomyias brunneata nicobarica</i>	W	n
84	Small Cuckoo <i>Cuculus poliocephalus poliocephalus</i>	LM	n
85	Eastern Small Minivet <i>Pericrocotus cinnamomeus vivideus</i>	R	n
86	Andaman Blackheaded Bulbul <i>Pycnonotus atriceps fuscoflavescens</i>	R	-
87	Large Andaman Parakeet <i>Psittaculaeupatria magnirostris</i>	ED	n
88	Andaman Blue-eared Kingfisher <i>Alcedo meninting rufigaster</i>	R	n
89	Andaman Teal <i>Anas albogularis</i>	ED	-
90	Golden Oriole <i>Oriolus oriolus oriolus</i>	V	-
91	Andaman Tree Pie <i>Dendrocitta bayleyi</i> *	ED	-
92	Kentish Plover <i>Charadrius alexandrinus alexandrinus</i>	PM	-
93	Andaman Scarlet Minivet <i>Pericrocotus flammeus andamanensis</i>	R	-
94	Whitebreasted Swallow-Shrike <i>Artamus leucorhynchus humei</i>	ED	-
95	Brown Shrike <i>Lanius cristatus cristatus</i>	W	-

Annexure 5.2: Most distinctively/poorly species nested islands, according to the resident and migratory birds largely confined to the outer islands in Andaman listed from top to bottom in row order presented in **Figure 5.9b** (nested islands are denoted by 'n' and idiosyncratic islands with an 'i') along with dependent and independent variables.

Row position (in nested matrix)	Island Name	Independent variable						
		Regions	Species richness (Dependent var.)	Degree of Nestedness	Area in Sq. km (size class)	Elevation (m)	Latitude	Water Resources
1	Tarmugli #	S	40	-	9.45-(III)	\$		\$
2	Cinque *	S	38	-	9.53-(III)	163	11-14'	1P-7S
3	Point *	N	35	-	3.07- (II)	23	13-24'	0
4	Reef *	N	32	-	1.74- (II)	27	13-30'	0
5	Smith Island, NA @	N	33	-	6.95-(III)	\$		\$
6	Redskin #	S	33	n	3.47- (II)	\$		\$
7	Landfall *	N	28	-	29.48-(IV)	41	13-40'	1P-9S
8	Table (Excelsior) *	N	31	n	1.69- (II)	30	13-25'	0
9	Alexandra #	S	28	-	4.09-(III)	\$		\$
10	Bluff *	S	27	n	1.14- (I)	UN	12-14'	0
11	Rose *	N	25	-	1.01- (I)	47	13-17'	0
12	North Reef *	N	24	-	3.48- (II)	UN		0
13	Inglis Island @	S	22	-	1.54- (II)	\$		\$
14	Thorn Hill @	N	26	n	0.33- (I)	\$		\$
15	Table (Dalgarno) *	N	25	n	2.29- (II)	2	13-24'	0
16	Porlob island @	M	24	-	10.11-(III)	\$		\$
17	Stewart @	N	22	n	19.83-(IV)	\$		\$
18	Jhan Lawherence @	S	20	-	34.15-(IV)	\$		\$
19	Spike *	M	19	-	11.70-(IV)	88	12-13'	28S
20	Anderson island @	M	20	n	11.96-(IV)	\$		\$
21	Paget *	N	19	-	7.36-(III)	34	13-25'	2S

22	West *	N	20	n	6.4-(III)	18	13-34'	0
23	Chatam Island @	N	19	-	1.96- (II)	\$		\$
24	Ross @	S	17	-	0.31- (I)	\$		\$
25	Ox *	N	20	n	0.13- (I)	22	13-19'	0
26	Trilby *	N	21	n	0.96- (I)	32	13-24'	0
27	Bennette *	M	17	n	3.46- (II)	58	12-49'	0
28	Henry Lawrence @	S	13	-	53.4- (IV)	\$		\$
29	Wharf *	N	15	-	0.11- (I)	23	13-20'	0
30	Sound Island @	N	17	-	12.09-(IV)	\$		\$
31	Dottrill *	N	12	-	0.13- (I)	UN	12-55'	0
32	Bamboo *	N	13	-	0.05- (I)	9	13-02'	0
33	Curlew (B.P.) *	N	13	-	0.16- (I)	52	12-56'	0
34	Talabaicha *	S	15	-	3.21- (II)	46	12-14'	0
35	North *	N	15	-	0.49- (I)	67	13-20'	0
36	Outram @		11	-	13.15-(IV)	\$		\$
37	Cone @	N	15	-	0.77- (I)	\$		\$
38	White Cliff *	N	13	-	0.47- (I)	20	13-32'	0
39	Dot *	N	11	-	0.18- (I)	30	13-01'	0
40	Swamp *	N	7	-	4.09-(III)	92	12-54'	0
41	Brown Hill @	N	13	-	0.45- (I)	\$		\$
42	Bellie *	S	12	-	0.08- (I)	30	12-06'	0
43	Brush *	N	7	i	0.23- (I)	UN	13-17'	0
44	Boat #	S	10	i	1.80- (II)	\$		\$
45	East *	N	10	i	6.11-(III)	56	13-37'	1S
46	South Reef *	N	7	i	1.17- (I)	UN		0
47	Helicopter @	N	5	i	0.06- (I)	\$		\$
48	Avis @	N	8	i	0.10- (I)	\$		\$
49	Oyster 1 *	N	3	i	0.08- (I)	2	12-59'	0
50	Oyster 2 *	M	6	i	0.21- (I)	33	12-24'	0
51	Mayo *	N	8	i	0.10- (I)	X	13-26'	0
52	Oliver *	N	8	i	0.16- (I)	25	12-59'	0

Note: # -inside National Park boundary, *-Sanctuary, @- unprotected, UN-unknown, P-perennial, S-seasonal. Regions: N-North, M-Middle, S-South Andaman. \$- not known.

Annexure 6.1: The estimated bird species (actively used study area) density (density =bird/km²) for different region in Andaman Islands.

S. No	Synopsis No. (Ali's)	Species code	Region (Total no. of points covered)					Ranking		
			North (455)	Middle (122)	South (873)	Little (200)	Overall (1650)	Against 2 to 4	Among four	Overall
1	39	LGH	-	-	0.2	-	0.11			121
2	42	IPH	0.19	-	0.61	5.75	1.07	63	55	80
3	43	CPH	-	-	-	0.44	0.05			130
4	44	CE	0.19	2.17	0.91	0.88	0.8	57	81	84
5	45	LE	0.97	-	3.34	3.09	2.41	70	73	62
6	49	LiE	1.36	8.69	0.51	9.28	2.41	39	46	60
7	51	ERH	14.76	-	5.97	10.61	8.52	61	32	30
8	56	CnBit	0.39	-	-	0.88	0.21	93	92	108
9	58	BBit*	0.19	2.9	-	-	0.27	83	76	104
10	88	LWT	-	-	-	29.17	3.54			50
11	94	CT	-	-	2.83	0.88	1.61	84	77	73
12	96	AT	7.38	12.32	66.11	1.33	38.09	4	5	3
13	97	SBDu	-	-	-	4.42	0.54			93
14	128a	ABCB	-	-	0.2	-	0.11			122
15	162	ACHE	-	0.72	0.3	-	0.21	98	98	111
16	173	WBSE	1.94	2.9	1.01	3.09	1.66	54	74	72
17	202a	ADSE	5.63	5.07	2.94	3.09	3.86	46	56	48
18	246	SIGP	-	-	0.2	-	0.11			123
19	311	IPF	-	-	0.4	-	0.21			114
20	333	ABC	3.11	5.07	1.32	0.88	2.04	48	59	67
21	337	BC	-	-	-	0.44	0.05			131
22	345	AWBWH	1.17	1.45	1.11	6.63	1.82	43	52	70
23	346	WaC	-	-	-	3.98	0.48			96
24	347	IMH	0.97	2.17	0.51	-	0.7	71	82	88
25	349	IPM	-	-	0.1	-	0.05			132

26	371	GP	1.94	-	1.62	1.77	1.61	72	84	74
27	374	LSP	3.5	-	3.85	-	3	82	66	54
28	381	KP	26.61	6.52	6.78	28.73	14.89	18	19	26
29	384	LesSP	-	-	0.3	-	0.16			119
30	385	W	5.63	4.35	7.39	11.49	7.18	32	37	34
31	387	Cur	8.16	27.53	5.37	2.21	7.39	22	23	33
32	391	BtGw	0.19	-	-	0.88	0.16	94	93	115
33	393, 394	CRS	8.55	9.42	9.31	1.33	8.14	38	45	32
34	396	GS	8.55	-	0.2	-	2.46	78	48	59
35	398	WSP	0.19	-	0.71	-	0.43	100	100	99
36	400	TerSP	-	-	0.1	2.65	0.37	85	78	101
37	401	CSP	5.05	5.8	5.97	8.84	6.05	40	47	37
38	402	TSt	0.97	-	-	-	0.27			106
39	407	SwSn	-	-	-	0.44	0.05			133
40	409	CS	-	-	0.2	0.44	0.16	102	102	117
41	413	EKnot	0.39	-	-	-	0.11			124
42	416	LS	-	0.72	1.82	-	1.02	88	85	81
43	418	LtS	0.78	-	-	0.44	0.27	97	97	105
44	422	CuSP	0.97	-	0.51	-	0.54	92	90	91
45	425	BBSP	2.91	0.72	0.51	0.88	1.23	55	75	79
46	437	GSP	3.69	-	0.71	0.44	1.45	67	67	76
47	461	JGBT	10.88	-	1.92	-	4.02	77	40	46
48	468	EBNT	62.74	118.8	1.62	-	26.94	59	4	9
49	474	ST	-	0.72	-	-	0.05			134
50	475	LitT	-	-	0.71	-	0.37			102
51	478	LaCT	2.91	-	-	-	0.8			85
52	479	ILCT	3.69	-	-	-	1.02			82
53	500	APP	34.58	38.4	4.35	7.07	15.53	12	13	23
54	508a	AGIP	71.1	87.66	137.8	92.36	110.2	2	2	2
55	516	BRP	-	-	0.81	-	0.43			100

56	525	AWP	4.47	1.45	4.86	3.54	4.34	50	61	45
57	527a	ACD	0.19	0.72	1.62	-	0.96	73	87	83
58	536	BRTD	23.12	28.98	13.16	14.14	17.2	17	18	20
59	544	AED	1.75	5.8	2.63	0.88	2.41	45	54	61
60	544b	NP	0.39	-	-	0.88	0.21	95	94	109
61	548	LAP	7.38	10.14	1.72	5.3	4.34	37	44	43
62	552	ARBP	7.58	21.01	18.63	121.1	28.18	3	3	7
63	555	ARCP	21.76	26.08	20.86	15.03	20.78	23	25	16
64	566, 567	IL	33.22	33.33	23.59	22.1	26.78	14	15	11
65	576	ICu	-	-	1.52	-	0.8			86
66	578	Cuc	-	-	0.2	-	0.11			125
67	580	HC	5.83	5.07	2.73	11.49	4.82	33	38	42
68	581	SCu	0.19	-	-	0.44	0.11	103	103	120
69	587	VCu	-	-	0.1	-	0.05			135
70	588	IDC	-	-	7.29	3.98	4.34	79	50	44
71	592	AK	4.08	-	2.94	1.77	2.89	66	65	55
72	603	ACP	27.39	22.46	17.11	28.28	21.69	19	20	15
73	618a	ASO	2.33	-	1.21	-	1.29	86	80	77
74	646	AHO	0.58	-	0.1	-	0.21	101	101	112
75	671	MNJ	0.39	-	0.2	-	0.21	105	105	113
76	675	ALTNJ	0.39	3.62	0.2	-	0.48	68	69	94
77	723	ISBKF	-	0.72	-	-	0.05			136
78	726a	ABEKF	-	0.72	-	-	0.05			137
79	731	ASBKF	1.17	0.72	4.45	-	2.73	64	62	57
80	734	ARKF	0.39	-	-	0.44	0.16	104	104	118
81	738	AWBKF	8.35	10.87	4.86	-	5.68	62	41	38
82	739	BCKF	5.24	4.35	2.83	1.77	3.48	47	58	51
83	742	AWCKF	0.58	1.45	4.25	-	2.52	65	64	58
84	745	ACHBE	4.08	12.32	5.47	2.65	5.25	30	35	39
85	748	BTBE	-	-	4.15	-	2.2			64

86	762	ABBR	0.78	0.72	0.51	-	0.54	74	96	92
87	831	ABWP	16.51	13.77	14.17	28.28	16.5	20	21	21
88	846	ASBPWP	5.24	6.52	2.53	3.09	3.64	44	53	49
89	917	Sw	-	0.72	-	4.42	0.59	81	63	90
90	920	JHS	-	-	5.06	5.3	3.32	80	57	53
91	949	BS	0.78	4.35	8.2	10.16	6.11	36	43	36
92	950	PS	0.58	0.72	0.91	0.44	0.75	58	91	87
93	952	GO	0.39	2.17	1.01	3.54	1.23	52	71	78
94	956	ABNO	52.25	23.18	16.6	16.79	26.94	7	8	10
95	958, 959	BHO	0.19	-	-	-	0.05			138
96	970	CBD	0.19	3.62	3.04	-	1.93	69	70	68
97	975	SAD	8.74	4.35	13.67	22.54	12.7	24	26	28
98	980	ARTD	28.17	28.25	22.68	21.65	24.48	21	22	14
99	983	WBSS	1.55	1.45	0.1	10.61	1.87	35	42	69
100	986	AGS	24.67	46.37	24.8	19.44	25.71	8	9	12
101	990	AWHM	17.68	15.94	16.4	29.61	18.32	16	17	18
102	995	DM	-	-	0.51	1.77	0.48	89	86	95
103	1006	IM	5.44	-	27.03	-	15.8	75	24	22
104	1018	AHM	12.63	5.07	12.76	33.14	14.62	15	16	27
105	1040	ATP	2.14	3.62	6.28	7.07	5.04	42	51	41
106	1055	EJC	13.02	7.97	5.16	12.37	8.41	29	34	31
107	1075	ALCS	1.17	3.62	2.53	2.21	2.2	51	68	63
108	1076	BCS	-	-	0.51	-	0.27			107
109	1079a	NPCuS	-	-	-	0.88	0.11			126
110	1080a	ASM	17.68	13.77	21.06	8.4	18.05	25	27	19
111	1095, 1092	ESM	39.63	26.08	30.68	23.42	31.93	11	12	5
112	1109, 1110	FBB	12.24	21.01	17.92	7.95	15.37	26	28	25
113	1113	ABHB	1.36	6.52	2.23	11.05	3.37	34	39	52

114	1122	ARWB	173.9	131.1	110.2	146.7	133.7	1	1	1
115	1402	OFC	0.58	2.17	-	-	0.32	87	83	103
116	1407	BFC	3.3	5.07	0.2	0.88	1.5	49	60	75
117	1442	TBFC*	-	-	0.1	-	0.05			139
118	1448	GHFC*	-	-	0.1	-	0.05			140
119	1467	ABNM	38.27	24.63	18.53	29.17	25.71	13	14	13
120	1470	MW	6.99	11.59	4.25	0.88	5.14	31	36	40
121	1475	APFBW	-	-	1.11	0.44	0.64	91	89	89
122	1552	AsGReWar	0.39	0.72	-	-	0.16	99	99	116
123	1556	BL.RWar	-	-	0.2	-	0.11			127
124	1584	DLW	-	-	0.1	-	0.05			141
125	1586	SiDuW	-	-	-	0.44	0.05			142
126	1600	AW	0.39	-	-	-	0.11			128
127	1601	LBLW	-	-	0.2	0.88	0.21	96	95	110
128	1604	EGLW	1.55	0.72	2.63	1.77	2.09	56	79	66
129	1664	AMR	17.29	7.24	18.12	5.3	15.53	27	29	24
130	1668	AS	14.96	16.66	53.05	23.42	36.27	6	7	4
131	1682	BFR*	-	-	0.1	-	0.05			143
132	1732	WBGT	1.36	-	0.1	-	0.43	90	88	98
133	1735	AGT	3.11	2.9	2.43	3.54	2.79	53	72	56
134	1863	BPipit	-	-	0.91	-	0.48			97
135	1874	FW	7.77	2.17	2.02	4.42	3.91	41	49	47
136	1875	YW	0.39	-	-	-	0.11			129
137	1884	GW	5.83	16.66	3.54	15.91	6.64	28	30	35
138	1903	AFP	6.6	5.8	41.51	25.63	27.32	10	11	8
139	1913	AOBS	43.9	53.61	20.45	37.56	31.44	5	6	6
140	1931	LSH	-	-	0.1	-	0.05			144
141	1936	NWE	43.71	24.63	10.43	2.21	19.66	9	10	17
142	1938	IHS	-	-	0.2	13.26	1.71	76	33	71
143	1941	TrSp	-	-	-	17.68	2.14			65
144	1969	AWBM	7.58	-	9.62	15.47	9.05	60	31	29

further data from the field. However, the absence of breeding records and the scarcity of non-breeding records of this species from relatively well-visited intervening areas such as western Sichuan, south-east Xizang and north-west Yunnan argue against a broad extension of the breeding range from the north-east, but instead suggest that breeding in Arunachal Pradesh is in geographical isolation from the main breeding range. Similarly, the absence of previous breeding records of this species from the Himalayan wintering grounds, which include areas such as Nepal that have historically received much ornithological attention, strongly indicates that breeding on the wintering grounds has arisen only recently, potentially in response to climate change or anthropogenically induced habitat change.

Instances of long-distance migrants commencing breeding activity in their wintering grounds have been known for decades, most famously exemplified by the White Stork *Ciconia ciconia* breeding in South Africa (Roberts 1941). However, anthropogenically induced climate change has been documented to affect the phenology, physiology and distributions of hundreds of animal and plant species since the 1990s (e.g. Visser *et al.* 1998, Dunn and Winkler 1999, Hughes 2000, Stevenson and Bryant 2000). The Long-billed Plover's nesting habitat is restricted to the vicinity of rivers and lakes—often in the neighbourhood of villages—and nesting birds are conspicuous and easy to find. Therefore, it is exceedingly unlikely that the species has been overlooked as a breeding bird in vast areas of its range for centuries. Instead, breeding in Arunachal Pradesh and potentially in neighbouring areas is probably a recent phenomenon. If so, this geographical extension of breeding activity would fall into a time-frame that is characterised by a global influx in patterns of distributional change in birds and other animals in response to the rising levels of greenhouse gases in our atmosphere (Hughes 2000). It will therefore be important to see if the coming years produce more breeding records of this species from areas that have hitherto been assumed to be outside of its breeding range.

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Three new bird records from the Andaman Islands, India

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The Andaman Islands in the Bay of Bengal cover 6,408 km², spread over >325 islands and rocks (21 inhabited). During a study of the avifaunal diversity of these islands between 2003 and 2004, we surveyed five major and 52 outer islands, relying on Ali and Ripley (1983), Grimmett *et al.* (1998) and Kazmierczak and van Perlo (2000) for identification and information on distribution and status. In the study, we recorded 153 species, including three species new to the archipelago (Vijayan *et al.* 2005). These latter three species, evidently vagrants, are described here.

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TICKLE'S BLUE FLYCATCHER *Muscicapa (Cyornis) tickelliae*

An individual was seen on a *Ficus* species in moist deciduous/semi-evergreen forest near Sonapahar Reservoir, South Andaman (c.11°42'–11°43'N 92°36'–92°38'E) on 19 March 2004 at 08h30. We observed it for c.12 minutes at a distance of 20 m while it foraged in the area. The blue body, orange-rufous throat and breast, prominent white belly, and the sharp tick tick vocalisation accompanied by tail-flicking were diagnostic.

GREY-HEADED FLYCATCHER *Culicicapa ceylonensis*

An individual was observed perched on bushes in forest on 12 March 2004 at 07h30 near Navasahar Reservoir, Silviculture Division, Sippighat, South Andaman (c.11°34'N 92°40'E). We watched it for c.25 minutes in poor weather and light conditions. Despite poor visibility, the prominent ashy grey on the head, throat and breast, and yellowish belly and rump, were diagnostic of this species.

BLUE-FRONTED ROBIN *Cincludium frontale*

A male was sighted at close range in moist deciduous forest at Chidiyatapu, South Andaman (c.11°30'N 92°42'E) on 3 and 4 December 2003. The long graduated tail (lacking white), deep blue upperparts, deep slaty blue on the belly and whitish tail-coverts were diagnostic.

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Spectacled Finch *Callacanthus burtoni*: another new country record for Bhutan

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At 07h30 on the morning of 19 April 2008 at an elevation of c. 3,000 m I was driving a tour party from the Paro Valley in western Bhutan slowly uphill through an extensive stand of mature silver fir, hemlock and rhododendron forest on the road to Chelila at c.4,000 m. We were looking for pheasants along the roadside when my attention was drawn to a finch-like bird foraging on the edge of the birumen. Initially I was distracted by the presence of several Himalayan Monal *Lophophorus impejanus* nearby but after they dispersed I focused my attention on this distinctive and somewhat familiar passerine. At first I could not place it, but knew I had seen it illustrated. Checking Rasmussen and Anderton (2005) while the bird was still a few metres in front of me, I realised that we were looking at a female Spectacled (or Red-browed) Finch *Callacanthus burtoni*. I and several members of the tour then took a series of images, unfortunately all through the front window of the bus and thus less than ideal (one photograph supplied to the editors).

The bird was a stocky, drab-coloured medium-sized passerine with three immediately noticeable features: a quite striking area of yellow-orange skin surrounding the eye; a heavy yellowish bill; and a pronounced, rather patchy white band across what seemed to be the greater coverts. Other features were the dark crown and cheek, which highlighted the colour of the facial skin; the slightly

grey-brown nuchal collar; dark wings highlighted by white tips to the primaries; finely streaked dusky-brown underparts; and pink legs. The bird continued hopping on the roadside, picking at the ground and seemingly feeding on seeds. We watched it for some 20 minutes.

Spierenburg (2005) in his recent review of the Bhutan avifauna does not mention Spectacled Finch, and this would appear to be the first published record of this species for Bhutan and the most easterly record of this species. Spectacled Finch is endemic to the Indian subcontinent (Rasmussen and Anderton 2005) and ranges from north-west Pakistan, Chitral and Safed Koh (possibly also into extreme eastern Afghanistan) and south-east along the Himalayas marginally to Sikkim where it is known from one record (but see below). In parts of its range it is erratic in occurrence and east of Kumaon, Uttar Pradesh, it is very local (Clement *et al.* 1993, Rasmussen and Anderton 2005), although there appear to be increasing numbers of observations from this region (Manoj Sharma pers. comm.; orientalbirdimages.org). In Pakistan Spectacled Finch is local and generally a scarce resident, and undergoes small altitudinal movements, summering from 2,740 m up to the tree-line. In north-west India it is locally frequent in Kashmir and breeds from 2,400 m up to the tree-line and winters from 3,000 m down as low as 800 m (Grimmett *et al.* 1998). In Nepal this species is chiefly a

Table 1. Number of Andaman Teals counted during the surveys in the Andaman Islands (*not surveyed)-

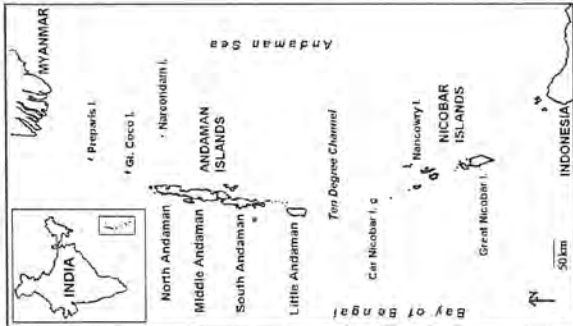
Place	1995-98		2003-04	
	Min	Max	Min	Max
North Andaman				
1 Paschim Sagar	4	4		0
2 Sheema Island	1	1		*
3 Interview Island	0	46		14
4 North Reef Island	3	33		26
5 Mohanpur	6	28		4
6 Hanspur	12	24		*
Middle Andaman				
7 Kadamtala	0	15		12
8 Betapur	0	55		1
South Andaman				
9 John Lawrence Island	0	107		*
10 Constance Bay (Jarawa Reserve)	7	7		410
11 Dhaninla (Rutland)	30	230		110
12 Redskin	0	7		0
13 Dhanikari Reservoir	0	1		76
14 Sippighat	0	4		0
15 Katakatchang	0	6		0
16 Sonapahar Reservoir (Jarawa Reserve)	*	*		18
Little Andaman				
17 At km 6	0	6		0
18 At km 2	0	2		0
19 Jackson creek	6	6		*
20 Vishnunala Dam	0	0		3
Total	69	582		674

numbers was very high because of local movements and the counts were not simultaneous, hence it was difficult to get a realistic population estimate. Taking the maximum number counted at each location during the two studies, the totals seen were 582 and 674 during 1995-98 and 2003-04, respectively. The population of the Andaman Teal was previously estimated at between 500 and 600 (Vijayan 1996; Vijayan *et al.* 2000)

RESULTS AND DISCUSSION
Population and distribution
Some 20 sites held Teals in 1995-98 or 2003-04 (Table 1). Constance Bay (Jarawa Reserve), Dhaninla (Rutland) and Dhanikari Reservoir held the majority of birds in 2003-04. Four sites, namely Dhanihala, John Lawrence Island, Betapur, Interview Island and North Reef Island, held fewer Teal in 2003-04 than during previous surveys. Fluctuation in

13°41'N and 92°12' to 93°57'E) (Figure 1). Surveys were conducted in four main areas, namely North (1,348 km²), Middle (1,070 km²), South and Little Andaman (3,990 km² combined).

Figure 1. Study area: Andaman and Nicobar Islands, India



The approximate area of forests and wetlands surveyed in each of the four areas was 87 km², 42 km², 130 km² and 39 km², respectively. Although more localities were surveyed during 2003-04 for general bird counts, five sites with Teal records could not be covered. Most Teal localities were covered in summer (as these birds concentrate at this time of year at specific locations) with the exception of Dhaninla (Rutland) which was surveyed in winter.

CONSERVATION OF ANDAMAN TEAL

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INTRODUCTION

The Andaman Teal *Anas gibberifrons albigularis*, once abundant, has always been restricted to the Andaman Islands, a group of oceanic islands in the Bay of Bengal in India (Figure 1). This endemic species (Fullagar 2005) has traditionally been considered a sub-species of the Australasian Grey Teal *Anas gracilis*, and it has long been considered globally endangered at the sub-species level (Anon. 2001). This species is the only threatened endemic duck in India, with the exception of the Pink-headed Duck, which is believed to be extinct. The Andaman Teal inhabits freshwater streams, ponds, swamps and brackish water swamps, tidal creeks and estuaries (Ali & Ripley 1987; Green 1992). This species has three closely related taxa also distributed in the islands and Australasia (Howard & Moore 1991) of which one (*A. g. remissa*) is considered extinct (Green 1992). The Andaman Teal is considered a priority species requiring immediate attention and conservation action (Rao 1989; Vijayan 1996; Vijayan *et al.* 2000; Vijayan *in press*). Hence, a study was conducted during 1995-98 to determine the status of the Andaman Teal and understand its biology with emphasis on the ecological requirements. Another rapid survey was undertaken recently (2003-04) to assess the status.

STUDY AREA

The study was conducted in the Andaman and Nicobar Islands (6°45' to

population has been the major conservation problem (Vijayan *et al.* 2000). Site-specific recommendations for the conservation of the rare endemic avifauna of the Andaman Islands, especially the Andaman Teal (Vijayan *et al.* 2000; Vijayan in press), include:

1. Declaring Dhaniala and the surrounding areas in Rutland Island as an Andaman Teal Sanctuary.
2. Providing increased protection to a few sites, namely John Lawrence and Henry Lawrence Islands in Jhansi Rani Marine National Park, South Andaman, and Jackson Creek, Little Andaman.
3. Declaring Mohanpur and Hanspuri (North Andamans), and Kakatchang and Spighat-Simbilang (South Andaman) as 'Andaman Teal Conservation areas'.
4. Wetlands, both freshwater and brackish water, have not been given proper attention, and hence need extensive surveys and studies for their conservation and management.

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on the monsoon. The nest is a platform of grass or reed mat 20-35 cm above water among the reeds, 20-50 cm from open water. Nesting pools were 20-50 cm deep, mainly brackish and located in coastal areas, 50-100 m from the high tide line. All these wetlands had natural or man-made bunds for collecting rainwater which reduced salinity. This species selected a nesting site based on optimum water levels and availability of food for the young, as found in many other studies (Sridharan 1989; Vijayan 1991; Swingen & Anderson 1998). Nesting success was high during the study (85%) as there were very few predators. However, poaching of eggs by humans and predation by Water Monitor Lizards were the major causes of egg loss. Predation by raptors may also occur. Parents with ducklings spent most of their time in thick vegetation, coming into open water with sparse vegetation only for very short periods.

Conservation perspectives and recommendations

The rarity of a species with a small distribution and a declining population, as is the case for many island endemics, is the most important issue in the conservation of the Andaman Teal. This bird is hence considered as endangered (Anon. 2001). Historically there was a drastic decline in the population of this species, mainly because of habitat loss due to reclamation of wetlands, over-hunting and poaching of eggs (Abdullah 1964; Kear & Williams 1978). An accurate population estimate for this species is still lacking. Long-term monitoring and information on the extent of wetlands are very desirable for the management of the species and the sustainable utilisation of wetland resources. Although the species is legally protected under the Wildlife (Protection) Act 1972, very few of the Teal habitats are within protected areas. Lack of awareness of the status of this species and the value of wetlands to the local

and it seems that this estimate remains valid after the recent survey. However, a detailed and long-term study is required involving population counts along with banding and telemetry techniques to gain a better picture of the status of this species.

Ecology

Habitat

Andaman Teal used a variety of habitats at different times. Feeding locations in summer were shallow areas with sparse vegetation, whereas during the breeding season (autumn) they foraged among reeds, *Phragmites karka* and *Scirpus* sp., with thicker cover nearer to the nest. Teal were found loafing in open water or resting on wooden logs, mounds, small trees, or bushes in water or on the banks and mud banks (Vijayan *et al.* 2000). Teal were in single species flocks or mixed flocks with the Lesser Whistling-duck *Dendrocygna javanica*. Detailed analysis comparing feeding and non-feeding sites showed that insects and small molluscs in the soil were crucial factors in determining feeding locations for Teal (Vijayan in press).

Food

Molluscs and arthropods formed the major part of the Andaman Teal's diet. Seasonal differences in food were observed: a higher proportion of animal food (88%) was found in the diet in summer than during the monsoon (60%), similar to observations of Grey Teal in North Queensland (Lavery 1971; Lavery 1972). Andaman Teal was previously recorded as mostly vegetarian, feeding also on invertebrates (Ali & Ripley 1987).

Breeding

Altogether 13 nests were found in two locations during 1997 and 1998, six at Mohanpur and seven at Hanspuri, birds were apparently breeding at 10 further sites but nests could not be located. Nesting was found from July to October with a variation in the peak, depending

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was estimated as 2,400–4,500 individuals in the 1990s, and at least 10,000 in the early 2000s (Hughes & Hunter 1994; BirdLife International 2001; Shokhrin & Solovieva 2003). The majority of the breeding population occurs in the Primorye (BirdLife International 2001). The breeding population of the Sikhote-Alin mountain range declined significantly during the 1960s to the early 1980s when numbers started to stabilize and even slightly increased in early 1990s (Kolomyitsev 1992; Bocharnikov & Shiblyev 1994). The Scały-sided Merganser is included in the Red Data Books of IUCN, Russia (category 3 – rare), China and South Korea. This cavity-nesting duck inhabits clean fast mountain rivers fringed with old broadleaved forest.

This paper presents up-to-date results of annual breeding surveys along the rivers of the Primorye. The sex and age structure of the breeding population is also described.

STUDY AREA AND METHODS

Spring surveys for breeding Scały-sided Mergansers were conducted in 2003–05 with summer surveys for broods conducted in 2002–05. Large-scale surveys took place in spring 2003 (Table 1, Figure 1). In some years we surveyed various other rivers in the Southern Primorye in order to study annual fluctuations in breeding numbers (Tables 1 & 2). Rivers under investigation ranged between 40 and 450 km in length and were situated on both slopes of the Sikhote-Alin Range. We distinguish between large and small rivers, those shorter than 60 km being considered as small. All large rivers of the east slope are independent and flow into the Sea of Japan while all large rivers of the western slope are tributaries of the Ussuri River; no small rivers were surveyed on the west slope. Short rivers were completely surveyed while large rivers were only surveyed in part.

SCAŁY-SIDED MERGANSER SURVEYS IN PRIMORYE, RUSSIA, 2003–05

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ABSTRACT

Surveys for pairs and broods of Scały-sided Mergansers *Mergus squamatus* took place in the Primorye in 2003–05. In 2003, 19 rivers were surveyed: low densities (less than 0.1 pairs/km) occurred along four rivers, medium densities (0.1–0.3) along 11 rivers, and high densities (>0.3) along four rivers. River size, mountain slope, human population, visual estimate of broadleaved forest and water transparency did not explain breeding density. Low densities on upper and lower reaches, and high densities on middle reaches, characterize the Scały-sided Merganser's distribution. The spring population consisted of 32% adult males, 41% adult females, 7% subadult males, 6% subadult females, 3% non-breeding subadult males, and 11% non-breeding subadult females. Brood density was correlated with breeding pair density in the Kievka basin ($R^2=0.908$) during 2000–05.

INTRODUCTION

The Scały-sided Merganser is among the rarest seabirds in the Old World. The world population is poorly known and

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