KFRI Research Report No.343

Ecology and behaviour of forest owls in the Western Ghats and developing a habitat model for their conservation

(FINAL REPORT OF THE RESEARCH PROJECT KFRI/465/05)

E. A. Jayson

M. Sivaram

Division of Forest Ecology and Biodiversity Conservation

Division of Forest Information Management System

Kerala Forest Research Institute
Peechi- 680 653, Kerala, India

October 2009

ABSTRACT OF THE PROJECT PROPOSAL

1. Project No. : KFRI/465/05

2. Title of Project : Ecology and behaviour of forest owls in the Western Ghats and developing a habitat model for their conservation

3. Objectives :

a) Inventory of forest owls in the southern Western Ghats to find out the factors that influence the owl distribution and abundance.

b) To characterise the micro habitat parameters of forest owls

c) To predict areas of forest that has high value for owls, by modelling the habitat parameters.

4. Date of commencement : February 2005

5. Scheduled date of completion : January 2008

6. Funding agency : Ministry of Environment and Forests. Govt. of India.

7. Project Team

Principal Investigator : Dr. E. A. Jayson

Associate Investigator : Dr. M. Sivaram

Research Fellows : S. Babu (Wildlife)
Prajitha Nair (Statistics)
Eldo Varghese (Statistics)
Smitha Mohan (GIS)

8. Study area : Kerala and Tamil Nadu

9. Duration of study : 3 Years

10. Project budget : Rs.12 Lakhs

CONTENTS

ABSTRACT

Distribution, status and habitat use of forest owls in the southern Western Ghats of India was studied from February 2005 to January 2008. The objectives were to make an inventory of forest owls in the study area, to find out the factors that influence the owl distribution and abundance and to characterise the microhabitat use of owls. Intensive surveys were carried out in 276 census points, using dusk watch, initial quiet listening, call playback and spotlighting. One hundred and thirty seven points were surveyed from Kerala and 139 points from Tamil Nadu State. Thirteen species of owls were recorded from the southern Western Ghats of Kerala and Tamil Nadu. Out of the sixteen species of owls distributed in Kerala part of the Western Ghats, eleven species are found in the forests and others in the cultivation and in open country. Two species are migratory and 14 species are resident. Thirteen species of owls were recorded from the Kerala State and a new report of the short eared owl (*Asio otus*), a migrant species, was obtained from the Peechi-Vazhani Wildlife Sanctuary. The Ceylon bay owl, an endemic species, was newly reported from the Idukki and Neyyar Wildlife Sanctuaries. Southern distributional limit of seven species of owls was reported for the first time from the Western Ghats. New reports of several owl species in various protected areas are also obtained in this study.

Distribution pattern of owls was characterised using vegetation types, topographic variables, disturbance level and protection status of the areas. Highest encounter rate of owls was recorded from the Nelliampathy-Parambikulam-Vazhachal-Anamalai hill complex. Species of owls were grouped into two, namely large owls and lesser owls based on the size. Lesser owls namely jungle owlet, Indian scops owl, oriental scops owl and brown hawk owl were recorded from all the protected areas than the large owls (forest eagle owl, brown fish owl, mottled wood owl, brown wood owl and Indian eagle owl). Jungle owlet was the predominant lesser owl and the Indian eagle owl was the dominant in the large owl category. Highest species richness was recorded from the Indira Gandhi Wildlife Sanctuary. The encounter rate of lesser owls was higher in the protected areas; whereas that of larger owls was significantly higher in the reserve forests.

Habitat use of owls was studied by estimating habitat parameters at the field level and landscape level. Twelve variables were measured at field level and twenty two parameters at landscape level. Point centered quarter method was employed to sample the

vegetation structure and tree diversity. The values of landscape parameters were estimated from the digital maps using GIS tools. Habitat use of jungle owlet, brown hawk owl, Indian scops owl, oriental scops owl, brown fish owl, Indian eagle owl, and forest eagle owl was given in detail. Response of owls to inter and intra specific calls were also described. In the last chapter, the predictive performance of the two presence/absence modelling approaches namely binary logistic regression model and decision tree model was assessed. The model developed after assessing the distribution of owl species in the various vegetation types and topography can be utilized for locating their habitats in the dense forest terrains of the Western Ghats and to narrow down the search to probable locations. The habitats of seven species of owls namely jungle owlet, brown hawk, Indian scops, oriental scops, Ceylon bay, Indian eagle and brown fish owl have been mapped.

Jungle owlet preferred highly disturbed, mid altitude and moist deciduous forests. At field scale, it occupied areas with significantly higher tree girth, tree height, canopy height and canopy cover where as at landscape level, large extent of moist deciduous forests, plantations and availability of water influenced its presence. Logistic and classification tree models showed that the species was highly associated with the moist deciduous forests in the mid altitude of high rainfall areas. With respect to MAXENT model, *i.e.* presence only model, highly probable locations were predicted in the low altitudes of western slopes and it showed that, around 23 % of the southern Western Ghats is suitable for the species. The encounter rate of brown hawk owl was significantly higher in low disturbed, mid altitude and moist deciduous forests. Dense tree growth, higher tree height, girth, canopy coverage and canopy height were influencing the habitat use at field scale, however at landscape level, large extent of wet evergreen, moist deciduous forests and water bodies were crucial. The presence-absence model revealed that the species has high association with low disturbed, mid altitude moist deciduous and wet evergreen forests of high rainfall zones. Predicted geographic distribution showed that the low and mid altitude forests of western slopes had large extent of potential sites for the species. Based on the predicted model, around 20 % of southern Western Ghats was found suitable for the conservation of brown hawk owl ($p= 0.5$). The rainfall had an influence on the vocal behaviour and response of brown hawk owl.

Indian scops owl was significantly higher in highly disturbed, low altitude, moist deciduous or semi evergreen forests. Higher tree density, tree height, girth, canopy coverage and low canopy height were found to influence the presence of Indian scops owl at field

scale and large extent of semi-evergreen forests, wet evergreen forests, moist deciduous forests and water body were found to influence at landscape scale. Logistic regression and classification tree models showed a strong association of the species with least disturbed evergreen forests in the low altitudes of eastern slopes. Low altitude forests of eastern and western slopes of the Ghats were predicted as highly suitable areas for this owl. Around 21 per cent (11,451 km^2) of the southern Western Ghats was found suitable for the Indian scops owl (p= 0.5). The presence of Oriental scops owl was high in mid altitude, moist deciduous, low sloppy and moderately disturbed areas. Occurrence of Oriental scops owl was influenced by higher tree height, girth and canopy height at field scale and large extent of moist deciduous forests, dry deciduous forests and water body at landscape level. Based on the presence-absence model, Oriental scops owl showed a strong association with the areas having high rainfall, high altitude, moist deciduous with high anthropogenic pressure. Most of the predicted sites of the species using MAXENT model fall over the western slopes and large extent of potential sites were available south of the Aryankavu *i.e.* Agasthyamalai biosphere reserve. Around 22 per cent of the southern Western Ghats was found suitable for the Oriental scops owl (p=0.5).

Although the brown fish owl preferred wide array of vegetation types, encounter rate was higher in highly disturbed, low sloppy areas in the low altitude. Field scale variables failed to explain the habitat use of the owl however, landscape scale variable namely the large extent of water body was alone found to influence the distribution of brown fish owl in the Ghats. The predicted distribution map showed that the species have highly suitable sites at lower and mid altitude forests than the high altitudes. Around 22 per cent of the southern Western Ghats was found suitable for the brown fish-owl. The encounter rate of the Indian eagle owl was high, when census points were at dry forests, low altitude, mid sloppy and low disturbed sites. Due to its restricted distribution, all the habitat characteristics of occupied sites were different from the absence sites at field scale. At landscape scale, the Indian eagle owl preferred large extent of non-forest areas, dry thorn forest and dry deciduous forests and avoided extensive stretches of wet evergreen forests and moist deciduous forests. The MAXENT model predicted the potential sites of owl in the low altitudes of eastern slope and 22 per cent of the southern Western Ghats was found suitable for the Indian eagle owl (p=0.5). Forest eagle owl was utilizing the riparian forest adjacent to the dry thorn forest, which supported good population of blacknaped hare and giant squirrels. Mottled wood owl utilized the open rocky areas with scattered woody vegetation in the low altitude.

Owl species of the southern Western Ghats are not facing any serious threats, though they are found few in numbers. Most of the species need mature forest with long and tall trees and old forest growth for survival. The expansion of plantations into natural forests could put pressure on the owl population and mining activities for granite are destroying the habitat of the Indian eagle owl and brown fish in the eastern slopes of the Western Ghats in Tamil Nadu.

1. Introduction

In recent years, much importance is given for the conservation of tropical forests and its biodiversity all over the world (Prins and Wind, 1993; Mittermeier *et al.*, 1997; Myers *et al.*, 2000) because, the rate of tropical forest degradation is comparatively higher in the tropics (Bawa and Dayanandan, 1997) and the loss is often irreplaceable (Nair, 1999). Annual deforestation rate between 1920's and 1990's was estimated as 0.57 % for the Western Ghats (Menon and Bawa, 1997) and within the Western Ghats, degradation rate was 0.28 % for Kerala State (Prasad, 1998). Within Kerala 0.33 % was for the Agastyamalai region (Ramesh *et al.*, 1997). However, the trend was accelerated between 1973 and 1995, when the loss of forest cover was estimated as 25.6% (Jha *et al.*, 2000). Based on the available literature, it is obvious that the deforestation rate was between 0.28 and 0.57 % per year in the Western Ghats and the variation in the deforestation rate between the places was associated with population density and other socio-economic factors (Bawa and Dayanandan, 1997). Jha *et al.*, (2000) reported that the Nilgiris District alone lost about 19 % of its dense forest from 1973 to 1995 and an increased trend in the degraded forest (11 % in 1973 to 17 % in 1995) and open forests (31 % in 1973 to 36 % in 1995). The need of the hour is to conserve these pristine habitats before they are completely lost. Myers *et al.* (2000) and Nayar (1999) have identified such pristine forests all over the world for effectively managing certain range restricted and threatened biodiversity. The Western Ghats is one of the threatened ecosystems, which also supports high rate of endemic animals and plants (Nayar, 1999; Myers *et al.*, 2000). Sound policy strategy for the conservation of entire biological diversity of a predefined area requires detailed and precise information on the distribution of animal and plants (Nair, 1999). Moreover, extent of distribution and current population status of the species is prerequisite for identifying ecologically fragile zones for the conservation of a group of organisms.

Owls are nocturnal avian predators, which possess large home range and occupy multifaceted habitats to conquer certain life history characteristics *viz.*, breeding, roosting and foraging. Altogether 216 species of owls are found in the world (Owl pages, 2008) of which 15 % is found in India (Ali and Ripley, 1983; Grimmet and Inskipp, 2003). Out of the 33 species of owls found in India, the majority are concentrated in the north-eastern part of Country (ENVIS, 2007) and about 16 species are reported from Kerala (Easa and Jayson, 2004) and 15 species from Tamil Nadu (Ali and Ripley, 1983; Grimmet and Inskipp, 2003;

ENVIS, 2007) portions of Western Ghats. Ceylon bay owl (*Phodilus assimilis*) is endemic to the Western Ghats and Sri Lanka. Earlier it was considered as subspecies of the Oriental bay owl (*Phodilus badius*) (Ali and Ripley, 1983; Hussain and Khan, 1986) but in the recent classification it has been categorised as a new species (*Phodilus assimilis*) and its distribution is known to be from Western Ghats and Sri Lanka (Rasmussen and Anderton, 2005). Mottled wood owl *Strix ocellata* is endemic to India (Jathar and Rahmani, 2006) and three owls namely Indian eagle owl *Bubo bubo*, Indian scops owl *Otus bakkamoena* and jungle owlet *Glaucidium radiatum* are endemic to South Asia and Sri Lanka (Jathar and Rahmani, 2006). IUCN (2008) and Zarri and Rahmani (2005) have listed the threatened birds of India and except the forest owlet none of them was included in the threatened bird list including the range restricted Ceylon bay owl.

Other than the occasional observation records, no systematic survey was undertaken so far on the owls of the Western Ghats. However, some intensive studies were carried out on the threatened species namely the forest owlet (Rasmussen and Collar, 1998) and human commensally owls for instance common barn owl (Santhanakrishnan, 1987; Nagarajan, 1998; Nagarajan *et al.*, 1998) and spotted owlet (Kumar, 1985). Some breeding and behavioural studies were also carried out on the Indian eagle owl from the east coast of Tamil Nadu (Ramanujam, 2000). This is the first detailed ecological study on the owls of the southern Western Ghats.

Forest owls pose special challenges to forest managers because they are top predators, with large home ranges and complex habitat requirements. A landscape approach is necessary for modelling distributions of forest owls and conserving habitat for them. Some owl species need extensive areas of natural forest within their home range, as reported for sooty owls (*Tyto tenebricosa*) in Australia (Milledge *et al.*, 1991) and Northern spotted owls (*Strix occidentalis caurina*) in North America (Bart and Forsman, 1992). All forest owls need tree hollows for nesting and some species need them for roosting. Arboreal mammals form a high percentage of their prey and most of those mammals depend on tree hollows for daytime shelter (Higgins, 1999). Large hollows suitable for these species do not form until trees are very old and large trees tend to contain many more hollows than small trees (Soderquist, 1999).

Owls are a worldwide order of birds known as Strigiformes and the 216 species range in size from the tiny, sparrow size elf owl, to the Indian eagle owl, which has a wing

span of nearly 2 meters and can weigh almost 5 kg. They are a group of predatory birds, characterised by an upright posture and large forward facing eyes surrounded by disk of short stiff feathers. A large proportion of owls are nocturnal. They occupy the equivalent niche as the diurnal birds of prey such as hawks, falcons, eagles and buzzards, but they are not actually related. The resemblance to the daytime birds of prey is just an example of convergent evolution, where both groups have evolved several features such as the hooked beak and talons, independently to perform the same function. Owls are all very closely related to each other, much more so than the diurnal raptors, which include birds as dissimilar as vultures, secretary birds, falcons etc. Even so they are separated into two fairly distinct families.

The first family is the Tytonidae which is made up of 17 species of barn and Eastern grass owl, and one species of bay owl. This family is quite distinct from other owls and has several differences. The most obvious external differences are the heart-shaped, rather than round facial disk, the longer skull and beak, longer legs, longer more pointed wings and a forked tail. Grass owls come from Africa, South East Asia and Australia and are very similar to common barn owls but have longer legs. All of the other 198 owls are in the family Strigidae. The collective noun for owls is "Parliament".

Rasmussen and Anderton (2005) nomenclature was followed throughout the report, as several species of owls were newly described. Based on the morphometric characters, the owls were classified into three major groups namely larger owls, moderate owls and lesser owls. Webb *et al* (2007) and Gaston and Blackburn (2000), have considered body size as key macro ecological variable along with range size and population. With the above view, the owls with more than 400 mm of body length are classified as larger owls, owls with less than 400 mm and greater than 270 mm of body length are classified as moderate owls and those owls, which are lesser than these owls, are classified as lesser owls. All the morphometric details were collected from Rasmussen and Anderton (2005) and Ali and Ripley (1983). With the above classification, jungle owlet *Glaucidium radiatum*, Indian scops owl *Otus bakkamoena*, Ceylon bay owl *Phodilus assimilis*, oriental scops owl *Otus scops*, brown hawk owl *Ninox scutulata* and spotted owlet *Athene brama* were classified as lesser owls. Dusky horned owl, forest eagle owl, mottled wood owl, brown wood owl, brown fish owl and Indian eagle owl were classified as larger owls. Long eared owl, short eared owl, Eastern grass owl and common barn owl were classified as moderate owls.

The Zoological Classification of Owls is as follows

Kingdom: Animal

Phylum: Chordata (having a hollow dorsal nerve cord and flexible skeletal rod)

Sub-Phylum: Vertebrata (having a backbone)

Class: Aves (Birds)

Order: Strigiformes (Owls)

Objectives

The aim of the study was to find out the details of the ecology and behaviour of the owl species and to assess the threats to the survival of the species. The specific objectives were,

1. To make an inventory of forest owls in the Western Ghats of Kerala and Tamil Nadu
2. To find out the factors that influence the owl distribution and abundance
3. To characterise the micro habitat parameters of forest owls
4. To predict areas of forest that has high value for owls, by modelling the habitat parameters.

All owls are predators and the size of the prey generally reflects the size of the owl. Owls prey on a variety of insects, spiders and other invertebrates, although, some are quite voracious and can take birds as large as themselves. Eagle owls at the other extreme have been recorded to take such formidable prey as Golden eagle and a Roe deer of 13 kg as well as foxes, herons, domestic dogs. Hunting is normally carried out in two different ways, the first is perch hunting, where the bird sits and waits from a suitable perch until a prey item is located. The other technique is flight hunting where the owl slowly quarters the ground from a low altitude looking and listening for prey and diving down when food is detected. The length of the wings is normally a good indication to the preferred method of hunting (short wings for perch hunting and long wings for flight hunting). Most owls are opportunists and virtually anything that moves is caught. Some species are more specialised feeders in particular the fishing owls. These are two genera of owls, one from Asia and the other from Africa whose members feed mainly on fish, amphibians and aquatic invertebrates snatched from beneath the water surface.

No other species are quite so specialised but some have a preference for particular prey. The milky eagle owl of Africa feeds on a wide variety of prey, but where the ranges overlap

it seems particularly partial to hedgehogs. The Indian eagle owl appears to have a vendetta against other birds of prey especially other owls. In some areas they form 10 % of the bird's diet, which is much greater than one would expect from chance.

Protected area managers should focus on owls for special consideration in forests (Lugg *et al.*, 1993) because of their large home ranges and known needs for elements of old forest to provide nest sites in large hollow-bearing trees and support high densities of arboreal mammal prey (Loyn *et al.*, 1980; Milledge *et al.*, 1991; Kavanagh and Bamkin, 1995). The implication is that they are the species with the most demanding requirements, and if they are conserved many other species will be well conserved also. This fits the concept of owls as umbrella species (Simberloff, 1998).

In the forest habitats, commercial rotations for timber production are usually shorter than the time needed to develop hollows in the trees, which are the favourite places for nesting and breeding of the forest owls. Three primary strategies are available to conserve hollow-dependent fauna in forests used for wood production: selected stand retention (and replacement over time) is the most popular and generally the most effective. The other primary strategies are extended rotations or tree retention on coupes (Loyn, 1985a). Species of owls found in the southern Western Ghats are given below.

1. Common barn owl (*Tyto alba)* LC
2. Eastern grass owl (*Tyto longimembris)* LC
3. Ceylon bay owl (*Phodilus assimilis*) LC
4. Oriental scops owl (*Otus sunia*) LC
5. Indian scops owl *(Otus bakkamoena)*LC
6. Indian eagle owl *(Bubo bengalensis)* LC
7. Forest eagle owl (*Bubo nipalensis)* LC
8. Brown fish owl (*Ketupa zeylonensis)*LC
9. Jungle owlet (*Glaucidium radiatum)*LC
10. Brown hawk owl (*Ninox scutulata)*LC
11. Spotted owlet *(Athene brama)* LC
12. Mottled wood owl (*Strix ocellata)* LC
13. Brown wood owl (*Strix leptogrammica)*LC
14. Long-eared owl (*Asio otus*) (Migratory) LC
15. Short eared owl (*Asio flammeus)* (Migratory) LC
16. Dusky eagle owl (*Bubo coromandus)* LC

Out of the sixteen species of owls distributed in Kerala part of the Western Ghats, nine species are found in the forests and others in the cultivation and open country. Two species are migratory and 13 species are resident in nature. Owls are easily identified based on their calls. They utilise their calls and songs for attracting mate and also to defend their territories. Pitch and volume of the call reflect the size of the territory of the owl and thus how far the call has to travel. Diurnal species are far less vocal than the nocturnal ones, because they use visual displays to advertise for partners and defend their territories.

Tree hollows and cavities are the preferred site for many species but nest sites vary. Larger species scratch a scrape or use old stick nests of crows, pigeons or diurnal birds of prey. Many owls are territorial, during the breeding season and even other owl species are not tolerated. Some species are known to defend the nest sites but will share the hunting habitat. Breeding seasons coincides with the peak availability of food for rearing chicks. Owls lay white eggs, which suggest that they all evolved from a hole-nesting ancestor. The number of eggs laid varies from species to species, year to year and between individual birds. Owl eggs are relatively spherical. In most species, the female starts incubating as soon as the first egg is laid. During incubation and until the smallest chick is large enough to maintain its own body temperature, all the food is provided by the male, the female rarely leaving the nest site. The female dispatches the food and feeds the chicks with small slivers until they can swallow the prey; she then helps the male with the hunting. The age of fledging varies greatly and some species even remain in the area until the following year. Gradually the young learn to hunt, often starting on insects or food brought in by the parents, which may still be alive.

Because of their predominantly nocturnal tendencies, owls have evolved several physical adaptations, which facilitate catching prey in the dark. All owls have large forward facing eyes giving good stereoscopic vision vital for judging distances of all birds. In smaller species, the head often appears flattened so that the eyes can be as widely spaced as possible to increase the stereoscopic effect. The present study reports detailed information on distribution, population status and behaviour of the owl species. Population status of the owl species gathered will enhance our knowledge on the present conservation status of the species and to understand whether some species are to be included in the list of endangered species.

1.1. Study areas

The study was carried out in the Western Ghats of Kerala and Tamil Nadu. Kerala part of the Western Ghats forest is comprised of fourteen protected areas including 12 Wildlife Sanctuaries and 2 National Parks. During the study period, three more National Parks were newly announced. A brief account of the protected areas where the study was conducted is given below.

1.1.1. Forests of Kerala

The study was carried out in the twelve wildlife sanctuaries and two National Parks of Kerala namely Peppara, Neyyar, Shendurney, Idukki, Periyar Tiger Reserve, Chinnar, Parambikulam, Peechi, Chimmony, Wayanad, Aralam, Thattekkad Wildlife Sanctuaries and Silent Valley and Eravikulam National Parks (Fig. 1). Some of the reserve forests were also surveyed for the study.

Aralam Wildlife Sanctuary

Aralam Wildlife Sanctuary has a forest area of 55 km^2 accommodating rich diversity of flora and fauna. The Sanctuary is located in the southeastern side of the Kannur District of Kerala State. The area geographically lies between 11°50' to 11°52' N and 75°49' to 75°57' E. Geologically the area can be grouped into two main rock types *viz.*, laterites and crystalline rocks. The habitat constitutes evergreen forests of 21.52 km^2, semi evergreen forests with an extent of 25.97 km^2 areas and moist deciduous forest of 1.11 km^2. The estimated area of other minor cover types is 6.12 km^2 (Menon, 1999).

Wayanad Wildlife Sanctuary

Wayanad, consisting of the forests under the administration of North Wayanad, South Wayanad and Wayanad Wildlife Sanctuary form a major portion of Nilgiri Biosphere Reserve. The Sanctuary has a total extent of 344.44 km^2 and is a part of the Mysore Plateau (Fig.2). The terrain is almost flat and the slope varies from 5^0 to 10^0 in the western part (Easa and Sankar, 2001). The altitude varies between 850 m and 1147 m. The broad type of soil is Ferrolite and sub type is Ustic Altisol. The forest types could be broadly classified into the following categories (Champion and Seth, 1968) namely the West coast semi-evergreen forests, southern moist mixed deciduous forests, southern dry mixed deciduous forests and plantations. The name 'Wayanad' derives its name from the numerous swamps locally called as *vayals*. Francis (1994) studied the earlier political history, forest, agriculture and wildlife in Wayanad.

Silent Valley National Park

Situated in the Palghat District of Kerala between latitude 11^0 3' and 11° 15' N and longitude 76° 23' and 76° 30' E, Silent Valley National Park is one of the core zones of the Nilgiri Biosphere Reserve. The area was declared as a National Park in 1984 and it falls under the Malabar Rainforest Realm. Covering an area of about 90 km^2, this reserve is situated more or less on a plateau of about 1000 m (KFRI, 1999). The altitude of the habitat varies between 658 to 2383 m above msl. The vegetation is of west coast tropical evergreen type. Manilal (1988) made a detailed account of the flora of Silent Valley, which consists of 966 species belonging to 134 families and 559 genera. Jayson and Mathew (2000, 2002, and 2003) have studied structure, diversity and seasonal distribution of birds.

Parambikulam Wildlife Sanctuary

The Parambikulam Wildlife Sanctuary is located in the Palghat District of Kerala State. Geographically the area lies between 76° 35' and 76° 50' E and 10° 20' and 10° 26' N at an elevation of 600 m above msl. The altitude varies between 300 m and 1400 m. The Sanctuary was declared in 1962 and has an extent of 270 km^2. The topography is hilly terrain with undulating plains interspersed with marshy fields in the valleys. The mountain ridges of the Sanctuary have well defined valleys and slopes to streams, which permit denser growth of vegetation in those regions. Some of the hilltops have stretches of grasslands above 1000 m. Vegetation includes moist deciduous forests to tropical wet evergreen rain forests. Semi-evergreen forests appear where moist deciduous forests merge into evergreen forests. Nair and Jayson (1988) have described the habitat use of herbivores in the Sanctuary.

Peechi- Vazahani Wildlife Sanctuary

The Peechi-Vazahani Wildlife Sanctuary is situated in the Trichur District, Kerala State between 10° 28' and 10° 38' N and 76° 18' and 76° 28' E. The Sanctuary was established in 1958 with an extent of 125 km^2. The area includes the Reservoirs of Peechi and Vazahani dams. The reservoir area is of 12.95 km^2 and 1.843 km^2 respectively (Narayanankutty and Nair, 1990). The Sanctuary is well connected with the forest areas of Nelliampathy and Palappilly Reserves and Chimmony Wildlife Sanctuary. The continuity of the Peechi Forest Range with the Vazahani side is lost due to the Trichur-Palakkad National Highway. The terrain is undulating and the elevation varies from 45 to 900 m. The habitat is

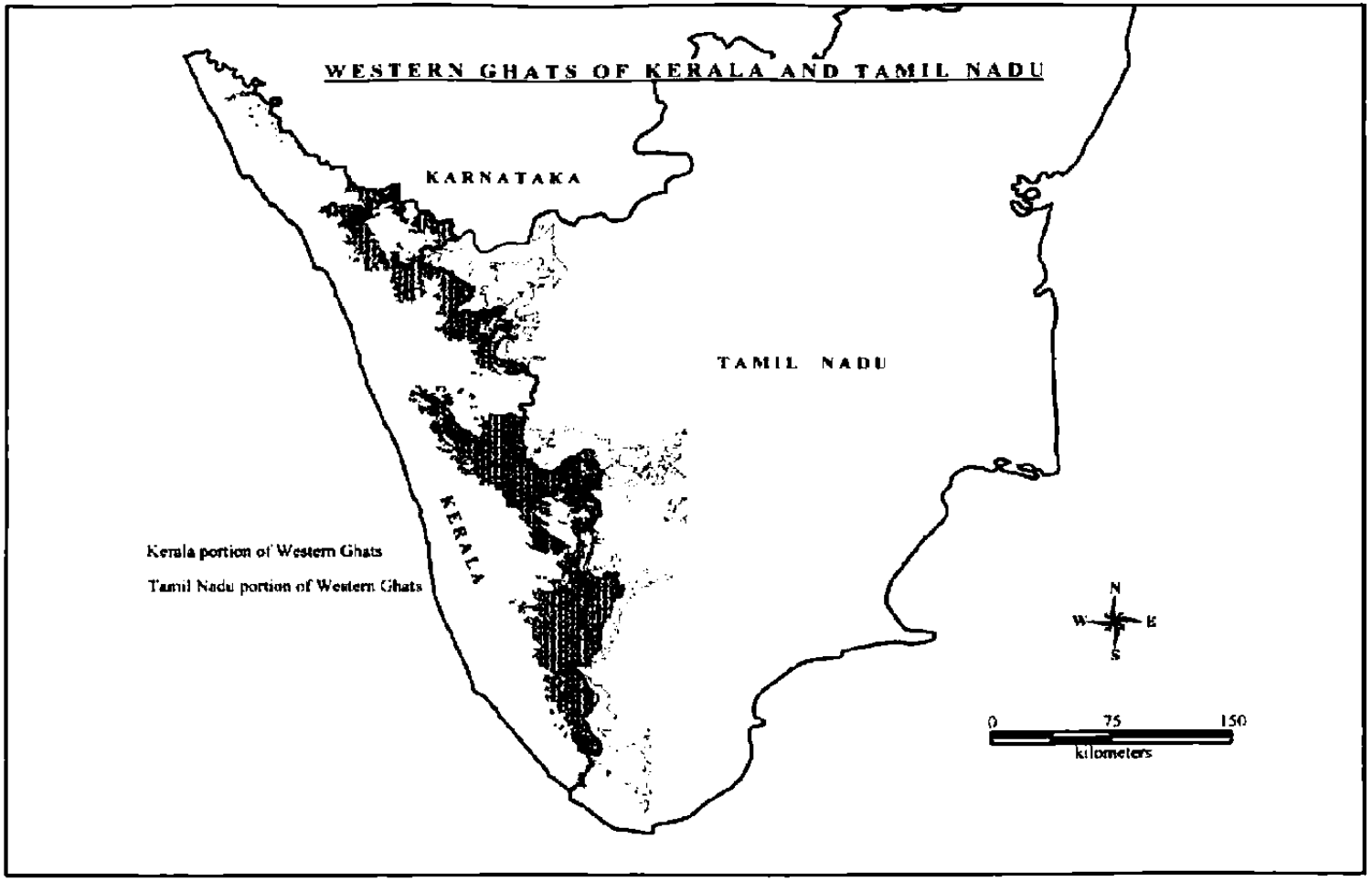


Fig. 1. Location of the study area.

dominated by the tropical moist deciduous forests and semi evergreen forests, which are confined to the upper regions.

Chimmony Wildlife Sanctuary

Chimmony Wildlife Sanctuary is located in the Thrissur District of Kerala State between 10° 22' and 10°26' N and 76 °31' and 76 °39'E on the western slopes of Nelliampathy forests. The extent of the Sanctuary is 85.067 km^2 of which the reservoir of Chimmony Dam occupies 5.68 % (Menon, 1997). The habitat is contiguous with Parambikulam and Peechi-Vazahani Wildlife Sanctuaries. Elevation of the terrain varies from 1126 m to 2500 m above msl. The vegetation of the Sanctuary consists of west coast tropical wet evergreen forests at higher reaches, west coast semi evergreen forests of an extent of 35.03 km^2 and south Indian moist deciduous forests of 31.20 km^2. Jayson (1997; 1999) reported the status and habitat utilization of large mammals of the Sanctuary.

Chinnar Wildlife Sanctuary

Chinnar Wildlife Sanctuary, geographically located between 10° 15' - 10° 21' N and 77° 05' - 77° 16' E comprises 90.44 km^2. The Sanctuary comes under the political boundary of Idukki District of Kerala State. The terrain is highly undulating. The different regions of the area experience varying climate reflecting in the different vegetation types (Sasidharan, 1999). The altitude ranges from 400 to 1883 m above msl. The terrain is much undulated with hills and hillocks of varying altitude from 400 m at Chinnar to 1883 m at Vellakkalmalai. The vegetation of the Sanctuary can be broadly classified into six types (Champion and Seth, 1968). They are southern tropical thorn forest (scrub jungle), southern dry mixed deciduous forest (dry deciduous forest), southern moist mixed deciduous forest (moist deciduous forest), tropical riparian fringing forest (riparian forest), southern montane wet temperate forest (hill shola forest) and southern montane wet grassland (grassland). The habitat is also rich in fauna and Jayson (2004) reported the habitat utilization of large mammals.

Eravikulam National Park

Eravikulam National Park is famous as the natural habitat of the world's largest population of Nilgiri Tahr (*Hemitragus hylocrius*). Rice (1984) has given a detailed description of Eravikulam National Park. The flora could be subdivided into grassland, shrub land and forests. The terrain above 2000 m is covered primarily by rolling grasslands with small patches of shola forests. The shola forests mostly located in the (Plate 3) valley

can be classified as southern montane wet temperate forest (Chandrasekharan, 1962). Sixteen mammalian species were reported from the National Park (Easa, 1995).

Thattekkad Bird Sanctuary

Thattekkad Bird Sanctuary well known for the birds has an extent of 25 km^2 and it lies between 77^0 - 76^0 E and 10^0 - 11^0 N. This Sanctuary has low altitude forest with elevation varying from 60 to 450 m above msl. The habitat consists of evergreen, semi evergreen and moist deciduous forest types and teak, mahogany and rosewood plantations. All the plantation activities were stopped for the last 15 years and the regeneration is copious in the old plantations. The Sanctuary is situated around the reservoir area of Bhoothathankettu Dam.

Idukki Wildlife Sanctuary

Idukki Wildlife Sanctuary with an area of about 77 km^2 is located between 09°45' - 09°55' N and 76°50' - 77°05' E. The area includes 33 km^2 reservoir area of the Idukki dam. The terrain is undulating with an elevation varying from 800 m to 1272 m above msl. Vegetation consists of west coast tropical evergreen forest, west coast tropical semi-evergreen forest, south Indian moist deciduous forest and south Indian sub-tropical hill savannah. West coast tropical evergreen forests are mainly confined to Vagavanam and Kizhukalachimala and in some isolated locations. West coast tropical semi evergreen forests are found in the transitional zones of evergreen and deciduous forests and occupy only a very small patch. South Indian moist deciduous forest forms sixty per cent of the vegetation in the Idukki Wildlife Sanctuary. South Indian subtropical hill savannah type of forests is dominated by grasslands and sparse tree growth occurs mostly in the hilltops (Easa, 1997).

Periyar Tiger Reserve

Periyar Tiger Reserve is a protected area with an extent of 777 km^2. The altitude of the area is up to 1808 m and lies between 76^0 55' - 77^0 25'E and 9^0 18' - 9^0 40'N. The soil is mainly fine loamy in character as it is derived from disintegrated laterites and gneisses. In higher altitudes, the soil is coarse with large amount of quartz gravel formed from crystalline rock. The underlying rock formations consist mainly of granites and gneisses. Laterite occurs at the lower reaches of the Reserve. By following Champion and Seth (1968), the vegetation of the Periyar Tiger Reserve can be classified into seven types namely, West coast tropical evergreen forests (evergreen), West coast semi-evergreen forests (semi-evergreen), Southern moist mixed deciduous forests (moist deciduous),

Plate 1.

Plates 1,2,3, Various habitat types in the southern Western Ghats.

Plate 4. Varagaliyar shola

Plate 5. Bamboo mixed MDF (Top slip)

Southern hill-top tropical evergreen forests (hill-top evergreen), Southern montane wet temperate forests (shola), South Indian sub-tropical hill savannahs (savannah) and Southern wet montane grasslands (grassland). The flora of Periyar Tiger Reserve was studied in detail by Sasidharan (1998).

Shendurney Wildlife Sanctuary

Shendurney Wildlife Sanctuary is located between 77° 4' and 77° 17' E longitude and between 8° 48' and 8° 58' N latitude in Kollam District, Kerala State. The name 'Shendurney' is derived from a rare timber tree *Gluta travancorica, which* is locally called *'Chenkurinji'*. The elevation of the area varies from 120 m to 1550 m above msl. As per the management plan (Vighnarajan, 1990) there are 40 km^2 of evergreen forests, 10 km^2 of semi-evergreen forests, 15 km^2 of moist deciduous forests, 5 km^2 of grasslands and 6 km^2 of reed and canebrakes in the Sanctuary.

Neyyar Wildlife Sanctuary

Neyyar Wildlife Sanctuary with an extent of 128 km^2 forest lies at the southern tip of Kerala part of the Western Ghats. The area lies between 8^0 17' - 8^0 53' N and 76^0 40' - 77^0 17' E. The Sanctuary has a varying altitude up to 1868 m above msl at Agastyamalai peak. The forests consist of evergreen, semi evergreen and moist deciduous types and the Sanctuary includes the reservoir of Neyyar Dam. Jayson *et al.* (2006) reported an evaluation of the crocodile introduction programme carried out in the sanctuary.

Peppara Wildlife Sanctuary

Peppara Wildlife Sanctuary situated in the southern tip of the Western Ghats in the Agasthiamalai ranges in the extreme South to the Aryankavu pass, the Peppara Wildlife Sanctuary comes under Nedumangad Taluk of Thiruvanathapuram District, Kerala State. It is located between 8° 34' to 8° 42' N latitude and 77° 7' to 77° 14' E longitude. The State capital is 50 km away from the Sanctuary. The extent of the sanctuary is 76 km^2 and is under the control of Assistant Wildlife Warden stationed at Peppara Dam site and the Wildlife Warden stationed at Thiruvanathapuram. The altitude varied from 98 m to 1594 m above msl. Forests surround all the sides of the Sanctuary. On the northern side lies the Bonacord estate and eastern side borders with the Mundanthurai-Kalakkad Tiger Reserve of Tamil Nadu. Southern portion adjoins with the Neyyar Wildlife Sanctuary and western portion borders with the eucalyptus plantations of Trivandrum Division. The highest peak is Athirumudi Peak (1594 m) and the entire area is the catchment of Karamana River, which

originates from the Chemmungi peak. The area forms the part of the Agasthiamalai Biosphere Reserve.

The Sanctuary has a tropical hot and humid climate with a dry summer. Even during this period, the high ranges maintain a cool and dry climate. Daily temperature varies from 32^0 C to 20^0 C in plains whereas it varies from 25^0 C to 16^0 C in high altitude. Average rainfall is around 4810 mm in the catchment of Peppara Dam. The Peppara Wildlife Sanctuary has all typical vegetation types found in the tropical areas like tropical moist deciduous forests (29 km^2), tropical evergreen forests (10 km^2), tropical semi evergreen forest (14 km^2), shola forests (0.79 km^2), reed brakes (2 km^2), bamboo areas (0.5 km^2) and grass lands (2 km^2) (Menon, 1999). Nair (1991) has also described the vegetation of the area in detail. A recent floristic study by Mohanan *et al.* (1997) documented 1084 species of flowering plants from the area. *Terminalia paniculata*, *T. bellirica*, *Carea arborea*, *Dillenia pentagyna*, *Pterocarpus marsupium*, *Phyllanthus emblica*, *Lannea coromandelica*, *Lagerstroemia microcarpa*, *Hopea parviflora*, *Olea dioica*, *Buchanania longan*, *Bombax insigne* and *Wrightia tinctoria* were seen in the moist deciduous forest.

1.1.2. Protected Areas in Tamil Nadu

Mudumalai Wildlife Sanctuary

Mudumalai Wildlife Sanctuary and National Park is situated at the tri-junction of Tamil Nadu, Kerala and Karnataka on the North Eastern slopes of the Nilgiris part of Western Ghats descending to the Mysore Plateau. It lies between 11° 30' N and 11° 42' N and 76° 30' E and 76° 45' E. Rainfall ranges from 800 – 2000 mm. Temperature varies from 14° C to 33° C. Altitude ranges from 100 MSL to 1200 MSL. With Bandipur Tiger Reserve (Karnataka) in the North, and Wayanad Wildlife Sanctuary (Kerala) in the west, the region forms a single, continuous viable habitat for a varied range of wildlife and is a part of the Nilgiri Biosphere Reserve. While the western half of the protected area receives the southwest monsoon, the eastern tracts receive the relatively gentler northeast monsoon, which results in a diversity of vegetation types and typical migration of herbivores. The Sanctuary has an area of 321 km^2 with 108 km^2 as National Park. Tropical moist deciduous vegetation towards the western parts of the Sanctuary gives way to dry deciduous and thorn-scrub along the east.

Palani Hills

The Palani Hills are an eastward spur of the Western Ghats with a maximum East-West length of 65 km and a North-South width of 40 km. (area 2064 km^2). These Hills may be divided into four distinct zones, the foothills up to 800 m consisting of thorn forest at the lower range and then dry deciduous forest typical of Peninsular India. There are also some very good stretches of evergreen riverine forest at these altitudes. Sub-montane evergreen forest accompanied by shrub savannah to 1600 m. Although most of the area has been converted to plantations from 1600 m to 2000 m, the outer montane slopes characterised by grassland savannah and shola still remains.

The undulating plateau interspersed with occasional peaks rising to 2,500 m. (area 385 km^2, average altitude 2,200 m) largely consisting of grasslands interspersed with sholas. The grassland component is now largely dominated by forest plantation. The Palani differ greatly from much of the Western Ghats in that it lies in the rain shadow of the backbone of the range, *i.e.* it receives only light rainfall during the June-September S.W. monsoon. The bulk of the rain falls on the Annamalai in the West in Kerala. The dense luxuriant tropical rainforests of the Western lowlands are absent. Moist areas though exist along the ravines and in the sheltered pockets of shola forest at 2000 m. Balachandran *et al.* (2005) reported on the revaluation of bird community structure of Palani Hills with special reference to threatened and endemic species.

Indira Gandhi Wildlife Sanctuary

The Indira Gandhi Wildlife Sanctuary and National Park is one of the largest protected areas in Tamil Nadu covering an area of 958 km2. The elevation ranges from 220 meters in the foothills to 2500 meters in grass hills. This Sanctuary lies geographically between 10° 12′ - 10° 54′ N and 76° 44′ - 77° 48′ E. The Sanctuary has long tradition of disturbance even during the British period and popularly known as Anamalais. Though highly disturbed, to certain extent, the Sanctuary still holds some remnant patches of natural forests which harbour wide array of vertebrates including herpetofauna (Kumar *et al.*, 2002), birds (Raman and Mudappa, 2003) and mammals (Umapathy and Kumar, 2000)

There exists a clear gradient for rainfall received as one moves from the west to the east of the protected area. The western windward regions receive approximately 3500 mm of rainfall annually and contain tropical evergreen and moist deciduous forests. As one move eastward, the rainfall reduces to as little as 500 mm annually and the vegetation

changes to tropical dry deciduous forest in the hills and thorn forest in the plains. Most of the rainfall is received during the southwest monsoon with moderate amounts during the northeast monsoon. Seasonally, a year in this area can be divided into three periods namely January to April (dry), May to August (wet) and September to December (moderately wet).

Given the strong gradients in altitude and rainfall, it is not surprising that the area encompasses a number of vegetation types including tropical thorn, dry deciduous, moist deciduous, evergreen forest and montane shola-grassland. Most of the evergreen forest found in this area falls under the *Cullenia–Mesua–Palaquium* type (Pascal, 1988). As already mentioned, this forest type is found in a few large patches within the Sanctuary and as small fragments varying in size, altitude and human disturbance levels on the Valparai plateau. Kannan (1992) reported the possible sighting of a bay owl in Anamalai Hills. Kumar *et al.* (2002) reported the distribution patterns, relative abundance and management of mammals in the Sanctuary.

Srivilliputtur Grizzled Giant Squirrel Wildlife Sanctuary

The Grizzled Giant Squirrel Wildlife Sanctuary at Srivilliputtur in southern Tamil Nadu spreads over 480 km^2. This Sanctuary is contiguous to Periyar Tiger Reserve on the southwestern side and the Megamalai Reserve Forest on the northwestern side and its southern limit is contiguous with the Sivagiri Reserved Forest of Tirunelveli Forest Division.

This Grizzled Giant Squirrel Wildlife Sanctuary lies mostly in Virdhunagar District. The altitude varies from 100 m MSL to 2010 m MSL. It receives both southwest and northeast monsoons. The varied climate and topographic conditions prevailing in the Sanctuary present remarkable diversity both in flora and fauna. The Sanctuary is located in the eastern slopes of the Western Ghats with a number of peaks reaching up to 1800 m. It is the eastern watershed boundary for the River Periyar and one of the best-preserved forests south of the Palghat Gap. The tributaries of the River Vaipaar and few rivulets draining into the River Gundaar are originating in these hill tracts of the Sanctuary. The climate is generally hot and dry in the foothills. The average annual rainfall ranges from 800- 2300 mm. The Sanctuary has a wide range of habitats - from the higher elevation upper montane forests and grasslands, mid elevation wet evergreen, semi evergreen, moist deciduous, open deciduous, closed deciduous forests and grasslands with scrub jungles in the foothills.

Kalakkad - Mundanthurai Tiger Reserve

Kalakkad - Mundanthurai Tiger Reserve (KMTR), the southernmost protected area in Tamil Nadu, announced officially as a tiger reserve during 1988 for conserving southern population of threatened tiger and also for certain arboreal mammals and herpetofauna. KMTR is situated between latitudes 80 25' N and 80 53' N and longitude 770 10' E and 770 35' E. It also harbours a continuous stretch of rainforests, which supports rich diversity of endemic fauna. The altitude of the reserve ranges from 100 m in the foothills to 1800 m in Agasthiyar malai peak. The reserve has long tradition of disturbance including private estates inside the reserve and continuing until now. The water received in the reserve has been stored in four major dams including Karaiyar, Servalar, Manimuthar and Upper Kodayar and supply water to three Districts. Hence, the reserve is also called as "river sanctuary". The total extent of area is 895 km^2. The reserve is located within the political boundary of Tamil Nadu in the District limits of Tirunelveli. The famous plateau within the reserve is Mundanthurai plateau, which extends for about 50 km^2. Johnsingh (2001) represented the Kalakad-Mundanthurai Tiger Reserve as a global heritage of biological diversity.

Kanyakumari Reserved Forests

The southernmost natural forests of Western Ghats are located in the Kanyakumari Forest Division with highly undulating terrain and array of altitudinal ranges from 100 m in the foothills to 1645 m in the Mahendragiri peak. Kanyakumari Forest Division is located between 77° 10'and 77° 35' East and 8° 5' and 8° 35' North. The highest point is 1829 m at the trijunction of Mahendragiri, Kalakad and Veerapuli Reserved Forests. Other important peaks are Mahendragiri (1645 m) in Mahendragiri RF. The valleys and flat lands between the spurs are accessible and contain valuable forests. Various types of forests from luxuriant tropical wet evergreen forests to southern thorn scrub forests occur in this Division because of diverse locality factors (edaphic and biotic) varying rainfall from 50 to 310 cm.

1.2. Review of Literature

Studies on the owls in India started from the 18 th century onwards (Blanford, 1894). Earlier studies on owls mainly appeared as occurrence records. Inglis (1901) described the snaring of owls in nooses. The same author described (Inglis, 1941) the Long-eared owl in the

Darjeeling District and reported on the Northern bay owl (Inglis, 1945). Owls are easily identified based on their calls. Many authors reported on the calls and sounds made by owls (Abdulali, 1948). Henry (1933) and Holme (1965) also reported on the owl calls and sound. Brahmachary *et al.* (1973) reported on the daily screeching time of a colony of spotted owls. Breeding habits and behaviour of owls have been worked extensively in India (Dharmakumarsinhji, 1939). Dubae and Rawal (1968) have studied anatomy of the feeding apparatus of spotted owlet. Gunathilagaraj (1991) described the perches of owls. Katoch and Sambyal (1992) reported on the isolation of *Salmonella newport* from Himalayan horned eagle owl. Guchhait and Haldar (1998) have reported reproductive physiology of Indian spotted owlet (*Athene brama*). Similarly, Haldar and Guchhait (2000) have also reported morphological and endocrine observations of pineal gland of Indian spotted owlet.

Many authors (Gupta, 1967; Haldar, 1998) have also reported behavioural aspects of owls. Jose (1964) described a southern spotted owlet *Athene brama* being attacked by crows. A new species of owl was reported from Hussain and Khan (1978) from Peninsular India. Dwarakanath (1983) explained attack by a spotted owlet. Ishitaq, Ishitaq and Rahmani, 2000 and 2000b, described status survey of elusive forest spotted owlet. Many authors (Jain and Advani, 1984) have described food habits of owls. Jameson (1973) has reported about the brown wood owl in the Nilgiris. Kanaksabai *et al.* (1996, 1996 b, 1996c, and 1994) reported many aspects of the behaviour and breeding habits of common barn owl. Kannan (1993, 1995) reported on the man-owl superstitions concept and on the spotted owlet. Many authors (Mc Cann, 1933) reported food of different species of owls. Nagarajan *et al.* (1995a, 1995 b, 1993) reported on many aspects of the common barn owl from Tamil Nadu.

Neelakantan (1972, 1980) reported on the voice of the Malabar Jungle owlet and call of brown hawk owl. Ramanujam (2000) attempted to rationalize on the vocalisations and displays of captive Indian eagle owl. Rasmussen (1998) had reported on the rediscovery of forest owlet after 113 years. Rasmussen and Collar (1998) reported on the identification, distribution and status of the forest owlet. Rasmussen also reported on the vocalisations and behaviour of the forest owlet *Athene belwittie* (1999).

Ripley (1981) reported on the range extension of brown owl (*Strix leptogrammica*). Roberts and King (1986) reported on the vocalisations of the owls of the genus Otus in Pakistan. Sugathan and Jacob (1995) reported on the records of the bay owl from Kerala. Thom (1965) reported on the owl noises and similarly Wemmer and Derrickson (1994)

reported on the duetting in the Indian eagle owl *Bubo nipalensis*. Many workers have reported on the owls from other countries. Kavanagh (1997) reported on the ecology and management of large forest owls in southeastern Australia. Simberloff (1998) had reported on the flagship, umbrellas and keystone species.

Owls in India

Dudgeon (1901) elaborated an incident of large-barred owlet *Glaucidium cuculoides*, capturing quail on the wing. Coltart (1904) reported the occurrence of the Malay fish-owl *Ketupa javanensis* in Assam. Similarly, Dodsworth (1913) described the Himalayan wood-owl *Syrnium nivicola*. Sound of owls attracted many authors and several works were reported on this aspect from the early period. Holmes (1965) described the sound of owls. Similarly, many authors commented on the calls and sound made by the owls (Abdulali, 1948; Thom, 1965). Neelakantan (1972, 1980) gave an account on the voice of Malabar jungle owlet call and brown hawk owl. Brahmachary *et al.*, (1973) gave details on the daily screeching time of a colony of spotted owls. Dharmakumarsinhji (1978) explained a strange behaviour of Indian barn owl *Tyto alba stertens*. Wemmer and Derrickson (1994) accounted the duetting in the Indian eagle owl *Bubo nipalensis*. Ramanujam (2000) attempted to rationalize on the vocalisations and displays of captive Indian eagle owls.

Many authors (Mc Cann, 1933; Jain and Advani, 1984) discussed food of different species of owls. Similarly, Gupta (1967) and Haldar (1998) have described behavioural aspects of owls. Dubale and Rawal (1968) have studied anatomy of the feeding apparatus of spotted owls. Hussain and Khan (1978) explained a new species of owl from Peninsular India. Kumar (1985 and 1985) gave an account on the man–owl superstitions concept and on the spotted owlet. Allen (1920) reported the hovering habit of the spotted owlet *Athene brahma*. Kannan (1993, 1995) rediscovered the Ceylon bay owl in Annamalai Hills. Kanaksabai (1996), Kanaksabai *et al.* (1996, 1996 b, 1996 c, and 1994) worked out many aspects of the behaviour and breeding habits of common barn owl. Nagarajan *et al.* (1993, 1995, 1995 b) elucidated many aspects of the common barn owl from Tamil Nadu. Sugathan and Jacob (1995) documented the bay owl from Kerala. Reproductive physiology of Indian spotted owlet (*Athene brama*) had been studied by Guchhait and Haldar, 1998). Desai *et al.* (1997) described the nest of the Indian eagle owl, *Bubo bubo*, sighted on Nrupatunga Betta of Hubli.

Status survey of elusive forest spotted owlet was carried out by Ishitaq (1998) and

Ishitaq and Rahmani (2000 a and 2000 b). Ishtiaq and Rahmani (2005) described the vocalization, breeding biology and conservation of the forest owlet *Heteroglaux blewitti*. Birdlife International (2001) also reported on the forest owlet. King and Rasmussen (1998) reported the recovery of the forest owlet *Athene blewitti*. Similarly, morphological and endocrine observations of pineal gland of Indian spotted owlet have also been observed (Haldar and Guchhait, 2000). Ripley (1981) elucidated on the range extension of brown wood owl (*Strix leptogrammica*). Feeding habits of the Central Indian collared scops owl *Otus bakkamoena marathae* (Ticehurst) in captivity and on the fledglings of the northern spotted owlet were described by Khajuria (1972 and 1974).

Incubation period in Northern spotted owlet, *Athene brama indica* (Franklin) was described by Lamba and Tyagi (1975). Krishnan (1985) described about the great and small owls in his book. Role of *Eucalyptus* woodlots in the conservation of owls of Punjab was described by Rishi and Sandhu (1999). Ramanujam (2004) reported inter-specific intimidatory behaviour of adult Indian eagle owl *Bubo bengalensis* (Franklin) in defence of their nestlings. Sebastian (1991) described the barn owl as man's silent ghostly friend. Williams (1998) reported the uneven sex ratio of the long-eared owl *Asio otus* in northern India.

Other countries

Owls have been studied extensively in the neighbouring countries (Ekanayaks, 1994). Friedmann and Deignan (1939) described the Asiatic owls of the genus *Otus*, with description of a new form. Roberts and King has reported on the vocalisations of the owls of the genus Otus in Pakistan. Liyanage (1972) described the Ceylon bay owl as one of Ceylon's rarest birds. A new owl species was discovered from Sri Lanka by Gunawardena (2001). Kavanagh (1997) reported on the ecology and management of large forest owl in Southeastern Australia. Simberloff (1998) reported on the flagship, umbrellas and keystone species. Appleby and Redpath (1997) reported on the indicators of male quality in the hoots of tawny owls *Strix aluco*. Similarly, Appleby *et al.* (1999) reported on the sex-specific territorial responses in the same species. Kavanagh *et al.*, (1995 b) reported on the diet and habitat of the barking owl *Ninox connivens* in New South Wales. Miller *et al.* (1997) described the habitat selection by spotted owls during natal dispersal in western Oregon. Klein Baum and Klein (2002) described about the logistic regression in their report.

2. Methods

The study was mainly based on direct observational methods (Altman, 1974). The study areas were surveyed on foot and vehicle. Observations were done with the help of binoculars (10 x 40) and on an average 20 days were spent in the field in a month. Reserve Forest areas namely the Vazhachal, Nelliampathy and Munnar were visited to familiarise with the survey methodology. Owls were surveyed during these reconnaissance surveys and the performa needed for the surveys finalised (Appendix I). Intensive surveys were carried out in the fourteen protected areas of Kerala, reserve forests and in the protected areas of Tamil Nadu. Four hours after sunset were utilised in each survey point and the details are given in Table 1. Detailed methodology of each aspect is given in the concerned Chapter.

Eight sampling points were sampled for the study from the Chimmony wildlife sanctuary. Survey was carried out during September 2005. The dominant vegetation in the sanctuary is semi-evergreen and moist deciduous forests and small portion of teak plantations. Three methods were adopted except the call playback method, as the equipment was not available during that period. Vegetation sampling was carried out during the daytime, where the census of owls was carried during the evening hours. Details of work done in other protected areas are given in the Table 1.

Table 1. Details of survey carried out in the protected areas of Kerala and Tamil Nadu

Sl.No.	Protected Areas	Period	No. of days spent in PA	No of census points
1.	Aralam Wildlife Sanctuary	10-15/09/07	6	7
2.	Attappady Reserve forest	10-12/12/07	2	4
3.	Peechi - Vazhani Wildlife Sanctuary	14-20/10/05 8-18/12/05	18	34
4.	Periyar Tiger Reserve	2-9/12/07	8	13
5.	Chimmony Wildlife Sanctuary	22-29/09/05	8	7
6.	Thattekkad Wildlife Sanctuary	14-18/11/05	5	5
7.	Parambikulam Wildlife Sanctuary	22-26/11/06	5	6

8.	Nelliampathy Reserved Forest	15-19/02/06 21-24/11/05	14	9
9.	Vazhachal Reserved Forest	7-15/03/06	9	9
10.	Chinnar Wildlife Sanctuary	4-9/09/06	6	5
11.	Neyyar Wildlife Sanctuary	20-22/05/07	2	3
12.	Peppara Wildlife Sanctuary	23-26/05/07	3	4
13.	Palani Hills	06-13/11/06	8	9
14.	Srivilliputtur Grizzled Squirrel Wildlife Sanctuary	26-30/06/06 19-20 /03/07	8	9
15.	Indira Gandhi Wildlife Sanctuary	13-19/09/06 21-26/09/06	13	13
16.	Kalakkad Mundanthurai Tiger Reserve	20-25/12/06 24/4-3/5/07 15-20/08/07	21	67
17.	Eravikulam National Park	November 2006	7	2
18.	Silent Valley National Park	02-03/11/06 01-05/02/07	6	7
19.	Shendurney Wildlife Sanctuary	27-30/05/07	3	4
20.	Wayanad Wildlife Sanctuary	19-24/02/07	6	7
21.	Idukki Wildlife Sanctuary	5-10/03/07	5	11
22.	Kanyakumari Reserve Forest	9-14/01/08	6	12
23.	Mudumalai Wildlife Sanctuary	22-28/01/08	7	9
24.	Theni Reserve forest	27/12/07- 06/01/08	11	20
	Total		**187**	**276**

Two field trips were made to Kalakad- Mundanthurai Tiger Reserve, (KMTR) and twenty one census points were covered in two forest ranges of Kalakad- Mundanthurai Tiger Reserve, which includes Papanasam and Mundanthurai Plateau. Places like Kodamadi, Karaiyar, Servalar and Papanasam were visited. Description of survey carried out in other areas is given in the Table 1. Vegetation type of the surveyed areas is given in Table 2.

Table 2. Vegetation of the surveyed study areas in Kerala and Tamil Nadu

No	Protected areas	Vegetation types
	Kerala	
1.	Peechi-Vazhani Wildlife Sanctuary	Moist deciduous forest, wet evergreen and teak plantation
2	Nelliampathy Reserved Forest	Wet evergreen, coffee and tea plantation
3.	Parambikulam Wildlife Sanctuary	Teak, wet evergreen and moist deciduous forest
4	Thattekkad Bird Sanctuary	Riparian, teak and moist deciduous forest
5	Chimmony Wildlife Sanctuary	Moist deciduous and semi evergreen
6	Chinnar Wildlife Sanctuary	Dry thorn forest and riparian forest
7	Vazhachal Reserved Forest	Wet evergreen, moist deciduous and teak plantation
	Tamil Nadu	
8	Palani Hills	Sholas, plantations and low altitude dry forests
9	Indira Gandhi Wildlife Sanctuary	Wet evergreen forest, teak plantation, dry deciduous forest and low altitude dry forests
10	Srivilliputtur Grizzled Squirrel Sanctuary	Dry deciduous forest, wet evergreen and plantations
11	Kalakkad Mundanthurai Tiger Reserve	Wet evergreen, dry deciduous forest and riparian

3. Results

3.1. STATUS AND DISTRIBUTION OF OWLS

3.1.1. Introduction

Owls of southern Western Ghats are classified into three major categories namely large owls, moderate owls and lesser owls based on the morphometric characters. Webb *et al.* (2007) and Gaston and Blackburn (2000), have considered body size as key macro ecological variable along with range size and population. With the above view, the owls with more than 400 mm of body length are classified as larger owls and owls with less than 400 mm and greater than 270 mm of body length are classified as moderate owls and those owls, which are lesser, are classified as lesser owls. Habitat preference of the owls differs with the size of bird and prey requirement differs with the body weight (Hutchinson, 1957). The lesser owls include jungle owlet, Indian scops owl, oriental scops owl, brown hawk owl and spotted owlet and among them few are common in most of the protected areas whereas agriculture depended species such as barn and spotted owlet were reported only from the fringes of the forest. Larger owls include forest eagle owl, brown fish owl and Indian eagle owl. Medium sized owls are short eared owl, mottled wood owl, brown wood owl, Ceylon bay owl and common barn owl. Sixteen species of owls have been reported from the Western Ghats and not all the owl species in the southern Western Ghats are endangered. As the study area falls in the State of Kerala and Tamil Nadu, the status of owls is presented State wise. The occurrence and distribution pattern of owls in the protected areas of Kerala and Tamil Nadu is described in this Chapter.

3.1. 2. Methods

Intensive field surveys was carried in the different vegetation types of the Western Ghats like evergreen forests, moist deciduous forest, dry deciduous forest, shola forests and grasslands. Surveys were conducted at 276 sites in the Western Ghats, using call playback and standard spotlighting as the main methods. Two other methods were also used at subsets of these sites: dusk-watch at 187 sites and a period of quiet initial listening before playback at 276 sites. Following methods were employed for the survey of owls. A total of 137 points were covered in Kerala and 139 points were censused in Tamil Nadu.

Site selection

Relevant vegetation maps and Survey of India topo sheets were collected. Sites were chosen by a stratified random sampling approach based on geographical areas (eight standard 1: 100,000 map-sheets) and different vegetation types. If preselected sites proved impractical to access, nearby alternative sites were sampled. The initial selection included more sites than needed to allow for such redundancy. Each site was at least 2 km from other site, as broadcast tapes was audible to human observers for up to 2 km.

Dusk-watch

A standard period of 15 minutes (after many trials in the field) was spent at dusk at selected sites, watching and listening quietly for unsolicited calls or movements of animals in adjacent forest. A 55 watt hand-held spotlight was used occasionally to check the identity of animals seen, but this was done sparingly to avoid disturbance. All animals seen or heard were recorded.

Initial quiet listening

A standard period of 10 minutes was spent on arrival at each site, watching and listening quietly for unsolicited calls or movements of animals in adjacent forest. A longer period of 20 minutes was used initially, but 10 minutes was found sufficient after many surveys.

Call playback

A standard call playback tape was constructed with a sequence of owl calls. This was of 2 m listening period. The sequence was planned to give maximum time for owls to respond to their own calls, as delayed responses are common in this species. This sequence was broadcast at selected sites using a 10 watt speaker, at a volume of about 120 % of the owls' natural level. Call playback surveys were conducted on calm nights with little or no rain, as wind and rain noise reduce the effectiveness of this survey method (Kavanagh and Peake, 1993; Debus, 1995). While tapes were running the observer remained several metres away to avoid distraction from tape noise. All owls and other wildlife seen or heard were recorded, along with basic information on wind, temperature and other weather conditions. For recording the calls, exploratory observations were made at Trichur Zoo and at Kannur

where owls are kept in captivity. Calls of five species of owls were collected from the Internet, which was employed for census using call playback method.

Spotlighting

At the completion of playback a 10 minute spotlighting session was conducted to check for any owls, which may have flown in silently and to survey arboreal mammals or other nocturnal wildlife. During this session, the observer walked for about 100 m in each direction along the track, searching adjacent forest by listening and using a hand-held spotlight. All animals seen or heard were recorded.

Equipments: A digital Sound Recorder and accessories (Sound Devices, U.S.A.) (Fig. 3) were imported for the use in the project and the features are given below. Call playback was done using a Sony car stereo player and two speakers.

a. Two-channels of Sound Devices next generation microphone preamps with phantom, limiters, and high-pass filters
b. Records to internal 40 GB hard drive, removable Compact Flash, or both storage medium
c. AES3 (XLR) or AES3id (unbalanced AES on BNC) digital inputs and AES3id outputs
d. Programmable, sunlight-viewable LED level metering
e. WAV format, mono or poly files, uncompressed PCM audio
f. 24-bit or 16-bit (with or without dither) and sampling at 32 kHz-192 kHz
g. MP3 encode and decode, 32 to 320 kb/s stereo file
h. Fire Wire (IEEE-1394) port for high-speed data transfer to computers

Encounter rate, Detection percentage and Relative abundance were calculated using the following formulae.

Encounter Rate = Number of owl presence encountered in a domain / total number of census point taken in that domain

Relative abundance = No. of individuals observed in a domain/ No. of census points taken in that domain

Detection percentage = Number of points where owls detected / Total number of census points.

3.1.3. Result

3.1.3.1. Western Ghats (Kerala)

Thirteen species of owls were recorded from the Western Ghats of Kerala and lesser owls namely; the jungle owlet, Indian scops owl, oriental scops owl and brown hawk owl were recorded from all the protected areas than the large owls. Out of the sixteen species of owls distributed in Kerala part of the Western Ghats, nine species are found in the forests and others in the cultivation and in open country. Two species are migratory and 14 species are resident in nature. Species of owls were recorded from the Kerala and the distribution of owls recorded from different protected areas in Kerala is given in Table 3. Number of species recorded from different protected areas is given in Fig. 4.

Eleven species of owls were recorded from the three protected areas namely the Chimmony Wildlife Sanctuary, Peechi-Vazahani Wildlife Sanctuary and Thattekkad Bird Sanctuaries. Out of the eleven species, only one species, jungle owlet *Glaucidium radiatum* was recorded from all the sampling points and from the three protected areas and other species were rare.

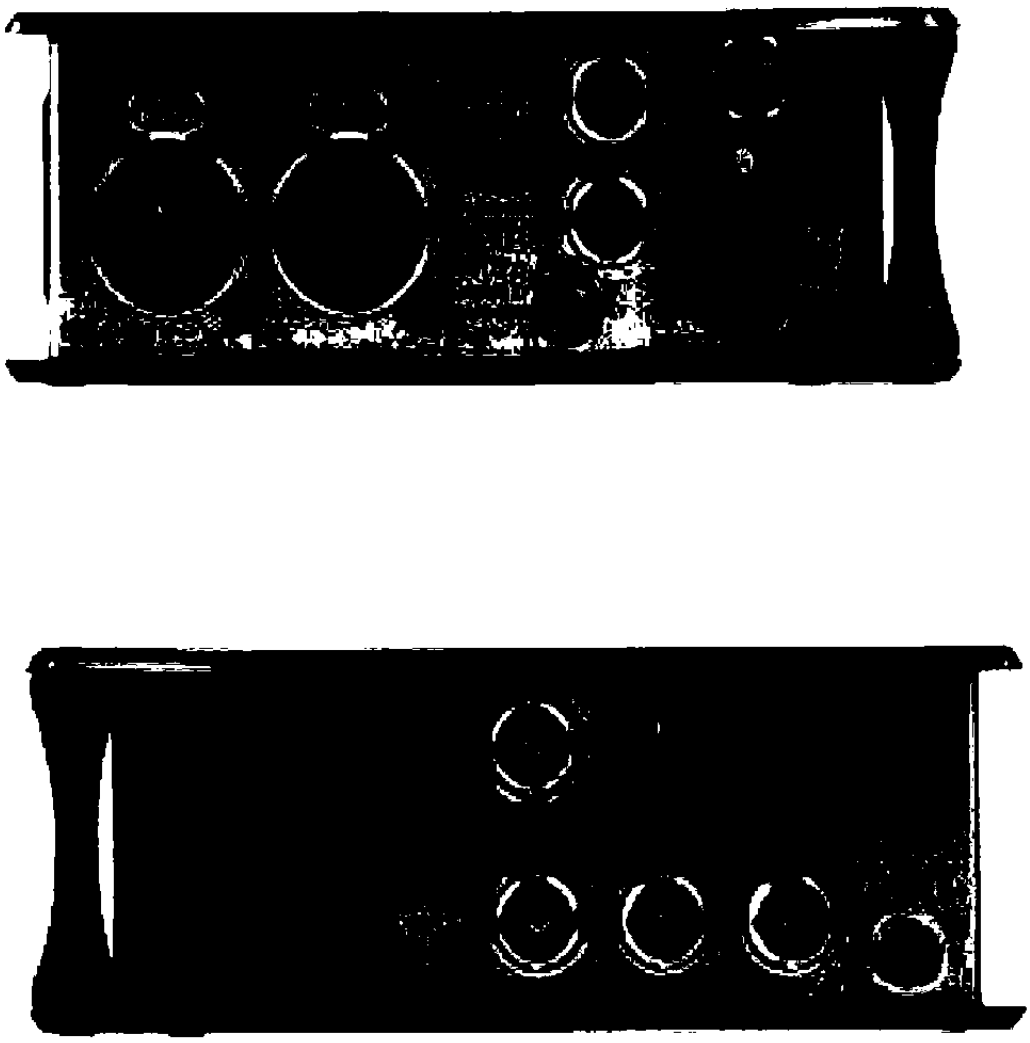
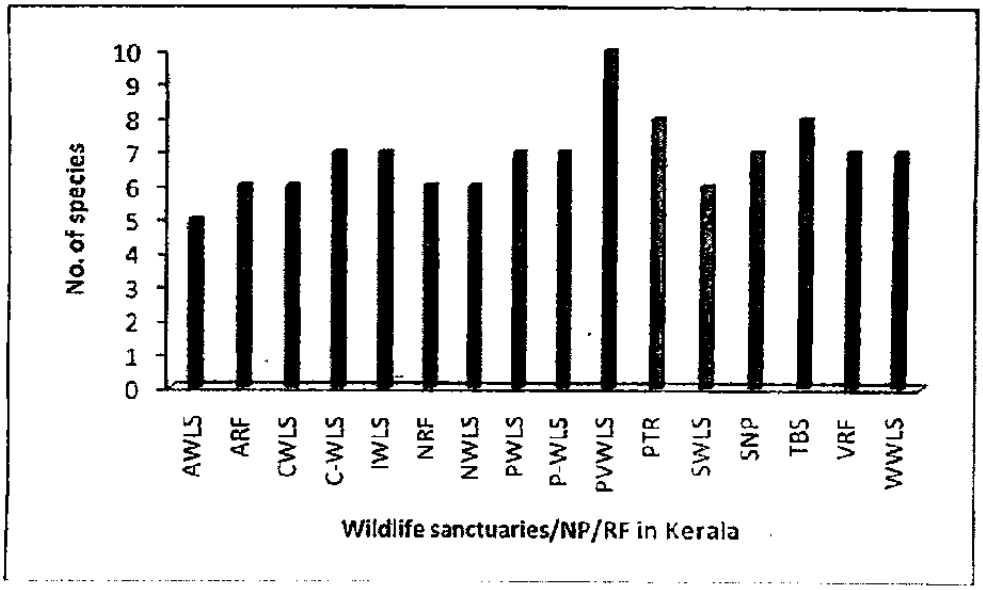


Fig. 3 Digital sound recorder used for the Call play back experiment (Sound Devices, USA)



AWLS= Aralam Wildlife Sanctuary; ARF=Attappady Reserved Forest; CWLS=Chimmony Wildlife Sanctuary; C-WLS=Chinnar Wildlife Sanctuary; ENP=Eravikulam National park; IWLS= Idukki Wildlife Sanctuary; NRF=Nelliampathy Reserved Forests; NWLS=Neyyar Wildlife Sanctuary; PWLS=Peppara Wildlife Sanctuary; P-WLS=Parambikulam Wildlife Sanctuary; PVWLS= Peechi-Vazhani Wildlife Sanctuary; PTR= Periyar Tiger Reserve; SWLS=Shendurney Wildlife Sanctuary; SNP=Silent Valley National Park; TBS=Thattekkad Bird Sanctuary; VRF=Vazhachal Reserved Forest; WWLS=Wayanad Wildlife Sanctuary.

Fig. 4 Number of species recorded from the protected areas of Kerala.

Table 3. Number of owls recorded from the protected areas of Kerala

S.No.	Species	AWLS	ARF	CWLS	C-WLS	IWLS	NRF	NWLS	PWLS	P-WLS	PVWLS	PTR	SWLS	SNP	TBS	VRF	WWLS
1	Jungle owlet (*Glaucidium radiatum*)	6	3	6	2	14	3	6	6	5	47	19	8	1	9	5	7
2	Brown hawk owl (*Ninox scutulata*)	5	-	1	-	7	8	3	7	4	20	13	7	10	2	14	12
3	Indian scops owl (*Otus bakkamoena*)	1	1	6	1	7	3	2	4	2	28	8	2	RAC(2)	4	3	1
4	Oriental scops owl (*Otus sunia*)	-	-	1	1	2	RAC (2)	-	RAC (1)	1	28	10	2	-	4	1	4
5	Brown fish owl (*Ketupa zeylonensis*)	1	2	RAC (2)	2	RAC (3)	4	RAC (2)	RAC (1)	RAC (1)	13	RAC (1)	RAC (1)	RAC (2)	RAC (3)	2	RAC (1)
6	Forest eagle owl (*Bubo nipalensis*)	1	-	-	2	-	-	-	2	1	1	1	-	2	-	RAC (1)	RAC (2)
7	Ceylon bay owl (*Phodilus asstmilis*)	-	-	-	-	1	-	1	-	-	-	2	-	RAC (1)	RAC (1)	-	-
8	Brown wood owl (*Strix leptogrammica*)	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-
9	Short eared owl *(Asio flammeus)*	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
10	Indian eagle owl (*Bubo bengalensis*)	-	IN	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Spotted owlet *(Athene brama)*	-	RAC (1)	-	-	-	-	-	-	-	RAC (4)	-	-	-	RAC (1)	-	-
12	Mottled wood owl *(Strix oceliata)*	-	1	-	IN	-	IN	IN	IN	IN	-	IN	IN	IN	RAC (2)	IN	IN
13	Indian Common Barn Owl *(Tyto alba)*	-	-	-	IN	IN	-	-	-	-	RAC (1)	-	-	-	-	-	-
Total		14	7	16	8	31	18	12	19	13	140	53	19	13	19	25	24

AWLS= Aralam Wildlife Sanctuary; ARF=Attappady Reserved Forest; CWLS=Chimmony Wildlife Sanctuary; C-WLS=Chinnar Wildlife sanctuary; ENP=Eravikulam National park; IWLS= Idukki Wildlife Sanctuary; NRF=Nelliampathy Reserved Forests; NWLS=Neyyar Wildlife Sanctuary; PWLS=Peppara Wildlife Sanctuary; P-WLS=Parambikulam Wildlife Sanctuary; PVWLS= Pecchi-Vazhani Wildlife Sanctuary; PTR= Periyar Tiger Reserve; SWLS=Shendurney Wildlife Sanctuary; SNP=Silent valley National Park; TBS=Thattekkad Bird Sanctuary; VRF=Vazhachal Reserved Forest; WWLS=Wayanad Wildlife Sanctuary.
IN=Indirect; RAC=Recorded After Census
RAC = Recorded After the Census period; IN=Indirect Evidences

Apart from the dry forests of Chinnar Wildlife Sanctuary and Attappady Reserve Forest, brown hawk owl was recorded in all the protected areas and the population highly varied between the protected areas. A pair of forest eagle owls was recorded near the Chinnar River in the Chinnar Wildlife Sanctuary. This species utilized riparian forest adjacent to the dry thorn forest, which supported good population of black-naped hare and grizzled giant squirrels. These two species are the major known prey of the Forest eagle owl. Number of owls detected using different census methods are given in Fig. 4.

Efficiency of survey methods: Out of the four methods applied to locate the owls in the sampling points, call play back yielded highest encounter rate (0.64) followed by initial quiet listening (0.51). Spot lighting method produced lowest encounter rate (0.18).

Dusk – watch

Table 4 shows the importance of dusk watch method for detecting owls in southern Western Ghats. Out of the 187 census points surveyed using the dusk watch method, only in 52 points (28 %) one owl species was detected. Dusk watch method was not efficient in six of the surveyed areas, and no owls could be detected. Highest encounter rate of owls using the dusk watch method was observed in Peppara Wildlife Sanctuary.

Table 4. Encounter rate of owls using the dusk- watch method

Sl. No.	Protected areas /Reserved Forest	No. of points where owls detected	Total census points	Encounter rate
1.	Aralam Wildlife Sanctuary	0	6	0.00
2.	Attappady Reserve Forest	0	2	0.00
3.	Chimmony Wildlife Sanctuary	0	8	0.00
4.	Chinnar Wildlife Sanctuary	1	6	0.17
5.	Eravikulam National Park	0	7	0.00
6.	Idukki Wildlife Sanctuary	3	5	0.60
7.	Indira Gandhi Wildlife Sanctuary	4	13	0.31
8.	Kanyakumari Reserve Forest	0	6	0.00
9.	Kalakkad Mundanthurai Tiger Reserve	7	21	0.33

10.	Mudumalai Wildlife Sanctuary	2	7	0.29
11.	Nelliampathy Reserved Forest	2	14	0.14
12.	Neyyar Wildlife Sanctuary	1	2	0.50
13.	Palani Hills	1	8	0.13
14.	Parambikulam Wildlife Sanctuary	0	5	0.00
15.	Peechi - Vazhani Wildlife Sanctuary	11	18	0.61
16.	Peppara Wildlife Sanctuary	3	3	1.00
17.	Periyar Tiger Reserve	1	8	0.13
18.	Shendurney Wildlife Sanctuary	1	3	0.33
19.	Silent Valley National Park	1	6	0.17
20.	Srivilliputtur Grizzled Squirrel Wildlife Sanctuary	1	8	0.13
21.	Thattekkad Wildlife Sanctuary	3	5	0.60
22.	Theni Reserve Forest	6	11	0.55
23.	Vazhachal Reserved Forest	2	9	0.22
24.	Wayanad Wildlife Sanctuary	2	6	0.33
	Grand Total	**52**	**187**	**0.28**

Initial quiet listening (IQL)

Encounter rate of owls is comparatively higher than the dusk watch and spotlight searches when IQL method is employed (Table 5). The overall encounter rate showed that more than 57 % of census points had high chance to sight at least one owl species using this census method. Except in eight locations, the encounter rate was higher than 50 %, using this method.

Table 5. Encounter rate of owls using initial quiet listening method

Sl. No.	Protected areas /Reserved Forest	No. of points where owls detected	Census points	Encounter rate
1.	Aralam Wildlife Sanctuary	3	7	0.43
2.	Attappady Reserve forest	1	4	0.25
3.	Chimmony Wildlife Sanctuary	6	7	0.86
4.	Chinnar Wildlife Sanctuary	1	5	0.20
5.	Eravikulam National Park	0	2	0.00
6.	Idukki Wildlife Sanctuary	9	11	0.82
7.	Indira Gandhi Wildlife Sanctuary	7	13	0.54
8.	Kanyakumari Reserve Forest	3	12	0.25

9.	Kalakkad Mundanthurai Tiger Reserve	26	67	0.39
10.	Mudumalai Wildlife Sanctuary	7	9	0.78
11.	Nelliampathy Reserved Forest	4	9	0.44
12.	Neyyar Wildlife Sanctuary	3	3	1.00
13.	Palani Hills	4	9	0.44
14.	Parambikulam Wildlife Sanctuary	4	6	0.67
15.	Peechi - Vazhani Wildlife Sanctuary	26	34	0.76
16.	Peppara Wildlife Sanctuary	4	4	1.00
17.	Periyar Tiger Reserve	10	13	0.77
18.	Shendurney Wildlife Sanctuary	2	4	0.50
19.	Silent valley National Park	4	7	0.57
20.	Srivilliputtur Grizzled Squirrel Wildlife Sanctuary	7	9	0.78
21.	Thattekkad Wildlife Sanctuary	4	5	0.80
22.	Theni Reserve Forest	13	20	0.65
23.	Vazhachal Reserved Forest	4	9	0.44
24.	Wayanad Wildlife Sanctuary	5	7	0.71
	Grand Total	**157**	**276**	**0.57**

Call playback

Call playback of conspecific calls of the owls was not employed in the nineteen points of Peechi-Vazhani, five points of Thattekkad and seven points of Chimmony Wildlife Sanctuary, as these surveys were carried out in the initial period of the study. Only, 245 census points were surveyed with call playback method and it elicited response 159 times from owls. Overall encounter rate of owls in the southern Western Ghats using the call playback method was higher, when compared to other methods including dusk watch, initial quiet listening and spotlight searches. In 65 % of the census points, at least one owl species responded to its interspecific or intraspecific calls. In most of the protected areas, the encounter rate of the owls using call playback method was more than 50 %, which is largely due to the existence of the territorial behaviour among the owls (Table 6).

Table 6. Encounter rate of owls using call playback method

Sl. No.	Protected areas /Reserved Forest	No. of points where Owls detected	Census points	Encounter rate
1.	Aralam Wildlife Sanctuary	5	7	0.71
2.	Attappady Reserve forest	2	4	0.50
3.	Chinnar Wildlife Sanctuary	2	5	0.40
4.	Eravikulam National Park	0	2	0.00
5.	Idukki Wildlife Sanctuary	10	11	0.91
6.	Indira Gandhi Wildlife Sanctuary	8	13	0.62
7.	Kanyakumari Reserve Forest	9	12	0.75
8.	Kalakkad Mundanthurai Tiger Reserve	31	67	0.46
9.	Mudumalai Wildlife Sanctuary	8	9	0.89
10	Nelliampathy Reserved Forest	7	9	0.78
11	Neyyar Wildlife Sanctuary	3	3	1.00
12	Palani Hills	0	9	0.00
13	Parambikulam Wildlife Sanctuary	5	6	0.83
14	Peechi - Vazhani Wildlife Sanctuary	11	15	0.73
15	Peppara Wildlife Sanctuary	4	4	1.00
16	Periyar Tiger Reserve	13	13	1.00
17	Shendurney Wildlife Sanctuary	4	4	1.00
18	Silent Valley National Park	7	7	1.00
19	Srivilliputtur Grizzled Squirrel Wildlife Sanctuary	6	9	0.67
20	Theni Reserve forest	9	20	0.45
21	Vazhachal Reserved Forest	8	9	0.89
22	Wayanad Wildlife Sanctuary	6	7	0.86
	Grand Total	**158**	**245**	**0.64**

Spotlight method

The effectiveness of the spotlight method indicated that the encounter rate of owls is lower than the other three census methods (Table 7). In most of the surveyed areas, the encounter rate was zero, which is largely due to the thick canopy. Similar problems have also been reported while surveying nocturnal mammals using spotlight searches. However in Australia (Lyon *et al.*, 2001) and other temperate countries (Forsman,1984) the encounter rate of owls was reported in higher numbers using spotlight and call playback methods because the available tree assemblage in those

countries is temperate and would allow the researcher to scan through the trees without missing an owl during night hours.

Table 7. Encounter rate of owls using spotlight method

Sl. no.	Protected areas / Reserved Forest	No. of points where owls detected	Census points	Encounter rate
1.	Aralam Wildlife Sanctuary	1	7	0.14
2.	Attappady Reserve forest	1	4	0.25
3.	Chimmony Wildlife sanctuary	3	7	0.43
4.	Chinnar Wildlife Sanctuary	0	5	0.00
5.	Eravikulam National Park	0	2	0.00
6.	Idukki Wildlife Sanctuary	0	11	0.00
7.	Indira Gandhi Wildlife Sanctuary	5	13	0.38
8.	Kanyakumari Reserve Forest	3	12	0.25
9.	Kalakkad Mundanthurai Tiger Reserve	8	67	0.12
10.	Mudumalai Wildlife Sanctuary	1	9	0.11
11.	Nelliampathy Reserved Forest	0	9	0.00
12.	Neyyar Wildlife Sanctuary	0	3	0.00
13.	Palani Hills	4	9	0.44
14.	Parambikulam Wildlife Sanctuary	2	6	0.33
15.	Peechi - Vazhani Wildlife Sanctuary	13	34	0.38
16.	Peppara Wildlife Sanctuary	1	4	0.25
17.	Periyar Tiger Reserve	0	13	0.00
18.	Shendurney Wildlife Sanctuary	0	4	0.00
19.	Silent valley National Park	1	7	0.14
20.	Srivilliputtur Grizzled Squirrel Wildlife Sanctuary	2	9	0.22
21.	Thattekkad bird sanctuary	2	5	0.40
22.	Theni Reserve forest	2	20	0.10
23.	Vazhachal Reserved Forest	0	9	0.00
24.	Wayanad Wildlife Sanctuary	1	7	0.14
	Total	**50**	**276**	**0.18**

Chimmony Wildlife Sanctuary

Seven selected points were sampled and 16 owls belonging to six species were recorded. Among the three species, jungle owlet was the common and the rest of them were scarce (Table 3). Calls of the brown hawk owl were heard during daytime, which indicated that they are active even up to 10 am during the month of September. Three jungle owlet calls were heard during the initial quiet listening. No animals were found except two bats during the spot lighting. Two calls of jungle nightjar was heard, which was like *uk, trootroo.* One more jungle owlet call also heard at 2015 hours. While doing vegetation sampling an Indian scops owl was sighted on a dead branch at 6 m height. Two brown wood owl calls were heard in the initial quiet listening period. All the points were adjoining to the Reservoir. Two jungle owlet calls were heard in the dense forest, which was dominated by semi-evergreen and riverine forests.

Two nightjars namely the jungle and long-tailed nightjars were recorded. One Indian scops owl, roosted near the census points, but exact location could not be located due to the dense climbers. These owls were making calls before leaving the daytime roosts. The duration of calls and bouts varied from species to species. It was eleven to fifteen call notes in two bouts for brown hawk owl, while it was only eight to nine for Indian scops owl. While leaving the roosting site, the owls produced dispersal calls then immediately the neighbouring species also started to produce its own call. This behaviour was observed between Indian scops owl and jungle nightjar and jungle owlet.

Peechi –Vazahani Wildlife Sanctuary

In this Sanctuary also, the jungle owlet was the common species. Calls of brown fish owl were heard twice in the moist deciduous forest, where the under canopy was recently cleared for plantation activities and the site was adjacent to a check dam. Two daytime roost sites of jungle owlet were observed and both were on dead vertical branches of old trees. A total of 140 owls of eight species were recorded in the pre-selected points during 18 days of night survey. In addition to this, two more species were observed outside the census points, which included common barn owl

and short cared owl. Among them, short eared owl was a wintering migrant to the Western Ghats. Out of the ten observed, jungle owlet has the highest probability of being encountered (3.67 owls per point) and this species was highly vocal during the breeding season. In an incident during the month of October at 6.30 pm, a brown hawk owl in a teak plantation was chased away by a racket tailed drongo while feeding.

Thattekkad Bird Sanctuary

Nineteen individual owls of eight species were recorded from the Sanctuary. Majority of the sampling points in this Sanctuary were placed not exceeding more than 500 m from the reservoir. Teak (*Tectona grandis*) was the dominant species in the area and a small portion of natural tropical wet evergreen patch exists at the fringes of the teak plantation. Four sampling points provided at least one owl during the census. Daytime roost of three species namely Indian scops owl, mottled wood owl and brown fish owl was recorded.

Silent Valley National Park

Three days were initially spent in the Silent Valley National Park during August 2006. However, the surveys did not yield any sighting of owls mainly due to the heavy rainfall experienced during the period. Another trip was again made to the National Park, seven census points were additionally surveyed during February, and seven species of owls were recorded. Altogether thirteen individuals were recorded from the National Park. In all the census points, at least a single individual of brown hawk owl was recorded. Moreover, two responses were heard from the forest eagle owl once at Puchapara and another near the wet evergreen forests of Panthanthodu. In both the cases, the census points were adjacent to open rocky areas and dominated by grass, which provided suitable hunting place in the thick wet evergreen forest.

Parambikulam Wildlife Sanctuary

Thirteen owls of five species were observed in the six preselected census points and a maximum of five jungle owlets were recorded. Forest eagle owl was recorded near the Parambikulam Guest House. Large owls were very low in number.

Nelliampathy Reserve Forest

Seven points were selected for the survey in the Nelliampathy Reserve Forest, from which 18 owls of four species were recorded. In addition to this, two more species were sighted outside the census points namely the mottled wood owl and oriental scops owl. Among the four species, brown hawk owl was often encountered in the census points than the other species. This may be due to the evergreen habitat of Nelliampathy. The relative abundance of owl in the Nelliampathy Reserve Forest was 2 owls per point.

Vazhachal Reserve Forest

A total of 25 owls of 5 species were encountered in the Vazhachal Reserve Forest in which brown hawk owl was predominant. The vocal response of brown hawk owl was found to be higher in this Sanctuary than in the other protected areas. The brown hawk owl was highly vocal during the breeding season (January to March). Number of sightings of owls was increasing with the breeding season of the year. The relative abundance of this owl in the protected area was 2.78 owls per point.

Chinnar Wildlife Sanctuary

Eight owls of five species were recorded from the Chinnar Wildlife Sanctuary and two species were recorded outside the census points. A pair of Indian scops owl responded to call playbacks and similarly it responded immediately to the Jungle owlet call. Indian scops owl was aggressive over inter and intra species calls due to the defending of the breeding territory. Encounter rate of owls in the protected areas of Kerala is given in Table 8 and species -wise encounter rate of owls is given in Table 9.

Table 8. Relative abundance of owls in the protected areas of Kerala*

Sl. no.	Protected Areas/RF	No. of owls	No. of census points	Relative abundance
1	Aralam Wildlife Sanctuary	14	7	2.00

2	Attappady Reserved Forest	7	4	1.75
3	Chimmony Wildlife Sanctuary	16	7	2.29
4	Chinnar Wildlife Sanctuary	8	5	1.60
5	Idukki Wildlife Sanctuary	31	11	2.82
6	Nelliampathy Reserved Forests	18	9	2.00
7	Neyyar Wildlife Sanctuary	12	3	4.00
8	Peppara Wildlife Sanctuary	19	4	4.75
9	Parambikulam Wildlife Sanctuary	13	6	2.17
10	Peechi-Vazhani Wildlife Sanctuary	140	34	4.12
11	Periyar Tiger Reserve	53	13	4.08
12	Shendurney Wildlife Sanctuary	19	4	4.75
13	Silent Valley National Park	13	7	1.86
14	Thattekkad Bird Sanctuary	19	5	3.80
15	Vazhachal Reserved Forest	25	9	2.78
16	Wayanad Wildlife Sanctuary	24	7	3.43
	Total	**431**	**135**	**3.19**

*Eravikulam National Park (2 census points) is not included in the Table as no owls were detected during census.

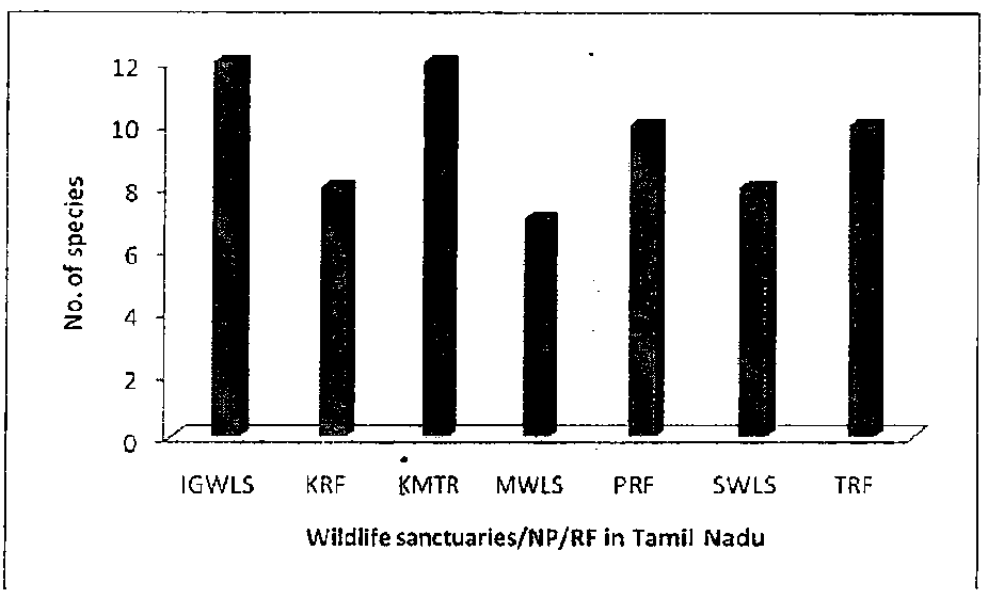
Table 9. Species wise encounter rate of owls from Kerala

Sl. no.	Species	Number of individuals	Encounter Rate
1	Jungle owlet	97	0.98
2	Brown hawk owl	86	0.87
3	Indian scops owl	56	0.57
4	Brown fish owl	16	0.16
5	Forest eagle owl	5	0.05
6	Ceylon Bay Owl	2	0.02
7	Brown wood owl	4	0.04
8	Oriental scops owl	2	0.02

9	Long eared owl	2	0.02
10	Short eared owl	1	0.01
	Total	**271**	**2.74**

3.1.3.2 Western Ghats (Tamil Nadu)

Areas surveyed in Tamil Nadu portions of the Western Ghats generally fall in the rain shadow areas and hence dry forests and hillocks dominated the vegetation. Status of owls in the protected areas of Tamil Nadu is given in Table 10. The overall distribution pattern of owls in the eastern side of the Western Ghats showed that the community was dominated by the larger owls than that of western side of Ghats. This is largely owing to the presence of hillocks and agricultural pastures. These patches support wide variety of rodents including rats and hares. Among the lesser owls, Indian scops owl dominated the lesser owl community than that of the western sides where jungle owlet was dominating the community. Mining, poaching and local hunting due to superstitious beliefs, grazing and occasional egg collections make their numbers less. Number of species recorded from Tamil Nadu is given in Fig. 5.



IGWLS=Indira Gandhi Wildlife Sanctuary; KRF=Kanyakumari Reserved Forest; KMTR=Kalakkad-Mundanthurai Tiger Reserve; MWLS=Mudumalai Wildlife Sanctuary; PRF=Palani Reserved forests; SWLS=Srivilliputtur grizzled giant Squirrel Wildlife Sanctuary; TRF=Theni Reserved Forests

Fig. 5 Species of owls recorded from the protected areas of Tamil Nadu

Mudumalai Wildlife Sanctuary

Although Nilgiris drastically changed with the increasing human population, still some untouched patches of deciduous and evergreen forests exist as home to larger mammals including tiger and elephant. Besides these, the area also supports wide array of avifauna. Altogether 9 census points were taken from this Wildlife Sanctuary and seven species of owls were recorded. Jungle owlet dominated the owl community of the Sanctuary followed by brown hawk owl and oriental scops owl. A forest eagle owl was sighted near water body and it was observed from a roosting site.

Palani Hills

Ten species of owls were recorded from the Palani Hills. Even though the Palani Hills is drastically changed due to the anthropogenic pressures during the last ten decades, the area still holds, some of the remnant patches of the natural forest in the mid and low elevations. Within the remnant forests, trees with multitier canopy, large DBH and good height support rich avifauna, especially the nocturnal and top predators such as owls and owlets. Poor midcanopy in the riparian and moist deciduous forests allows larger owls to fly freely and forage efficiently on the canopy dwelling rodents. Besides the large and live trees, the owls often utilize the dead vertical stumps or leafless branches for foraging and to perch. Selection of perch or foraging sites of large owls is also influenced by the availability of open rocks or clearings. The lesser owls utilize the tree gaps or evenly spaced habitats such as plantations and selectively logged forest during the dusk hours. Two species of owls namely the brown wood owl and brown hawk owl are good examples for this. In the case of brown wood owl and Indian eagle owl the selection of foraging sites was different. Indian eagle owl utilized the dry thorn forest where as the brown wood owl preferred the moist forest in the mid altitude. The forest eagle owl was also sighted from low altitude riparian forests. Brown wood owl was recorded twice in the mid altitude at Palani Hills, where riparian forests was less disturbed.

Among the habitat types, dry deciduous forest and riparian forests dominates the lower elevation and the annual rainfall of the low elevation forests were less than 1200 mm. Hence, the occurrence of jungle owlet and Indian scops owl in the low elevation dry deciduous forest was higher. Call playback response was high among

the lesser owls of the Sanctuary and the attacking behaviour and approaching to the responder was not recorded.

Indira Gandhi Wildlife Sanctuary

Altogether 30 individuals of eight species of owls were recorded during the survey and four more species were sighted after the census hours. A maximum of 12 individuals were recorded during the initial quite listening period. Jungle owlet was the dominant lesser owl and the Indian eagle owl was the dominant in the larger owl category. Both the species occupied different habitat niches and the previous one is often encountered in the mid and low altitude woodlands whereas the latter one was recorded in the dry thorn forest with large tracts of open rocky areas surrounded by agricultural areas.

Srivilliputtur Grizzled Giant Squirrel Wildlife Sanctuary

The topography of the Srivilliputtur Grizzled Squirrel Wildlife Sanctuary is highly undulating with high slope in the low elevations. The low altitude dry deciduous forests with heavy slope hold good population of the jungle owlet and the Indian scops owl. The Indian scops owl restricts its distribution to the riparian zones between the dry deciduous forest patches. Pair formation in jungle owlet was initiated during September. The reported breeding season was beginning only from December to March. This was revealed by the increased territorial calls during the early hours of the day and in late evenings. In the beginning of March 2007, two more census points were surveyed in the mango and coconut grooves adjacent to the dry deciduous forest. The results were similar to the Indira Gandhi Wildlife Sanctuary and the presence of two species of larger owls namely, the brown fish owl and mottled wood owl were recorded. A pair of juvenile mottled wood owls was also sighted during the daytime in a coconut groove. Old nesting trees and nest sites of mottled-wood owl were recorded in the mango trees. Two nests were on the broken branches and one nest was on a platform between the two primary branches.

Kalakkad Mundanthurai Tiger Reserve

During the initial survey in the .month of December 2006, the northeast monsoon was at its peak and the detection of owls in the Tiger Reserve was comparatively low. Five individuals of two species were recorded from the census points. Besides these, two more owls were recorded outside the census points. Nest of Indian scops owl was recorded in the semi evergreen forest of Kodamadi in the Mundanthurai Range. In another survey during the last week of December 2006, sixteen census points were covered in four low altitude habitats, which included dry thorn forest, riparian forest, dry deciduous forest and semi-evergreen forest. We were unable to record more species of larger owls in the low altitudes, even though the important sighting of the larger owls was mainly from the dry thorn forests in the Tamil Nadu part of the Western Ghats. Three individuals of Ceylon bay owl were detected in the semi evergreen forest of Kodamadi. Interestingly, a single Jungle owlet alone was sighted in the census points, even though the similar altitude (190 m) and habitat (Dry deciduous forest) hold good population of jungle owlet in the Srivilliputtur Grizzled Squirrel Wildlife Sanctuary and the Indira Gandhi Wildlife Sanctuary (Table 4). In both the sanctuaries, the dry deciduous forest was severely disturbed due to anthropogenic pressures. Similarly, the owlet was sighted from the Tiger Reserve near the Servalar dam, where the human pressure is common.

Kanyakumari Reserved Forests

This is the southernmost forest area of Western Ghats, which holds some remnant patches of evergreen and deciduous forest and it is contiguous with the Kalakkad Mundanthurai Tiger Reserve. The topography of the forests is highly undulating and in high altitude, the vegetation is modified into coffee and other cash crops. A total of 12 census points were taken and 8 species of owls were identificd. The jungle owlet and Indian scops owl dominated the owl community.

Table 10. Status of owls in the protected areas of Tamil Nadu

Sl. No.	Species	IGW LS	KRF	KMTR	MWLS	PRF	SWLS	TRF
1.	Jungle owlet (*Glaucidium radiatum*)	11	9	4	11	RAC (1)	8	6
2.	Brown hawk owl (*Ninox scutulata*)	1	1	26	8	RAC (1)	3	2
3.	Indian scops owl	6	9	29	5	2	3	7
4.	Oriental scops owl (*Otus sunia*)	4	2	5	8	RAC (2)	RAC (1)	1
5.	Brown fish owl (*Ketupa zeylonensis*)	RAC (2)	RAC (1)	14	1	-	RAC (3)	1
6.	Forest eagle owl (*Bubo nipalensis*)	RAC (1)	-	RAC (2)	1	3	-	1
7.	Ceylon bay owl (*Phodilus assimilis*)	RAC (1)	-	3	-	-	-	-
8.	Brown wood owl (*Strix leptogrammica*)	1	-	1	-	2	-	-
9.	Indian eagle owl (*Bubo bengalensis*)	3	-	6	-	2	-	15
10.	Spotted owlet (*Athene brama*)	1	1	4	-	2	RAC (1)	5
11.	Mottled wood owl ((*Strix ocellata*)	3	RAC (1)	4	IN	3	2	4
12.	Indian common barn owl (*Tyto alba*)	RAC (1)	RAC (1)	RAC (2)	-	RAC	RAC (1)	RAC (2)
Total		**30**	**22**	**96**	**34**	**14**	**16**	**42**

IGWLS=Indira Gandhi Wildlife Sanctuary; KRF=Kanyakumari Reserved Forest; KMTR=Kalakkad-Mundanthurai Tiger Reserve; MWLS=Mudumalai Wildlife Sanctuary; PRF=Palani Reserved forests; SWLS=Srivilliputtur grizzled giant Squirrel Wildlife Sanctuary; TRF=Theni Reserved Forests.

RAC = Recorded after the census period; Number of locations surveyed is given in parenthesis

Considering the importance of riparian forest for the conservation of nocturnal avian predators like owls, we initially focused on riparian forest areas of Mundanthurai and Papanasam. Detection of owls was comparatively higher in the habitats of semi evergreen and riparian forest of Mundanthurai. Relative abundance of owls in the protected areas of Tamil Nadu is given in Table 11. Similarly, species - wise encounter rate of owls in Tamil Nadu is given in Table 12.

Table 11. Relative abundance of owls in the protected areas of Tamil Nadu

Sl.No.	Protected Areas/RF	No. of owls	No. of census points	Relative abundance
1	Indira Gandhi Wildlife Sanctuary	30	13	2.31
2	Kanyakumari Reserved Forest	22	12	1.83
3	Kalakkad-Mundanthurai Tiger Reserve	96	67	1.43
4	Mudumalai Wildlife Sanctuary	34	9	3.78
5	Palani Reserved forests	14	9	1.56
6	Srivilliputtur grizzled giant Squirrel Wildlife Sanctuary	16	9	1.78
7	Theni reserved forest	42	20	2.10
	Total	**254**	**139**	**1.83**

Table 12. Species -wise encounter rate of owls in Tamil Nadu

Sl.No.	Species	Number of individuals	Encounter Rate
1	Jungle owlet	51	0.39
2	Brown hawk owl	37	0.28
3	Indian scops owl	54	0.41
4	Brown fish owl	21	0.16

5	Forest eagle owl	3	0.02
6	Ceylon bay owl	3	0.02
7	Brown wood owl	4	0.03
8	Oriental scops owl	13	0.10
9	Indian eagle owl	26	0.20
10	Spotted owlet	12	0.09
11	Mottled wood owl	13	0.10
	Total	**237**	**1.80**

3.1.3.3 Distribution of owl species

Jungle owlet

The overall encounter rate of the jungle owlet was 0.71 owls/point, which was highest among the owls. The distribution of the species is starting from the coastal areas of Kerala (Perambra, near Calicut and Kottayam) to the high ranges of Western Ghats (Munnar). However, the species was not recorded from the coastal areas of Tamil Nadu, which may be due to existence of agro-environments (Nagarajan, 1998) and dry zones (Mani, 1974). In certain places of Kerala like Peechi, both spotted owlet and jungle owlet were observed co-existing. Jungle owlet was not reported from the foothills of Tamil Nadu and it was mostly recorded above the dry deciduous forests in eastern portions (Fig. 6). In more than 8 protected areas, the species was present in more than 75 % of census plots.

Brown hawk owl

The distribution range of brown hawk owl in the southern Western Ghats is given in Fig. 7. This elusive species has been reported from most of the sanctuaries and reserved forests of Kerala and Tamil Nadu except the Chinnar Wildlife Sanctuary and Attappady Reserve Forest where the census was mainly carried out in the low altitudes and not yielded any sighting (Table 13). Brown hawk owl is not a common Strigidae and is usually found in the moist portions of the southern Western Ghats. The species was not observed earlier from the coastal areas of Tamil Nadu and Kerala but the results of Chennai bird race revealed the presence of the species from Chennai. Initial quiet listening is an efficient method to record the presence or

absence of brown hawk owl in census points before attempting the call playback sequences, which will help in deriving conclusions on interspecific as well as intra specific behaviour.

Table 13. Distribution and encounter rate of brown hawk owl in different protected areas

Sl.No.	Protected areas	Number of census points	Number of points where owls were detected	Percentage detection
	Kerala			
1.	Peechi-Vazhani WLS	16	6	37.50
2.	Chimmony WLS	6	1	16.66
3.	Thattekkad Bird Sanctuary	4	2	50.00
4.	Parambikulam WLS	4	1	25.00
5.	Nelliampathy Reserved Forest	6	4	**66.67**
6.	Vazhachal Reserved Forest	6	4	**66.67**
7.	Chinnar WLS	4	0	00.00
	Tamil Nadu			
8.	Palani Hills	6	0	00.00
9.	Srivilliputtur WLS	6	1	16.67
10.	Indira Gandhi WLS	12	1	08.33
11.	Kalakkad-Mundanthurai Tiger Reserve	5	1	20.00
	Total	**75**	**21**	

Indian scops owl

This is a rare owl species of the southern Western Ghats, which was recorded from most of the forest areas of Tamil Nadu and Kerala. The species was not recorded from the coastal areas of Kerala, but it was recorded from the coastal areas of Tamil

Nadu. Considerable number of sightings of this species was from the higher reaches of the Western Ghats. The call repertoire of the species varied between the populations of Western Ghats and the East coast. The earlier Western Ghats population produced an advertisement call like *wuk* and the latter produced the same call like *krok*. Further observations on the vocal behaviour of the species may help in identifying sub species. In the majority of the protected areas sighting of the species was less than 50% in the census plots (Fig. 8).

Oriental scops owl

A rare Strigidae found in the Western Ghats and the species was recorded mostly from the well-wooded zones of Kerala and Tamil Nadu. The species was not reported from the coastal areas of both the States and even from the interior parts. The species was mainly recorded from the forested areas.

Ceylon bay owl

The sub species of Ceylon bay owl is now considered as a separate species, which is endemic to the Western Ghats and Sri Lanka (Rasmussen and Anderton, 2005). The species has disjunctive distribution in India (Sikkim). Moreover, the species is quite rare in its distributional limits including the Western Ghats and Sri Lanka. The species has a narrow range of distribution in the southern Western Ghats. The occurrence of the species was confirmed from two extreme areas namely the Silent Valley in the North and the Kalakkad - Mundanthurai Tiger Reserve in the South. Nevertheless, the distribution range of the species has further extended towards North *i.e.* Upper Kanara of Karnataka (Vasudeva *et al.*, 2005).

Brown fish owl

It is a rare, larger owl of the southern Western Ghats. The species was not reported from the coastal areas of both the States, but recorded from the interior countryside (home gardens adjacent to the Ghats) of the Kerala. The species currently inhabits in southern Asia from Asia Minor in the West to Vietnam and southern China in the East (Milkovsky, 2003). The past distribution of the species is available from

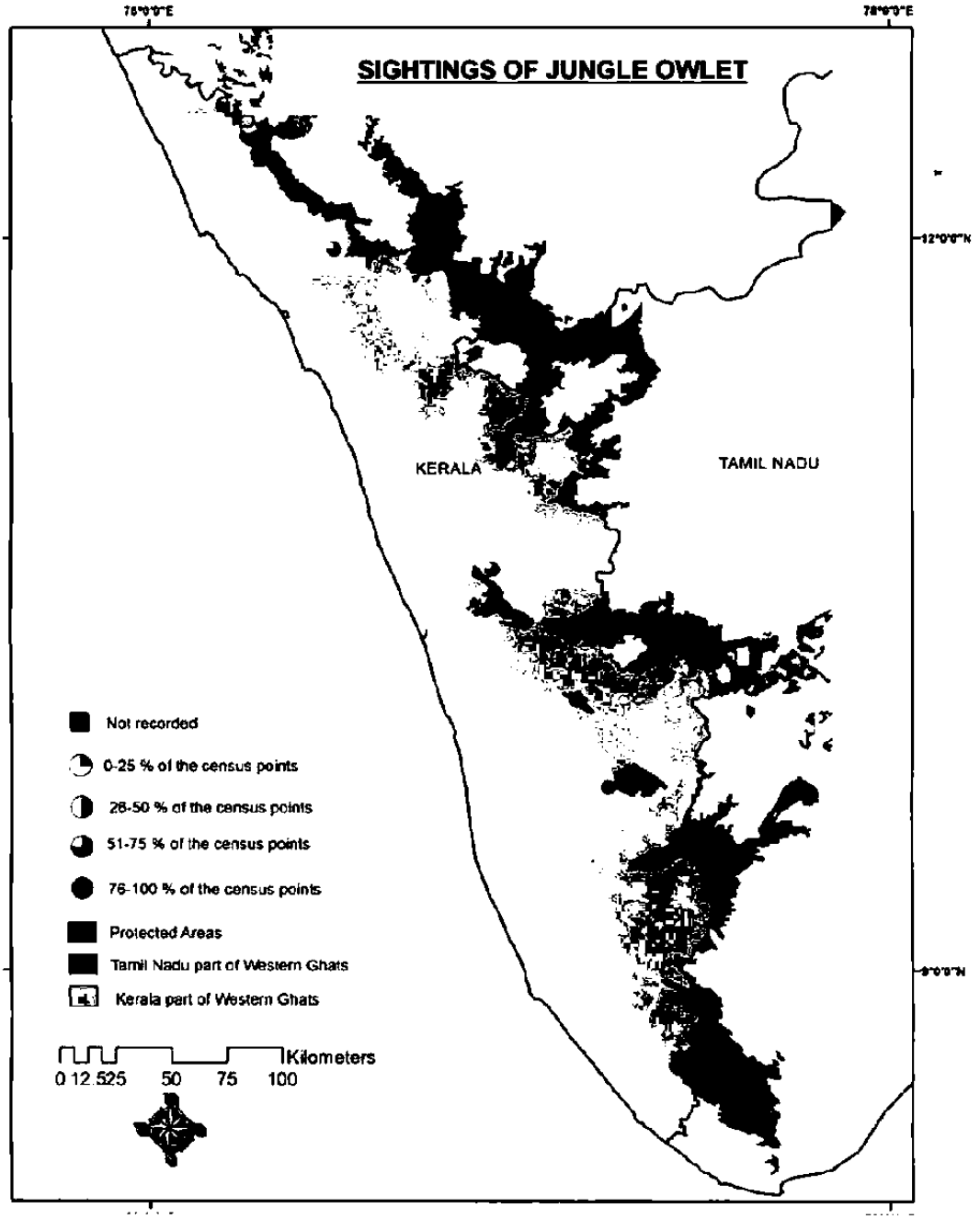


Fig. 6 Distribution of Jungle owlet

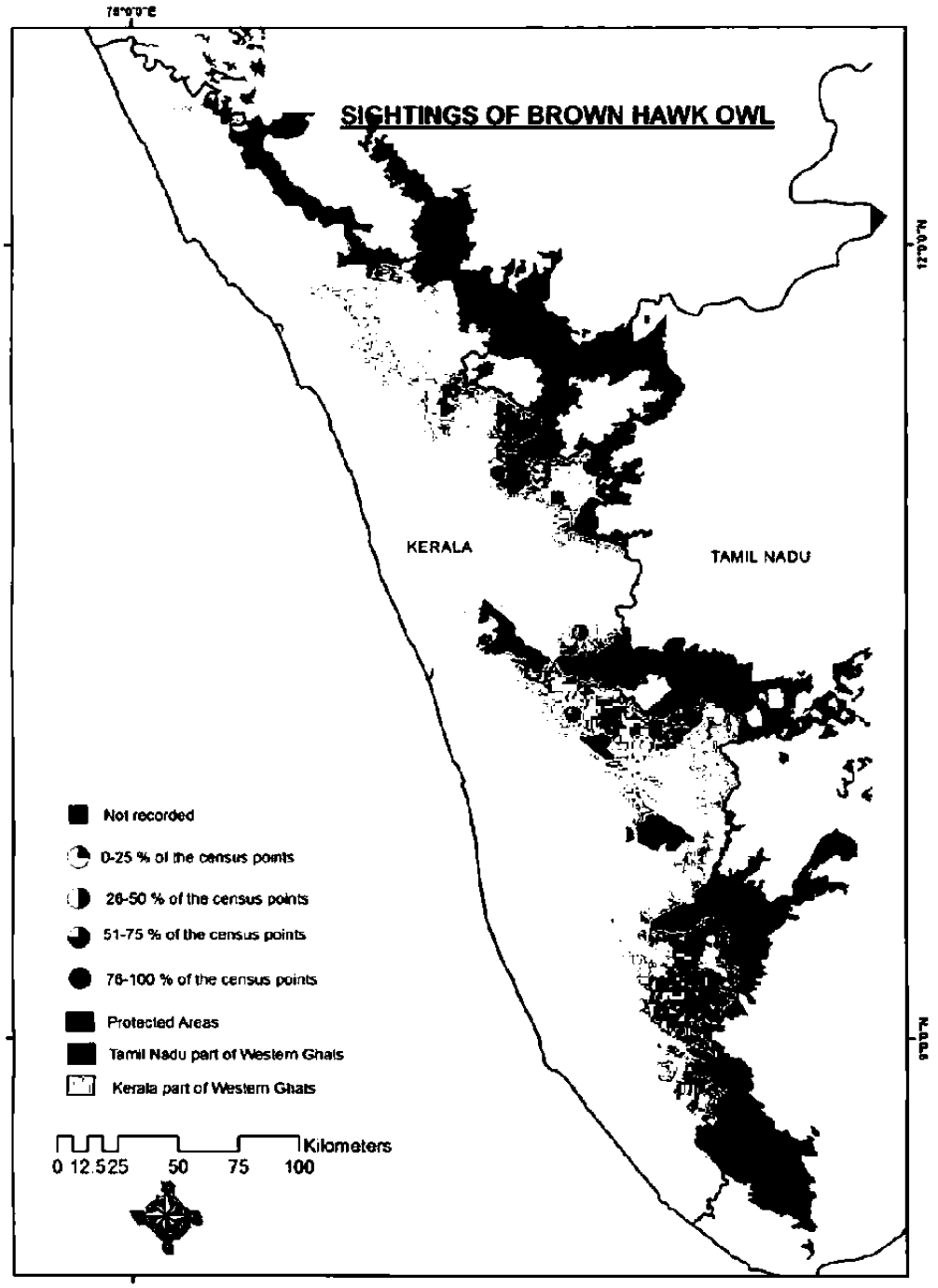


Fig. 7 Distribution of Brown hawk owl

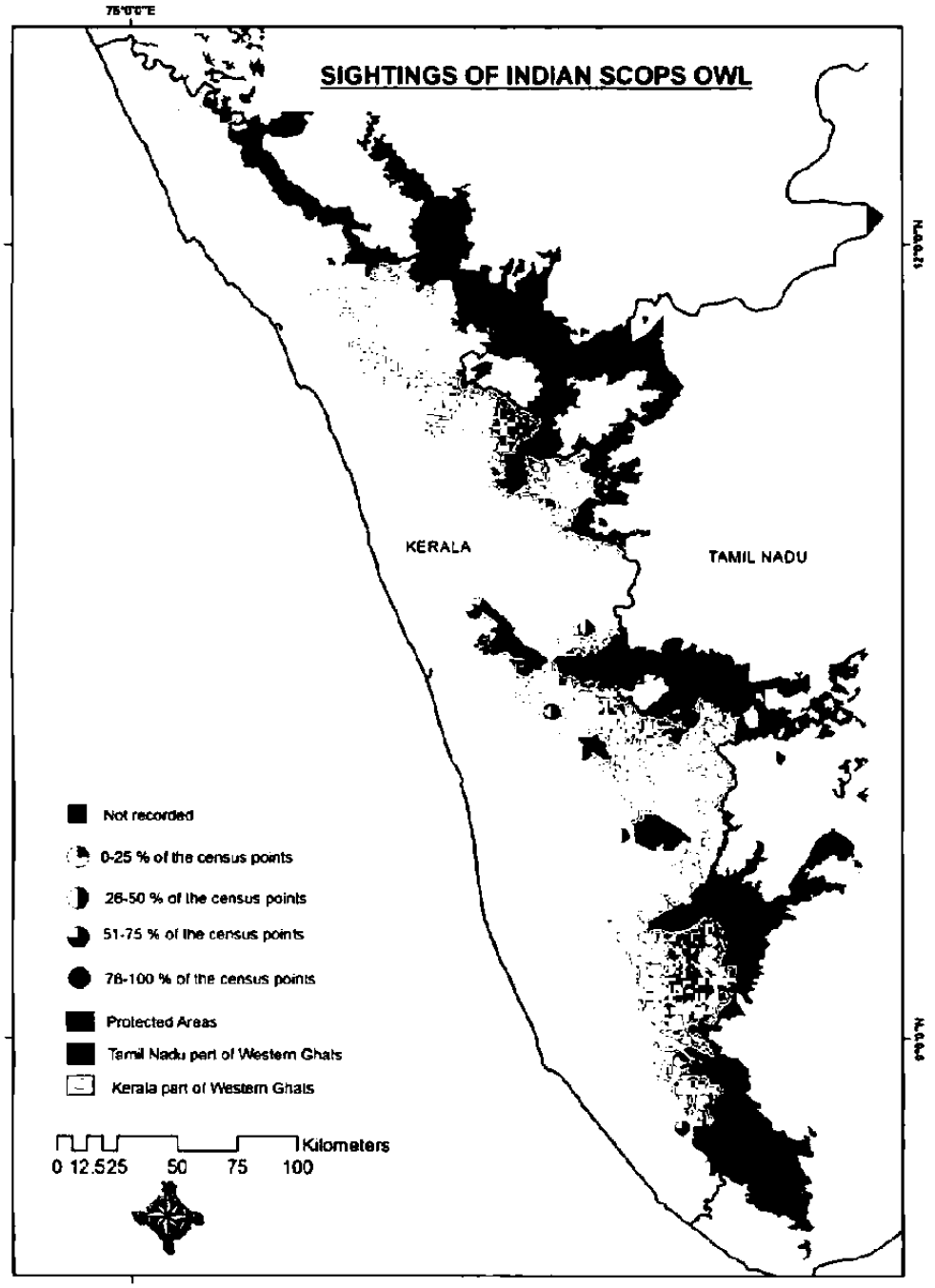


Fig. 8 Distribution of Indian scops owl

the Mediterranean regions and it was confirmed through fossil evidences (Milkovsky, 2003).

Indian eagle owl

It is a rare larger owl found in the plains and low altitude forests. The species was recorded from the coastal areas and even in the interior countryside's of the Tamil Nadu. This species is distributed in Nagamalai of Madurai, Aruville of Pondichery, Kolli and Shervarayan hills of Eastern Ghats and all the hillocks found intermediately in Tamil Nadu. The species was found breeding in a well near Sivakasi. The species was not recorded from Kerala. There is a possibility of recording the species from the dry zones of Palghat District especially in Mannarkad and Nemmara forest areas but during the survey, we failed to record them.

Forest eagle owl

It is one of the rarest species of larger owl, which was mostly recorded from the high canopy forests of the Western Ghats. Altogether, in 12 occasions, the species was recorded and most of the sightings of this species were from the riparian forests. The species was not observed from the coastal areas as well as from the interior areas of both the States, but the species was encountered in the low altitude dry forests.

Mottled wood owl

Mottled wood owl is now considered as endemic to India (Rahmani and Jathar, 2001). There was an earlier report of this from Pakistan but there is no recent report. The species was recorded in the low altitudes *i.e.* between 10 m and 300 m, but Zahari and Rahmani (2004) reported the species from Avalanche of Nilgiris and described it as a rare bird in the Upper Nilgiris. In Kerala, the species was mostly recorded from the home gardens and sacred grooves (Eringole, Perumbavur), which are rich in biodiversity. In Tamil Nadu, it was recorded from the plantations (coconut, mango and tamarind) adjacent to dry forests. The species was reported from the coastal areas (Vypin, Ernakulam) as well as from the interior countryside of Kerala and not reported from the coasts of Tamil Nadu.

Brown wood owl

Brown wood owl is rare in the southern Western Ghats and was recorded rarely during the survey. The species was not recorded outside the forest areas or Ghats. It was recorded only from 7 census points and only thrice the species was encountered from the moist deciduous forests. Maximum encounter rate of the species was in the low altitude forests (0-400 m) and not observed above 1200 m. All the encounters of the species were from the highly disturbed sites or near to the human settlements. All the encounters were between 10^0 and 20^0 slope.

Short-eared owl

One individual was encountered in the Peechi dam of the Peechi-Vazhani Wildlife Sanctuary during the month of January 2006 and it was perched on a dead vertical branch of a tree. This record was the first report of the species from the Peechi - Vazhani Wildlife Sanctuary. The species was relocated after sixty years from Kerala in Bharathapuzha River (Chandrasekhara and Nameer, 2003) and this is the second report from Thrissur District.

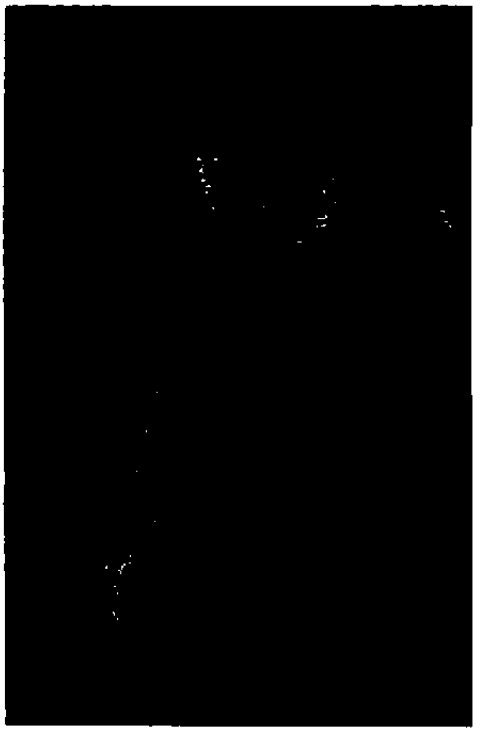
Spotted owlet

A human commensal that was recorded mostly in the foothills of Tamil Nadu and rarely encountered in the foothills of the Kerala. However, the species is reported to occur up to the coastal area and the species is the only widespread owl in the Indian subcontinent (Ali and Ripley, 1983). It is quite vocal even in the mid-days from the tamarind or neem trees, where they can roost in the holes to maintain the thermoregulatory process, which is known to influence the roost site selection in owls. In the southern Western Ghats, the species was reported only from two habitats namely the dry deciduous and dry thorn forests. The species was also recorded frequently from the populated areas. The species mainly utilized low altitude forests (0-400 m), no preference was recorded for slopes, and it mainly occupied plains.

Common Barn Owl

Common barn owls were seldom recorded during the survey. Twice it was recorded in the census points and both the points were adjacent to the agro

Plate 6 a. Mottled Wood Owl (*Strix ocellata*)



b. Common Barn Owl (*Tyto alba*)

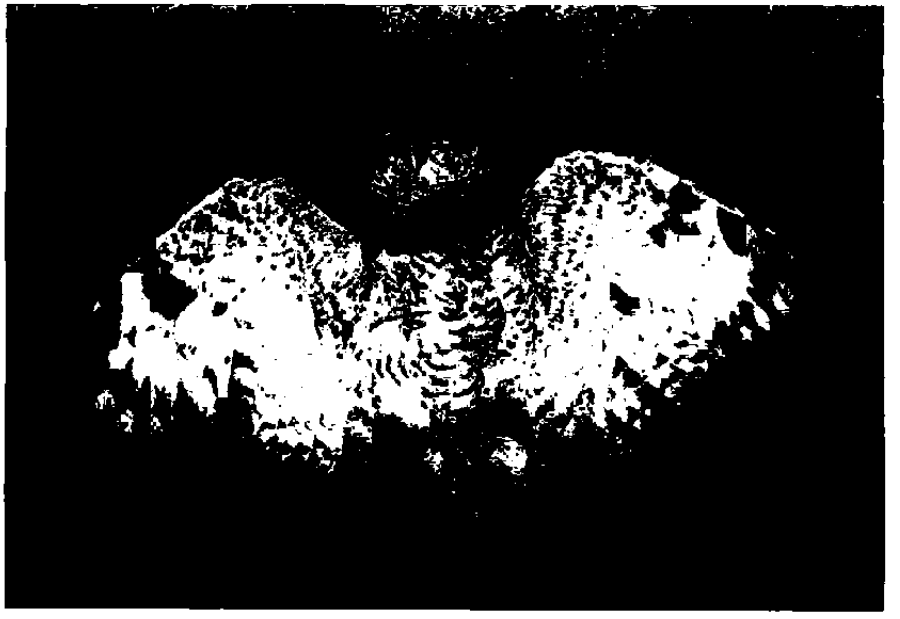


Plate 7 Forest Eagle Owl (*Bubo nipalensis*)

Plate 8 Brown hawk owl (*Ninox scutulata*) at daytime roost site

Plate 9 Indian scops owl (*Otus bakkamoena*)

environments or barren lands. However, once the species was recorded near the Kalakkad Rest House, which is little far from the human habitation.

3.1.3.4. Distribution of lesser owls

Encounter rate of lesser owls from various protected areas is given in Table 14.

Table 14. Encounter rate of lesser owls in various protected and reserved forests

	Protected areas	BJO	BHO	CSO	OSO	OBO	SPO
1.	Aralam WLS	0.57	0.43	0.14	-	-	-
2.	Attappady RS	0.50	-	0.25	-	-	-
3.	Chimmony WLS	0.57	0.14	0.57	0.43	-	-
4.	Chinnar WLS	0.40	-	0.20	0.20	-	-
6.	Idukki WLS	0.82	0.45	0.45	0.18	0.09	-
7.	Indira WLS	0.54	0.08	0.31	0.23	0.08	0.08
8.	Kanyakumari WLS	0.50	0.08	0.50	0.08	-	0.08
9.	KMTR	0.06	0.24	0.28	0.03	0.04	0.04
10.	Mudumalai WLS	0.78	0.44	0.33	0.56	-	-
11.	Nelliampathy RF	0.33	0.44	0.33	-	-	-
12.	Neyyar WLS	1.00	0.67	0.33	-	0.33	-
13.	Palani RF	-	-	0.11	-	-	0.11
14.	Peppara WLS	1.00	1.00	0.75	-	-	-
15.	Parambikulam WLS	0.83	0.33	0.17	0.33	-	-
16.	Peechi-Vazhani WLS	0.71	0.41	0.56	0.44	-	-
17.	Periyar Tiger Reserve	0.85	0.77	0.38	0.62	0.15	-
18.	Shendurney WLS	1.00	1.00	0.25	0.25	-	-
19.	Silent Valley NP	0.14	0.86	0.14	-	-	-
20.	Srivilliputtur WLS	0.56	0.22	0.22	-	-	-
21.	Thattekkad WLS	1.00	0.40	0.40	0.40	-	-
22.	Theni RF	0.25	0.05	0.30	0.05	-	0.10
23.	Vazhachal RF	0.44	0.89	0.33	0.11	-	-
24.	Wayanad WLS	0.86	0.71	0.14	0.57	-	-

	Total	**0.45**	**0.34**	**0.34**	**0.18**	**0.03**	**0.03**

BJO- Jungle owlet, BHO- Brown hawk owl, CSO- Indian Scops Owl, OSO- Oriental scops owl, OBO- Ceylon Bay Owl, SPO- Spotted owlet.

Out of twenty- four forest areas surveyed, in more than 66 % of the areas, the encounter rate of jungle owlet was the highest followed by brown hawk owl (13 %) and Indian scops owl (13 %). No owls were recorded from Eravikulam National Park during the survey. In none of the forests, the oriental scops owl or spotted owlet dominated. Five of the lesser owls were reported from the three protected areas namely the Indira Gandhi Wildlife Sanctuary, KMTR, Theni and Kanyakumari Forest Divisions and four species of owls were reported from most of the forest areas of Kerala (Table 14). Notably the Indian scops owl was reported to occur predominantly in the points of eastern portion of the Ghats *i.e.* Tamil Nadu. Similarly, jungle owlet occurred dominantly in most of the census points that lie in the western portions of the Ghats. The brown hawk owl dominated in the census points of mid altitude forest areas such as Nelliampathy, Silent Valley National Park and Vazhachal Reserve Forest.

3.1.3.5. Distribution of larger owls

In the five protected areas, namely Eravikulam, Neyyar, Periyar Tiger Reserve, Shendurney and Idukki Wildlife Sanctuary no larger owls were reported from the census points, but some of the larger owls were reported in those areas during the opportunistic surveys. Brown fish owl was the larger owl with highest encounter rate (0.13 owl / point) followed by Indian eagle owl (0.05 owl/ point) and mottled wood owl (0.05 owl/ point). Indian eagle owl and mottled wood owl were encountered frequently in the eastern portions, where the dry forests dominated the low altitude (0-400). In the western portions of the southern Western Ghats, brown fish owl was maximum recorded. Not all the larger owls were recorded together in a Sanctuary or Reserve Forest; however, four species were recorded together in few forest areas of Tamil Nadu (Indira Gandhi Wildlife Sanctuary, KMTR, Palani Hills and Theni Forest Division, Table 15).

Table 15. Encounter rate of larger owls in different protected and reserved forests

No.	Protected areas	Brown fish owl	Forest eagle owl	Short eared owl	Indian eagle owl	Brown wood owl	Mottled wood owl
1.	Aralam WLS	0.14	0.14	-	-	-	-
2.	Attappady RF	0.25	-	-	-	-	0.25
3.	Chimmony WLS	-	-	-	-	0.14	-
4.	Chinnar WLS	0.20	0.20	-	-	-	-
5.	Indira Gandhi WLS	0.15	-	-	0.15	0.08	0.15
6.	KMTR	0.16	-	-	0.04	0.03	0.04
7.	Mudumalai WLS	0.11	0.11	-	-	-	-
8.	Nelliampathy RF	0.22	-	-	-	-	-
9.	Palani RF	-	0.22	-	0.11	0.11	0.22
10.	Peppara WLS	-	0.25	-	-	-	-
11.	Parambikulam WLS	-	0.17	-	-	-	-
12	Peechi-Vazhani WLS	0.29	0.03	0.03	-	0.06	-
13	Periyar Tiger Reserve	-	0.08	-	-	-	-
14	Silent Valley NP	-	0.29	-	-	-	-
15	Srivilliputtur WLS	0.22	-	-	-	-	0.11
16	Thattekkad WLS	0.40	-	-	-	-	-
17	Theni RF	0.05	0.05	-	0.40	-	0.20
18.	Vazhachal RF	0.11	-	-	-	-	-
19.	Wayanad WLS	0.14	-	-	-	-	-
	Total	0.13	0.04	-	0.05	0.03	0.05

(Owls encountered in the census points)

3.1.3.6. Comparison between Protected Areas *vs* Reserve Forests

The encounter rate of lesser owls was higher in the protected areas, whereas the larger owls were significantly higher in the unprotected forests (Table 16). This is

mainly due to the existence of dry forests and grassy hillocks just outside the protected areas and the dry forests are pristine habitats for these owls to attain various life history characteristics. Lesser owls were observed to nest in the secondary holes, which are enriched in well-wooded tracts of forests with lofty trees. Therefore, they depended on such forest zones and most of the pristine vegetation types like wet evergreen, moist deciduous and dry deciduous forests are in the protected areas.

Table 16. Comparison of encounter rate of owls in protected areas and reserve forests.

Sl. no.	Species	Encounter rate in protected areas	Encounter rate in reserve forests
1.	Jungle owlet	0.493	0.317
2.	Indian scops owl	0.343	0.317
3.	Brown hawk owl	0.380	0.222
4.	Ceylon bay owl	0.038	0.000
5.	Peninsular scops owl	0.225	0.048
6.	Short eared owl	0.005	0.000
7.	Spotted owlet	0.019	0.063
8.	Brown fish owl	0.146	0.079
9.	Forest eagle owl	0.042	0.048
10.	Brown wood owl	0.028	0.016
11.	Indian eagle owl	0.023	0.143
12.	Mottled wood owl	0.028	0.111

3.1.4. Discussion

Sixteen species of owls have been reported from the Southern Western Ghats and among them, 13 species were recorded in this study. Maximum number of species was recorded from the Indira Gandhi Wildlife Sanctuary in Tamil Nadu. Two species of owls are migratory namely the long eared owl and the short eared owl and the conservation status of these owls is poorly known. Presence of brown hawk owl in all the census points at Silent Valley National Park can be attributed to the presence of

tropical wet evergreen forest in the National Park. The rainfall had an influence on the vocal behaviour and response of brown hawk owl. This was demonstrated when brown hawk owls were recorded from the census points, where they were absent during the survey, when rain was active and their recording from the same points when the area was devoid of rain. Roost sites of brown fish owl and mottled wood owl were recorded from the Thattekkad Bird Sanctuary.

Territorial defence mechanisms in the smaller owls were understood by eliminating the conspecific calls within their breeding sites. Where as the larger owls do not show much response either to conspecific or inter-specific calls. Roosting sites of five owl species were recorded in three protected areas. Encounter rate and response to broadcasted calls were highest during the breeding season and in all the census points, more than one individual *i.e* either in pair or three individuals were detected. Besides conspecific responder, some sympatric species were also found to respond to the broadcasted calls of brown-hawk owl, where the brown-hawk owl was not detected during the initial quiet listening method. Moreover, approach of the sympatric species was observed only in the riparian strips and in rest of the habitats, they responded only with calls. Southernmost distribution limit of brown hawk owl was identified during the study.

Short eared owl is a new report from the Peechi-Vazhani Wildlife Sanctuary. Ceylon bay owl is reported for the first time from the Idukki Wildlife Sanctuary and the Neyyar Wildlife Sanctuary. Call playback of conspecific calls is an efficient census method to enhance the encounter rate of brown hawk owl. Brown-hawk owl was located in 75 % of sites using call playback method. For the floaters the spot light and dusk watch was found to be an applicable method, as they poorly respond to the call of conspecific.

Application of the call playback method using the conspecific calls proves to be an effective sampling method for many of the owl species (Forsman *et al.* 1984; Kavanagh and Peake, 1993; Debus, 1995; Zuberogoitia and Campos, 1998; Martinez and Zuberogoitia, 2002) but in some of the species, it is ineffective (Rohner, 1997; Martinez and Zuberogoitia, 2002). However, this study is supporting the call playback method as an effective census method in the tropical forests. Spontaneous call method

yielded in sighting of owls during 35 call sequences and 75 % of sequences got response from the territory holders. Using the call playback method, 15 new responses were additionally recorded, where the presence of brown hawk owl was not recorded during the spontaneous call method. Hence, the broadcasting of conspecific call method can be considered as an important method for the census of brown hawk owl. Repeated call sequences in the same census point would not be a problem for the owls because habituation did not appear to be a problem for owl census (Gerhardt, 1991).

In nine sites, the brown hawk owl did not respond, but other two sympatric species responded (jungle owlet and Indian scops owl). Why the target individuals of brown hawk owl did not respond to the conspecific calls, is not analysed here because of the inadequate data to support the hypothesis "does the presence of Indian scops owl and jungle owlet influence the vocal and response behaviour of brown hawk owl?" Rohner (1997) reported a significant difference in the encounter rate between floaters and pair male territorial owners in great horned owl *Bubo virginianus*. Such an influence was also observed between the barred owl and the boreal owl, where barred owl influences the vocal behaviour of boreal owl (Takats and Holroyd, 1997).

Most of the spontaneous calls were heard during the pre-breeding and breeding season, than in other seasons and we tried twice the broadcast survey in a known site during daytime. Then it responded from the roost site but did not approach. In this experiment, only one individual responded and other partner was silent. Several factors are known to vary the vocal and response behaviour and among them wind velocity, rainfall and social context are the major ones (Olsen *et al.*, 2002). As wind velocity increases, a "sound shadow" will be created, resulting in a marked attenuation of sound with greater distance. Attenuation also will be increased during rain because water molecules can absorb sound and noise created by rainfall probably makes it more difficult to hear owl vocalization (Morrell *et. al.*, 1991). Hence, the survey was not carried out during heavy rainfall and windy days to avoid bias in the data. The presence or absence of a breeding partner may also influence the rate of vocalization (Klatt and Ritchison, 1994). Therefore, the dry forest adjacent to a riparian patch in a Sanctuary may hold some good population of owls.

The survey identified the southernmost limit of eight species of owls for the Western Ghats, namely the brown hawk owl, Indian eagle owl, brown fish owl, mottled wood owl, forest eagle owl, Ceylon bay owl, jungle owlet and brown wood owl. Among them, brown hawk owl, Indian eagle owl, brown fish owl and jungle owlet were recorded from the Kanyakumari Forest Division, where the Western Ghats ends. However, rest of them namely the brown wood owl, forest eagle owl and Ceylon bay owl were recorded from the Kalakkad Mundanthurai Tiger Reserve. As no sightings of these owls were recorded from further south, KMTR is considered as the southern range limit of these populations.

We failed to detect three species of owls, which were reported earlier in the southern Western Ghats namely the long eared owl, dusky horned owl and eastern grass owl. Although Neelakantan *et al.* (1993) has sighted the long-eared owl from the low altitude forests of Palghat, Ali and Ripley (1983) and Grimmet *et al.*, (2003) mentioned that the species was not observed south of Gujarat. The present survey also did not yield any sighting of this charismatic migrant. Some census was also carried out in the grassy hills of Eravikulam National Park, but we could not find eastern grass owl. This showed that this species is quite rare in the hills of southern Western Ghats. Similarly, dusky horned owl was also not reported during the survey but for few sight records from the Wayanad (Pers. Comm. Vishnudas) and Attappady hills (Pers. Comm. Somasundaram) in recent years, which suggest that it is a vagrant to Kerala and Tamil Nadu part of the Western Ghats. Moreover, even occasional reports on this species were also obtained from the north of the Palghat gap and no reports from south of Palghat gap. Further records from south of Palghat gap will be new information for understanding the distribution of the species.

Regarding the Ceylon bay owl, the previous observers (Kannan, 1993, Mudappa, 1998; Raman, 2001) recorded the species repeatedly from the same locations of Indira Gandhi Wildlife Sanctuary and Kalakkad-Mundanthurai Tiger Reserve. In this study, the species was located in a few pockets of protected areas and mostly restricted to the rainforest tracts. However, one report of the species is from the low altitude forests near the Kannur coast (Anon, 2000). The sub species of Ceylon bay owl, which is distributed in Malaysian Peninsula, is reported mostly from the low altitude forests and rarely recorded from the oil plantations (Puan and Zakaria,

2007). Results suggest that the species is quite rare in its distributional limit in the Western Ghats and the populations are low even from the already known sites like Indira Gandhi Wildlife Sanctuary; it is recorded mostly above 600 m altitude in the southern Western Ghats. The northern limit of the species is assumed to be in the Upper-Kanara of Karnataka (Vasudeva *et al*., 2001) and from this study it is observed that the southernmost population limit is from south of Kalakkad-- Mundanthurai Tiger Reserve. The KMTR is the southernmost protected area of the Western Ghats (Johnsingh, 2001). The species was newly reported from two protected areas of Kerala namely the Neyyar and Idukki Wildlife Sanctuaries. The easternmost population of the Ceylon bay owl is found in the Indira Gandhi Wildlife Sanctuary.

The known breeding season of jungle owlet is between March and May, but in June and July two mating sequences of the species was observed from a teak plantation. The observations indicated that the breeding season is extending to June and July also. It is noted that this season is similar with the rare forest owlet (Ishitaq and Rahmani, 2000). Jungle owlet was known to nest between three to eight meters above the ground (Ali and Ripley, 1983) but in the Palani hills, a nest was observed with a juvenile at a height of one meter above the ground. Detailed studies may be required to delimit the extent of breeding season in these taxa.

Regarding larger owls, the Indian eagle owl was not recorded during the present study from the western portion (Kerala) but there is some possibility to encounter this species in the down hills of Nelliampathy, Mannarkad and Walayar of Palghat forests. Similarly, the mottled wood owl was not reported from the census points of western portions, but recorded during opportunistic surveys. Ali and Ripley (1983) have noted that the brown fish owl was not reported above 1400 m but during the survey, it was recorded to occur above 2000 m altitude in the Palani hills. Consequently, Rahmani and Zarin (2005) also reported it from the Upper Nilgiris. The altitudinal shift has occurred in three species of owls, which may be an indication of the effect of climate change on birds of the Western Ghats.

Common barn owl was not recorded from the higher altitudes of the Western Ghats (Ashwaq, 2004). The species is known to breed in the old buildings, all sorts of towers, temples, church and mosque (Nagarajan, *et al.* 2002). The species was

observed to build nest in the underground wells over platforms built to keep water pump. The area is located amid the paddy fields of Srivilliputtur in Tamil Nadu.

Owls were encountered from a variety of gradients that range from the coastal zones to the higher reaches of the Western Ghats. However, some of them have restricted range of distribution; for instance, Ceylon bay owl, which are breeding and maintaining sustainable populations. A distinct pattern of distribution was observed for each species of the owls. Maximum number of owls was reported from the moist deciduous vegetation type, which is facing serious threats due to anthropogenic pressures.

3.1.5. Conclusions

The study recorded the rare wintering migrant, the short eared owl, from the Peechi- Vazhani Wildlife Sanctuary for the first time. Ceylon bay owl, an endemic species was newly reported from two protected areas namely the Idukki and Neyyar Wildlife Sanctuaries. Southern distributional limit of seven species of owls were reported for the first time from the Western Ghats. New reports of several owl species in various protected areas are also obtained in this study. Distribution pattern of owls in the southern Western Ghats was distinguished using vegetation types, topographic variables, disturbance level, level of protection in the forests and sanctuaries. Three species of owls could not be located and among them, the presence of long eared owl was not confirmed so far and the other two species, eastern grass owl and the dusky eagle owl were not sighted. Highest encounter rate of owls were from the Nelliampathy-Parambikulam-Vazhachal-Anamalai hill complex, which indicates the conservation potential of this belt for the protection of owls.

3.2. HABITAT USE OF OWLS

3.2.1. Introduction

Information on the habitat utilization and behaviour of owls in the tropical forests of India is scarce. Conservation of the owl community is dependent on understanding their habitat use and behaviour in the natural habitat. Forest owls pose special challenges to forest managers because they are top predators, with large home ranges and complex habitat requirements. A landscape approach is necessary for modelling distributions of forest owls and conserving habitat for them. Some owl species need extensive areas of natural forest within their home range, as reported for sooty owls (*Tyto tenebricosa*) in Australia (Milledge *et al.*, 1991). Many forest owls need tree hollows for nesting and some species need them for roosting. Rodents form a high percentage of their prey and most of those mammals depend on tree hollows for daytime shelter. Food of different species of owls was discussed by many authors (McCann, 1933; Jain and Advani, 1984). Similarly, behavioural aspects of owls have been described by (Guptha, 1967). Kavanagh (1988) showed that Powerful owls might select areas with abundant arboreal mammals but then serially reduce populations of prey species within different parts of their large home range. Many arboreal mammals respond positively to densities of old hollow-bearing trees (e.g. Smith and Lindenmayer, 1988, 1992; Lindenmayer *et al.*, 1990; Nelson *et al.*, 1996), as well as to a range of factors such as stand age (Macfarlane 1988) and foliar nutrient levels (Braithwaite *et al.*, 1984). Measures to conserve arboreal mammals at reasonably high population levels are also likely to benefit the owls, and *vice versa*. In this chapter the habitat use owls is described. Due to the rarity of species, only five species have been studied for habitat use in detail (jungle owlet, brown hawk owl, Indian scops owl, brown fish owl and Indian eagle owl).

3.2. 2. METHODS

Survey design utilised for the census of owls and the detailed methodology are given in the Chapter 3.1. Data from 14 protected areas, two reserve forests in Kerala and seven protected areas and one reserve forest in Tamil Nadu is used for the

analysis. Even though several factors, both spatially and locally, influence the distribution and habitat selection of owls in the tropical forests, we selected the vegetation type as the main criterion for the selection of survey points in different protected areas. Stratified random sampling method was adopted to estimate the number of sampling points needed in each habitat type. Each protected area was spatially gridded using MAP INFO software version 7 at 3.1 km interval. Number of census points per vegetation type was proportionately allotted to get maximum sampling in the dominant vegetation. Survey was conducted in 276 locations in the southern Western Ghats covering all the seasons.

Habitat parameters (Site level)

Ten distinct vegetation types were identified based on the tree assemblage (dry deciduous forest, dry thorn forest, moist deciduous forest, miscellaneous forest, semi evergreen, wet evergreen, non forested area, grassland, teak and other plantations (including rubber, coffee and tea)). All the vegetation types were classified based on the information collected from the vegetation plots. Point Centered Quarter (PCQ) method was employed (Fig. 9) to sample the vegetation structure and tree diversity in the survey plots (Mueller-Dombois and Ellenberg, 1974). Many environmental factors like altitude, vegetation type, soil, slope and human pressure influence the distribution of owls. Therefore, for selecting the sites for field surveys, the above parameters have been taken into consideration and stratified random sampling method was adopted. Stratification was done mainly based on vegetation types. A standard grid cell size of 3.1 km X 3.1 km was laid on the digitized vegetation map of various forest divisions/ protected areas to select the census points. Number of census sites per vegetation was determined in proportion to total number of grids in each vegetation types. Similar method was adopted for all the protected areas surveyed.

Landscape parameters

As the distribution of owls is influenced by the landscape parameters also, we estimated the values of landscape parameters from the digital maps using GIS technology.

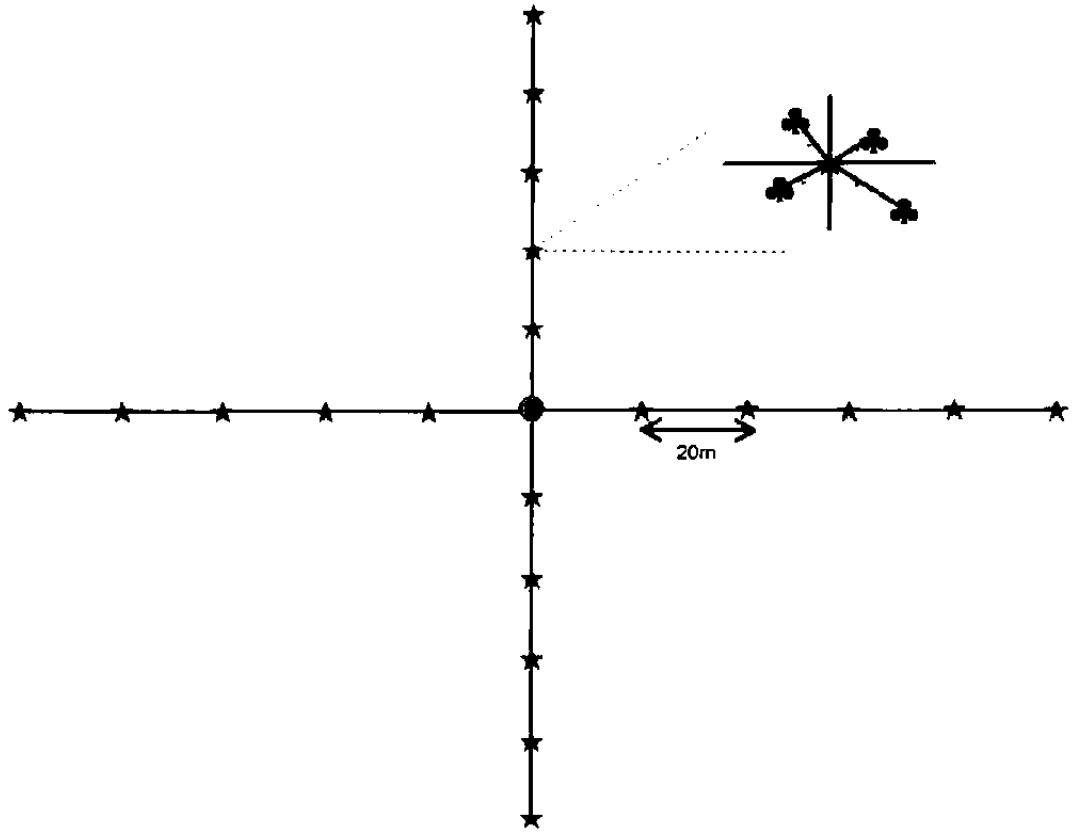


Fig. 9 Diagrammatic representation of vegetation plots sampled

(Point centered Quadrat method)

Hectares of tropical wet evergreen forest in 500 m and 2 km radius from site (WE)

Hectares of tropical semi evergreen forest in 500m and 2 km radius from site (SE)

Hectares of tropical moist deciduous Forest in 500 m and 2 km radius from site (MDF)

Hectares of tropical dry deciduous Forest in 500 m and 2 km radius from site (DDF2)

Hectares of scrub forest in 500 m and 2 km radius from site (DDF1)

Hectares of teak plantation (Age) in 500 m and 2 km radius from site (TE)

Hectares of other plantation (Age) in 500 m and 2 km radius from site (PL)

Hectares of water body in 500 m and 2 km radius from site (W)

Hectares of other vegetation types (miscellaneous) in 500 m and 2 km radius from site (MI)

Hectares of no forested areas in 500 m and 2 km radius from site (NF)

Slope gradient: The slope values were obtained from the SRTM Digital Elevation Model (DEM) with 90 m resolution and the software Global Mapper 9 was employed for this purpose. Seven slope categories were classified at 5 degree interval to get a clear picture of distribution of owls over various slope gradients.

Elevation gradient: The altitude of each census point was collected from the SRTM DEM with 90 m resolution and the software Global Mapper 9 was used. Five major elevation gradients were defined at 400 m interval to assess the extent of distribution of the raptor in each segment or gradient.

Anthropogenic disturbance index: As there was no information available on extent of disturbance in each Sanctuary, the disturbance index was calculated by measuring the distance between the census points and nearest human settlements. Topo sheets of Survey of India (1:50,000) were used to measure the distance. Disturbance index was calculated at three levels; high disturbance (0 to 1.9 km); moderately disturbed (>1.9 to 3.9 km) and least disturbed (>3.9 km).

Nature of protection: Forest areas were divided into three categories namely protected areas, non protected or reserved forest based on nature of protection.

Vegetation was considered as the major stratum for classification (Jayson *et al.* 2000). Information regarding the occurrence of owls in the protected areas was also collected from the literature. The distribution for certain rare species of owls namely the Ceylon bay owl, short-eared owl and forest eagle owl were lacking so secondary data was collected. Encounter rate of each species in the four variables (two topographic variable (slope and altitude), one vegetation type and one disturbance index) was estimated using the following formula.

Encounter Rate = Number of owl presence encountered in a domain / total number of census point taken in that domain

The distribution map of each species of owls was drawn on the vegetation layers using the Geographical Information System software ARC GIS 9. In addition, their previous recorded sites were also marked, if available. World geodetic system 1984 projection was used to register the raster images. Four parameters were incorporated to acquire the apparent scrutiny of the distribution pattern of owls. Geographical location of each census point was marked using the Global Positioning System Map 60 CX.

Behavioural observations

Limited behavioural observations were made on the owls mainly on the response of owls to the call playback experiments. Latency is the time taken to elicit vocal or physical response from the initiation of broadcasting, has been measured in seconds. Approaching distance and height, (Distance from the centre of the census point to the tree where owl is perched) was measured in meters using tapes and height from the ground, also recorded. Type of detection *ie.* whether the first detection of owl was visual or acoustic was also recorded. Response from the owl was classified as physical, vocal or aggressive behaviour towards the observer.

Statistical tests

For studying the habitat use of jungle owlet, data collected from 64 census points were used. Data were analysed using the Mann-Whitney U- test. To know the significant difference between the sites of presence and absence of jungle owlet, with

respect to its selected field level habitat characteristics, Mann Whitney U test was carried out. It has an approximation to normal distribution as the number of sample points (n) become large (>20).

3.2.3. RESULTS

3.2.3.1. Habitat use

3.2.3.1.1 Jungle owlet

Site parameters: Of the 12 habitat variables estimated to characterise the presence and absence sites of jungle owlet, seven showed significant difference. They were tree height, tree girth at breast height, tree canopy height and tree canopy cover, herb cover and grass cover (Table 17). The sites in which jungle owlet was present indicated a narrow range (less deviation from the mean) of habitat niche in all the four tree parameters than the sites in which these species was absent (high deviation from the mean). This shows a narrow range of habitat requirement at field scale. Number of dead logs was not significantly different between the sites but mean number of dead logs was comparatively higher in site where the owlet was present. Jungle owlet was more in sites with low tree density and high canopy height, tree height, GBH, grass cover and dead logs.

Table 17.Preference of habitat parameters by jungle owlet (n= 276)

Parameters	Owl Present (Mean)	Owl Absent (Mean)	Z	P
Tree Density (Ha)	422.11 (237.37)	481.99 (317.36)	-1.0	0.29
Tree Height (m)	13.06 (3.12)	10.10 (5.01)	-4.2	**0.00**
Tree GBH (cm)	84.03 (27.87)	61.12 (32.56)	-4.9	**0.00**
Tree canopy height (m)	6.85 (2.55)	5.66 (3.18)	-2.4	**0.01**
Tree canopy cover (%)	26.17 (8.04)	21.82 (8.88)	-2.1	**0.00**
Shrub cover (%)	24.44 (18.20)	24.63 (15.27)	-0.6	0.51
Herb cover (%)	25.62 (13.58)	19.22 (12.85)	-3.1	**0.00**
Grass cover (%)	29.90 (25.00)	24.13 (27.56)	-2.0	**0.04**
Litter cover (%)	35.62 (18.81)	34.30 (23.29)	-0.5	0.58
Overall canopy cover (%)	51.02 (17.89)	42.98 (22.94)	-2.1	**0.03**
Dead log (No.)	3.30 (3.60)	1.96 (2.21)	-1.4	0.14
Climbers (No.)	16.40 (15.55)	14.69 (15.41)	-0.7	0.50

SD in parenthesis

Vegetation: Jungle owlet preferred moist deciduous forests followed by teak plantation and miscellaneous forests (Fig. 10). The encounter rate of the owls showed a distinct pattern of distribution in relation to the vegetation types (χ^2=51.496; df=9; p<0.01).

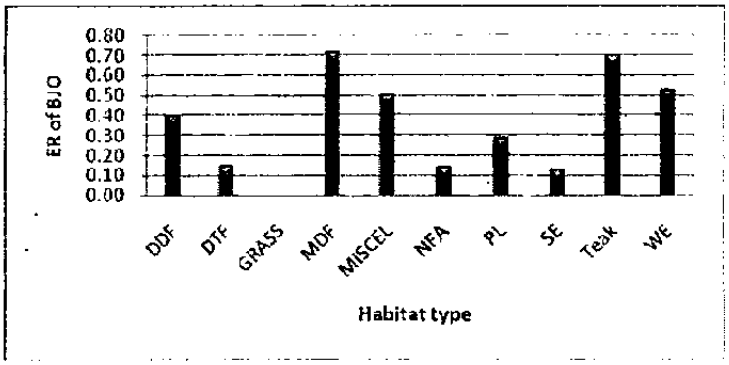


Fig. 10 Encounter rate of jungle owlet in various vegetation types

Elevation: The species was observed up to 2000 m and the most of the sightings of the species were between 0 and 1200 m (Fig. 11). The species followed a definite pattern of distribution in altitudinal gradient (χ^2=16.617; df=4; p=0.002). Highest encounter rate of 0.65 owls/ point was recorded in the 800 to 1200 m gradient.

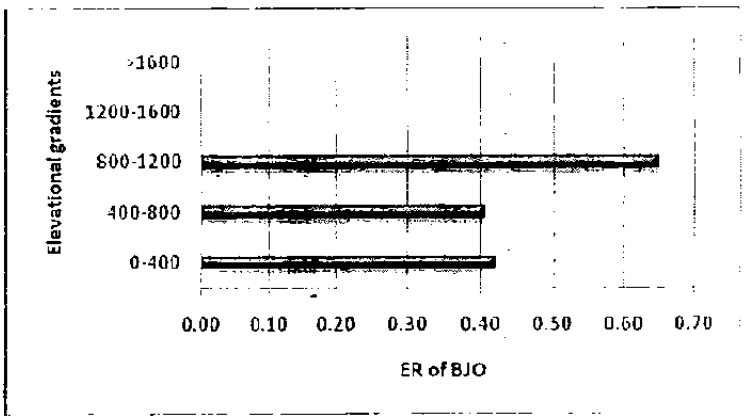


Fig. 11 Encounter rate of Jungle owlet in various altitudinal gradients

Slope: Jungle owlet did not prefer any particular gradient of slope. It occupied a wide range of slope and distributed more or less evenly in all slope gradients (χ^2=7.015;

df=6; p=0.319). The highest encounter rate was recorded from areas with high slope (0.64 owls / point) (Fig. 12).

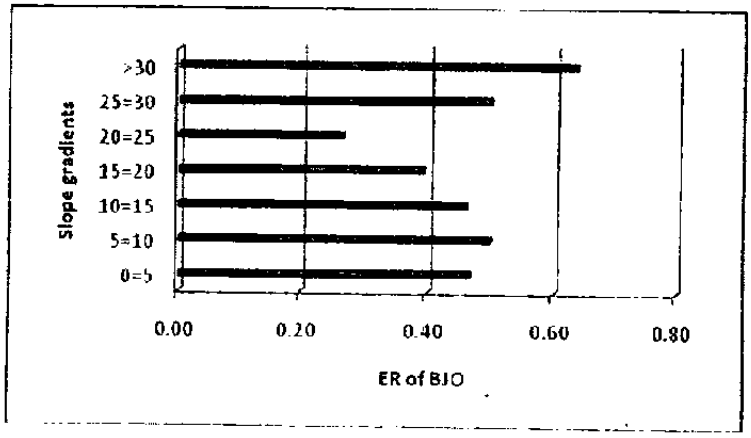


Fig. 12 Encounter rate of jungle owlet in various slope gradients

Disturbance level The disturbance index values showed that the jungle owlet preferred highly disturbed and moderately disturbed portions and no significant difference was observed among various disturbance levels (χ^2=1.752; df=2; p=0.416). The species did not prefer undisturbed sites but showed affinity towards disturbance (Fig. 13). In addition, low encounter rate of the species was recorded from less disturbed areas like Kalakkad-Mundanthurai Tiger Reserve, Silent Valley and interior forests of Peppara Wildlife Sanctuary.

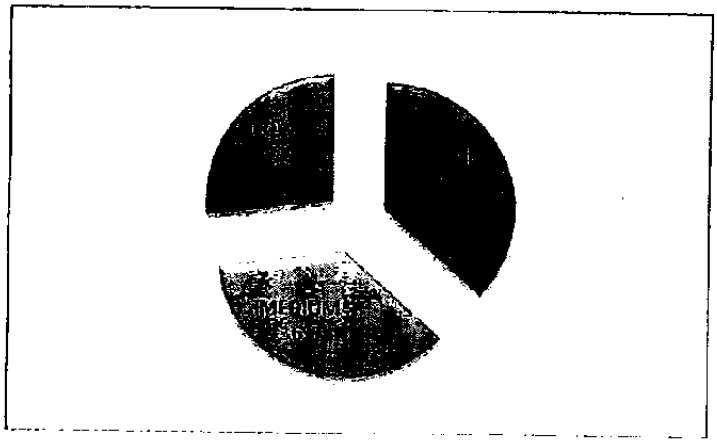


Fig. 13 Encounter rate of jungle owlet in various disturbance levels

Most of the individuals were recorded on dead or live horizontal branches without leaves for perching. Four sightings of jungle owlet were on dead twigs with or without lichens. Tree species with larger leaves such as *Calophyllum inophyllum, Tectona grandis* or trees with dense canopy were the preferred daytime roosts. Where as the brown hawk owl and jungle owlet selected trees with less canopy, branches without leaves or dead branches. These two owl species challenged the artificial calls made by the observer even at 1 m distance. This behaviour indicated the aggressiveness during the breeding.

Table 18 shows the mean values of the different habitat variables at landscape level for the survey sites where jungle owlet was present/absent. The results indicate that all the variables except the litter cover influenced the habitat preference of jungle owlet. Out of all the forest areas surveyed, except KMTR, the jungle owlet has been reported in good number mainly due to the low disturbance level in the hill range. Most of the observations were from the low altitude dry deciduous and moist deciduous forests of Kerala and Tamil Nadu. Jungle owlet used habitats, with large extent of moist deciduous and dry deciduous forest, teak plantation and water body at 500 and 2000 m radius. It avoided semi evergreen and dry thorn forests. Vegetation composition around the preferred sites of jungle owlet consisted of 23 % of moist deciduous and 16 % of dry deciduous forests, 9 % each of teak plantation, water and non-forest areas at 500 m radius. At 2 km radius, the vegetation consisted of 22 % of moist deciduous and 15 % of dry deciduous forests, 9 and 7 % of water and teak respectively.

Table 18. Preference of landscape level habitat parameters by jungle owlet

Parameters	Jungle owlet				Z	p
	Absence		Presence			
	Mean	SD	Mean	SD		
Altitude (m)	466.10	395.42	467.88	346.83	-0.11	0.91
Slope (degree)	12.63	8.56	12.35	9.46	-0.65	0.51
WE_500 (ha)	12.93	26.97	17.86	29.49	-1.59	0.11
SE_500 (ha)	5.87	19.08	1.61	9.36	-2.53	**0.01**
MDF_500 (ha)	5.92	17.61	17.72	28.01	-4.48	**0.00**

DDF_1_500 (ha)	16.12	29.53	3.88	14.61	-4.26	**0.00**
DDF_2_500 (ha)	6.78	18.76	11.83	27.38	-0.33	0.74
TE_500 (ha)	3.56	14.96	7.21	20.50	-1.75	**0.08**
PI_500 (ha)	2.63	13.10	0.82	4.22	-0.47	0.64
MI_500 (ha)	3.51	15.05	2.88	12.69	-0.01	0.99
W_500 (ha)	4.95	15.29	7.29	14.87	-2.98	**0.00**
NF_500 (ha)	16.22	28.85	7.40	20.05	-2.42	**0.02**
WE_2000 (ha)	233.33	364.15	277.83	386.58	-1.58	0.11
SE_2000 (ha)	91.36	242.31	17.25	81.72	-4.22	**0.00**
MDF_2000 (ha)	93.37	193.78	266.89	328.21	-5.56	**0.00**
DDF_1_2000 (ha)	251.28	372.13	75.61	227.25	-5.72	**0.00**
DDF_2_2000 (ha)	144.22	277.12	182.71	398.81	-2.15	**0.03**
TE_2000 (ha)	49.84	149.17	96.07	231.92	-1.82	**0.07**
PI_2000 (ha)	33.37	144.81	25.98	84.14	-0.86	0.39
MI_2000 (ha)	59.07	214.41	45.58	164.87	-0.38	0.70
W_2000 (ha)	67.23	128.03	122.90	162.18	-2.51	**0.01**
NF_2000 (ha)	234.08	364.71	145.18	266.54	-0.72	0.47

500= 500 m radius, 2000=2000 m radius

3.2.3.1.2. Brown hawk owl

Site parameters

Brown hawk owl occupied areas with high tree density without much variation, but there was no significant difference in tree density between the sites showing its presence or absence. Three of the tree parameters including tree height, tree girth at breast height and tree canopy height were significantly higher in the sites showing the presence with little deviation from the mean from the sites showing absence (Table 19). Climbers and dead logs did not have any significant impact on the habitat use of brown hawk owl. Herb coverage was comparatively higher in the sites where the owl was present.

Table 19. Preference of habitat parameters by brown hawk owl (n= 276)

Parameters	**Brown hawk owl**			
	Presence (Mean)	Absence (Mean)	Z	P
Tree density (Ha)	481.00 (266.73)	428.96 (285.30)	-1.56	0.12
Tree height (m)	13.01 (2.78)	10.78 (4.97)	-2.92	**0.00**

Tree GBH (cm)	77.80 (23.49)	70.32 (36.73)	-1.78	**0.08**
Tree canopy height (m)	7.06 (1.92)	5.77 (3.34)	-3.49	**0.00**
Tree canopy cover (%)	24.98 (6.92)	23.57 (9.70)	-1.20	0.23
Shrub cover (%)	26.92 (18.86)	22.90 (15.21)	-1.07	0.29
Herb cover (%)	24.42 (12.53)	21.43 (14.19)	-1.67	**0.10**
Grass cover (%)	26.84 (24.87)	27.46 (27.36)	-0.16	0.88
Litter cover (%)	42.44 (20.27)	29.94 (19.99)	-3.54	**0.00**
Overall canopy cover (%)	53.17 (17.22)	43.26 (22.01)	-3.09	**0.00**
Dead log (No.)	2.71 (3.13)	2.65 (3.09)	-0.14	0.89
Climbers (No.)	13.38 (14.32)	17.11 (16.09)	-1.49	0.14

SD in parenthesis

***Vegetation*:** Brown hawk owl was frequently encountered in the mixed habitats of evergreen and moist deciduous forests *i.e.* in the transition habitats (0.75 owls / point) followed by plantations (0.57 owls /point) and moist deciduous forests (0.57 owls / point) (Fig. 14). Lowest number of owls was recorded in dry thorn forests and no owls were observed from the grassy hills and non forested areas. The encounter rate of the species was not uniform among the vegetation types (χ^2=49.060; df=9; p=0.000).

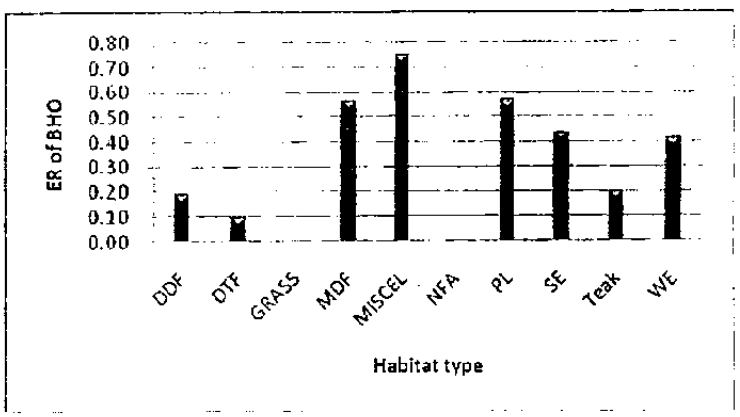


Fig. 14. Encounter rate of brown hawk owl in various vegetation types

Elevation: Frequent sightings of the species were from the mid altitude forests, *i.e.*, 800 to 1600 m. In low altitudes (0-800 m), the species preferred moist deciduous forests and dry deciduous forests (Fig. 15). The encounter rate of hawk owl was significantly different (χ^2=19.866; df=4; p=0.000) between the elevation gradients.

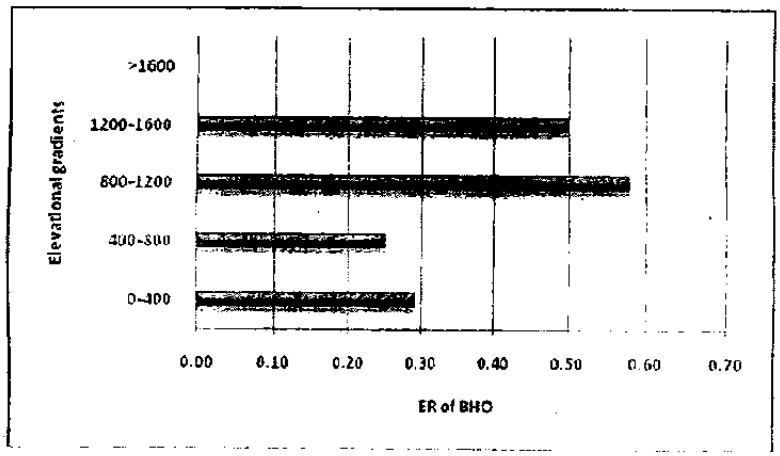


Fig. 15 Encounter rate of Brown hawk owl in various altitudinal gradients

Slope: Encounter rate of the Brown hawk owl was highest in the mid sloppy areas (10-15^0). No significant difference was observed between various slope gradients (χ^2=7.737; df=6; p=0.258) (Fig. 16).

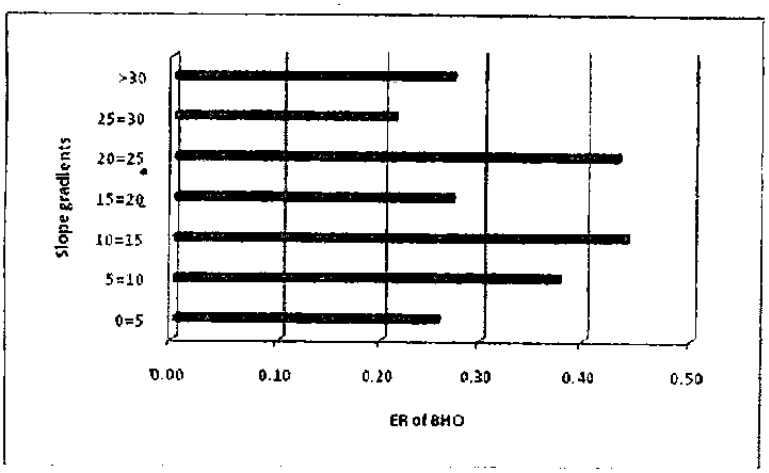


Fig. 16 Encounter rate of Brown hawk owl in various slope gradients

Disturbance: Encounter rate of brown hawk owl in different disturbance indices was not significantly different (χ^2=1.208; df=2; p=0.547) (Fig. 17).

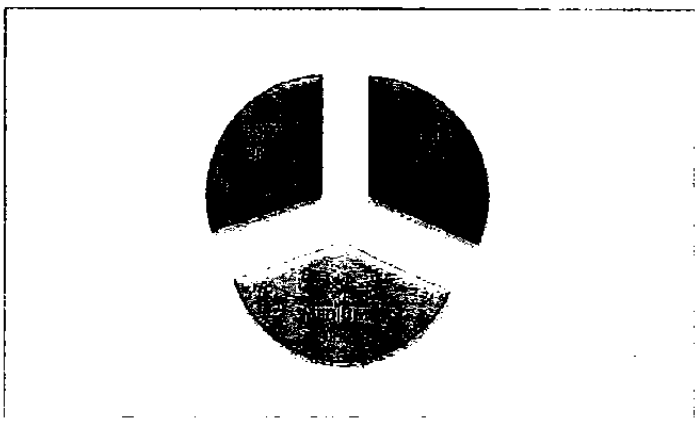


Fig. 17 Encounter rate of Brown hawk owl in various disturbance levels

Mid altitude, (300–1200 msl) forest includes tropical semi-evergreen, tropical moist deciduous forest and wet evergreen forest hold viable population of brown hawk owl in the sampling points. Out of 75 sites, the presence of brown hawk owl was recorded in 19 (26.03 %) sampling points, which indicates its rarity and scattered distribution. Brown hawk owl is highly selective in habitat use; altitude, canopy thickness and high ambient moisture influence its distribution in the southern Western Ghats.

The distribution pattern of brown hawk owl showed that the Kerala part of the Western Ghats support a viable population in most of the protected areas. Owls were detected in most of the census points of the two reserved forests such as Vazhachal (67 %) and Nelliampathy (67 %). Tropical wet evergreen and tropical moist deciduous forest were the preferred habitats of the brown-hawk owl. No significant seasonal difference was observed in the habitat utilization but seasonality was observed in the response and the approaching distance to the conspecific calls broadcasted. Additionally, the response to the conspecific calls indicated that the owls

are responding to the conspecific calls throughout the year. Most of the climatic factors such as temperature, rainfall and wind velocity were found to influence the detection probability of brown hawk owl. Among them, the rainfall and the wind velocity are the major factors, which obstruct efficient sampling.

A total of 143 call sequences of brown hawk owl were broadcasted across seventy-five census points and response was obtained for 41 call sequences. Out of these, 35 call sequences showed confirmed presence of owl. Among the 35 call sequences, only 75% got a response and in nine sequences, the response was not received. Moreover, the broadcast call yielded 15 new observations where the presence of this elusive species was not known to occur. Preference of landscape level habitat parameters by brown hawk owl is given in Table 20. Presence of wet evergreen, moist deciduous and miscellaneous forest and water body influenced the presence of brown hawk-owl at 500 m and 2000 m radius. The species avoided dry thorn forests and non-forested areas (Table 20). Vegetation composition around the presence sites of brown hawk-owl consisted of 25 % of wet evergreen, 22 % of moist deciduous forests, 9 % of water and 7 % of miscellaneous at 500 m radius. Similarly in 2000 m radius, 28 % of wet evergreen, 18 % of moist deciduous and 9 % of water body recorded.

Table 20. Preference of landscape level habitat parameters by brown hawk owl (n=276)

Parameters	Brown hawk owl					
	Absence		Presence		Z	p
	Mean	SD	Mean	SD		
Altitude (m)	427.88	364.46	541.27	381.20	-2.3	**0.02**
Slope (degree)	12.39	9.39	12.71	8.14	-0.9	0.39
WE_500 (ha)	12.98	26.79	19.33	30.40	-2.3	**0.02**
SE_500 (ha)	3.55	14.53	4.67	17.46	-0.4	0.69
MDF_500 (ha)	7.92	20.43	17.62	27.74	-3.4	**0.00**
DDF_1_500 (ha)	14.46	27.88	3.19	14.48	-3.1	**0.00**
DDF_2_500 (ha)	9.17	22.93	8.89	23.70	-0.1	0.88
TE_500 (ha)	6.08	19.39	3.55	14.05	-1.4	0.18
PI_500 (ha)	1.53	8.81	2.34	12.26	-0.6	0.56

MI_500 (ha)	2.24	12.46	5.09	16.47	-2.1	**0.00**
W_500 (ha)	5.54	15.78	6.91	13.82	-2.2	**0.03**
NF_500 (ha)	15.02	27.57	6.91	20.42	-2.9	**0.00**
WE_2000 (ha)	198.80	338.56	357.69	417.08	-4.2	**0.00**
SE_2000 (ha)	52.69	178.66	67.53	212.68	-0.0	0.97
MDF_2000 (ha)	143.14	263.11	226.87	294.48	-3.3	**0.00**
DDF_1_2000 (ha)	235.14	362.55	50.89	193.29	-5.8	**0.00**
DDF_2_2000 (ha)	160.97	323.63	162.96	364.52	-0.1	0.90
TE_2000 (ha)	78.89	208.71	55.30	155.67	-0.7	0.50
PI_2000 (ha)	28.87	105.97	32.24	146.04	-1.2	0.21
MI_2000 (ha)	36.00	168.31	85.27	231.29	-3.1	**0.00**
W_2000 (ha)	80.25	140.01	115.67	157.30	-1.1	**0.05**
NF_2000 (ha)	241.39	361.22	103.17	221.82	-2.76	**0.01**

_500 = 500 m radius, _2000 =2000 m radius

3.2.3.1.3. Indian scops owl

Site parameters

Habitat use of Indian scops owl was characterised by the presence higher tree density, higher the tree height, GBH, canopy coverage but lesser canopy height (Table 21). Tree density and the mean tree density per hectare was comparatively higher in owl-inhabited sites since this owl occupied wide array of habitats ranging from dry thorn forest to wet evergreen forests. Tree canopy cover alone was found to differ significantly between the two types of sites due to its shy and skulking nature. The scops owl utilized higher tree height and girth at breast height, but occupied lower canopy height because it required dense canopy coverage.

Table 21. Preference of habitat parameters by Indian scops owl (n= 276)

Parameters	Indian Scops Owl			
	Presence (Mean)	Absence (Mean)	Z	P
Tree density (Ha)	477.74 (300.14)	433.89 (264.90)	-0.59	0.56
Tree height (m)	12.25 (3.27)	11.34 (4.86)	-1.19	0.23

Tree GBH (cm)	75.16 (26.56)	72.29 (35.10)	-0.74	0.46
Tree canopy height (m)	6.27 (2.09)	6.31 (3.31)	-0.02	0.99
Tree canopy cover (%)	26.72 (6.17)	22.64 (9.58)	-2.10	**0.00**
Shrub cover (%)	21.76 (15.71)	26.14 (17.34)	-1.67	**0.09**
Herb cover (%)	24.14 (14.07)	21.77 (13.29)	-0.92	0.36
Grass cover (%)	25.48 (25.83)	28.22 (26.64)	-0.77	0.44
Litter cover (%)	39.87 (20.34)	32.17 (20.89)	-2.27	**0.02**
Overall canopy cover (%)	53.34 (16.81)	43.74 (22.03)	-2.84	**0.00**
Dead log (No.)	2.78 (3.07)	2.61 (3.13)	-0.5	0.62
Climbers (No.)	14.92 (13.67)	16.00 (16.46)	-0.15	0.89

SD in parenthesis

Vegetation: Maximum encounter rate of the species was recorded in the natural forests including the semi-evergreen forest, moist deciduous forest and the wet evergreen forest. The species was also recorded from the dry thorn forests and plantations (Fig. 18). Significant difference was obtained in the distribution of the species between the different vegetation types (χ^2=23.505; df=9; p=0.005).

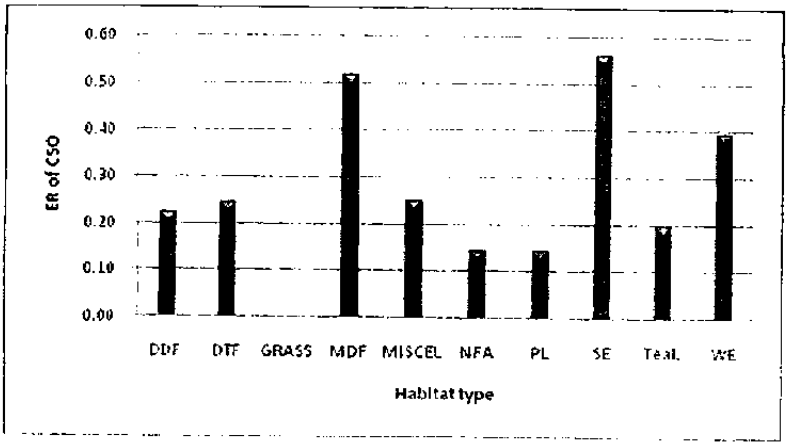


Fig. 18 Encounter rate of Indian scops owl in various vegetation types

Elevation: Most of the sightings of the species were from the low altitude forests, but a good population was also reported in the mid elevation zones (Fig. 19). No significant difference was obtained in distribution between the various altitudinal gradients (χ^2=3.113; df=4; p=0.539).

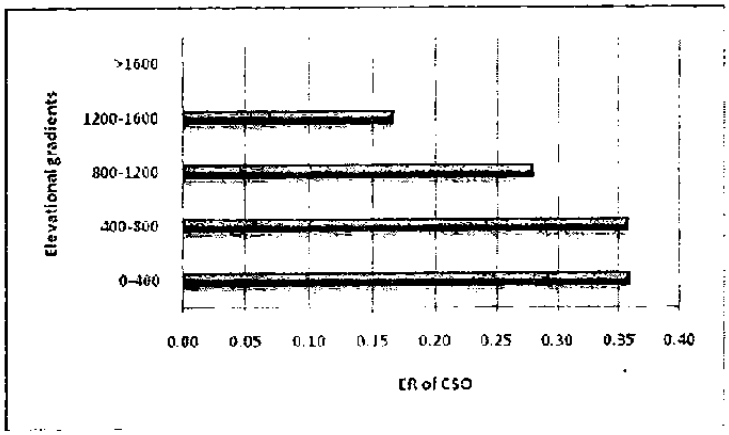


Fig. 19 Encounter rate of Indian scops owl in various altitudinal gradients

Slope: Indian scops owl preferred high sloppy areas *i.e.* above 30° slope (Fig. 20). Though the species was reported to occur in all the gradients of slopes, the encounter rate of the species was significantly different in various slope gradients (χ^2=15.835; df=6; p=0.015).

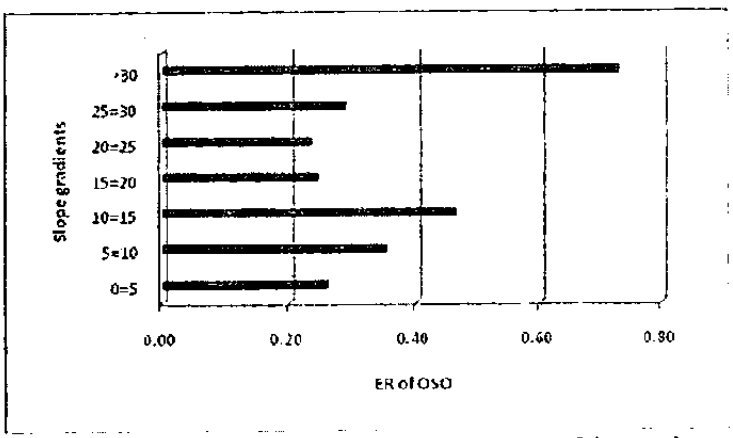


Fig. 20 Encounter rate of Indian scops owl in various slope gradients

Disturbance: This owl utilized habitats with all the levels of disturbance and the same encounter rate was recorded in highly disturbed points and lowly disturbed

points (Fig. 21). No significant difference in distribution was observed between the various disturbance levels (χ^2=4.517; df=2; p=0.11).

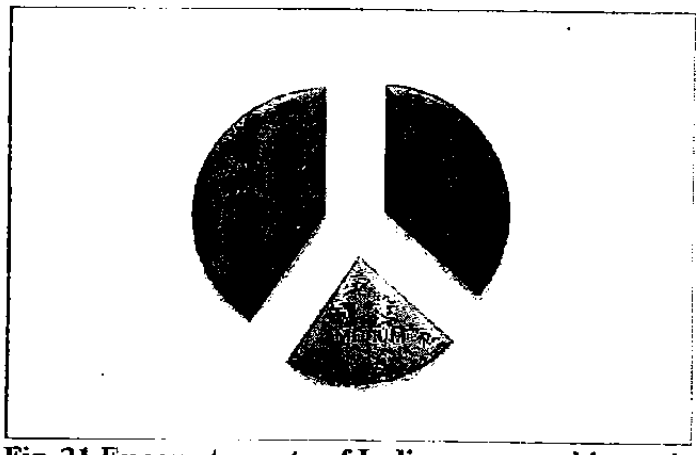


Fig. 21 Encounter rate of Indian scops owl in various disturbance levels

Preference of landscape level habitat parameters by Indian scops owl is given in Table 22. Indian scops owl preferred semi evergreen forests, wet evergreen forests, moist deciduous forests and water body. It avoided dry thorn forests, dry deciduous forests and miscellaneous forests. At the landscape level the preferred vegetation composition showed 20 % moist deciduous and 10 % semi evergreen forests at 500 m radius, whereas in 2000 m radius it was 24 % of wet evergreen forest, 18 % of moist deciduous forest and 8 % of water body.

Table 22 Preference of landscape level habitat parameters by Indian scops owl

Parameters	Indian scops owl					
	Absence		Presence		Z	p
	Mean	SD	Mean	SD		
Altitude (m)	491.59	393.91	418.36	326.36	-1.44	0.15
Slope (degree)	12.00	8.60	13.48	9.61	-1.21	0.23
WE_500 (ha)	14.11	27.55	17.23	29.47	-0.88	0.38
SE_500 (ha)	1.98	10.42	7.80	22.09	-2.46	**0.01**
MDF_500 (ha)	8.95	21.35	15.81	27.08	-2.15	**0.03**
DDF_1_500 (ha)	11.57	25.62	8.63	22.74	-1.22	0.22
DDF_2_500 (ha)	11.15	25.32	4.97	17.57	-2.36	**0.02**
TE_500 (ha)	5.90	19.12	3.85	14.68	-0.89	0.38
Pl_500 (ha)	2.36	12.15	0.72	3.53	-0.08	0.94
MI_500 (ha)	3.63	15.00	2.42	11.84	-1.12	0.26

W_500 (ha)	5.61	15.10	6.79	15.20	-1.24	0.22
NF_500 (ha)	13.22	26.32	10.28	24.09	-0.93	0.35
WE_2000 (ha)	230.64	371.63	298.44	377.89	-1.87	**0.06**
SE_2000 (ha)	35.97	138.16	100.75	261.23	-1.34	0.18
MDF_2000 (ha)	142.28	249.55	230.35	316.85	-2.46	**0.01**
DDF_1_2000 (ha)	194.92	336.62	126.08	301.65	-2.18	**0.03**
DDF_2_2000 (ha)	193.38	363.35	99.22	271.25	-1.68	**0.09**
TE_2000 (ha)	83.65	215.54	45.44	132.23	-1.45	0.15
PI_2000 (ha)	32.77	136.53	24.63	82.76	-0.70	0.49
MI_2000 (ha)	63.89	212.32	31.46	147.80	-1.85	**0.07**
W_2000 (ha)	86.25	143.86	104.63	152.68	-1.76	**0.08**
NF_2000 (ha)	193.22	327.85	194.99	325.37	-0.02	0.98

_500 = 500 m radius, _2000 =2000 m radius

Softwood tree species in teak plantations were the preferred habitat of the Indian scops owl, which was highly secretive in behaviour. This species did not vary between altitudes and habitats but was influenced by the availability of suitable tree species and perch sites. Indian scops owl preferred trees with thick canopy while maintaining or defending territory.

3.2.3.1.4. Oriental scops owl

Site parameters

Height of trees, GBH of trees and canopy height showed significant difference between the owl inhabited and uninhabited sites. All other parameters showed no significant difference. Preference of habitat parameters of oriental scops owl is given in Table 23.

Table 23. Preference of habitat parameters by Oriental scops owl (n= 276)

Parameters	**Oriental scops owl**			
	Presence (Mean)	Absence (Mean)	Z	P
Tree density (ha)	427.80 (191.13)	455.89 (297.36)	-0.14	0.89
Tree height (m)	13.29 (2.60)	11.25 (4.62)	-2.33	**0.02**
Tree GBH (m)	82.98 (24.41)	70.81 (33.54)	-2.36	**0.02**

Tree canopy height (m)	7.23 (2.25)	6.05 (3.03)	-2.19	**0.03**
Tree canopy cover (%)	24.07 (7.27)	24.16 (9.05)	-0.20	0.84
Shrub cover (%)	26.80 (19.03)	23.93 (16.25)	-0.52	0.60
Herb cover (%)	24.67 (10.78)	22.10 (14.22)	-1.50	0.14
Grass cover (%)	29.79 (24.65)	26.53 (26.77)	-0.97	0.33
Litter cover (%)	33.13 (17.64)	35.50 (21.79)	-0.70	0.49
Overall canopy cover (%)	51.46 (17.89)	46.17 (21.35)	-1.19	0.24
Dead log (Nos)	3.65 (3.83)	2.41 (2.83)	-1.24	0.22
Climbers (Nos)	15.12 (14.41)	15.73 (15.78)	-0.11	0.92

SD in parenthesis

Vegetation: The species was mainly observed in the natural forests and the maximum encounter rate was from moist deciduous forests (0.43 owls / point) followed by dry deciduous forests (0.19 owls /point) and wet evergreen forest (0.15 owls/ point) (Fig. 22). A clumped pattern of distribution was observed among various vegetation types (χ^2=38.148; df=9; p=0.000).

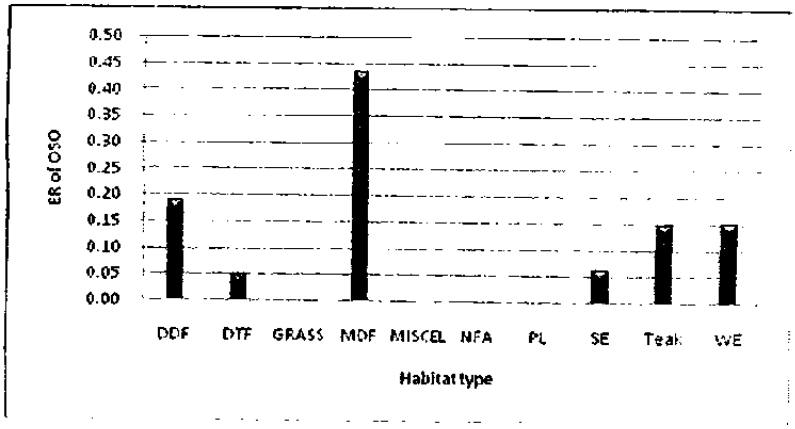


Fig. 22 Encounter rate of Oriental scops owl in various vegetation types

Elevation: The distribution of the species showed a preference towards mid altitude forests but the species was not recorded above 1200 m (Fig. 23). Highest encounter

rate of the species was observed between 800 m to 1200 m gradients (0.32 owls / census point).

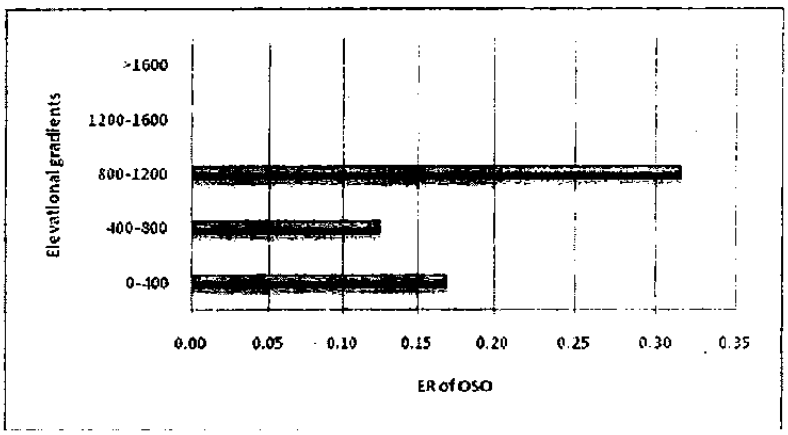


Fig. 23 Encounter rate of Oriental scops owl in various altitudinal gradients

Slope: Oriental scops owl was recorded mostly in the low sloping areas and the encounter rate decreased slightly with the increasing slope gradients (Fig. 24). Maximum encounter (0.351 owls / point) rate of this owl was noted from plains or plateau.

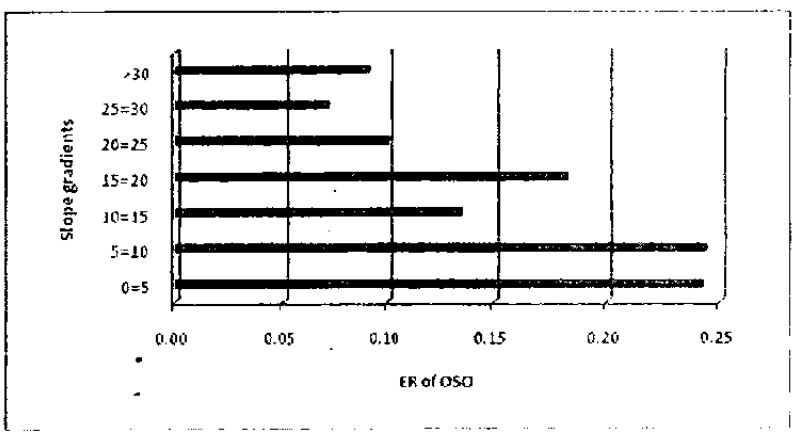


Fig. 24 Encounter rate of Oriental scops owl in various slope gradients in the SWG

Disturbance: This owl was recorded mostly from highly and medium disturbed areas and it is obvious that the species preferred habitats with anthropogenic disturbances

(Fig. 25). However, no significant difference was observed in the encounter rates between the sites (χ^2=0.620; df=2; p=0.73).

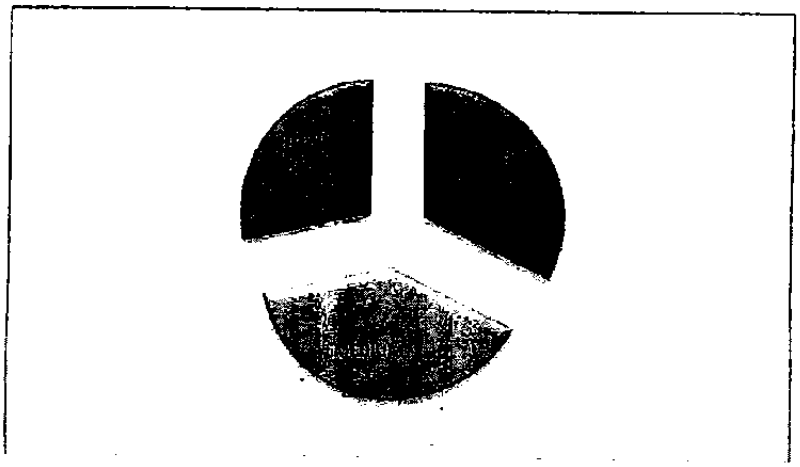


Fig. 25 Encounter rate of Oriental scops owl in various disturbance levels

Preference of landscape level habitat parameters by Oriental scops owl is given in Table 24. The presence of the species was characterised at landscape level with the presence of moist deciduous forests, dry deciduous forests and water body at 500m and 2 km radius. It avoided semi evergreen and dry thorn forests at both levels. At landscape level 30 % moist deciduous, 20 % of dry deciduous and 16 % of water body was preferred at 500 m radius, where as it was 25 % of moist deciduous forests and 14 % water body at 2000 m radius.

Table 24. Preference of landscape level habitat parameters by Oriental scops owl (n=276)

Parameters	Oriental scops owl				Z	P
	Absence		Presence			
	Mean	SD	Mean	SD		
Altitude (m)	461.39	374.99	491.27	369.71	-0.02	0.98
Slope (degree)	12.95	9.02	10.53	8.52	-1.92	**0.05**
WE_500 (ha)	16.30	29.22	10.14	22.67	-0.64	0.52
SE_500 (ha)	4.83	17.13	0.00	0.00	-2.26	**0.02**

MDF_500 (ha)	8.37	20.62	24.03	30.96	-4.21	**0.00**
DDF_1_500 (ha)	12.38	26.29	2.62	13.22	-3.22	**0.00**
DDF_2_500 (ha)	7.59	20.82	15.62	30.88	-1.64	**0.10**
TE_500 (ha)	5.38	18.20	4.49	15.74	-0.60	0.55
PI_500 (ha)	2.17	11.16	0.22	1.32	-0.59	0.56
MI_500 (ha)	3.81	15.38	0.64	3.25	-1.21	0.23
W_500 (ha)	4.50	13.61	12.67	19.27	-5.39	**0.00**
NF_500 (ha)	13.18	26.66	8.06	19.87	-1.12	0.26
WE_2000 (ha)	262.56	386.09	213.45	318.32	-0.62	0.54
SE_2000 (ha)	68.59	207.65	10.19	64.85	-2.60	**0.01**
MDF_2000 (ha)	139.56	260.36	314.89	302.87	-4.56	**0.00**
DDF_1_2000 (ha)	205.11	348.36	24.40	122.04	-4.22	**0.00**
DDF_2_2000 (ha)	136.80	293.24	271.32	476.01	-0.87	0.38
TE_2000 (ha)	69.90	196.59	74.61	172.95	-0.73	0.47
PI_2000 (ha)	34.04	131.99	12.34	45.86	-0.82	0.41
MI_2000 (ha)	60.43	211.10	20.02	67.62	-0.25	0.81
W_2000 (ha)	72.72	132.95	179.45	173.18	-4.36	**0.00**
NF_2000 (ha)	207.03	344.67	135.51	222.64	-0.23	0.82

_500 = 500 m radius, _2000 = 2000 m radius

3.2.3.1.6. Ceylon bay owl

Vegetation: Altogether eight individuals were sighted during the survey and 11 more records were collected from the secondary information. Out of the 19 sightings of the species, majority (79 %) were from the evergreen forests (Fig. 26). Most of the encounters were from roost sites. However, none of the observations was associated with the foraging activity of this elusive raptor. Majority of the sightings were by spotlighting and they rarely responded by call playbacks.

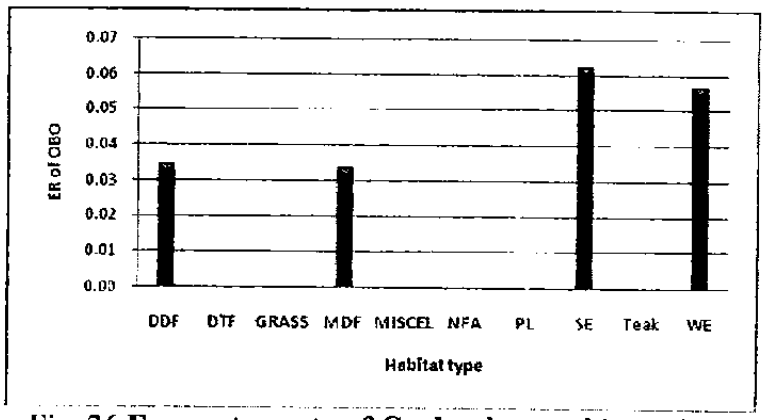


Fig. 26 Encounter rate of Ceylon bay owl in various vegetation types

Elevation: Most of the sightings of the species were above 400 m especially on the evergreen forest patches (Fig. 27).

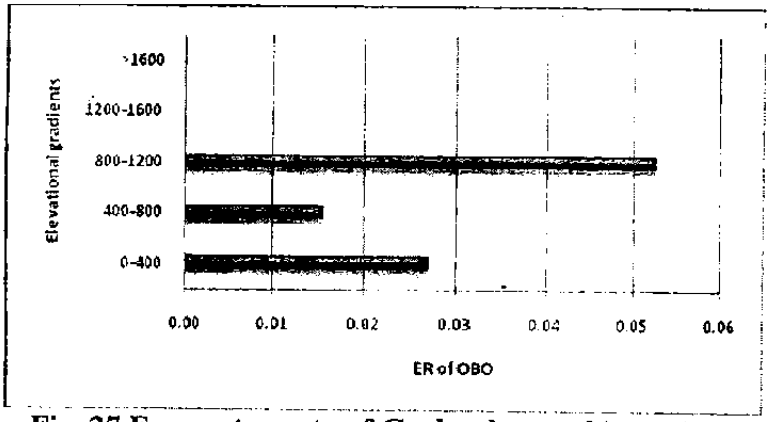


Fig. 27 Encounter rate of Ceylon bay owl in various elevation gradients

Slope: Ceylon bay owl was recorded often from the high and low sloping areas from 5 - 20^0 (Fig. 28).

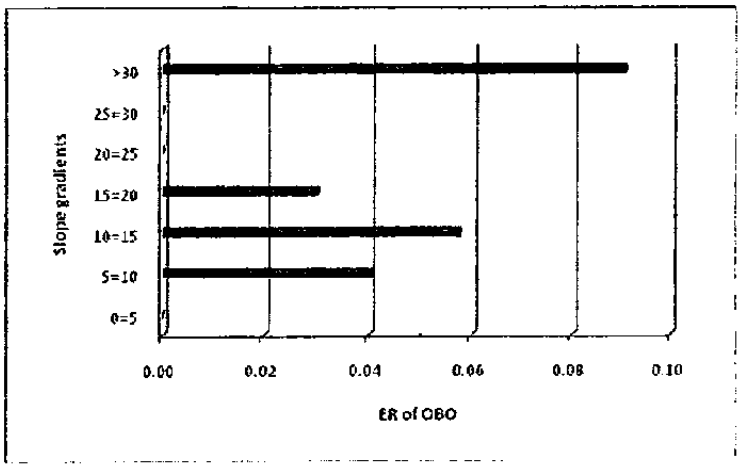


Fig. 28. Encounter rate of Ceylon bay owl in various slope gradients

Disturbance: The species preferred both disturbed as well as undisturbed sites evenly without any preference (Fig. 29).

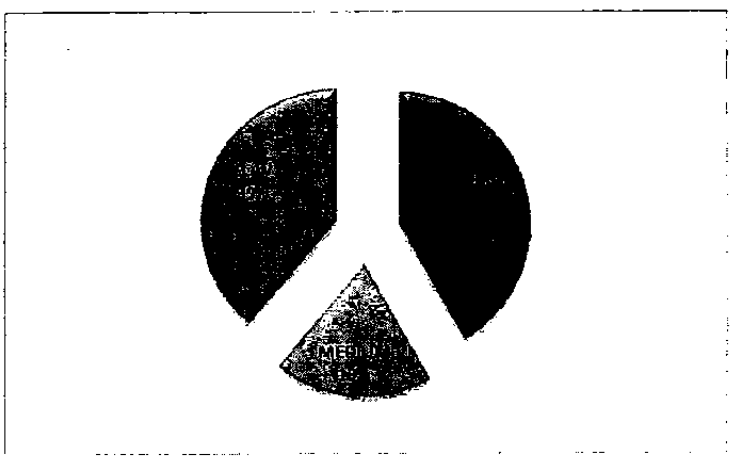


Fig. 29 Encounter rate of Ceylon bay owl in various disturbance levels

3.2.3.1.7. Brown fish owl

Brown fish owl preferred thick bushes, consisting of bamboo or *Ochlandra* reed or thorny bushes, which were near river/stream/pond/check dams/dams and the population were high along the perennial riverbeds. Two old nests were located on a riparian forest cliff and the species was encountered rarely during daytime.

Site parameters

Field scale habitat characteristics of brown fish owl especially tree and ground parameters do not explain any significant difference in habitat use; however, climber alone recorded to influence the distribution of this larger owl. Climbers are necessary to their diurnal roosting sites. Vegetation-wise tree parameters varied significantly. Preference of habitat parameters of brown fish owl is given in Table 25.

Table 25 Preference of habitat parameters of brown fish owl

Parameters	Brown fish owl			
	Presence (Mean)	Absence (Mean)	Z	P
Tree density (ha)	465.04 (250.95)	447.81 (282.84)	-0.58	0.56
Tree height (m)	11.94 (3.73)	11.64 (4.45)	-0.49	0.62
Tree GBH (m)	74.72 (27.21)	73.14 (32.91)	-0.27	0.79
Tree canopy height (m)	6.06 (2.890	6.33 (2.93)	-0.79	0.43
Tree canopy cover (%)	25.15 (5.61)	23.99 (9.06)	-0.80	0.42
Shrub cover (%)	21.57 (14.45)	24.96 (17.17)	-0.69	0.49
Herb cover (%)	23.82 (15.10)	22.46 (13.40)	-0.14	0.89
Grass cover (%)	22.63 (20.86)	27.89 (27.01)	-0.34	0.73
Litter cover (%)	33.62 (21.71)	35.21 (20.92)	-0.31	0.76
Overall canopy cover (%)	47.81 (17.35)	47.19 (21.24)	-0.18	0.86
Dead log (No.)	3.63 (3.35)	2.53 (3.04)	-1.30	0.19
Climbers (No.)	21.07 (17.20)	14.79 (15.08)	-1.56	0.12

SD in parenthesis

Elevation: The altitudinal distribution of this larger owl showed preference to a range of altitudes but the highest encounter rate (0.082 owls/ point) was recorded in the low

altitude; *i.e.*, 0-400 m (Fig. 30). Occasionally the species was encountered in the higher reaches (2000 m) of the southern Western Ghats. The species was also recorded from the village streams away from the Ghats.

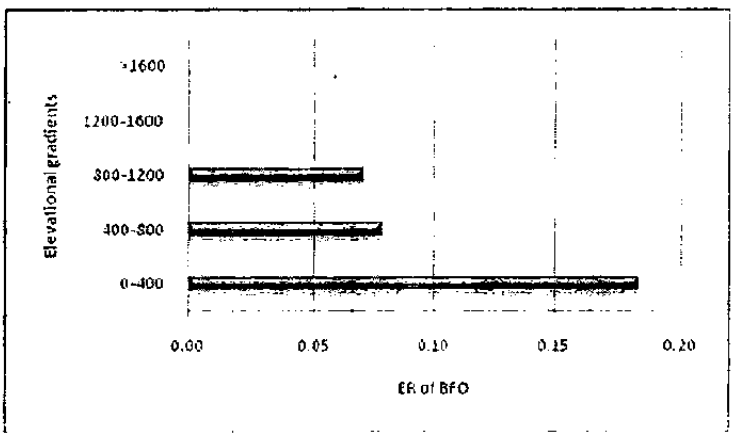


Fig. 30 Encounter rate of brown fish owl in various altitudinal gradients

***Vegetation*:** Non-forested areas including grassy hillocks, orchids, coconut and mango groves were the most frequently utilized habitats by this larger owl followed by the plantations and teak (Fig. 31).

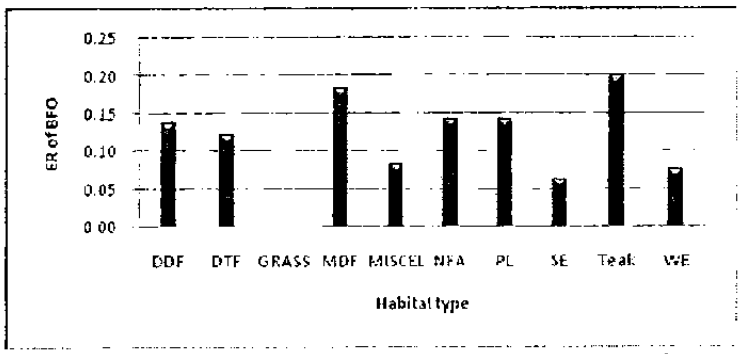


Fig. 31 Encounter rate of brown fish owl in various vegetation types

***Slope*:** Brown fish owl preferred wide range of slope gradients that ranged from 0 to 30 degree (Fig. 32). Maximum sighting was recorded from the low slopes or plains than highly undulating terrain. However, the species preferred to build nest (five sites) in cliffs of grassy hillocks.

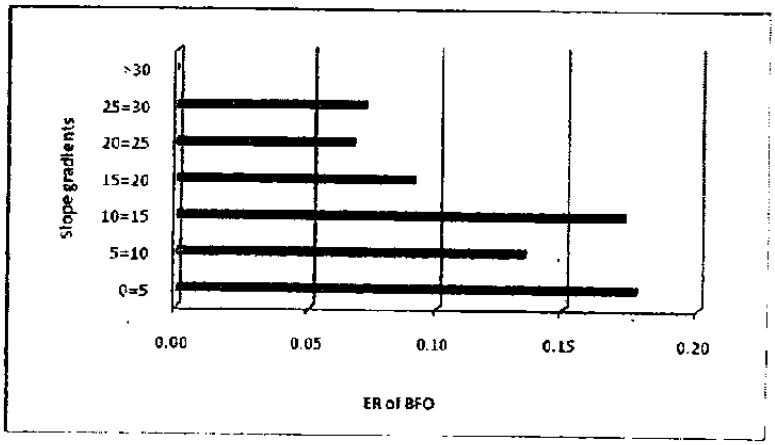


Fig. 32 Encounter rate of brown fish owl in various slope gradients

Disturbance Brown fish owl was recorded mostly in the highly disturbed areas (Fig. 33). Even though the orchards and coconut grooves are located near the human settlements, people seldom visited these areas during the non-harvesting periods. Therefore, the possibility of disturbance to their nest and nestlings were low during the non-harvesting seasons.

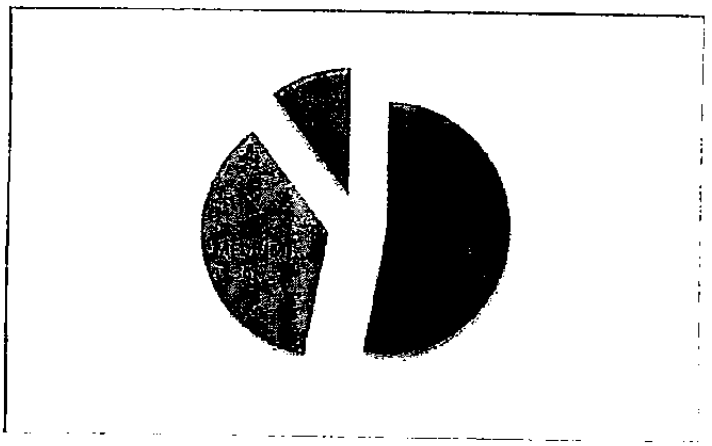


Fig. 33 Encounter rate of brown fish owl in various disturbance levels

Distribution of brown fish owl was influenced by the presence of water bodies and all the sightings of this species were on the riparian forest or near the dam sites. In general, this species was highly secretive during night hours and never perched on

open or dead branches, but while feeding the crabs they preferred rocks in the riparian forest. Preference of brown fish owl to landscape level parameters is given in Table 26. The brown fish-owl showed a preference towards water logged sites near to the open forested areas and avoided the thick-canopied forests like wet evergreen. Due to its fish eating habit, the species thrived near water bodies such as river, dam and stream. Landscape parameters did not show any significant preference at 500 m radius but at 2000 m radius 10 % of water body in a census point influenced the detection of brown fish owl.

Table 26. Preference of landscape level habitat parameters by brown fish owl

Parameters	Brown fish owl				Z	P
	Absence		Presence			
	Mean	SD	Mean	SD		
Altitude (m)	491.31	378.30	304.26	296.26	-3.14	**0.00**
Slope (degree)	12.91	9.21	9.76	6.56	-1.74	**0.08**
WE_500 (ha)	15.81	28.76	10.85	23.96	-1.01	0.31
SE_500 (ha)	4.23	16.30	2.02	9.36	-0.54	0.59
MDF_500 (ha)	11.07	23.62	12.54	23.89	-0.70	0.49
DDF_1_500 (ha)	10.21	24.16	13.04	28.19	-0.01	0.99
DDF_2_500 (ha)	9.48	23.74	6.33	18.85	-0.01	0.10
TE_500 (ha)	5.28	18.08	4.79	15.58	-0.51	0.61
PI_500 (ha)	1.69	9.65	2.60	12.97	-0.06	0.96
MI_500 (ha)	3.37	14.52	2.25	10.07	-0.05	0.96
W_500 (ha)	5.91	15.32	6.69	13.88	-0.72	0.47
NF_500 (ha)	11.46	24.82	17.39	30.11	-1.32	0.19
WE_2000 (ha)	269.56	386.93	146.36	256.34	-1.92	**0.06**
SE_2000 (ha)	63.18	202.00	21.91	76.58	-0.89	0.37
MDF_2000 (ha)	168.74	275.37	193.44	288.23	-0.18	0.86
DDF_1_2000 (ha)	163.32	319.20	227.71	370.54	-1.29	0.20
DDF_2_2000 (ha)	165.62	342.92	135.24	302.78	-1.20	0.23
TE_2000 (ha)	72.04	201.65	62.35	111.08	-1.37	0.17
PI_2000 (ha)	26.88	118.04	51.03	139.23	-1.26	0.21
MI_2000 (ha)	54.94	202.33	39.74	117.96	-0.03	0.98
W_2000 (ha)	88.31	146.08	120.01	151.27	-1.79	**0.07**
NF_2000 (ha)	184.06	316.45	258.89	385.21	-1.64	**0.10**

_500 = 500 m radius, _2000 = 2000 m radius

3.2.3.1.8. Indian eagle owl

Site parameters

In the case of Indian eagle owl, the habitat characteristics of observed sites were drastically differed from the absence sites largely due to the restricted range of habitat niche. Almost all the tree parameters and ground parameters of observed sites have low mean value than that of the absence sites and most of them were statistically significant. Preference of Indian eagle owl to habitat level parameters is given in Table 27.

Table 27. Preference of habitat parameters of Indian eagle owl

Parameters	Indian eagle owl			
	Presence (Mean)	Absence (Mean)	Z	P
Tree density (ha)	205.69 (200.49)	472.99 (273.96)	-3.96	**0.00**
Tree height (m)	3.48 (2.57)	12.45 (3.64)	-5.89	**0.00**
Tree GBH (m)	25.28 (21.70)	77.86 (29.19)	-5.43	**0.00**
Tree canopy height (m)	1.58 (1.55)	6.74 (2.61)	-5.73	**0.00**
Tree canopy cover (%)	12.71 (10.83)	25.22 (7.67)	-4.18	**0.00**
Shrub cover (%)	25.70 (22.61)	24.42 (16.30)	-0.00	1.00
Herb cover (%)	12.41 (10.80)	23.60 (13.45)	-2.83	**0.01**
Grass cover (%)	38.64 (42.67)	26.14 (24.16)	-0.57	0.57
Litter cover (%)	3.66 (3.80)	37.95 (19.45)	-5.91	**0.00**
Overall canopy cover (%)	12.26 (12.84)	50.56 (18.14)	-5.46	**0.00**
Dead log (No.)	0.43 (0.85)	2.05 (2.27)	-3.32	**0.00**
Climbers (No.)	10.18 (9.53)	16.11 (15.83)	-1.09	0.28

SD in parenthesis

Elevation and slope: More than sixty per cent of sightings of the Indian eagle owl were below 400 m altitudes and no individuals were observed above 600 m altitude

(Fig. 34). This showed that the species often utilized the downhill. The species also preferred high slope gradients (Fig. 35).

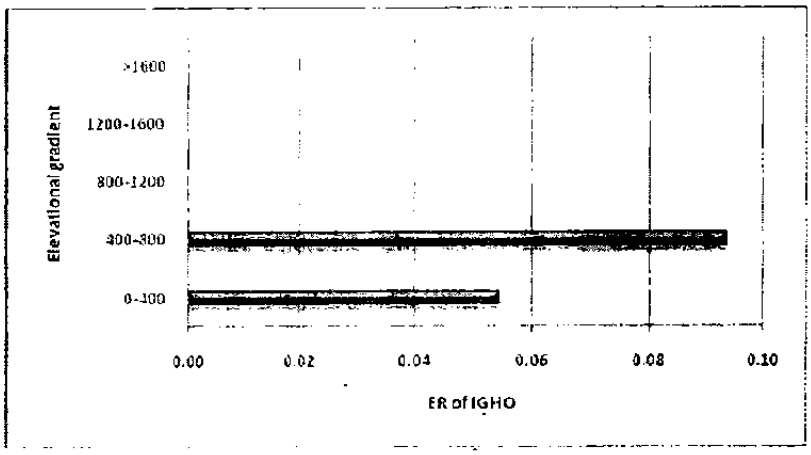


Fig. 34 Encounter rate of Indian eagle owl in various altitudinal gradients

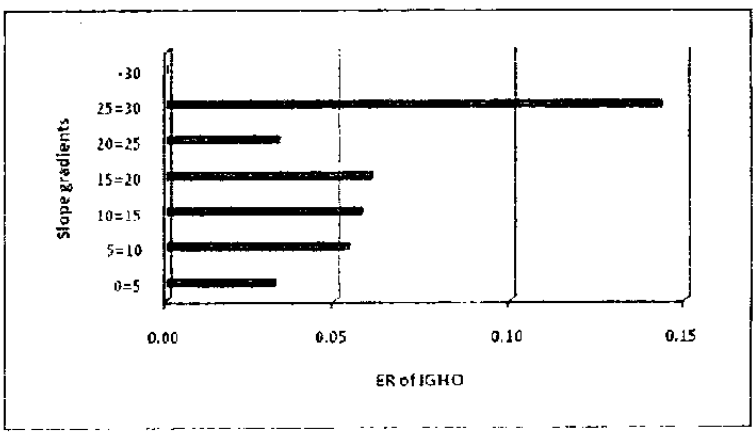


Fig. 35 Encounter rate of Indian eagle owl in various slope gradients

Vegetation and disturbance: The owl was recorded from two vegetation types namely dry deciduous forests (0.31 owls / point) and dry thorn forests (0.19 owls/ point) (Fig. 36). The species was mostly recorded from the least disturbed sites (0.15 owls / point) than the disturbed sites (0.07 owls/ point) (Fig. 37).

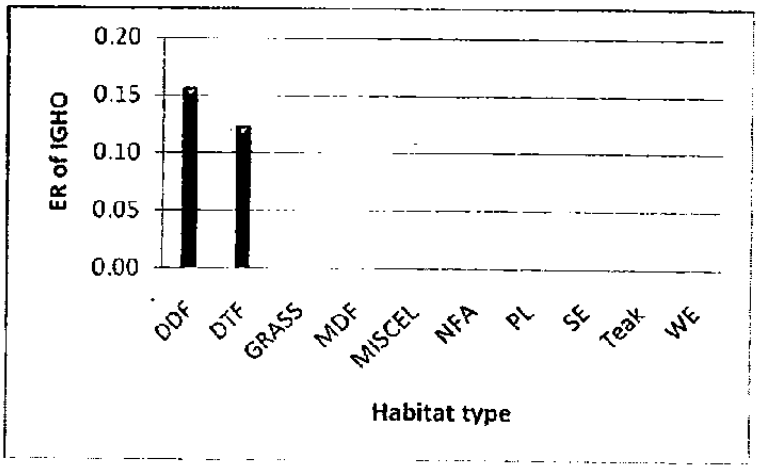


Fig. 36 Encounter rate of Indian eagle owl in various vegetation types

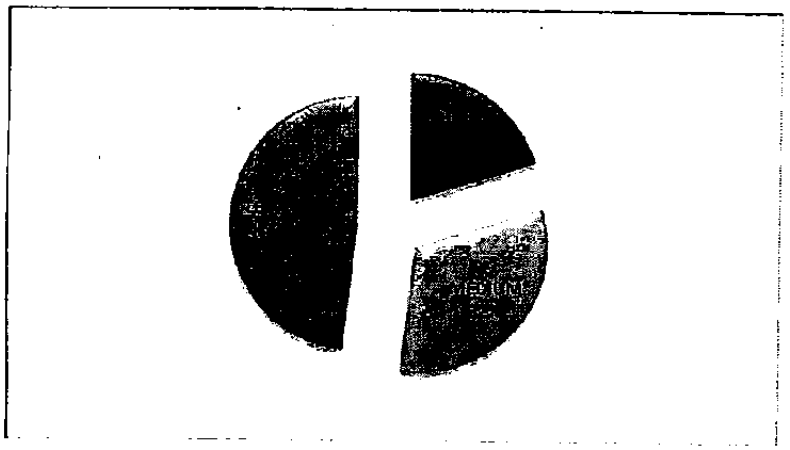


Fig. 37 Encounter rate of Indian eagle owl in various disturbance levels in the SWG

Preference of Indian eagle owl to landscape parameters is given in Table 28. The species used large extent of non forest areas, dry thorn forest and dry deciduous forests and avoided extensive stretches of wet evergreen forests, moist deciduous forests. The presence of 57 % of non forested area and 21 % of dry thorn forests have higher probability to encounter a Indian eagle-owl at 500 m radius and in 2000 m radius good chance exist at places with 51 % of non forested area, 26 % dry thorn forests and 21 % of dry deciduous forests.

Table 28. Preference of landscape level habitat parameters by Indian eagle owl

Parameters	Indian eagle owl				Z	P
	Absence		Presence			
	Mean	**SD**	**Mean**	**SD**		
Altitude (m)	472.53	381.52	361.66	129.15	-0.28	0.78
Slope (degree)	12.45	8.98	13.51	8.88	-0.59	0.56
WE_500 (ha)	15.97	28.71	0.00	0.00	-2.38	**0.02**
SE_500 (ha)	4.15	15.96	0.00	0.00	-1.10	0.27
MDF_500 (ha)	11.86	24.09	0.00	0.00	-2.18	**0.03**
DDF_1_500 (ha)	10.00	24.21	21.51	31.35	-2.62	**0.01**
DDF_2_500 (ha)	8.71	23.02	15.80	25.53	-1.58	0.11
TE_500 (ha)	5.49	18.17	0.00	0.00	-1.34	0.18
Pl_500 (ha)	1.91	10.38	0.00	0.00	-0.92	0.36
MI_500 (ha)	3.39	14.36	0.16	0.60	-0.18	0.86
W_500 (ha)	6.33	15.45	0.00	0.00	-2.08	**0.04**
NF_500 (ha)	10.69	24.31	41.03	32.32	-4.49	**0.00**
WE_2000 (ha)	266.49	379.88	10.09	37.45	-3.17	**0.00**
SE_2000 (ha)	60.88	195.36	0.00	0.00	-1.66	**0.10**
MDF_2000 (ha)	181.14	281.03	0.00	0.00	-3.31	**0.00**
DDF_1_2000 (ha)	163.49	322.97	325.69	362.87	-3.69	**0.00**
DDF_2_2000 (ha)	156.01	336.38	267.27	355.84	-1.78	**0.08**
TE_2000 (ha)	74.38	196.56	3.25	12.14	-1.55	0.12
Pl_2000 (ha)	31.57	124.02	1.21	4.54	-0.54	0.59
MI_2000 (ha)	55.43	198.06	6.86	25.65	-0.82	0.41
W_2000 (ha)	97.21	149.25	3.16	8.66	-2.80	**0.01**
NF_2000 (ha)	170.06	308.13	638.42	351.54	-4.85	**0.00**

_500 = 500 m radius, _2000 = 2000 m radius

3.2.3.1.9. Forest eagle owl

Elevation and slope: Maximum encounter rate of the forest eagle owl was recorded from the high altitude forests with high undulating terrains but seldom encountered from the Plateau in the low altitudes like Kalakkad Mundanthurai Tiger Reserve (Figs. 38, 39).

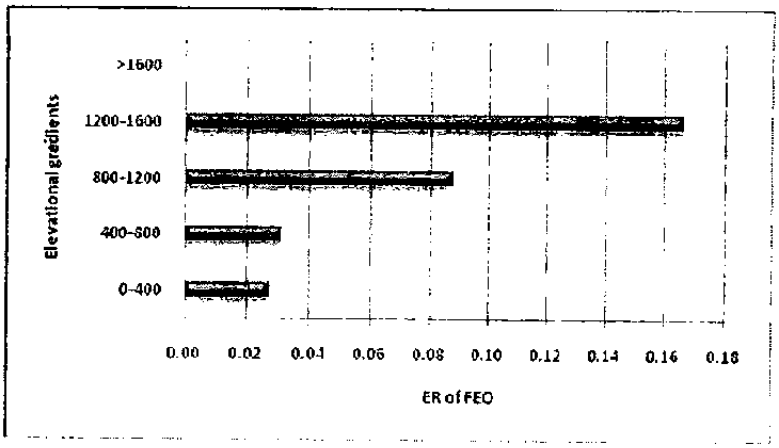


Fig. 38 Encounter rate of forest eagle owl in various altitudinal gradients in the SWG

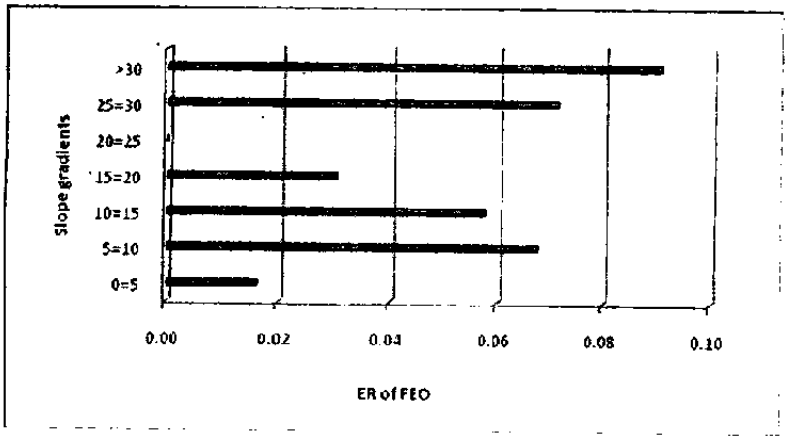


Fig. 39 Encounter rate of forest eagle owl in various slope gradients

Vegetation and disturbance: Interestingly the species was recorded to utilize mostly the natural forests and maximum encounter rate was recorded from the wet evergreen forests followed by the moist deciduous forests and dry deciduous forests (Fig. 40). Among the disturbance levels, maximum encounter rate was from the least disturbed sites than the disturbed sites (Fig. 41).

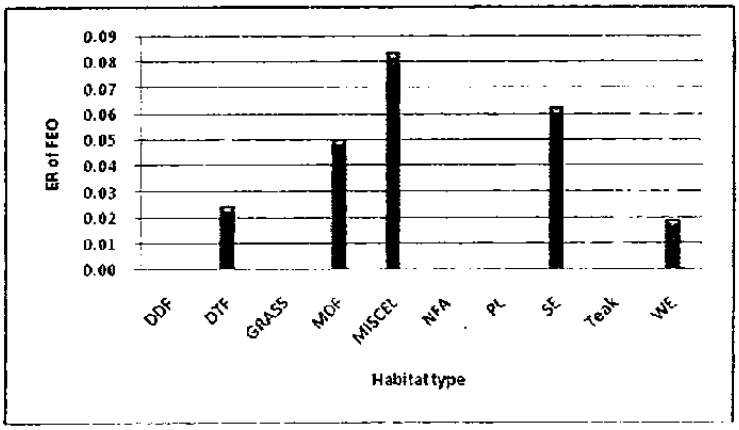


Fig. 40 Encounter rate of Forest eagle owl in various vegetation types

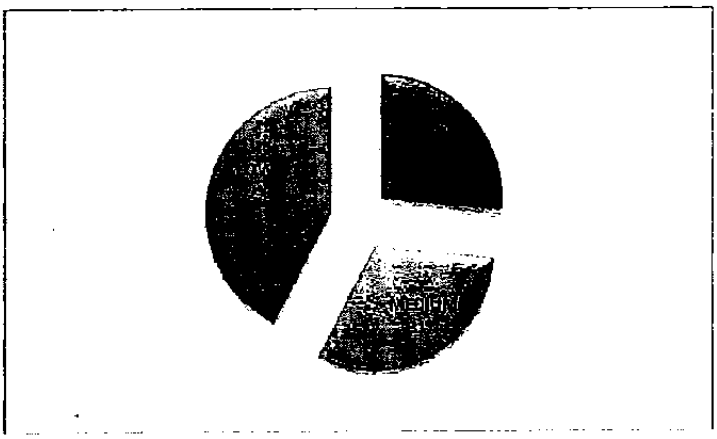


Fig. 41 Encounter rate of Forest eagle owl in various disturbance levels in the SWG

Forest eagle owl also preferred dead vertical branches than live branches and the preferred perch height was 14 m in the riparian forests (N=4).

3.2.3.1: 10. Mottled wood owl

Vegetation: The encounter rate of mottled wood owl was highest in the non-forested areas (0.571 owls/ point) and these areas mostly belonged to the private plantation, orchard or grooves. It was followed by the dry thorn forests including hillocks.

Elevation: The species was not recorded above 500 m and in one occasion in the Theni Forest Division, the species was reported at 500 m altitude. Highest encounter rate of the owl was at 0-400 m gradients.

Slope: Plateau or plains were the maximum utilized slope of mottled wood owl but some observations were also obtained from the highly undulating hills of the Ghats.

Disturbance: Owls utilized more often the low disturbed sites (0.094 owls/ point) than the highly disturbed sites (0.067 owl/ point). This is clear because the species purely depended on the home gardens and groves adjacent to the hillocks or dry forests where they bred. Habitat use of owls in the Kalakkad –Mundanthurai Tiger Reserve is given in the Table 29,

Table 29. Habitat use different species of owls in the Kalakad - Mundanthurai Tiger Reserve

Sl. No.	Name of the species recorded	Locations
1.	Indian scops owl (*Otus bakkamoena*)	Servalar teak plantation and Karaiyar dam site
2.	Jungle owlet (*Glaucidium radiatum*)	Teak plantation and Vazhamarathu way
3.	Brown hawk owl (*Ninox scutulata*)	Riparian forest and semi evergreen
4.	Brown fish owl (*Bubo zeylonensis*)	Around the dam site
5.	Eurasian scops owl (*Otus sunia*)	Semi evergreen
6.	Indian eagle owl (*Bubo bubo*)	Dry thorn forest of Papanasam
7.	Spotted owlet	Dry thorn forest of Papanasam
8.	Ceylon Bay Owl (Phodilus assimilis)	Semi evergreen and dam site of Karaiyar
9.	Mottled wood owl	Dry thorn forest

Interspecific interaction in habitat use

Table 30. Comparison of habitat characteristics of presence sites of the selected owl species

Parameters	JO	BHO	ISO	BFO	OSO	IEO
Tree density (ha)	422.11	481.00	477.74	465.04	427.80	205.69

	(237.37)	(266.73)	(300.14)	(250.95)	(191.13)	(200.49)
Tree height (m)	13.06 (3.12)	13.01 (2.78)	12.25 (3.27)	11.94 (3.73)	13.29 (2.60)	3.48 (2.57)
Tree GBH (cm)	84.03 (27.87)	77.80 (23.49)	75.16 (26.56)	74.72 (27.21)	82.98 (24.41)	25.28 (21.70)
Tree canopy height (m)	6.85 (2.55)	7.06 (1.92)	6.27 (2.09)	6.06 (2.890	7.23 (2.25)	1.58 (1.55)
Tree canopy cover (%)	26.17 (8.04)	24.98 (6.92)	26.72 (6.17)	25.15 (5.61)	24.07 (7.27)	12.71 (10.83)
Shrub cover (%)	24.44 (18.20)	26.92 (18.86)	21.76 (15.71)	21.57 (14.45)	26.80 (19.03)	25.70 (22.61)
Herb cover (%)	25.62 (13.58)	24.42 (12.53)	24.14 (14.07)	23.82 (15.10)	24.67 (10.78)	12.41 (10.80)
Grass cover (%)	29.90 (25.00)	26.84 (24.87)	25.48 (25.83)	22.63 (20.86)	29.79 (24.65)	38.64 (42.67)
Litter cover (%)	35.62 (18.81)	42.44 (20.27)	39.87 (20.34)	33.62 (21.71)	33.13 (17.64)	3.66 (3.80)
Overall canopy cover (%)	51.02 (17.89)	53.17 (17.22)	53.34 (16.81)	47.81 (17.35)	51.46 (17.89)	12.26 (12.84)
Dead log (No.)	3.30 (3.60)	2.71 (3.13)	2.78 (3.07)	3.63 (3.35)	3.65 (3.83)	0.43 (0.85)
Climbers (No.)	16.40 (15.55)	13.38 (14.32)	14.92 (13.67)	21.07 (17.20)	15.12 (14.41)	10.18 (9.53)

JO=Jungle owlet; BHO=Brown hawk owl; ISO= Indian scops owl; OSO=Oriental scops owl; BFO=Brown fish owl; IEO=Indian eagle owl

Six sympatric owls were put together to elucidate the existing pattern of resource partitioning based on the habitat parameters. Mean and standard deviation of habitat characteristics at field scale of selected owl species were tabulated to understand the different level of habitat partitioning (Table 30). While pooling six species together for analysis, most of the habitat characteristics were found statistically significant because of Indian eagle owl, as it has restricted range of distribution in the lower altitude forests. Hence, the analysis was done for lesser owl (JO, BHO, ISO and OSO) alone and it was found that jungle owlet occupied similar ecological niche as like brown hawk owl and Oriental scops owl; however, differed from Indian scops owl with respect to the girth at breast height of perch tree. Brown hawk owl was significantly different from Indian scops owl with regard to tree canopy height and brown hawk owl occupied higher tree heights than the Indian scops owl. However brown hawk owl shares similar ecological niche with the Oriental scops owl in the above mentioned habitat parameters. Canopy height and canopy coverage varied between Indian scops owl and Oriental scops owl.

3.2.3.2. Behavioural observations

Response to broadcasted calls

Table 31. Latency of jungle owlet to its congeneric species

Seconds	Latency to jungle owlet calls	Relative value of interspecific calls
While broadcasting	0	00.00
5-10 seconds	2	18.18
11-20 seconds	2	18.18
21-40 seconds	4	36.36
41-60 seconds	3	27.27
60-120 seconds	0	00.00
Total	**11**	**100.00**

Table 32. Latency of Brown hawk owl to its conspecific call

Seconds	Latency to conspecific calls	Relative value of interspecific calls
While broadcasting	3	7.32
5-10 seconds	16	**39.02**
11-20 seconds	10	24.39
21-40 seconds	6	14.63
41-60 seconds	3	7.32
60-120 seconds	3	7.32
Total	**41**	**100.00**

Interspecific responses

The Indian scops owl and the jungle owlet responded more to the broadcasted calls of brown hawk owl. Among these two, Indian scops owl responded for 16 call sequences but brown hawk owl did not respond to any of the Indian scops owl calls. Similarly, brown hawk owl responded rarely to the jungle owlet call at a considerable distance (100-150 m) from the broadcasting station. Jungle owlet also responded to the brown hawk owl calls during 11 call sequences (Table 31).

Intra specific responses

Immediately after its conspecific call, the brown hawk owl responded within a short interval (5-10 seconds). However, at certain occasions if responded even after one minute after the initiation of call sequences (Table 32). This shows variations of individuals in recognition of conspecific intruders. Similarly, on a few occasions, the brown hawk owl responded while broadcasting in the census station (7.32 %). Even

though the presence of brown hawk owl was known during the 35 call sequence, it responded only to 26 call sequences (75 %) and in nine sequences jungle owlet and Indian scops owl responded. Only in one site, no response of any of the species was observed. More than 60% of the responses of brown hawk owl were within 20 seconds and jungle owlet took 40 seconds for responses. Latency of calls recorded is shown in Table 31 and 32.

Approaching distance and height

Difference in approaching distances of brown hawk owl between the breeding and non-breeding seasons showed a significant difference (Fig. 42). Similarly, the height occupancy while defending the intruder of conspecific call differed between the breeding and non-breeding seasons. The reasons for such behaviour may be the territory ownerships and maintenance of breeding pair. They attacked the observer twice when the approaching distance was near to the broadcasting station, *i.e.*, around 0-5 m distance at a low height (4-8 m). Interestingly they were very aggressive during the breeding season than in the non-breeding season.

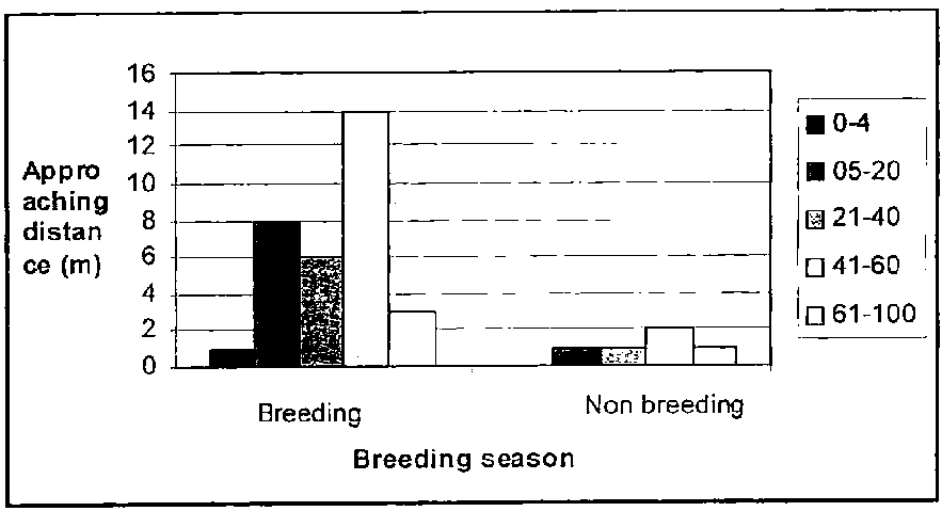


Fig. 42 Difference in the approaching distances during the breeding and non breeding seasons.

Response of owls to inter and intra specific calls

During the initial months of the survey, the observer used to mimic the call of brown hawk owl and usually the response was far from the point. The species never

attempted to attack the observer during this period but during the breeding season (January to April), the birds tried to attack. The birds attacked the caller from a distance of 1 m to 40 m and usually only one partner alone was engaged in attacking the caller. Though another bird was sighted adjacent to the attacker, it never joined the effort. This behaviour was not previously recorded. This species is highly aggressive towards the intruders into the territory during the breeding season and used to chase the intruder even after 100 m from the point. Apparently, all the three recorded territory holders responded to inter and intra specific calls.

The brown hawk owl's attacking distance depended on the canopy cover of the particular point (Table 33). Owls preferred to stay away from the caller when the canopy cover and tree density was low, where as it preferred closeness towards the caller, when the canopy cover and tree density was high. The owls never came below 4 m from the ground to attack the caller and the height preference was purely depending on the availability of suitable perch sites. Indian scops owl responded to the calls, but it never attacked the caller directly. Whereas in the case of jungle owlet, it came close without making any calls.

3.2.3.3. Habitat use and body size

Species of owls were grouped into two groups, namely large owls and lesser owls based on the size. Habitat variables alone were used for the preliminary habitat requirement analysis. Out of the 13 variables included in the analysis for extracting the difference in the habitat utilization of larger and lesser owl did not show any significant difference (Table 4). Some of the lesser owls like Indian scops owl and jungle owlet preferred variety of altitude ranges from the low altitude dry forest to high altitude montane forest (90-2100 m above msl). Moreover, certain larger owls like forest eagle owl and brown wood owl preferred the riparian and semi evergreen forest respectively; so the variables included here are not completely defining the existing difference.

In the present analysis, quantitative information on dead branches and cavities was not included as this may result in error due to the bias of the ground-based census methods. Many cavities were obscured from the ground view, while some were

recorded, may be those shallow holes made by the woodpeckers and other primary cavity nesters. Initial results of status and habitat utilization of forest owls in the Western Ghats of South India was reported earlier (Jayson *et al.*, 2007).

The brown hawk owl mostly preferred mid stratum of the canopy, which possessed dead branches where as the Indian scops owl preferred native trees with dense foliage in teak and softwood plantations. There was not much variation in the distribution of Indian scops owl population between different altitudes and habitats. The water bodies influenced distribution of brown fish owl. All the sightings of this bird were on the riparian forest or near the dam sites. In general, this owl was highly secretive during the night hours and never used to perch on open or dead branches but while feeding the crabs it preferred the rocks of riparian forest. Forest eagle owl utilized the riparian forest adjacent to the dry thorn forest, which supported good population of black naped hare and giant squirrels. Common barn owl screeches were heard from the nearby human habitations in the surveyed areas. Mottled wood owl utilized the open rocky areas with scattered woody vegetation in the low altitude.

Table 33. Latency of brown hawk owl to its conspecific calls

Sl. No.	Response time in seconds	%
1.	While broadcasting	7.32
2.	5-10	39.02
3.	11-20	24.39
4.	21-40	14.63
5.	41-60	7.32
6.	61-120	7.32

3.2.4. Discussion and Conclusions

The observations showed that a viable population of brown hawk owl exists in the mid-altitude moist forests of southern Western Ghats. This preference to the particular habitat makes the species an important indicator species of the mid-altitude

forest (Jayson, 2006). The quantity of canopy cover and tree density determines the approaching height and distance of brown hawk owl in response to conspecific calls. Increasing canopy coverage, vertical complexity and tree density decreases the visibility of approaching owls. It can be concluded that 1) Brown hawk owl responds to its broadcasted conspecific calls throughout the year with a highest encounter rate during the breeding season 2) More studies are needed to understand why the response behaviour is different during other seasons.

Habitat and microhabitat utilization of certain owl species have been brought into light for the first time. Number of owls was high in the moist deciduous and evergreen forest than in the dry deciduous forests. In the mid-altitude (600 m -1000 m) and high altitude (>1000 m) population of owls ranged from 5 to 9 individuals, whereas in the low altitudes like Peechi and Chinnar, the population was low. In the mid-altitude and high altitude, the abundance of brown hawk owl was higher than in the low altitudes. In Peechi-Vazahani Wildlife Sanctuary, jungle owlet population was higher than that in Nelliampathy and Vazhachal Reserved Forests (altitude 600-1000 m MSL). However, a similar trend was not recorded in the low altitude dry forests of Chinnar Wildlife Sanctuary.

As there is no previous study on the distribution/population status of owls in the country, no comparison is possible (Ali and Ripley, 1987; Easa and Jayson, 2004, Nameer *et al.*, 2008, Jayson, 2008, Maheshwaran *et al*, 2008). Distribution of the 16 species of owls were compiled for 25 States (ENVIS, 2007) and the results revealed that three species showed a narrow range of distribution namely the Ceylon bay owl, forest eagle owl and long eared owl (recorded in less than 50 % of the States). Rest of them are known to occur in more than 50 % of the states (Table 10). However, their current distribution/population status in those states remains doubtful. However, owls in the Western Ghats showed maximum species richness in the State of Kerala (ENVIS, 2007).

Ali and Ripley (1987) reported that the brown hawk owl was observed up to 1300 m altitude but in the present survey, they were recorded above 1450 m. The distribution range is further extended to 150 m and there is possibility to encounter the species further in higher reaches of Western Ghats. The known altitudinal distribution

of the Indian scops owl was known as 1200 m (Rasmussen and Anderton, 2005) but during the survey, it was recorded at 1300 m from Kalakkad - Mundanthurai Tiger Reserve. Short eared owl was reported from southern India in different periods; Ali and whistler (1936) reported it from Peermade and Santhanpara of Idukki District. The species was also reported from the coastal areas of Madras (Thyagaraju, 1933; Santharam, 1981) and from Bharathapuzha estuary (Chandrasekhara and Nameer, 2003). The species was recently reported from Thattekkad Bird Sanctuary and from Upper Nilgiris (Ashwaq, 2004). It clearly showed that the species does not prefer any particular gradient of altitude and it has been observed to occur from the coastal areas to higher reaches of southern India.

Pooled values of encounter rates showed highest mean encounter rates for the mid-altitude gradient (800 m -1200 m). All the 13 owl species were reported to utilize the low altitude gradient (0-500 m) rather than other gradients. Lower altitudes included many vegetation types ranging from dry thorn forests to evergreen forests. Similarly, in the north-eastern Australia also the highest number of species was reported from the low altitude forests, ie., below 400 m (Kavanagh *et al.*, 1995). Even though slope has certain importance in the habitat use of avian species especially raptors, in this study none of the species responded to these parameter. However, some studies have shown the influence of slope on nest site selection of certain diurnal raptors (Belleman and Andersen, 1996). Nest sites of certain larger owls namely the Indian eagle owl and brown fish owl was in high slopes.

In the selection of sites for hunting, structure of vegetation was more important than the abundance of prey (Aschwanden *et al.*, 2005). The present studies showed that, most of the lesser owls were utilizing deciduous forests (moist and dry) and to a certain extent, evergreen forests. However, the larger owls preferred the low altitude dry forests especially the dry thorn forests as these forests have good population of the black-naped hare (Prater, 1973) and the agricultural landscapes supported a good diversity of rodents (Nagarajan, 1998). Importance of the rodents in the food spectrum of the larger owls has been well documented in India (Ramanujam, 2000) and around the world. Moreover, the open landscapes with scattered trees help these owls to freely forage without much disturbance. Two of the larger owls (forest eagle owl and brown wood owl) were recorded mainly in the moist deciduous and wet

evergreen forests, and the first species feed extensively on small cervids (Ali and Ripley, 1983) and other arboreal rodents (flying squirrels and giant squirrels). Good population of large brown flying squirrel was reported in the moist deciduous forests and mostly recorded near the riparian forests (Babu and Jayson, 2009). They also reported that, large brown flying squirrels are highly responding to the call playback of owl calls as part of vigilance activity or predator avoidance activity.

Disturbance

Impact of human disturbance on avian fauna was extensively studied in India as well as in the Western Ghats. Influence of habitat disturbance on owls was assessed at habitat level and at landscape level. Except the jungle owlet, rest of the lesser owls preferred low and moderately disturbed sites. The Indian scops owl alone was encountered in many of the least disturbed sites, whereas brown hawk owl and peninsular scops owl utilized moderately disturbed sites. Among the larger owls, brown fish owl alone was frequently recorded in the highly disturbed sites and from the village streams near homesteads.

Most of the hillocks, adjacent to the forest fringes, are not included in the category of protected area network and these areas are under frequent fire and cattle grazing throughout the year. Hillocks are the predominant breeding site of Indian eagle owl and brown fish owl (Chapter 2). The effect of cattle grazing on the population of rodents and its secondary impact on the population of the larger owls requires further studies. Moreover, detailed ecological and behavioural studies will be required to further understand the driving factors of these elusive raptors in this biodiversity hotspot.

Call play back of owl vocalization had influence on other arboreal mammals, especially on brown flying squirrel (*Petaurista philippensis*) (Babu and Jayson, 2008). Babu and Jayson (2009) proposed a new method of census based on this observation. Microhabitat utilization of jungle owlet revealed that the species is abundant at low altitudes (less than 500 above msl) and disturbed forest areas. As already known, jungle owlets feed predominantly on insects, which are abundantly available in the thick canopies of trees, which explains the preference of the species to areas with tall trees and thick canopy. Jungle owlet is known to forage and move even during the

daytime. During this process, they have to prevent and avoid the diurnal raptors and mobbing birds like crow, jungle babbler and tree pie respectively. Two different call types were recorded namely the *Kaok, kaok, kaok* at regular interval of three to four seconds followed by *krrook krrok* call similar to the Barbets *wtroop* call. Single monotonous call of *krroook krrook krrook* was given continuously for few seconds when any mobbing bird approached the roosting sites. During dusk, they are making noisy *kao kuk* call. In addition, one more call was also recorded during the night hours. The call is verbally *tttrrrooooo*, which is continuous at regular intervals of three to five bouts per repertoire. Among the sympatric owls, Indian scops owl responded more to brown hawk owl calls. When Indian scops owl start producing the vocalization, brown hawk owl stops its response. Does the presence of Indian scops influence the vocal behaviour of brown hawk owl, which needs an answer?

3.3. HABITAT SUITABILITY MODELS

3.3.1. INTRODUCTION

Owls are a group of nocturnal raptors that occupy large home ranges and require complex habitats for the survival, which makes them a potential indicator of the environmental health. Understanding the population size and distribution of owls over a geographic area is needed for developing conservation priorities for the group (IUCN, 2001). Collecting data on distributional range of owls are difficult due to the expensive and time-consuming surveys. Direct sample surveys of owl species over vast landscape are time consuming, expensive and hence limit the quality of the data. Because of the impracticality in undertaking sampling over vast areas, habitat models have been developed to predict the distribution of owls by associating the characteristics of the owl species with the environment. The habitat models are useful for predicting distributions of owl species for geographical areas that have not been extensively surveyed. Developing models of owl habitat provides maps of the owls in its habitat and help us to monitor changes in their potential habitats so that the degradation of the habitats is prevented.

It is difficult and time consuming to gather information about the distribution and abundance of owl species in terms of quantitative measures like density and abundance. For owl species, especially the rare and endangered, the assessment could be made based only on qualitative criteria such as 'present only (absent not recorded)', 'present-absent', 'rare', 'common', 'abundant'. Sampling the presence / absence data is crucial part of any habitat modelling. Absence data is often difficult to obtain accurately. A given location may be classified in the 'absence' set because (1) the species could not be detected even though it was present (this might happen in the present survey as it is cross-sectional in nature) (2) for historical reasons the species is absent even though the habitat is suitable or (3) the habitat is truly unsuitable for the species. Only the last cause is relevant for predictions, but "false absence" may considerably bias analyses.

Elucidating the relationships between the owls and their habitats are fundamental to develop habitat-oriented management plan for the conservation of these elusive bird group (Jones, 2001; Ortego and Diaz, 2004). In this context, the managers/researchers have well recognised that modelling species distribution is an integral component in identifying potential sites for managing and restoring owls (Loyn *et al.*, 2001; Ortego and Diaz, 2004; Martinez, *et al.*, 2003; Piorecky and Prescott, 2006) although these modelling approaches have certain limitations to use in wildlife studies (Fielding and Bell, 1997). Such a prediction using standard statistical algorithms is increasingly used in recent years due to the availability of spatial data, including topographic, vegetation and climate data in a digital format (Hirzel *et al.*, 2000).

In general, based on the nature of the response variable, the modelling approaches are divided into presence only and presence/absence model (presence only means that no absence data available or absence could not be assessed with reasonable accuracy). Widely used presence/absence habitat suitability models in wildlife research include Generalised Linear Models (GLM), Generalised Additive Models (GAM), Classification and Regression Tree analysis (CART) (De'ath and Fabricius, 2000) and Artificial Neural Networks (ANN). However, CART and ANN are seldom applied in wildlife-based studies but often used in medicine and epidemiological research. The available presence only paradigms are GARP (Genetic Algorithm for Rules set Prediction), ENFA (Ecological Niche Factor Analysis) and MaxEnt (Maximum Entropy model) and these models are broadly used in wildlife research.

Presence/absence models require high quality data sets in terms of true presence and absence for evaluation and calibration of the habitat suitability model. Since the data quality affects the reliability of the model prediction (Stockwell and Peterson, 2002), important early issue in generating the model is better understanding the predictive performance of the algorithm with the available data, which are going to be applied for generating habitat suitability model. The performance of the model is also determined by the status of the focal species, because the species with more localised ecological niches has restricted distribution and such a species can be better

predicted though with the poor data quality; but wide ranging species requires high quality data for generating models (Brotons *et al.*, 2004).

Compared to presence only model, the presence/absence (GLM) model predicts more accurately the positive records as such. The predictive accuracies between evaluation data and calibration data sets were larger for presence/absence models than the presence only model. In addition, it indicates the loss in predictive performance when applied to an independent data set not included while constructing the model (Brotons *et al.*, 2004). Although, a few studies have compared the predictive performance between presence and presence/absence modelling (Hirzel *et al.*, 2000), studies testing and comparing the performance of various presence/absence models are seldom applied in conservation studies for example decision tree models. In this Chapter, the predictive performance of the two presence/absence modelling approaches namely binary logistic regression model and decision tree model was comparatively assessed.

3.3.2. METHODS

The details of census methods for the owls in the southern Western Ghats were given in the first two chapters of the report. In this chapter, the variables incorporated in the presence/absence models and comprehensive details about the analysis undertaken are presented.

Dependent variable for the analysis

Owl recorded and not recorded survey sites, otherwise presence and absence of each species at survey sites, was considered as a Boolean dependent variable for the analysis. Habitat suitability model was developed for only three species of owls (jungle owlet, Indian scops owl and brown hawk owl). With respect to other species, lack of sufficient positive records was a constraint. Presence records obtained using all the four methods were used for the analysis and ensured comprehensive set of positive records. Most of the positive records of owls were obtained by employing initial quiet listening and call playback methods (details presented in effectiveness of census methods).

Independent variable for the analysis

Most of the independent variables were extracted from the mapped data, which is available in digital format (www.worldclim.org). Owing to the high variability in the predictor variable, it is hard to explain functional relationship between outcome variables and independent variables (Hosmer and Lemeshow, 2000). One common way of reducing such variability and maintaining the same structure of relationship between the outcome and independent variable is to categorise the independent variable.

Rainfall

Intensity of rainfall is grouped into low rainfall or rain-shadow and rain fed or high rainfall based on the duration and amount of rainfall received during the southwest monsoon, which probably hit the Ghats during June to September. The areas falling beyond the crest of the Ghats are identified as rain-shadow areas and the areas within the crest of the Ghats are categorised as rain-shadow areas.

Altitude and slope

Topographical variables including altitude and slope were derived from SRTM (Shuttle Radar Topography Mission) Dem with 90 m resolution. Based on average values, the altitude and slope are grouped into low (<365 m for altitude and $<11^0$ for slope) and high (>365 m for altitude and $>11^0$ for slope) levels.

Vegetation types

Vegetation types were derived from the FIP (French Institute of Pondichery) map or the local vegetation assessed using field scale methods for example Point Centred Quarter method (discussed in detail in the second chapter). For the purpose of analysis, vegetation types of the Ghats are broadly classified into four vegetation types: i) dry deciduous forest (dry deciduous forest and dry thorn forest); ii) moist deciduous forest (moist deciduous forest and miscellaneous); iii) plantations (all the plantations); iv) evergreen forest (semi-evergreen, wet evergreen and shola grassland).

Anthropogenic disturbance

The disturbance level was measured by calculating the distance between survey site and the nearest human settlement. Survey sites less than 2 km from the human habitation were categorised as high disturbed sites and more than 2 km were categorised as low disturbed sites. Survey of India topo sheets 1:50,000 were used for this purpose.

3.3.2.1. Logistic regression analysis

Variable selection

The first step in modelling is selecting limited number of crucial predictor variables because including all the variables in the model will over fit the model and result in producing numerically unstable estimates like large estimated coefficient and standard errors (Hosmer and Lemeshow, 2000). The selection of crucial variable is based upon prior experience with the focal animal, through the published information about the pattern of habitat use and the factors that regulate the distribution of the animal.

In the beginning, the species distribution was modelled using both landscape and field habitat variables but the field habitat variables showed poor prediction on the habitat utilization of owls. Therefore, the modelling was attempted using landscape variables alone. The landscape variables *viz.*, rainfall, altitude, disturbance, vegetation type and slope were considered for developing habitat suitability models for the three owl species - Indian scops owl, jungle owlet and brown hawk owl.

Logistic regression model

Regression method is an important component in any data analysis, which concerned with describing the relationship between response variable and one or more explanatory variables. The most repeatedly applied regression method, which is acquainted to the biologist, is linear regression method. The outcome of the linear regression model is continuous whereas dichotomous in logistic regression model.

Logistic regression is the most widely used habitat suitability model. Logistic regression, sometimes called the logistic model, is generated to predict the probability of occurrence of an event by fitting data to a logistic curve. Consider a collection of p

independent variables x_1, x_2,.....x_p. Let the conditional probability that the outcome is present, for example the presence of owl, be denoted by P(y=1/x)=π (x). Then the logit of the multiple logistic regression models is defined by the equation

$$g(x) = \beta_0 + \beta_1 x_1 + ... + \beta_p x_p$$

In which case

$$\pi(x) = \frac{e^{g(x)}}{1 + e^{g(x)}}$$

If some of the independent variables are discrete, nominal scaled variables such as vegetation type, we use a collection of design variables (dummy variables)
In general, if a nominated scaled variable has *k* possible values, then *k-1* design variables will be needed. This is true since, unless stated otherwise *k-1* design variables will be denoted by F_{ju} and the co-efficient for these design variables will be denoted as

$$\beta_{ju}; u = 1,2,3.....k_{j-1}$$

Thus, the logit for a model with *p* variables and *jth* variable being discrete would be

$$g(x) = \beta_0 + \beta_1 x_1 + ... + \sum_{u=1}^{h_{j-1}} \beta_{ju} F_{ju} + \beta_p x_p$$

The most common method of estimating β's is *maximum likelihood* method (Hosmer and Lemeshow, 2000). The coefficients of the regression model are tested by Wald test. Exp (β) represents the ratio-change in the odds of the event of interest for a one-unit change in the predictor. Odds ratio is only the measure of association directly estimated from logistic model. Enter method was employed for fitting the model. In the enter method, all the independent variables are simultaneously included in the model. The cut off point for predicted probability value of the model is set as 0.5 and if the predicted probability value is equal to or greater than 0.5, it indicates the higher chances to encounter an owl species, otherwise lower.

3.3.2.2. Classification tree

Classification tree procedure can be used for segmentation, stratification, prediction, data reduction, interaction identification and category merging. This procedure creates a tree-based classification model by considering few statistical algorithms and assumptions. It classifies cases into groups or predicts values of a

dependent (target) variable based on values of independent (predictor) variables (Hair *et al.*, 2003). Independent variables selected in the procedure are nominal variables.

Frequently used decision tree models are CART (Classification and Regression Tree model), QUEST and CHAID (Chi-squared Automatic Interaction Detection). In this study, CHAID algorithm was applied for constructing tree based model. In CART all the splits are binary that is each parent node is split into only two child nodes. In CHAID model parent nodes can be split into either binary or many child nodes. At each step, CHAID chooses the independent variable that has the strongest interaction with the dependent variable. Categories of each predictor are merged if they are not significantly different with respect to the dependent variable. The significance of the split is assessed through the Chi-square test (De'ath and Fabricius, 2000).

The classification tree was built separately for rain-fed (high rainfall areas) and rain-shadow (low rainfall) areas of the southern Western Ghats; but no difference was perceived in the classification tree structure of the pooled and split up trees for Jungle owlet and Brown hawk owl. However, for Indian scops owl, different patterns of classification trees for rain-shadow and rain-fed areas were obtained. Therefore, three tree structures including rain-fed, rain-shadow and pooled trees were developed for Indian scops owl.

Tree depth controls the maximum number of levels of growth beneath the root node and the tree depth was set to four levels in all CHAID models irrespective of species and rainfall. Minimum number of cases required for splitting a parent node to child node was set as 10 cases for parent node and 5 cases for child node. Increase in the minimum cases, produces fewer nodes and decrease in the minimum cases produces higher the nodes. The significance level for splitting and merging the categories was set as 0.15. We used likelihood ratio of chi-square statistic for nominal dependent variable to determine the node splitting and category merging since it is more robust model when dealing with small samples.

Model comparison

The predictive performances of the models generated were assessed through several statistical measures, which are briefly presented below.

Sensitivity and Specificity

Sensitivity and specificity are measures of classification accuracy. The sensitivity measures the proportion of actual positives, which are correctly identified as such; and the specificity measures the proportion of negatives, which are correctly, identified (Table 34).

$$Sensitivity = \frac{True positive}{True positive + False negative}$$

$$Specificity = \frac{True negative}{True negative + False positive}$$

$$PPV = \frac{True positive}{True positive + False positive}$$

$$NPV = \frac{True negative}{True negative + False negative}$$

$$Accuracy = \frac{True positive + True negative}{No of observation}$$

Table 34. Statistical measures used for comparing the predictive performance of CHAID and logistic regression model

		Positive	*Negative*	
Test outcome	*Positive*	True Positive	False Positive (Type I error, P-value)	→ Positive predictive value
	Negative	False Negative (Type II error)	True Negative	→ Negative predictive value
		↓ Sensitivity	↓ Specificity	Accuracy

3.3.2.3. ROC (Receiver Operating Characteristic curve)

ROC curve is a graphical plot of the Sensitivity vs. 1 - Specificity for a binary classifier system. (Fielding and Bell, 1997). The area under the ROC function (AUC) is usually taken to be an important index because it provides single measure of overall accuracy that is not dependent upon a particular threshold (Deleo, 1993; Fielding and Bell, 1997). Suppose a value of 0.8 for the AUC means that for 80 % of the time a random selection from the positive group will have a score greater than a random selection from the negative class (Deleo, 1993). The AUC varies between 0 (worse-than-random model), 0.5 (random model) and 1 (best discriminating model).

3.3.3. RESULTS

3.3.3.1. Jungle owlet

Classification tree

A classification tree model of twenty nodes including ten terminal nodes was built for jungle owlet (Fig. 43). The terminal nodes of tree indicate that there were ten possible patterns of habitats available for jungle owlet. Rainfall is the best predictor of habitat use, because it emerged out to be the root node of the tree. The detection percentage was greater in high rainfall area (66.4 %) than the low rainfall area (27.8 %). Within the high rainfall area, the high level of anthropogenic disturbance (69.8 %) and low altitude (77.4 %) areas had higher detection percentage. In low rainfall areas, the detection percentage was greater in high altitude (37.3 %) and dry deciduous forests and plantations (46.4 %). The overall prediction accuracy of the tree model was 73.2 % indicating that 73.2 % of the survey sites were correctly classified.

Logistic regression

Six landscape variables including 3 dummy variables for vegetation types were considered for developing habitat suitability model for jungle owlet (Table 35), of which rainfall, altitude and vegetation type were found significant. The odds of sighting a jungle owlet in high rainfall survey sites were 4.4 times higher than the rain shadow areas. Odds of sighting a jungle owlet in a high altitude (>365 m) was 1.8 times higher than the low altitude survey sites but the odds of sighting an owlet in low

disturbance survey sites was lesser than the high disturbed sites. While the odds of sighting a jungle owlet was higher in MDF (2.1 times) and in plantations, (1.3 times) it was low in evergreen forests. The overall prediction accuracy of the logistic regression model was 69 per cent.

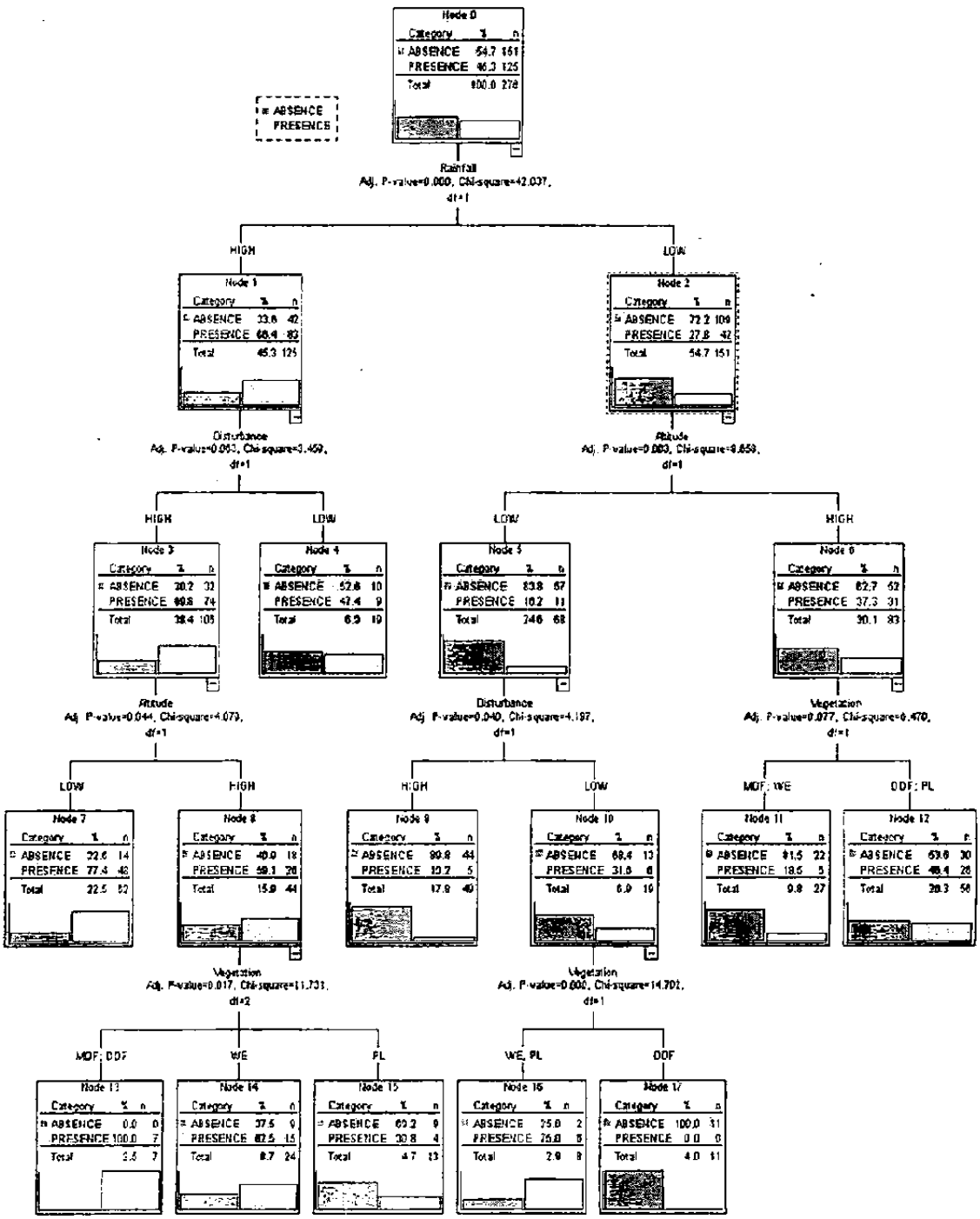


Fig. 43 Classification tree analysis using CHAID algorithm for jungle owlet

Table 35. Results of the logistic regression analysis for Jungle owlet

Variables	Regression coefficients (β)	Standard error (β)	Wald test statistic value	Degrees of freedom	Significance value	Odds ratio-Exp(β)
Rainfall	1.474	0.387	14.497	1	0.000	4.365
Altitude	0.557	0.297	3.509	1	0.061	1.745
Disturbance	-0.012	0.319	0.133	1	0.716	0.890
Vegetation type			7.613	3	0.055	
Evergreen	-0.434	0.428	1.029	1	0.310	0.648
Plantation	0.269	0.481	0.313	1	0.576	1.309
MDF	0.755	0.510	2.194	1	0.139	2.128
Constant	-3.079	0.848	13.170	1	0.000	0.046

Low rainfall = 1 (Reference category); High Rainfall = 2
Low slope = 1 (Reference category); high slope = 2
Low disturbance = 1 (Reference category); high disturbance = 2
Low altitude = 1 (<365 m) (Reference category); high altitude = 2 (>365 m)
Dry deciduous forest is considered as reference category for vegetation type dummy variable

3.3.3.2. Brown hawk owl

Classification tree

A classification tree was built for brown hawk owl with 17 nodes including 9 terminal nodes indicating that nine possible patterns of habitats available for brown hawk owl (Fig. 44). In this species also, rainfall was the best predictor because it emerged out to be the root node of the tree. The detection percentage was greater in high rainfall area (52 %) than the low rainfall area (19.9 %). In high rainfall area, the detection percentage was greater in areas with low anthropogenic disturbance (68.4 %) and high altitude (90.9 %). In low rainfall areas, the detection percentage was greater in moist deciduous and evergreen (40%). The overall prediction accuracy of the tree model was 73 % indicating that 73 % of the survey sites were correctly classified.

Logistic regression

With six variables, logistic regression model was developed (Table 36). All the variables in the model were significant. The odds ratio of sighting a brown hawk

owl in a survey site was greater in area with high rainfall (2.2 times); high altitude (2.4 times); evergreen (2.6 times); plantation (3.5 times); moist deciduous forest

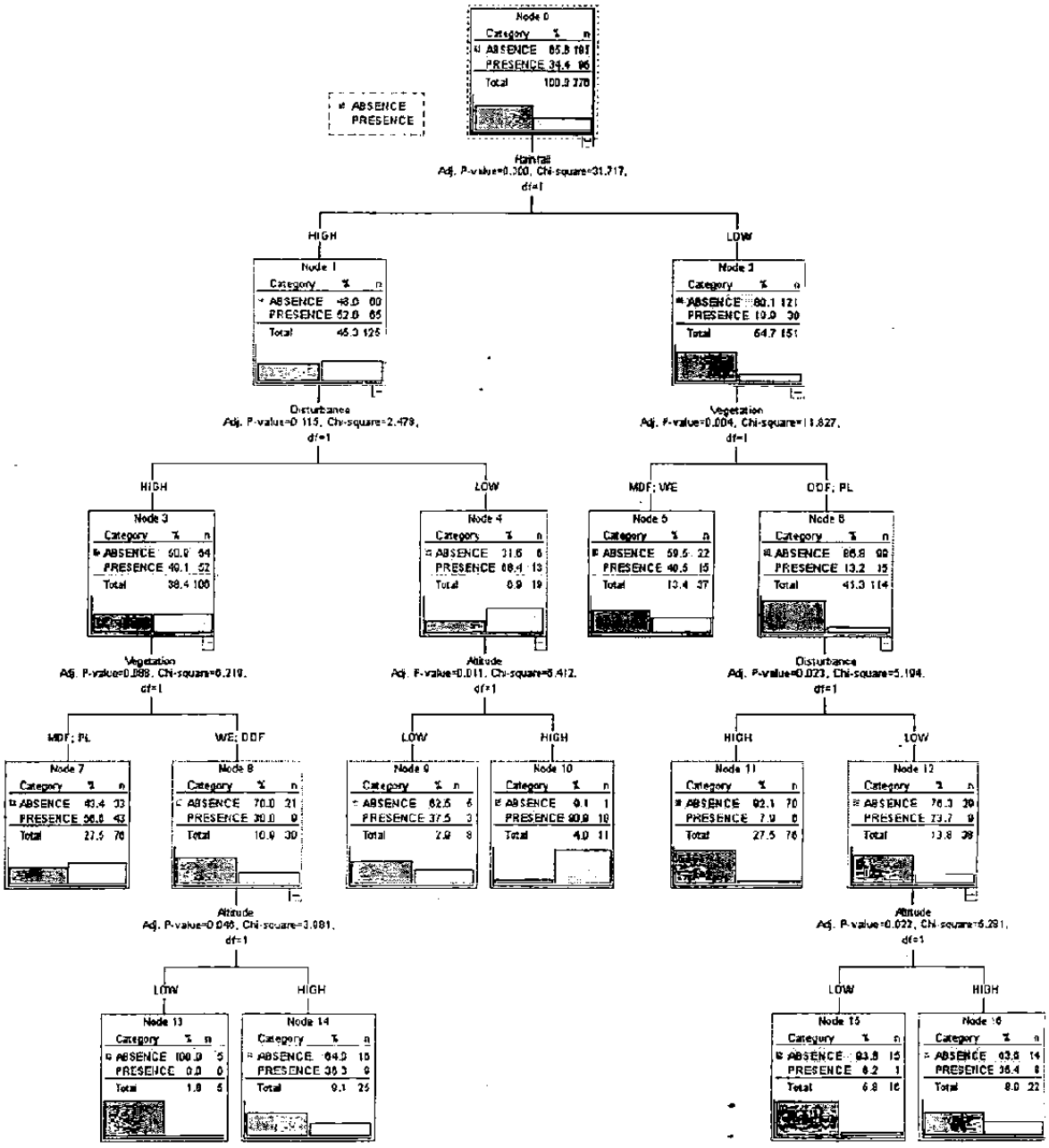


Fig. 44 Classification tree analysis using CHAID algorithms for brown hawk owl

(7.1 times) and low disturbance. The overall prediction accuracy of the logistic regression model was 71 per cent.

Table 36. Results of logistic regression analysis for brown hawk owl

Variables	Regression coefficients (β)	Standard error (β)	Wald test statistic value	Degrees of freedom	Significance value	Odds ratio-Exp(β)
Rainfall	0.783	0.378	4.285	1	0.038	2.187
Altitude	0.862	0.327	6.930	1	0.008	2.368
Disturbance	-0.681	0.345	3.886	1	0.049	0.506
Vegetation type			12.694	3	0.005	
Evergreen	0.955	0.450	4.512	1	0.034	2.600
Plantation	1.238	0.519	5.690	1	0.017	3.450
MDF	1.957	0.550	12.652	1	0.000	7.081
Constant	-2.916	0.883	10.898	1	0.001	0.054

Low Rainfall = 1 (Reference category); High Rainfall = 2
Low slope = 1 (Reference category); high slope = 2
Low Disturbance = 1 (Reference category); high disturbance = 2
Low Altitude = 1 (<365 m) (Reference category); high altitude = 2 (>365 m)
Dry deciduous forest is considered as reference category for vegetation type dummy variable

3.3.3.3. Indian scops owl

Classification tree

Habitat use of Indian scops owl was different between rain-fed and rain-shadow survey sites.

Rain-fed area

The detection percentage was greater in low altitude (48.6 %) and high disturbance (51.6 %). In high altitude, the detection percentage was greater in high sloping area (35.1%). Sixty two per cent of the cases were correctly classified using this tree (Fig. 45).

Rain-shadow area

In the rain-shadow area, the vegetation type was found significant in the model. The disturbance and altitude did not have influence. A model with five nodes including three terminal nodes was developed. The detection percentage was greater

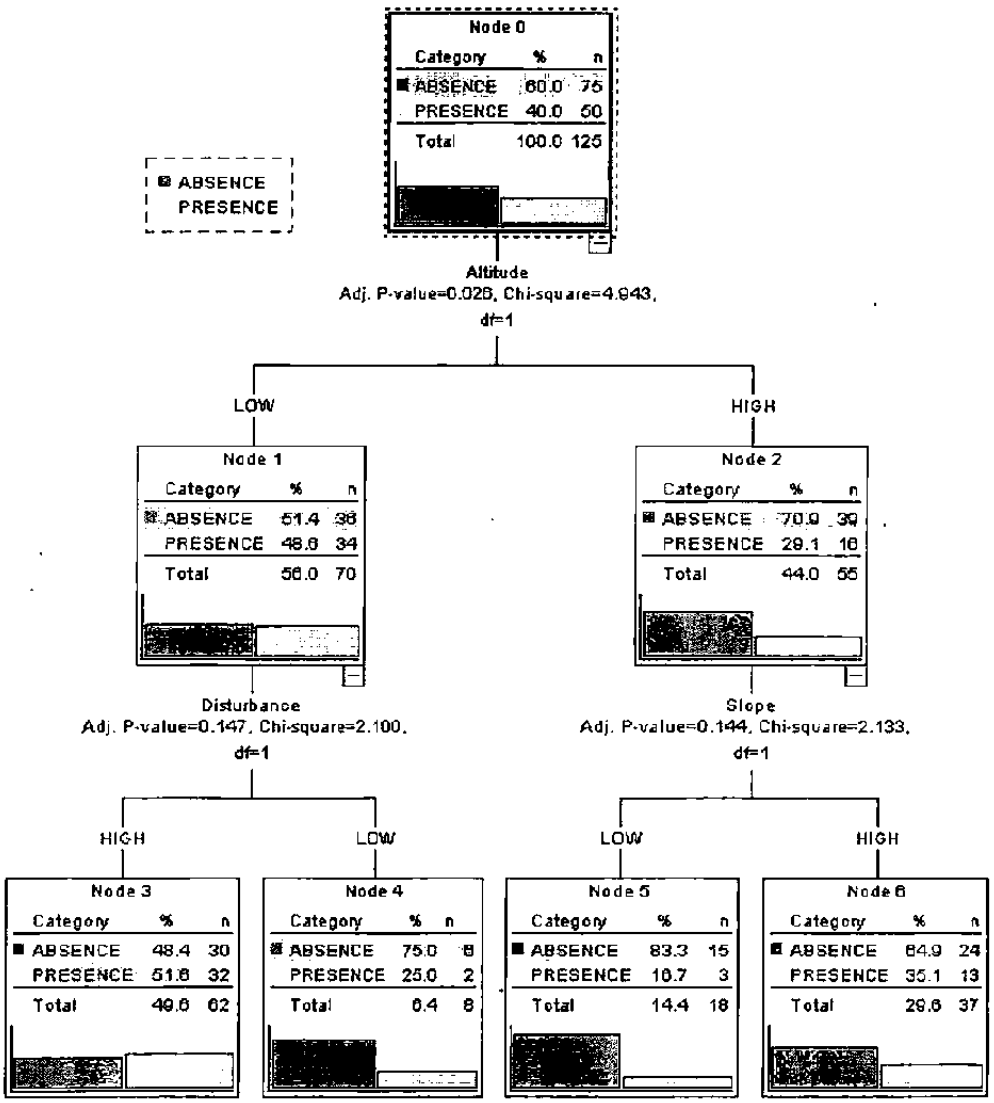


Fig. 45 Classification tree analysis using CHAID algorithms for Indian scops owl –rain fed area

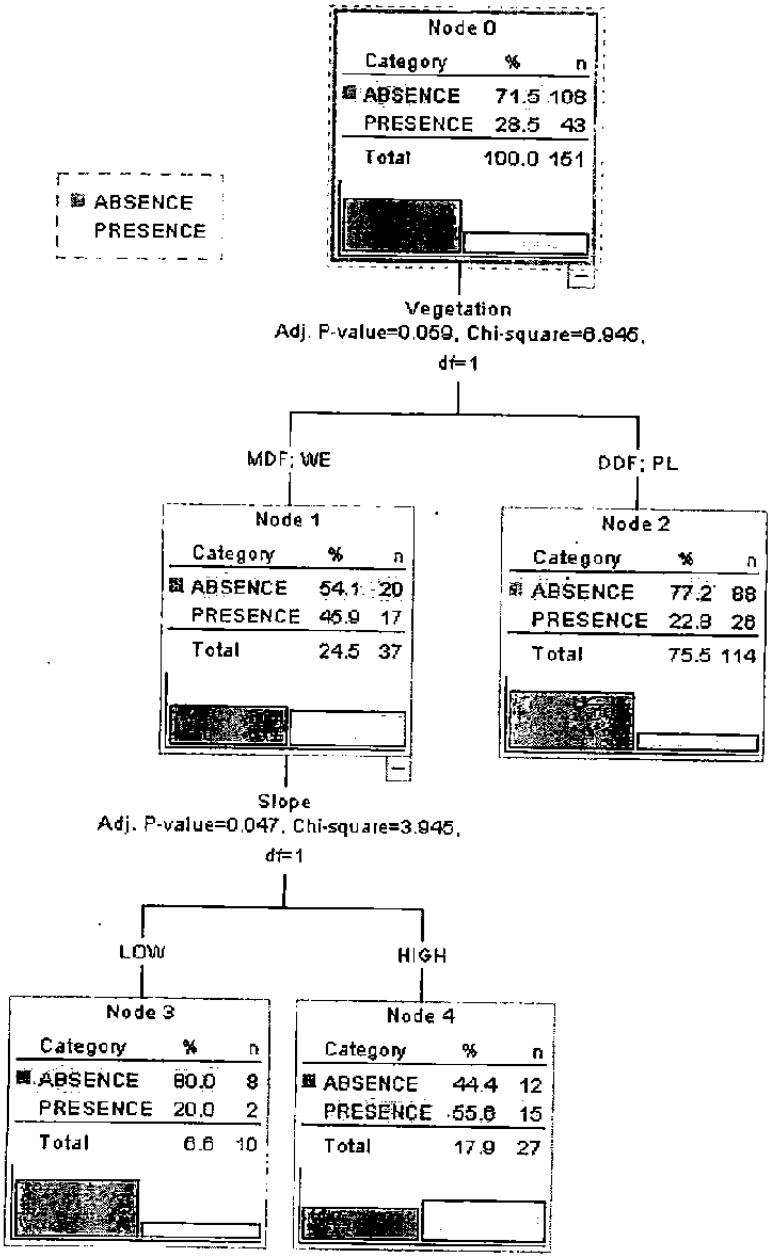


Fig. 46 Classification tree analysis using CHAID algorithms for Indian scops owl –rain shadow area

in moist deciduous forests (45.9 %) and in high sloping areas (55.6 %) (Fig. 46). This model classified 73.5 % of the cases correctly. In DDF/PL the detection percentage was 23 % and no further splitting emerged.

Logistic regression analysis

Habitat suitability model for Indian scops owl was built with seven landscape variables (Table 37). Two variables *viz.*, evergreen and moist deciduous forests were significant in the model. The odds ratio of sighting an Indian scops owl was greater in low rainfall, low altitude and low disturbance survey sites. While the odds of sighting an Indian scops owl was greater in evergreen (3 times); moist deciduous forest (4 times) and high sloping areas (1.2 times). It was low in plantations. The model correctly classified around 68 percent of the cases.

Table 37. Logistic regression analysis for Indian scops owl

Variables	Regression coefficients (β)	Standard error (β)	Wald test statistic value	Degrees of freedom	Significance value	Odds ratio-Exp(β)
Rainfall	-0.222	0.377	0.347	1	0.556	0.801
Altitude	-0.397	0.298	1.769	1	0.184	0.673
Disturbance	-0.018	0.324	0.003	1	0.956	0.982
Vegetation type			14.647	3	0.002	
Evergreen	1.093	0.414	6.957	1	0.008	2.984
Plantation	-0.055	0.523	0.011	1	0.916	0.946
MDF	1.393	0.498	7.819	1	0.005	4.026
Slope	0.203	0.284	0.508	1	0.476	1.225
Constant	-0.674	0.898	0.565	1	0.452	0.509

Low rainfall = 1 (Reference category); High Rainfall = 2
Low slope = 1 (Reference category); high slope = 2
Low disturbance = 1 (Reference category); high disturbance = 2
Low altitude = 1 (<365 m) (Reference category); high altitude = 2 (>365 m)
Dry deciduous forest is considered as reference category for vegetation type dummy variable

Model Comparison

Table 38. Statistical measures for comparing predictive performance of classification tree and logistic regression model

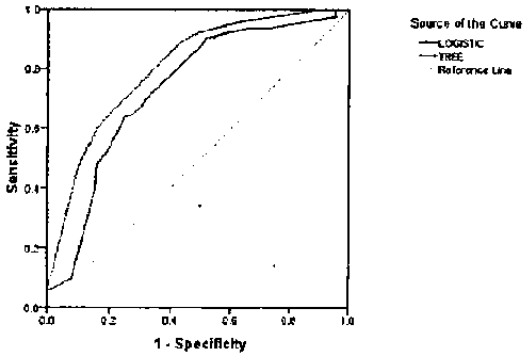
Statistical measures	Jungle owlet		Brown hawk owl		Indian scops owl	
	Logistic	Tree	Logistic	Tree	Logistic	Tree
Sensitivity	64.80	60.80	54.74	55.79	33.33	34.41
Specificity	72.19	83.44	77.90	81.22	85.25	83.61
PPV	65.85	75.24	58.82	60.91	53.44	51.61
NPV	71.24	72.00	76.43	77.77	71.55	71.49
Accuracy	68.50	73.20	66.65	72.50	67.80	67.00

AUC *	0.74 (0.68-0.78)	0.81 (0.76-0.86)	0.75 (0.69-0.81)	0.78 (0.72-0.83)	0.67 (0.59-0.74)	0.62 (0.55-0.69)

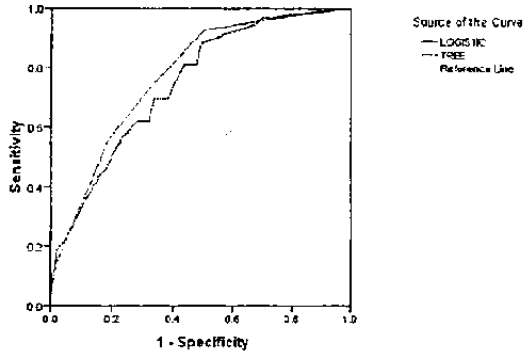
*= 95% confidence limits are given in parenthesis

The accuracy and AUC measures indicate that both classification tree and logistic regression model have significant prediction ability for all the owl species. Further, these measures reveal that in the case of jungle owlet and brown hawk owl, classification tree model predicted more accurately than the logistic regression model. Sensitivity was lesser than the specificity for all the models and the species (Table 38 & Fig. 47). Sensitivity of both the models was poor in the case of Indian scops owl. The absence sites (specificity) of jungle owlet and brown hawk owl were better predicted in classification tree than the logistic regression model. This shows that absence sites were better predicted than the presence sites.

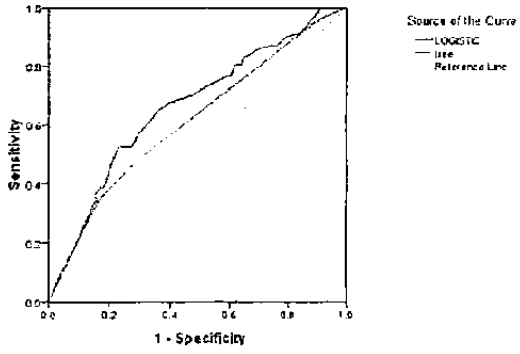
Ecological niche modelling of two sympatric owls (*Otus bakkamoena* and *Ninox scutulata*) was reported earlier based on limited data as an example (Babu *et al.* 2008). As the scope of data was limited, extensive analysis was not attempted here.



a. Jungle owlet



b. Brown hawk owl



c. Indian scops owl

Fig. 47 ROC curves for classification tree and logistic regression models

3.3.4. DISCUSSION

Aspects on the endangered forest owlet (Ishitaq and Rahmani, 2000) and studies on the habitat utilization of owls in India are meagre except a few ecological certain human commensally (Kumar, 1980; Ramanujam, 2000; Nagarajan *et al.*, 1998). Data on owls of southern Western Ghats remains with anecdotal notes (see the review for more references); no comprehensive study was done in the southern Western Ghats hitherto, though it has been identified as endemic bird area (Statterfield *et al.*, 1998). The results of our study highlighted the importance of landscape level factors that influence the distribution of three owl species in the southern Western Ghats of Kerala and Tamil Nadu and habitat suitability models developed using classification tree and logistic regression technique.

The larger owls in Australia have responded much to the landscape level variables rather than the field level variables since the home range of these owls are larger (Lyon *et al.*, 2001; Kavanagh and Bamkin, 1995). Similarly, the present study reveals that the lesser owls also responded to the landscape level variables and preferred varied landscape niches. Though the independent variables included in the models expressed the landscape characteristics, the data collected was from the individual survey sites. This means that the collected data may also be relevant at the field scale. However, the field level variables could not be included in the modelling because data at all the survey sites were not available.

Of the three species of owls, jungle owlet and brown hawk owl frequently utilized rain-fed areas of the southern Western Ghats than the rain-shadow areas but the Indian scops owl utilized both rain-shadow and rain-fed areas of the southern Western Ghats. The pattern of habitat use in two owl species, jungle owlet and brown hawk owl, was not different between rain-shadow and rain-fed areas. However, for Indian scops owl, a different pattern of habitat use was recorded between rain-shadow and rain-fed areas. Because, the Indian scops owl was reported to utilize wide range of habitats within India that extends from the coastal areas to the higher reaches of the Ghats (Ali and Ripley, 1987; see first chapter of the report for altitudinal distribution). Moreover, the competition between brown hawk owl and Indian scops owl was also reported from the southern Western Ghats (Babu and Jayson, 2008). Due to this, the

habitat utilization of the Indian scops owl in the rain-fed area was driven by sympatric species like brown hawk owl and jungle owlet but not in the rain-shadow areas, where these two sympatric species were seldom encountered in certain habitats (dry thorn forest and woodland savannah forests) therefore a different pattern of landscape was observed for Indian scops owl during the study. Verzhutskii and Ramanujam, (2002) highlighted that Indian scops owl has wide spectrum of prey species ranging from coleopteran insects to small mammals.

Jungle owlet and brown hawk owl used high altitude but Indian scops owl highly used low altitude forests. Three of the lesser owls were observed to use predominantly or partly the moist deciduous forests. In the moist deciduous forests, the trees are mature and more spaced that allows the owls to forage without any obstacles. All the species of owls used survey sites, which are far from the human settlements. Impacts of human disturbance on birds have well been documented elsewhere in the world (Francl and Schnell, 2002; Richardson and Miller, 1997; Millsap and Bear, 2000). All the studies resulted in negative influence on raptor communities (Richardson and Miller, 1997; Millsap and Bear, 2000). Besides these the intensity of dead log collection around the human habitation is high compared to interior forests and these dead logs are important during the nest site selection of owls (Lyon *et al.*, 2002).

Models generated for three species of owls have moderate accuracy ranging from 67 to 74 per cent and indicates that the independent variables included in the model were more relevant to habitat use of three lesser owls of southern Western Ghats. Classification tree and logistic regression models are broadly used in several epidemiological studies and remarked that the logistic regression model is better for early diagnosis of infection than classification tree model (Long *et al.*, 1993). However, another study suggested that the classification tree is relatively simple and clinically reasonable (Tsien *et al.*, 1998). The present study suggests that the classification tree has high predictive power than the logistic regression model. Logistic regression considers all the cases together while analysing the independent variables but the classification tree splits the cases into nodes which explain significant variation in split. The present study indicates that, the logistic regression can generate better model when the focal species had wide ecological requirements

and classification tree works well when the focal species had narrow range of ecological requirements. However, further studies on this line are required to survey more sites in order to improve the habitat suitability models developed in this study and also to explore other modelling approaches especially presence only models. Models having higher predictive value will be useful for accurate identification of owl areas which require management interventions and conservation initiatives.

3.4. ECOLOGICAL NICHE MODELLING OF SELECTED OWLS

3.4.1. INTRODUCTION

Traditionally the term 'niche' is described as position of a species and shape of that species' response to environmental gradients. Hutchinson (1957) defines niche as "a hyper-volume in the multidimensional space of ecological variables within which a species can maintain a viable population". In addition, the niche has been distinctly defined as fundamental niche (a range of suitable environmental conditions for survival of a species without the influence of biological factors including interspecific competition and predation) and realized niche (part of fundamental niche, where the species occurs). The ecological niche models are developed with the intention of identifying the fundamental niche of species (Hirzel *et al.*, 2002; Phillips *et al.*, 2006).

Fundamental aspect of conservation science depends on understanding the ecology and geographic distribution of a species. Sampling over difficult terrain and cryptic animals often demands a serious approach from the researchers in order to assess the spatial distribution pattern with limited data. In addition, it is time consuming and expensive to survey large landscapes. So, the species distribution models (SDMs) have been employed to derive distribution pattern by relating the presence or absence to a set of environmental variables (Phillips *et al.*, 2006). In recent years, several geographic applications have been developed for predicting fundamental niche of an organism. With the development of geographic information system, predicting spatial distribution of a species became simple, as most of the climatic, topographic and vegetation cover data for the world are available (for example *worldclim* and *MODIS*).

Based on the nature of dependent/response variable, modelling approaches can be divided into presence-absence and presence only modelling paradigms. All the niche models deal primarily with presence data, when the absence was not true. Most

of the presence-absence modelling approaches (GAM, GLM and Discriminant analysis) require systematically sampled data and more importantly, it requires high quality data, *ie.*, true absence and presence records. Obtaining true absence data requires repeated sampling and some studies have reported the presence of the focal species after several repeated samples. This indicates that, deriving true absence for the species requires long-term studies with repeated sampling but in the surveys that cover vast landscapes, it is not feasible to undertake repeated sampling. These drawbacks of the presence-absence data lead the researchers to find an alternative approach that deals primarily the presence records.

With the application of basics of niche concept (Hutchinson, 1957) several, "presence only" modelling paradigms were developed in recent years and each of them deals with different algorithms (Ecological Niche Factor Analysis, Genetic Algorithms for Rules set Prediction, Maximum Entropy, DOMAIN, BIOCLIM). Presence only modelling approach is widely used in the conservation science, as the presence records for most of the species is readily available in the form of museum and herbarium records. In addition, several research notes, articles and reports of the focal species can also be used to develop distribution model. Lack of sampling procedure is the major concern while using presence records of museum and herbarium collections and without understanding the collection or sampling strategies, the absence of the species cannot be inferred with certainty.

With the development of niche modelling, certain ecological hypothesis have been validated spatially such as the competitive exclusion theory (Anderson *et al.*, 2002) and such niche models also applied for other purposes, including endangered species conservation (Engler *et al.*, 2004; Traill and Bigalke, 2006; Ullah *et al.*, 2007; Giriraj *et al.*, 2008), invasive species ecology (Nyari *et al.*, 2006), potential area for reintroduction (Meyer *et al.*, 2006) and impact of climatic change (Anciaes and Peterson, 2006). Within Indian sub-continent, few attempts have been made so far for predicting the spatial distribution of species (Ullah *et al.*, 2007; Giriraj *et al.*, 2008), although the GIS technologies were widely used two decades before also. Here an attempt is made to predict the distribution pattern of owls spatially with a group of climatic, remote sensing and topographic variables.

The objective of the chapter is to predict the potential habitat for the conservation of the owls of the southern Western Ghats and to obtain the critical associated environmental variables on which the habitat use of owls is depending.

3.4.2. Methods

3.4.2.1. Census of owls: Most of the positive records of owls were obtained by combining all the four census methods and occasional sightings of the owls were considered as occurrence points. Presence records (Latitude and Longitude of animal sightings) were also obtained from the research notes, reports and personal communication with the concerned people (for Ceylon bay owl alone). The details of the presence records and source of collection were given in the appendix 00. All the presence localities of selected owls were marked using Global Positioning System and the co-ordinates were downloaded. For this purpose, presence data set alone were considered and not the absence data. Altogether, seven owl species were considered for developing ecological niche models and all the species had a range of occurrence (Table 39). Five of the species have wide range of distribution in the southern Western Ghats and two of the species have restricted range of distribution.

Table 39. Species and number of localities included in ecological niche models

Species	Common Name	Unique localities	Category of distribution
Phodilus assimilis	Ceylon bay owl	13	Restricted
Bubo bubo	Indian eagle owl	13	Restricted
Glaucidium radiatum	Jungle owlet	105	Wide range
Ninox scutulata	Brown hawk owl	95	Wide range
Otus bakkamoena	Indian scops owl	93	Wide range
Otus scops	Oriental scops owl	51	Wide range
Bubu zeylonensis	Brown fish owl	36	Wide range

3.4.2.2. Environmental data

Twenty five environmental variables consisting of climatic, vegetative and topographic were considered for developing distribution model for seven species of owls (Table 40). Nineteen bioclimatic variables and elevation (Digital elevation model) were obtained from the worldclim dataset. The slope and aspect were derived from the elevation data using the Arc GIS 9 software. Bioclimatic variables were derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. These are often used in ecological niche modelling (e.g., BIOCLIM, GARP). The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). A quarter is a period of three months (1/4 of the year). Detailed information about the interpolation technique for developing the climatic data were discussed in Hijmans *et al.*, (2005).

Table 40. Environmental variables used to generate ecological niche models

Sl. No.	Eco-geographical variables	Source
1.	BIO1 = Annual Mean Temperature	Worldclim; Hijmans *et al.*, 2005
2.	BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))	Worldclim; Hijmans *et al.*, 2005
3.	BIO3 = Isothermality (P2/P7) (* 100)	Worldclim; Hijmans *et al.*, 2005
4.	BIO4 = Temperature Seasonality (standard deviation *100)	Worldclim; Hijmans *et al.*, 2005
5.	BIO5 = Max Temperature of Warmest Month	Worldclim; Hijmans *et al.*, 2005
6.	BIO6 = Min Temperature of Coldest Month	Worldclim; Hijmans *et al.*, 2005

7.	BIO7 = Temperature Annual Range (P5-P6)	Worldclim; Hijmans *et al.*, 2005
8.	BIO8 = Mean Temperature of Wettest Quarter	Worldclim; Hijmans *et al.*, 2005
9.	BIO9 = Mean Temperature of Driest Quarter	Worldclim; Hijmans *et al.*, 2005
10.	BIO10 = Mean Temperature of Warmest Quarter	Worldclim; Hijmans *et al.*, 2005
11.	BIO11 = Mean Temperature of Coldest Quarter	Worldclim; Hijmans *et al.*, 2005
12.	BIO12 = Annual Precipitation	Worldclim; Hijmans *et al.*, 2005
13.	BIO13 = Precipitation of Wettest Month	Worldclim; Hijmans *et al.*, 2005
14.	BIO14 = Precipitation of Driest Month	Worldclim; Hijmans *et al.*, 2005
15.	BIO15 = Precipitation Seasonality (Coefficient of Variation)	Worldclim; Hijmans *et al.*, 2005
16.	BIO16 = Precipitation of Wettest Quarter	Worldclim; Hijmans *et al.*, 2005
17.	BIO17 = Precipitation of Driest Quarter	Worldclim; Hijmans *et al.*, 2005
18.	BIO18 = Precipitation of Warmest Quarter	Worldclim; Hijmans *et al.*, 2005
19.	BIO19 = Precipitation of Coldest Quarter	Worldclim; Hijmans *et al.*, 2005
20.	Altitude = elevation from sea level (m)	Worldclim; Hijmans *et al.*, 2005
21.	Slope = degree of flow	Generated in GIS
22.	Aspect = flow of direction	Generated in GIS
23.	MODIS Tree cover = Percent of tree cover	GLCF; Hansen *et al.*, 2003
24.	MODIS Herb cover= Percent of herb cover	GLCF; Hansen *et al.*

25.	MODIS Bare cover = Percent of bare cover	GLCF; Hansen *et al.*

3.4.2.3. Environmental data included in the model

All the twenty-five environmental variables were biologically meaningful to the focal species and several studies have used these variables for predicting spatial distribution of vertebrate species. Still, some of the environmental variables were highly correlating, so arbitrarily 700 points were taken from the southern Western Ghats and values for each random point were extracted from the 25 environmental layers using ARC GIS tools. Based on the values, Pearson correlation was carried out and highly correlating layers were removed from subsequent modeling. To include in the final model building, we selected ten environmental variables (Elevation, aspect, slope, MODIS tree cover, MODIS bared cover, isothermality, precipitation seasonality, mean diurnal temperature range, precipitation of wettest month and precipitation of driest quarter), which does not have correlation with other environmental layers. All the layers were converted to geographic projection of the study area.

3.4.2.4. Modeling approach

Recently many ecological niche models have been developed with the support of statistical algorithms. Ecological Niche Factor Analysis (ENFA) is working on the principle of Hutchinson concept and is similar to the Principle Component Analysis. It produces a set of uncorrelated factors. Spatial autocorrelation among the adjacent points were the major issue with this approach. Genetic algorithm for rules set prediction (GARP) is a genetic algorithms approach and the rules can be set to predict the suitability model. The drawback of the approach is that it predicts poorly when the sampling data is low. Another recently developed and overwhelmed approach is MAXENT. It works on the principle of Maximum Entropy of Jones (1959). This approach is working well with small number of occurrence localities (Phillips *et al.*, 2006). Here, we again tested the effectiveness of this paradigm for wide ranging and restricted ranging species.

3.4.2.5. MAXENT (Maximum Entropy Model)

Maximum Entropy modeling paradigm was applied to predict the distribution of owls and quantifying the extent of habitat available in the southern Western Ghats. MAXENT is a machine learning program, which estimates the probability distribution of owls across the southern Western Ghats especially the areas not covered during the survey. It computes habitat suitability map based on the presence records to a set of climatic and topographical features. It considers the background variables as absence set which is similar to other niche modeling approaches. Details about the principle and logic behind the algorithm were discussed in Philips *et al.* (2006).

3.4.2.6. Model evaluation

The model evaluation and partitioning differed with number of species occurrence localities available and two different evaluations and partitioning methods were used for this study. The species with more than 25 number of occurrence localities were randomly sampled to obtain 75 percent of localities for training and the remaining 25 percent of localities for model evaluation. The data were divided this way ten times to obtain ten replicate datasets for each of the five species of owls. The background pixel was set as 10,000. The remaining settings were maintained as default. The model was evaluated based on the values obtained from the ROC curve and it is widely used for model evaluation. ROC is part of the MAXENT output and it generates single measure of model performance, area under the curve (AUC) and independent of any particular choice of threshold (Elith, 2002; Fielding and Bell, 1997). Out of ten models generated for each of the five species, the best model was chosen by comparing the AUC values. The model with high ROC value (*i.e.* close to 1) was considered as best predictive model for the species. Details about the ROC were discussed in the previous chapter.

For range restricted or species with lower number of occurrence localities, the "leave-one-out" method was employed (Fielding and Bell, 1997; Pearson *et al.*, 2007). In this method, a total of thirteen models were built for two range restricted species. For each model, one occurrence locality of the species was randomly left and the model was built with remaining localities. This method was employed for two

species of owls namely Ceylon bay owl and Indian eagle owl. Here the models were evaluated for their ability to predict a positive occurrence at the locality left out of the model formulation. The prediction success rate was calculated for both the species. The arbitrary or random selection of threshold value can bias the model, so the prediction success rate was calculated at different threshold levels (10 percent interval).

3.4.3. RESULTS

3.4.3.1. Jungle owlet

The distribution of jungle owlet was predicted with ten environmental variables including three topographic, two vegetation and five climatic variables (Fig 48 a). The area under the ROC value (Mean= 0.9510) was higher (Fig. 49) and the model distribution was not random (0.5). The mean diurnal temperature range has the highest predictive gain when used in isolation and it appears to have useful information by itself (Fig. 49). But the jungle owlet was strongly associated with the MODIS tree cover (Table 41). Climatic variables such as mean diurnal temperature range, precipitation of driest quarter, isothermality and precipitation seasonality have also contributed to the distribution of jungle owlet.

The species have wide range of distribution in the southern Western Ghats and maximum potential habitats are available in the western slopes of the Ghats. The survey was not carried out in the Megamalai (Highways Mountains) but the predicted model showed that there is possibility to encounter this species in the area. Similarly, the high altitude areas such as Nilgiris, Eravikulam, Munnar and Agastyamalai have fairly good chance to detect the jungle owlet. Based on the predicted distribution model for the jungle owlet, the probability values were arbitrarily classified into three classes including low (0.1-0.3) – 27,389 sq km (58.49 %); Medium (0.4-0.6)-11,944.3 sq km (25.51 %) and High (0.7-1.0) – 7,486.7 sq km (15.99 %). The extent of occurrence of the owls was also calculated based on the commonly used threshold of 0.5 and it was estimated as 8,961 sq km (23.24 %). Around 23 per cent of the southern Western Ghats is found suitable for the conservation of the Jungle owlet in the region.

Table 41. Contribution of each environmental variable to the distribution of jungle owlet

Environmental Variable	Per cent contribution
MODIS Tree Cover	16.60
Mean diurnal temperature range	16.10
Precipitation of driest quarter	14.60
Isothermality	13.80
Precipitation seasonality	11.90
Slope	9.10
Altitude	8.60
Precipitation of wettest month	6.10
MODIS Bare cover	2.20
Aspect	1.00

3.4.3.2. Brown hawk owl

The predicted distribution of brown hawk owl is presented in Fig. 48 b. The average calculated AUC value was 0.9324 and it indicated that the model distribution was not random (0.5). In all ten replicates, the area under the ROC curve was almost similar between models and it ranged from 0.9263 to 0.9385 (Fig. 50). In all arbitrary combinations, there was not much variation in the AUC values and there was low possibility of spatial autocorrelation among the occurrence records. The Precipitation of driest quarter has the highest gain when used in isolation and therefore it has most useful information by itself (Fig. 50). Altitude decreases the overall gain of the model when it was removed from the model because the information in the altitude was not present in other variables (Fig. 50).

Precipitation seasonality and MODIS tree cover were strongly associated with the Brown hawk owl (Table 42). The predictive map showed that the higher reaches such as Nilgiris, Eravikulam and Munnar were found unsuitable for the species. The species was observed to utilize low altitude moist forests. The probability values of

the distribution model was arbitrarily classified into three classes namely low (0.1-0.3) –27,355 sq km (58.42 %); Medium (0.4-0.6) - 13,107.9 sq km (27.99 %) and High (0.7-1.0) – 6357.1 sq km (13.57 %). Around 20 per cent of the southern Western Ghats was found suitable for the brown hawk owl at 0.5 threshold level. Ubiquitous.

Table 42. Contribution of each environmental variable to the distribution of brown hawk owl

Environmental Variable	Per cent contribution
Precipitation seasonality	24.0
MODIS Tree cover	18.0
Mean diurnal temperature range	12.9
Isothermality	12.5
Altitude	9.2
MODIS Bare cover	8.5
Slope	6.1
Precipitation of driest quarter	5.0
Precipitation of wettest month	2.9
Aspect	1.0

3.4.3.3. Indian scops owl

Predicted distribution map of Indian scops owl is presented in Fig. 48 c. The average area under the ROC curve was calculated (Average AUC = 0.91098), which indicates that the predicted model is not random (AUC= 0.5). As the AUC has not varied highly in the ten random replicates (0.9033 – 0.9189), chances for spatial autocorrelation in occurrence records were low (Fig. 51). The climatic variable, isothermality and altitude, have the highest gain when used in isolation and the gain value decreased when the altitude and isothermality is omitted from the model (Fig. 51). Similarly these two variables were associated maximum with the species distribution model (Table 43).

The suitable habitat predicted for the Indian scops owl showed that the species has wide range of distribution in the Southern Western Ghats. The model predicted the grass hills and higher reaches as low suitable areas for the species. The suitable habitats are found in the low altitude forests of western slopes. The probability values of distribution model was arbitrarily classified into three classes namely low (0.1-0.3) –27,844.5 sq km (59.47 %); Medium (0.4-0.6) - 12290.4 sq km (26.25 %) and High (0.7-1.0) – 6685.1 sq km (14.27 %). Around 28 per cent of the southern Western Ghats was found suitable for the Indian scops owl at 0.5 threshold level.

Table 43. Contribution of each environmental variable to the distribution of Indian scops owl

Variable	Per cent contribution
Isothermality	29.6
Precipitation of driest quarter	23.9
Altitude	15.6
Mean diurnal temperature range	12.7
Precipitation of seasonality	6.7
MODIS Tree cover	5.0
Precipitation of wettest month	2.6
MODIS Bare cover	1.6
Aspect	1.2
Slope	1.1

3.4.3.4. Oriental scops owl

The predicted distribution model for the oriental scops owl was presented in Fig. 48 d. The average calculated AUC value was 0.94579 and it indicates that the distribution model was not a random (0.5). In all arbitrary replicate models, the standard deviation of AUC was not high and it showed that the species can well sustain in the environmental conditions (Fig. 57). The environmental variable with highest gain when used in isolation was MODIS bare cover and precipitation of

wettest month (Fig. 57). The contribution of these variables to the predicted model was higher (Table 44).

Low altitude forests of the Kerala portion were predicted as suitable habitat for the species. The predicted distribution of the species in the Tamil Nadu portion was scattered and high altitude forests were not predicted as suitable habitats. Most of the suitable habitats were predicted south of the Palghat gap. The probability values of distribution model was arbitrarily classified into three classes namely low (0.1-0.3) – 27,621 sq km (58.99 %); Medium (0.4-0.6) – 12,364.5 sq km (26.40 %) and High (0.7-1.0) – 6,834.5 sq km (14.59 %). Around 22 percent of the southern Western Ghats was found suitable for the Indian scops owl at 0.5 threshold level.

Table 44. Contribution of each environmental variable to the distribution of Oriental scops owl

Variable	Percent contribution
MODIS Bare cover	25.1
Precipitation of wettest month	19.4
Precipitation seasonality	17.0
Altitude	8.6
Slope	8.0
Isothermality	7.6
Precipitation of driest quarter	5.9
Mean diurnal temperature range	4.1
MODIS Tree cover	4.0
Aspect	0.2

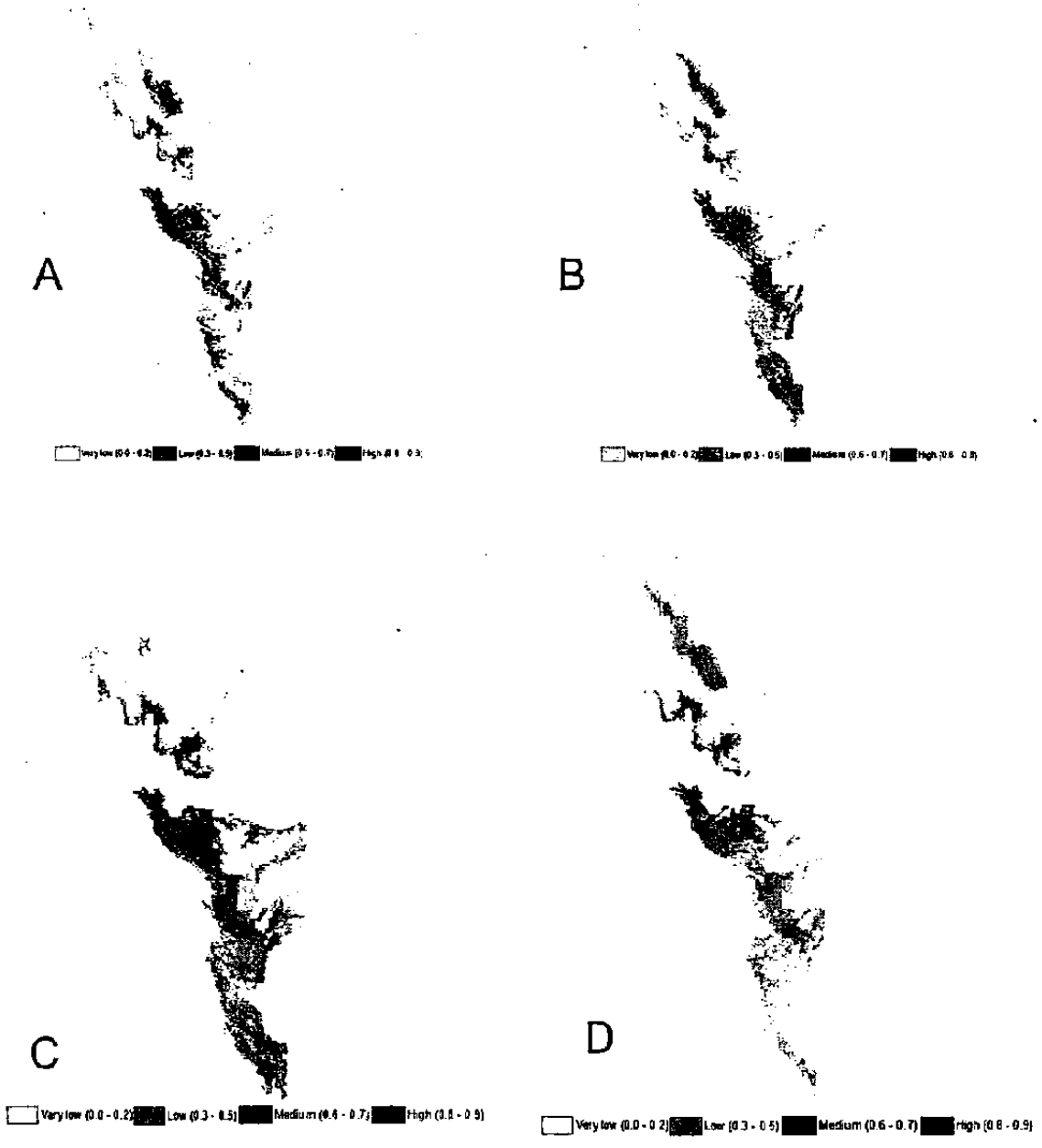


Fig. 48 Predicted distribution maps of A=Jungle owlet; B=Brown hawk owl; C=Indian scops owl; D= Oriental scops owl

Fig. 49 Receiver operating characteristics curve and Jackknife regularized training gain of Jungle owlet

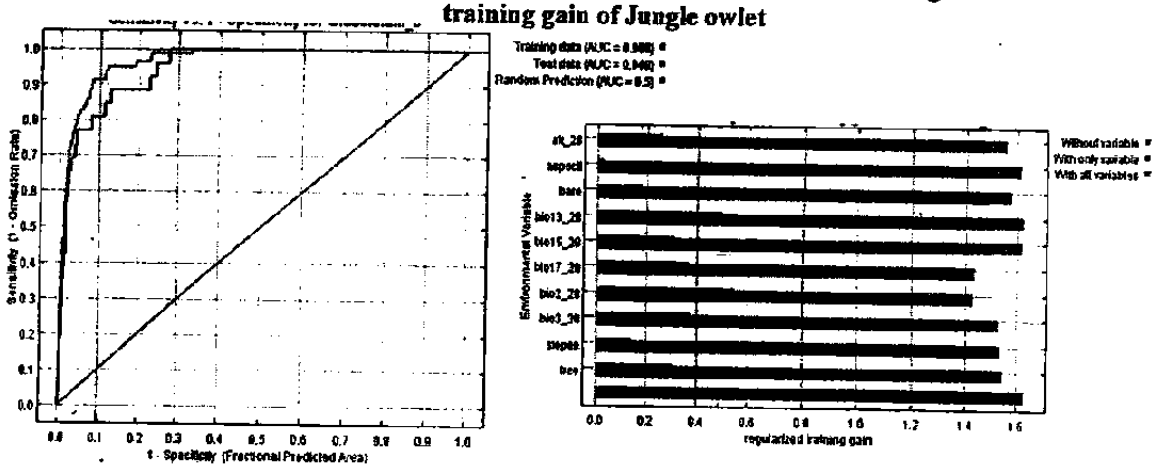


Fig. 50 Receiver operating characteristics curve and Jackknife regularized training gain of Brown hawk owl

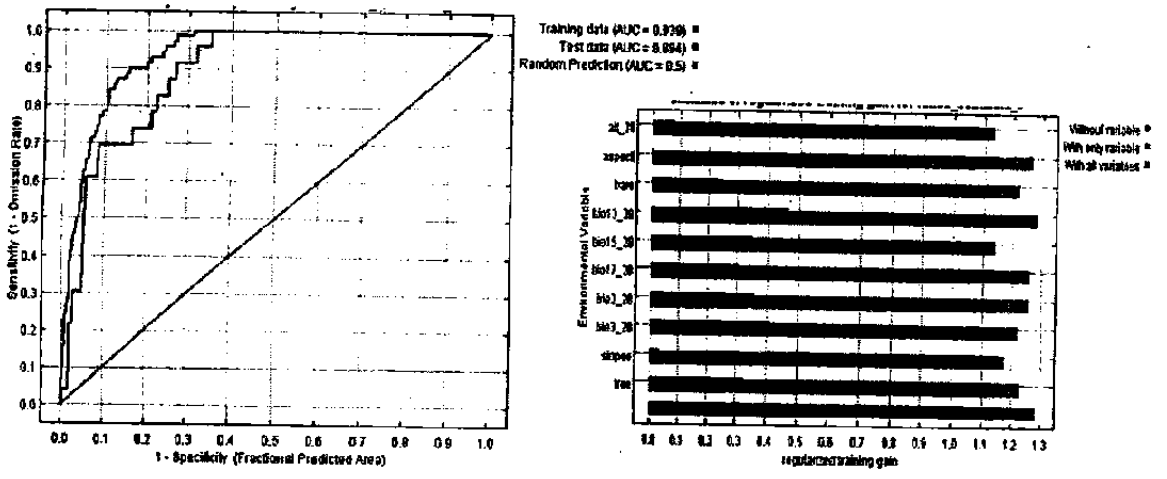
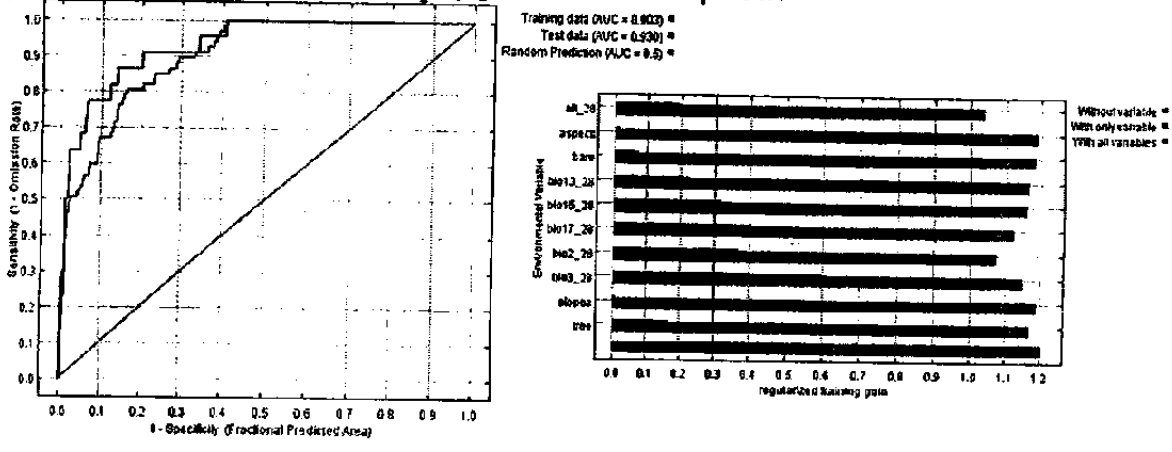


Fig. 51 Receiver operating characteristics curve and Jackknife regularized training gain of Indian scops owl



3.4.3.5. Brown fish owl

The predicted distribution map for brown fish owl was in Fig. 53 c. The average AUC value for the model was 0.91789 and the values indicated that the predicted model was not random (0.5). The environmental variable with highest predictive value was altitude and it contributed maximum to the predicated model as well (Fig. 59). The AUC values of the ten replicate models were not found highly fluctuating (0.8955 – 0.9445) (Fig. 59). Altitude and precipitation of driest quarter were well associated with the predicted model for brown fish owl (Table 45).

Low-altitude forest areas adjacent to the fringes were identified as suitable habitats for the owl. Although the species was observed up to 2500 m altitude, the predicted distribution map showed that the species have high suitable sites at lower and mid altitude forests than the high altitudes. The probability values of distribution model was arbitrarily classified into three classes namely low (0.1-0.3) – 27,521.4 sq km (58.78 %); Medium (0.4-0.6) – 12,394.9 sq km (26.47 %) and High (0.7-1.0) – 6,903.7 sq km (14.74 %). Around 22 per cent of the southern Western Ghats was found suitable for the brown fish owl at 0.5 threshold level.

Table 45. Contribution of each environmental variable to the distribution of brown fish owl

Variables	Percent contribution
Altitude	47.2
Precipitation of driest quarter	29.0
Mean diurnal temperature range	6.4
Isothermality	5.6
MODIS tree cover	5.6
Slope	3.2
Precipitation seasonality	1.2
Aspect	1.0

MODIS Bare cover	0.7
Precipitation of wettest month	0.2

3.4.3.6. Indian eagle owl

The distribution of the species in the southern Western Ghats is restricted to the low altitude forests hence the species was categorized as range restricted species (Fig. 53 b) The calibrated model was evaluated for the predictive success rate. Proportion of predictive success rate was higher in low threshold values and decreases with increasing the threshold values (Fig. 54). There was high predictive success rate even at 50 threshold value for the species. The environmental variable with highest gain when used in isolation was climatic and topographic variables (Fig. 52). The predicted model was strongly associated with precipitation of wettest month, isothermality, altitude and slope (Table 46).

Low altitude forests of the eastern aspects especially the fringes of the forests were found highly suitable habitat for the conservation of the Indian eagle owl. The western aspects of the Ghats are not found suitable for the species based on the predicted model. The probability values of distribution model was arbitrarily classified into three classes namely low (0.1-0.3) – 27,614.9 sq km (58.98 %); Medium (0.4-0.6) – 11,998.9 sq km (25.62 %) and High (0.7-1.0) – 7,198.9 sq km (15.37 %). Around 22 per cent of the southern Western Ghats was found suitable for the Indian eagle owl at 0.5 threshold level.

Table 46. Contribution of each environmental variable to the distribution of Indian eagle owl

Variable	Percent contribution
Precipitation of wettest month	31.7
Isothermality	23.4
Altitude	18.4
Slope	10.7
Aspect	9.1

MODIS Tree cover	6.5
MODIS Bare cover	0.2
Precipitation seasonality	0
Precipitation of driest quarter	0
Mean diurnal temperature range	0

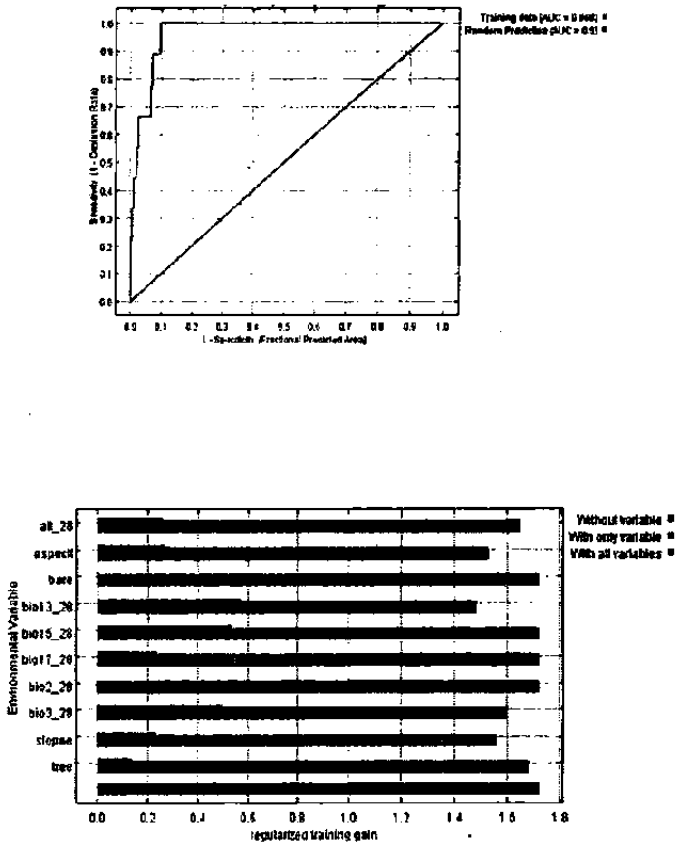


Fig. 52 Receiver operating characteristics curve and Jackknife regularized training gain of Indian Eagle owl

3.4.3.7. Ceylon bay owl

The predicted distribution map of Ceylon bay owl was in Fig. 53. The average AUC calculated from the predicted model was 0.8733 and it indicated that the distribution was not random (0.5). The predictive performance of the model was

assessed through proportion of prediction success rate at different threshold levels (Fig. 54). The proportion of the prediction success rate was observed to decrease with the increasing threshold level and the prediction success rate was zero at a threshold value of 100. The environmental variables, precipitation of wettest month, precipitation seasonality and mean diurnal temperature range, have the highest predictive gain when used in isolation (Fig. 58) and contributed maximum to the predicted model (Table 47).

Most of the suitable areas were predicted south of the Periyar plateau and extended up to the southern tip of Ghats. The predicted model indicated that there are potential opportunities for detecting the species from Palani hills, Megamalai, Wayanad and Nilgiris also. The probability values of distribution model was arbitrarily classified into three classes namely low (0.1-0.3) – 27,560.3 sq km (58.86 %); Medium (0.4-0.6) – 12,657.2 sq km (27.03 %) and High (0.7-1.0) – 6,602.5 sq km (14.10 %). Around 21 per cent of the southern Western Ghats was found suitable for the Indian scops owl at 0.5 threshold level.

Table 47. Contribution of each environmental variable to the distribution of Ceylon bay owl

Variables	Per cent contribution
Precipitation of wettest month	40.0
Precipitation seasonality	19.0
Mean diurnal temperature range	12.1
MODIS Tree cover	8.2
Slope	7.2
Aspect	6.3
Precipitation of driest quarter	5.3
Altitude	1.3
MODIS Bare cover	0.6
Isothermality	0.0

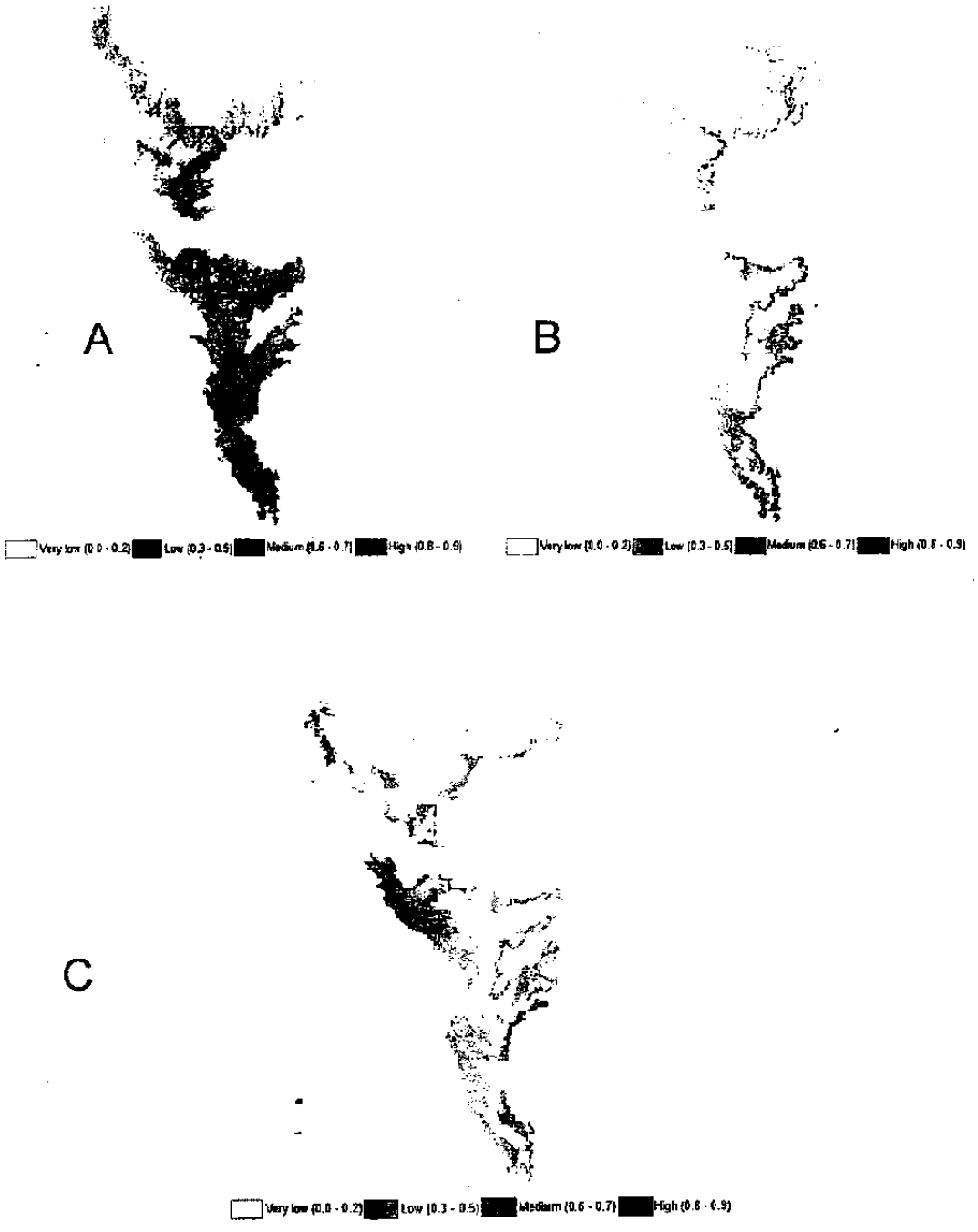
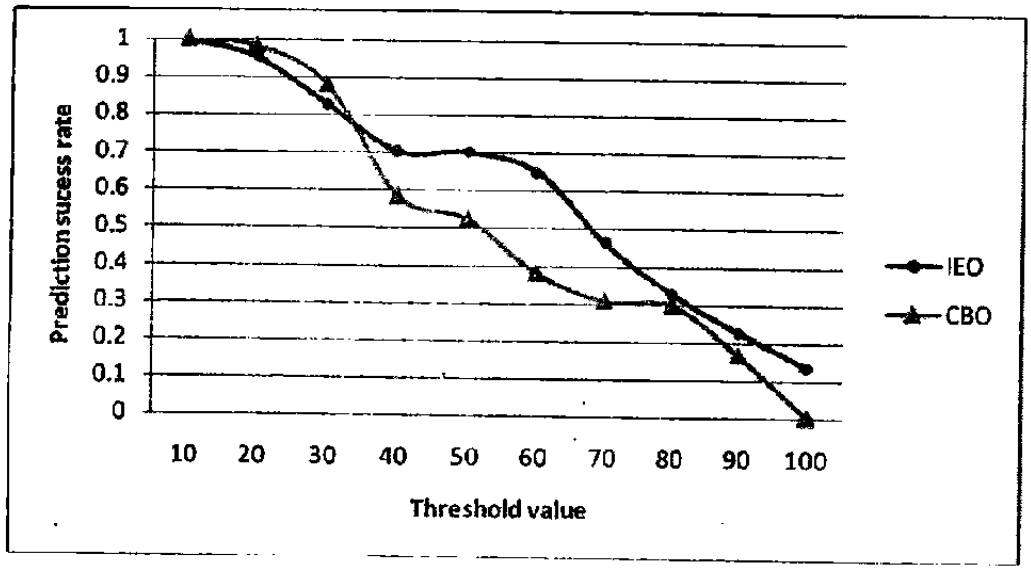


Fig. 53 Predicted distribution map of A=Ceylon bay owl; B=Indian eagle owl; C= Brown fish owl

Fig. 54 Proportion of prediction success rate of Indian eagle owl and Ceylon bay owl in different threshold levels



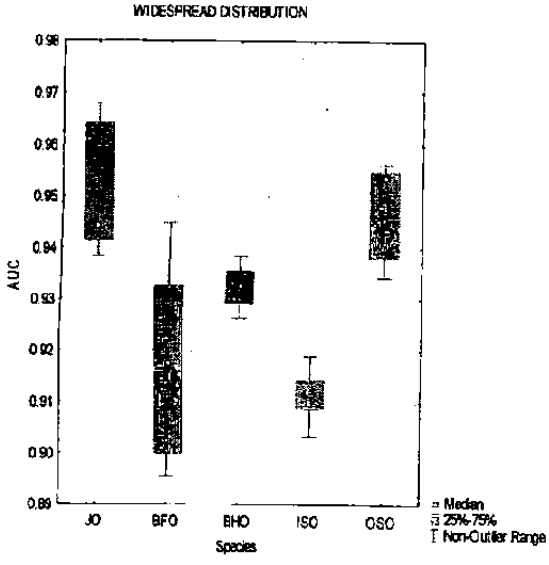


Fig. 55 Area under the ROC values of widely distributed species in ten replicate models

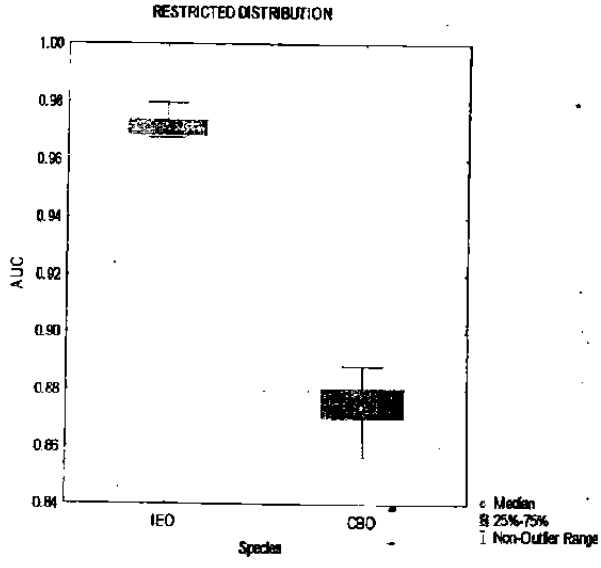


Fig. 56 Area under the ROC values of restricted distributional species one-leave-out method

Fig. 57 Receiver operating characteristics curve and Jack-knife regularized training gain of Oriental scops owl

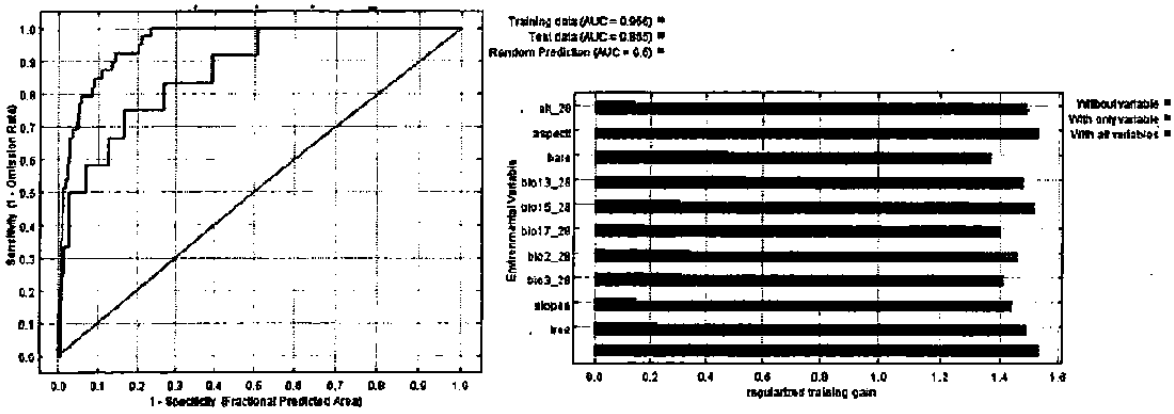


Fig. 58 Receiver operating characteristics curve and Jack-knife regularized training gain of Ceylon bay owl

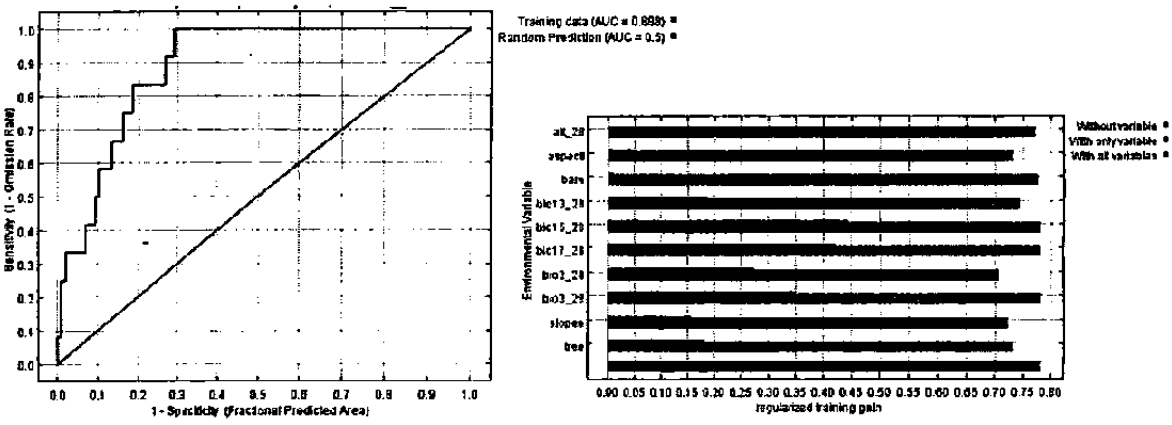
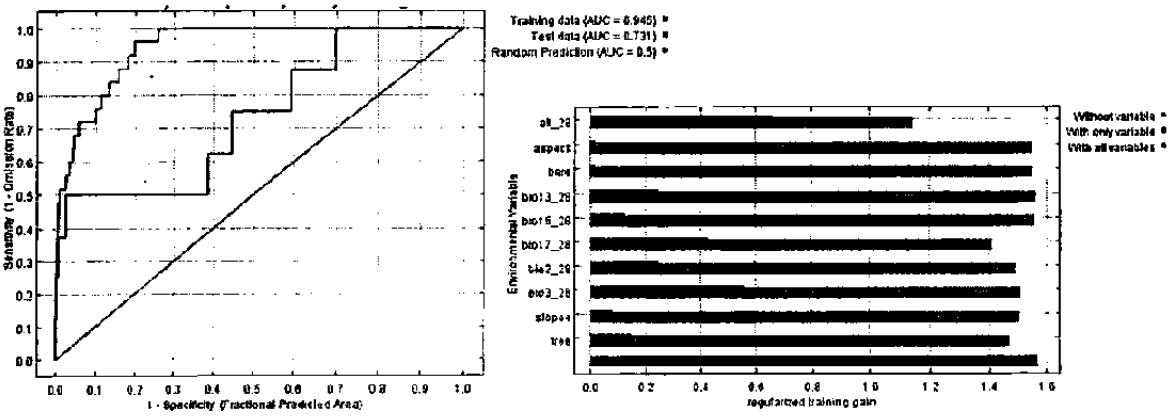


Fig. 59 Receiver operating characteristics curve and Jack-knife regularized training gain of Brown fish owl



3.4.4. DISCUSSION

Presence only modeling approaches are useful in predicting the species distributions. The presence data available in the digital libraries (Soberon *et al.*, 2000) and museum records and a set of high resolution spatial environmental data (Hijmans *et al.*, 2005) allows to compute distribution maps for any species whether range restricted or wide ranged (Hernandez *et al.*, 2008). The area under the ROC curve was higher in all the data partitions for all the species and it ranged from 0.85 (Ceylon bay owl) to 0.98 (Indian eagle owl) (Fig. 55 and 56). The AUC values 0.5-0.7 indicate poor discrimination, 0.7-0.9 indicates reasonable discrimination and 0.9-1.0 indicates very good discrimination (Swets, 1988). The predicted AUC values for the owls ranged from reasonable discrimination to very good discrimination.

The predicted models for the owls were better indicators of their distribution than the sketches and points over the maps that given in the field guides (for example Ali and Ripley, 1983; Grimmett *et al.*, 2000; Rasmussen and Anderton, 2005). Moreover, the algorithm has well predicted the potential habitats of both range restricted and wide ranged species and it works well with limited number of presence records. The high predictive performance of the algorithm with small set of occurrence records were also highlighted elsewhere (Phillips *et al.*, 2006; Herandez *et al.*, 2008; Kumar and Stohlgren, 2009). Although several niche based modeling algorithms were developed in recent years for predicting the species distribution, MAXENT was reported as superior modeling algorithm over the other niche based models including GARP, ENFA, BIOCLIM and DOMAIN (Elith *et al.*, 2006).

In addition to the climatic variable, newly available remote sensing data (MODIS) were found to be an important variable in predicting the contemporary geographical distribution of species and range shifts as a result of the large scale land-use change (Buermann *et al.*, 2008). Three owl species (jungle owlet, brown hawk owl and oriental scops owl) have showed a strong association with the vegetation data (MODIS tree cover and bare cover) and the remaining species were associated with the climatic and topographic variables. Interestingly, two larger owls (brown fish owl and Indian eagle owl) were much associated with the topographic variables rather than the remote sensed data. Highly correlating environmental variables were

excluded from the model instead of including all the environmental variables. However, in few studies all the environmental variables were applied together and some recent studies selected only the uncorrelated variables for model building.

Regarding the distribution of species, the MAXENT model has well predicted the areas where species does not occur. The distribution of the jungle owlet was not confirmed in high altitude i.e. above 2000 m and the model also not predicted those areas, marked as unsuitable habitats. Moreover, the distribution of the brown hawk owl was restricted to below 1500 m and the areas above 1500 m were identified as unsuitable areas for the species.

4. DISCUSSION AND RECOMMENDATIONS

Protected area managers should focus on owls for special consideration in forests (Lugg *et al.*, 1993), because of their large home ranges, known needs for elements of old forest to provide nest sites in large hollow-bearing trees, and they support high densities of arboreal mammal prey (Loyn *et al.*, 1980; Milledge *et al.*, 1991; Kavanagh and Bamkin, 1995). The implication is that they are the species with the most demanding requirements, and if they are conserved many other species will be well conserved also. This fits the concept of owls as umbrella species (Simberloff, 1998). The knowledge of distribution pattern and population abundance of owls in the Western Ghats of India will help to decide whether the group requires any special protection measures. The present study produced detailed information on distribution, population status and conservation status of the forest owls. Modelling provided potential areas suitable for the conservation of forest owls. Population status of the owls gathered will enhance our knowledge on the conservation status of the species and also to know whether some species is to be included in the list of endangered species.

1. As eleven species of owls recorded from Kerala inhabit the forests, the conservation of forests is important for the protection of owls.
2. As the highest encounter rate of owls was recorded from the Nelliampathy-Parambikulam-Anamalai Hill complex, these areas are important for the conservation of owls.
3. Indira Gandhi Wildlife Sanctuary in Tamil Nadu needs special attention as this protected area harbours highest owl diversity in the southern Western Ghats.
4. The model developed after assessing the distribution of owl species in the various vegetation types and topography can be utilized for locating their habitats in the dense forest terrains of the Western Ghats and to narrow down the search to probable locations.
5. Regulate the mining of granite, as this is destroying the habitat of the Indian eagle and brown fish owl in the eastern slopes of the Western Ghats in Tamil Nadu.
6. The nest sites and nestlings/fledgling of large owls were destroyed by the land owners/workers of private estates, cattle grazers in the foothills, and NWFP collectors for their inquisitiveness and superstitious beliefs. To avoid this basic

information on owls such as their ecological role in the agro/forest ecosystem, vocal communication, life history characteristics and most importantly the superstitious beliefs on them needs to be explained to them.

7. Another issue related to the conservation of raptorial birds including diurnal raptors is the rescue centres. The large owls are frequently killed/injured due to road accidents during the rainy season, when they try to forage frogs and snakes on the road. However, in the case of fledglings, they are often victim to the mobbing of birds or humans. During the study, several such fledglings and road kills were rescued and individuals were reared until they were able to fly. Due to lack of suitable aviaries, roosting and perch sites all the individuals could not be rescued. For rescuing such individuals, it is necessary to establish rescue centres in selected places.
8. Cattle grazing and fire in the hillocks have adverse impact on the nesting behaviour and nestlings of Indian eagle owl and brown fish owl. Moreover, the breeding season of these owls is coinciding with the peak dry season. So during these periods the fire should be controlled.
9. In most part of the eastern slopes, the grassy hillocks are under non-protected area category; hence, it is being highly exploited by the humans adjacent to these hillocks. Such hillocks need to be protected from exploitation.
10. The riparian forests adjacent to water bodies are utilised as critical habitats by all the owls, in order to avoid the extreme heat loss during the diurnal retreats. The riparian forests are also diverse in terms of vertebrate fauna; hence, it is important to keep these ecosystems as virgin.

5. ACKNOWLEDGEMENTS

The study was undertaken with the financial assistance of the Ministry of Environment and Forests, Govt. of India. Dr. K.V. Sankaran, Director, KFRI took keen interest in completing the study which is gratefully acknowledged. Dr. R. Gnanaharan, Former Director, Kerala Forest Research Institute and Dr. C. Renuka, Programme Coordinator keenly followed the study and offered encouragement and suggestions for the successful completion of the work.

Forest Departments of Kerala and Tamil Nadu States promptly given the necessary permissions for carrying out the field surveys in the protected areas. The two forest departments provided local support. All the local assistants are acknowledged for their immense support in carrying out the field studies during the night hours.

6. REFERENCES

Abdulali, Humayun 1948. The clicking noise made by Owls. *J. Bombay nat. Hist. Soc.* 47: 548.

Ali, S. and Whistler, H. 1936. The Ornithology of Travancore and Cochin. Part VI. *J. Bombay. nat. Hist. Soc.* 39: 3-35.

Ali, S. and Ripley, D. 1983. Handbook of Birds of India and Pakistan. Oxford Publications, 737 pp.

Allen, G.O. 1920. Hovering habit of the Spotted Owlet *Athene brahma. J. Bombay nat. Hist. Soc.* 26: 1045.

Altman, J. 1974. Observational study of behaviour - sampling methods. *Behaviour* 49: 227-267.

Anciaes, M. and Peterson, A.T. 2006. Climate change effects on neotropical manakin diversity based on ecological niche modelling. *The Condor.*108: 778-791.

Anderson, R.P., Peterson, A.T. and Laverde, M.G. 2002. Using niche based GIS modelling to test geogrphic predictions of competitive exclusion and competitive release in south Ameraican Pocket mice. *Okios* 98: 3-16.

Anon. 2000. Ornithological fraud. The case of the forest owlet (*Athene blewitti*). *Newsletter for Birdwatchers* 40: 15.

Appleby, B. M., Yamaguchi, N., Johnson, P. J. and McDonald, D. 1999. Sex-specific territorial responses in Tawny owls *Strix aluco. Ibis* 141: 91-99.

Appleby, B.M. and Redpath, S.M. 1997. Indicators of male quality in the hoots of Tawny owls *Strix aluco. Journal of Raptor Research* 31: 65-70.

Babu, S. and Jayson, E.A. 2008. Distribution and habitat characteristics of Large brown flying squirrel (*Petaurista philippensis*) in the southern Western Ghats. Oral presentation in the BIOCAM 2008. International Conference on Biodiversity, Cochin University of Science and Technology, Cochin.

Babu, S. and Jayson, E.A. 2009. Anti predator behaviour of Large brown flying squirrel (*Petaurista philippensis*): Is this an effective census method to survey the species? *Current Science* 96:772-773.

Babu, S. Jayson, E.A. and Sivaram, M. 2008. Ecological niche modelling of two sympatric Owls (*Otus bakkamoena* and *Ninox scutulata*) in the southern Western Ghats, India. Proceedings of the 20th Kerala Science Congress,

January, 28-31.

Babu, S., and Jayson, E. A., 2007. Habitat use and response behaviour of Brown hawk owl (*Ninox scutulata*) to the conspecific broadcasted calls. Abstract *of 31st Annual Conference of Ethological Society of India,* Bangalore, 107 pp.

Balachandran, S., Rahmani, A.R., Ezhilarasi, N., Babu, S., Chakravarthy, J.P. and Ramesh, T. 2005. Revaluation of bird community structure of Palani hills with special reference to threatened and endemic species. Final report, Bombay Natural History Society, Mumbai.

Bart, J. and Forsman, E.D. 1992. Dependence of Northern spotted owls *Strix occidentalis caurina* on old growth forests in the Western USA. *Biol. Conserv.* 62:95-100.

Bawa, K.S. and S. Dayanandan 1997. Socio-economic factors and tropical deforestation. *Nature* 386: 562-563.

Birdlife International 2001. Forest owlet *Heteroglaux blewitii. In*: *Threatened Birds of Asia: the Birdlife International Red Data Book.* Vol.2. (Eds: Collar, N.J.; Andreev, A.V.; Chan, S.; Crosby, M.J.; Subramanya, S. & Tobias, J.A.) Birdlife International, Cambridge, UK. pp. 1772-1775.

Birdlife International 2001. Nicobar Scops-Owl *Otus alius.* In: *Threatened Birds of Asia: the BirdLife International Red Data Book.* Vol. 2. (Eds: Collar, N.J.; Andreev, A.V.; Chan, S.; Crosby, M.J.; Subramanya, S. & Tobias, J.A.) Birdlife International, Cambridge, UK. pp. 2467-2468.

Blanford, W.T. 1894. Notes on the Indian Owls. *Ibis* 6: 524-531.

Brahmachary, R.L., Basu, T.K. and Sengupta, A. 1973. On the daily screeching time of a colony of Spotted Owls *Athene brama* (Temmnick). *J. Bombay nat. Hist. Soc.* 69: 649-651.

Braithwaite, L.W., Turner, J. and Kelly, J. 1984. Studies on the arboreal marsupial fauna of eucalypt forests being harvested for woodpulp at Eden, NSW. 3. Relationships between faunal densities, eucalypt occurrence and foliage nutrients and soil parent materials. *Australian Wildlife Research* 11:41-48.

Brotons, L., Thuiller, W., Araujo, M.B. and Hirzel, A.H. 2004. Presence-absence versus presence-only modelling methods for predicting bird habitat suitability. *Ecography* 27: 437-448.

Buermann, W., Saatchi, S., Smith, T. B., Zutta, B. R., Chaves, J. A., Milá, B. and Graham, C. H., 2008. Predicting species distributions across the Amazonian and Andean regions using remote sensing data. *J. Biogeogr.* 35: 1160-1176.

Champion, H. G. and Seth S. K.1968. A Revised Survey of Forest Types of India. *Manager Publications, New Delhi* 404 p.

Chandrasekhara, S. and Nameer, P.O. 2003. Short-eared owl (*Asio flammeus*) in Kerala, India. *Zoo's Print Journal* 18:1235.

Chandrasekharan, C. 1962 a. Forest types of Kerala State. *Indian Forester* 88: 660-674.

Chandrasekharan, C. 1962 b. Forest types of Kerala State. *Indian Forester* 88: 713-747.

Chandrasekharan, C. 1962 c. Forest types of Kerala State. *Indian Forester* 88: 837-847.

Coltart, H.N. 1904. The occurrence of the Malay fish-owl *Ketupa javanensis* in Assam. *J. Bombay nat. Hist. Soc.* 15: 719.

De'ath, G. and Fabricius, K.E. 2000. Classification and regression tress: a powerful yet simple technique for ecological data analysis. *Ecology* 81: 3178-3192.

Debus, S. J. S. 1995. Surveys of large forest owls in Northern New South Wales: methodology, calling behaviour and owl responses. *Corella* 19: 38-50.

Deleo, J.M. 1993. Receiver operating characteristic laboratory (ROCLAB): software for developing decision strategies that account for uncertainty. In: Proceedings of the second International symposium on Uncertainty Modelling and analysis, pp. 318-325. College Park, MD:IEEE computer Society Press.

Desai, G.; Tonshal, Prakash and Neginhal, Pankaj 1997. Nest of the Indian Great Horned Owl, *Bubo bubo*, sighted on Nrupatunga Betta of Hubli. *Newsletter for Birdwatchers* 37: 102.

Dharmakumarsinhji, K.S. 1939. Breeding of the Indian barn owl *Tyto alba javanica* (Gmelin) in Bhavnagar. *J. Bombay nat. Hist. Soc.* 41: 174.

Dharmakumarsinhji, R.S. 1978. Strange behaviour of Indian barn owl *Tyto alba stertens* (Hartert). *Pavo* 15: 164.

Dodsworth, P.T.L. 1913. The Himalayan Wood-Owl *Syrnium nivicola*, Hodgs. *J. Bombay nat. Hist. Soc.* 22: 626-629.

Dubale, M.S. and Rawal, U.M. 1968. Anatomy of the feeding apparatus of spotted owlet *Athene brama indica* (Franklin). *Pavo* 6: 12-24.

Dudgeon, G.C.1901. The Large-barred Owlet *Glaucidium cuculoides*, Vigors capturing Quail on the wing. *J. Bombay nat. Hist. Soc.* 13: 530-531.

Dwarakanath, K. 1983. Attack by Spotted Owlet. *Newsletter for Birdwatchers* 23: 13.

Easa, P. S. 1995. Prey predator studies in Eravikulam National Park. *KFRI Research Report* 105: 58.

Easa, P. S. 1997. Status, food and feeding habits of larger mammals in Idukki Wildlife Sanctuary, Kerala, *KFRI Research Report* 134. *Kerala Forest Research Institute.*

Easa, P. S. and Sankar, S. 2001. Study on man-wildlife interaction in Wayanad wildlife Sanctuary, Kerala. *KRFI Research Report* No. 166, 183 p.

Easa, P.S. and E. A. Jayson 2004. Biodiversity Documentation for Kerala, Part 11: Birds, *Kerala Forest Research Institute,* Peechi, Kerala 45 p.

Eates, K.R. 1937. The distribution and nidification of the rock horned owl B*ubo bubo bengalensis* (Frankl.) in Sing. *J. Bombay Nat. Hist. Soc.* 39: 631-633.

Eates, K.R. 1939. A note on the resident owls of Sind. *J. Bombay nat. Hist. Soc.* 40: 750-755.

Ekanayake, Upali 1994. The Ceylon bay owl, *Phodilus badius assimilis* Hume, another record from the hill zone. *Ceylon Bird Club Notes:* 27-28.

Elith, J., Graham, C. H., Anderson, R. P., Dudik, M., Ferrier, S., Guisan, A., Hijmans, R. J., Huettmann, F., Leathwick, J. R., Lehmann, A., Li, J., Lohmann, L. G., Loiselle, B. A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J. M., Peterson, A. T., Phillips, S. J., Richardson, K., Scachetti-Pereira, R., Schapire, R. E., Soberón, J., Williams, S., Wisz, M. S. and Zimmermann, N. E., 2006. Novel methods improve prediction of species distributions from occurrence data. *Ecography* 29: 129-151.

Engler, R., Guisan, A. and Rechsteiner, L. 2004. An improved approach for predicting the distribution of rare and endangered species from occurrence and pseudo-absence data. *Journal of Applied Ecology* 41: 263–274.

ENVIS, 2007. State-wise bird list. http://www.bnhsenvis.nic.in/State.html

Fielding A. H. and Bell J. F. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental Conservation* 24: 38-49.

Forsman, E.D., Meslow, E.C. and Wright, H.M. 1984. Distribution and biology of the spotted owl in Oregon. *Wildl. Monogr.* 87:1-64.

Francis, W. 1994. The Nilgiris. Madras District Gazetteers. *Asian Educational services New Delhi.* A reprint of 1908.

Francl, K.F. and Schnell, C.D. 2002. Relationship of human disturbance, bird communities, and plant communities along the land water interface of a large reservoir. *Environmental Monitoring and Assessment* 73: 67-93.

Friedmann, H. and Deignan, H.G. 1939. Notes on some Asiatic owls of the genus *Otus*, with description of a new form. *Journal of the Washington Academy of Sciences* 29: 287-291.

Fuller, R.M., Groom, G.B., Mugisha, S., Ipulet, P., Pomeroy, D., Katende, A., Bailey, R. and Ogutu-Ohwayo, R. 1998. The integration of field survey and remote sensing for biodiversity assessment: a case study in the tropical forests and wetlands of Sango Bay, Uganda. *Biol. Conser.* 86: 379-391.

Galeotti, P. 1998. Correlates of hoot rate and structure in male tawny owls *Strix aluco*: implications for male rivalry and female mate choice. *Journal of Avian Biology* 29: 25-32.

Galeotti, P. and Pavan, G. 1993. Differential response of territorial tawny owls (*Strix aluco*) to the hooting of neighbour and strangers. *Ibis* 135:300-304.

Galeotti, P., Sacchi, R. and Perani, E. 1997. Cooperative defence and intrasexual aggression in sops Owls (*Otus scops*): responses to playback of male and female calls. *Journal of Raptor Research* 31: 353-357.

Gaston, K. J., and Blackburn. T. M. 2000. Pattern and Processes in Macro Ecology, Blackwell Scientific, Oxford.

Gerhardt, R.P. 1991. Response of mottled owls to broadcast of conspecific calls. *J. Field Ornithol.* 62:239-244.

Giriraj, M. S. R. Murthy, Ramesh, B. R. and Dutt, C. B. S. 2008. A method for assessing evergreen habitats using phytodiversity and geospatial techniques in tropical rain forests of Southern Western Ghats (India). *Ecological Research* 24: 749-760.

Gole, T. 1988. Owls around Pune. *J. Ecol. Soc.* 1: 67-69.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley and Sons, New York, NY. 257 pp.

Grimmet, R Inskipp, T., and Inskipp, C. 1998. Birds of the Indian Subcontinent, UK: A&C Black.

Grimmett, Richard, Carol Inskipp and Tim Inskipp 2003. Birds of India: Pakistan, Nepal, Bangladesh, Bhutan, Sri Lanka, and the Maldives. Princeton University Press, 384 pp.

Guchhait, Prasenjit and Haldar, Chandana 1998. Effect of Melatonin and other 5-Methoxyindoles on the reproductive activity of the Indian spotted owlet *Athene brama*. Chap. 29. In: *Birds in Agricultural Ecosystem*. (Eds: Dhindsa, M.S.; Rao, P. Syamsunder & Parasharya, B.M.) Society for Applied Ornithology, Hyderabad pp. 190-196.

Gunathilagaraj, K. 1991. Owl perches. *Newsletter for Birdwatchers* 31: 8.

Gunawardena, Kithsiri 2001. New owl species from Sri Lanka. *Pitta* 119: 1-2.

Gupta, K.K. 1967. Aggressive behaviour of a spotted owlet *Athene brama* (Temminck). *J. Bombay nat. Hist. Soc.* 63: 441-442.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. 2003. Multivariate data analysis. Pearson Education (Singapore) Pte. Ltd. 730 pp.

Haldar, C. 1998. The pineal control of reproductive activity of the Indian spotted owlet *Athene brama*. In: *Birds in Agricultural Ecosystem*. (Eds: Dhindsa, M.S.; Rao, P. Syamsunder & Parasharya, B.M.) Society for Applied Ornithology, Hyderabad pp. 182-189.

Haldar, C. and Guchhait, P. 2000. Pineal gland of a nocturnal bird, Indian spotted owlet, (*Athene brama*); Morphological and endocrine observations. *Journal of Experimental Zoology* 287: 145-150.

Hansen M., DeFries R.S., Townshend J.R.G., Carroll M., Dimiceli C.and Sohlberg R. A. 2003. Global Percent tree over at a spatial resolution of 500 meters: First results of the MODIS Vegetation Continuous Fields Algorithm. *Earth Interactions* 7: 1-15.

Henry, G.M., 1933. The cry of the Ceylon scops owl *Otus sunai leggei*. *Spolia Zeylanica* 17: 246-248.

Hernandez, P. A., Franke, I., Herzog, S. K., Pacheco, V., Paniagua, L., Quintana, H. L., Soto, A., Swenson, J. J., Tovar, C., Valqui, T. H., Vargas, J. and Young, B. E., 2008: Predicting species distributions in poorly-studied landscapes. *Biodiver. Conserv.* 17: 1353-1366.

Higgins, P. (ed.), 1999. Handbook of Australian, Newzeland and Antartic Birds. Volume 4. Parrots to Dollarbird. OUP Melbourne.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G.and Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965-1978.

Hirzel, A. H., Hausser, J. and Perrin, N. 2002. Biomapper 2.1. Laboratory for Conservation Biology, University of Lausanne.

Hirzel, A. H., Hausser, J., Chessel, D. and Perrin, N. 2002 Ecological-Niche factor analysis: how to compute habitat suitability maps without absence data? *Ecology* 87: 2027-2036.

Holme, D. A. 1965. Owl noises. *Newsletter for Birdwatchers* 5: 7-8.

Hosmer, D.W. and Lemeshow, S. 2000. Applied Logistic Regression, second edition. John Wiley & Sons, Inc, New York.

Hussain, S. A. and Khan, M. A. R. 1978. A new subspecies of bay owl (*P badius*) from peninsular India. *J. Bombay nat. Hist. Soc.* 74:334-336.

Hutchinson, G.E. 1957. "Concluding remarks". *Cold Spring Harbor Symposia on Quantitative Biology* 22: 415–427.

Inglis, C.M. 1901. Snaring owls in nooses. *J. Bombay nat. Hist. Soc.* 13: 700.

Inglis, C.M. 1941. The long-eared owl in the Darjeeling District. *J. Bombay nat. Hist. Soc.* 15: 83-84.

Inglis, C.M. 1945. The Northern bay owl. *Journal of the Bengal Natural History Society* 19: 93-96.

Ishitaq, F. and Rahmani, Asad R. 2000. Cronism in the forest owlet *Athene blewitti*. *Forktail* 16: 172-174.

Ishitaq, Farah and Rahmani, Asad R. 2000. Further information on the status and distribution of the forest owlet *Athene blewitti* in India. *Forktail* 16: 125-130.

Ishtiaq, F. 1998. *Status survey of the forest spotted owlet* Athene *blewitti in India.* Bombay Natural History Society, Bombay.

Ishtiaq, F. and Rahmani, A. R. 2005. The forest owlet *Heteroglaux blewitti*: vocalization, breeding biology and conservation. *Ibis* 147:197-205.

IUCN 2001. IUCN Red List Categories and Criteria: version 3.1. IUCN, Gland, Switzerland and Cambridge, U.K.

IUCN 2008. IUCN red list. www.iucnredlist.org

Jadeja, S. 1971. Owlets. *Newsletter for Birdwatchers* 11: 11.

Jain, A.P. and Advani, Ranjan 1984. Winter food of spotted owlet *Athene brama indica. J. Bombay nat. Hist. Soc.* 80: 415-416.

Jameson, S. 1973. Brown wood owl *Strix leptogramica indranee* in the Nilgiris, South India. *Newsleter for Birdwatchers* 13: 2-5.

Jameson, S. 1976. An owl in Coonoor. *Newsletter for Birdwatchers* 16: 12-13.

Jathar, G. A. and Rahmani, A.R. 2006. Endemic birds of India. *Buceros* 11: (2&3).

Jayson, E. A. 1997. Rare and endangered mammals of Kerala. KFRI Hand Book No. 2. *Kerala Forest Research Institute*, Peechi.

Jayson, E. A. 2004. Habitat utilisation of large herbivores in the Chinnar Wildlife Sanctuary, Kerala. *In*: Kaul B.L. (ed) Advances in Fish and Wildlife Ecology and Biology Vol.3. 239-251. *M/S Daya publishing House, Ansari Road, Darya Ganj, New Delhi.*

Jayson, E. A. 2006. Status, distribution, food and feeding of Malabar spiny dormouse (*Platacanthomys lasiurus*) in the Western Ghats of Kerala. Kerala Forest Research Institute Research Report No. 293, *Kerala Forest Research Institute*, Peechi. p 118.

Jayson, E. A. and Easa, P.S. 1999. Documentation of vertebrate fauna in Mangalavanam mangrove area. KFRI Research Report No.183. *Kerala Forest Research Institute*, Peechi 42 p.

Jayson, E. A. and Mathew, D.N. 2000. Seasonal changes of tropical forest birds in Southern Western Ghats. *J. Bombay nat. Hist. Soc.* 97: 52-51.

Jayson, E. A. and Mathew, D.N. 2002. Structure and composition of two bird communities of in the southern Western Ghats. *J. Bombay nat. Hist. Soc.* 99: 8-25.

Jayson, E. A. and Padmanabhan, P. 2002. Evaluation of problems of captive/natural population of crocodile in Neyyar Wildlife Sanctuary and suggestions for their management with special emphasis on reduction of human animal conflict. KFRI Research Report No.237. *Kerala Forest Research Institute*, Peechi 95 p.

Jayson, E. A., Mathew, D.N. 2003. Vertical stratification and its relation to foliage in tropical forest birds in Western Ghats (India). *Acta Ornithologica* 38: 111-116.

Jayson, E. A., Babu, S. and Sivaram, M. 2007. Status and habitat utilization of forest owls in the Western Ghats of South India. World Owl Conference 2007, Groningen, The Netherlands.

Jha, C. S., Dutt, C. B. S. and Bawa, K. S. 2000. Deforestation and land use changes in Western Ghats, India. *Current Science* 79: 231-238.

Johnsingh, A. J. T. and Joshua J. 1989. The threatened Gallery forest of the River

Tambiraparani, Mundanthurai Wildlife Sanctuary, South India. *Biol. Conserv.* 47: 273-280.

Johnsingh, A. J. T. 2001. The Kalakad-Mundanthurai Tiger Reserve: A global heritage of biological diversity, *Current Science* 80: 378-388.

Jones, J. 2001. Habitat selection in avian ecology: a critical review. *Auk* 118:557-562.

Jose, T.V. 1964. A Southern spotted owlet *Athene brama* attacked by crows. *Newsletter for Birdwatchers* 4: 8.

Jose, T.V. 1999. Notes: rescue of an owlet and rare food source of cattle egrets. *Newsletter for Birdwatchers* 39: 38-39.

Kanakasabai, R. 1996. First record of fresh water crab *Paratelphusa* spp. in the barn owl's *Tyto alba* (Scopoli) diet in Tranquebar Taluk, Tamil Nadu, South India. *J. Bombay Nat. Hist. Soc.* 93: 90.

Kanakasabai, R, Neelanarayanan, P. and Nagarajan, R. 1996. Sexual dimorphism in adult barn owl, *Tyto alba stertens*, *Pavo* 34: 61-63.

Kanakasabai, R.; Neelanarayanan, P. and Nagarajan, R. 1996. Sexual dimorphism in Barn Owl *Tyto alba*. *Newsletter for Birdwatchers* 36: 55.

Kanakasabai, R., Subiah, K.S., Neelanarayanan, P. and Nagarajan, R. 1994. Nest box and "T" shape perching pole for common barn owl. *Newsletter for Birdwatchers* 34: 88-89.

Kannan, R.1992. Possible sighting of a bay owl in Anamalai Hills. *Newsletter for Birdwatchers* 32: 12.

Kannan, R. 1993. Rediscovery of the oriental bay-owl *Phodilus badius* in Peninsular India. *Forktail* 8: 148-149.

Kannan, R. 1995. Forest eagle owl (*Bubo nipalensis* Hodgson) - a predator of the Indian Giant Squirrel (*Ratufa indica*). *J. Bombay nat. Hist. Soc.* 91: 454.

Katoch, R.C. and Sambyal, D.S. 1992 Isolation of *Salmonella newport* from Himalayan horned eagle owl. *Indian Veterinary Journal* 69: 664.

Kavanagh, R. P. and Peake, P. 1993. Survey procedures for nocturnal forest birds: an evaluation of variability in census due to temporal factors, weather and technique. In P. Olsen (Ed.): Australian Raptor Studies. Australasian Raptor Association. R.A.O.U. Melbourne, pp. 86-100.

Kavanagh, R. P. and Bamkin, K.L., 1995. Distribution of nocturnal forest birds and mammals in relation to the logging mosaic in South-Eastern New South Wales, Australia. *Biol. Conserv.* 71: 41-53.

Kavanagh, R.P., 1997. Ecology and Management of large forest owls in South-eastern Australia. Ph. D. Thesis, University of Sydney, Sydney.

Kavanagh, R.P., Debus, S.J.S., Rose, A.B. and Turner, R.J. 1995b. Diet and habitat of the barking owl *Ninox connivens* in New South Wales. *Australian Bird Watcher* 16: 137-144.

KFRI. 1993. Ecological studies and long-term monitoring of biological process in Silent Valley National Park *KFRI Research Report* 239 p.

Khajuria, H. 1972. Feeding habits of the Central Indian collared scops owl *Otus bakkamoena marathae* (Ticehurst) in captivity. *Pavo* 8: 81.

Khajuria, H. 1974. Fledglings of the northern spotted owlet. *Pavo* 9: 86-87.

King, B.F. and Rasmussen, P.C. 1998. The recovery of the forest owlet *Athene blewitti. Forktail* 14:53-55.

Klatt, P.H. and Ritchison, G. 1994. The effect of mate removal on the vocal behaviour and movement patterns of male and female Eastern screech owls. *Condor.* 96:485-493.

Klein Baum, D.G. and Klein, M. 2002. Logistic Regression: A Self Learning Text. Springer-Verlag, New York.

Krishnan, M. 1985. Owls great and small. In: Krishnan, M (ed.) *Nights and Days. My Book of India's Wildlife*. Vikas Publishing House Pvt Ltd, New Delhi. pp. 56-61.

Kumar, M.A., Singh, M., Srivastava, S.K., Udayan, A., Kumara, H.N. and Sharma, A. K., 2002. Distribution patterns, relative abundance and management of mammals in Indira Gandhi Wildlife Sanctuary, Tamil Nadu, India. *J. Bombay nat. Hist. Soc.* 99: 184–210.

Kumar, S. 1995. Possible predation of blacknaped hare by great horned owl *Bubo bubo* in the Great Indian Bustard Sanctuary, Nanaj (Solapur), Maharashtra. *Newsletter for Birdwatchers* 35: 16-17.

Kumar, T. S. 1980. The life-history of the spotted owlet (Athene brama brama Temmnick) in Andhra Pradesh. Raptor Research Centre, Hyderabad. Pub. No. 4.

Kumar, T. S. 1985. *The Life History of the Spotted Owlet (Athene brama, Temmnick) in Andhra Pradesh.* Raptor Research Centre, Hyderabad. Pub. No.4 241 pp.

Kumar, S., and Stohlgren, T. J. 2009. Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *Journal of Ecology and Natural Environment* 1: 94-98.

Lamba, B.S. and Tyagi, A.K. 1975. Incubation period in Northern spotted owlet, *Athene brama indica* (Franklin). *Newsletter of the Zoological Survey of India* 2: 128-129.

Lindenmayer, D.B., Cunningham, R.B., Tanton, M.T. and Smith, A.P. 1990. The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, South-east Australia. 1. Factors affecting the occupancy of trees with hollows. *Biological Conservation* 54: 111-132.

Livesey, T.R. 1936. The brown wood owl (*Strix indranee* Sykes). *J. Bombay nat. Hist. Soci.* 38: 827-828.

Liyanage, C. 1972. Ceylon bay owl: One of Ceylon's rarest birds. *Loris* 12: 244-246.

Long, W.J., Griffith, J.L., Selker, H.P. and Dagostino, R.B. 1993. A comparison of logistic regression to decision-tree induction in a medical domain. *Comput. Biomed. Res.* 26: 74-97.

Loyn, R. H. 1985. Bird populations in successional forests of Mountain Ash *Eucalyptus regnans*. *Emu* 85: 213-230.

Loyn, R., Macfarlane, M., Chesterfield, E. and Harris, J. 1980. Effects of forest utilization on flora and fauna in Boola Boola state forest. Forests commission, Victoria. *Bulletin* 28.

Loyn, R.H., McCabe, E.G., Volodina, L., and Willig, R. 2001. Modelling landscape distribution of large forest owls as applied to managing forests in north-east Victoria, Australia. *Biological Conservation* 97: 361-376.

Lugg, A., Marsh P., Bartlett, A., King, F. (comp) 1993. Statement of resources, use, and values for the East Gippsland Forest Management Area. Department of Conservation and Natural Resources, Victoria.

Macfarlane, M.A., 1988. Mammal populations in Mountain Ash (*Eucalyptus regnans*) forest of various ages in the Central Highlands of Victoria. *Australian Forestry* 51:14-27.

Umapathy, G, Kumar, A., 2000. The occurrence of arboreal mammals in the wet evergreen forests of the Anamalai hills in the Western Ghats, South India. *Biol. Conserv.* 92: 311–319.

Vasudeva, R., Hareesh, T.S., Hombe Gowda, H.C., Bhat, S.D., Gunaga, R. and Raj, V.M. 2005. Report of an injured Ceylon bay owl *Phodilus assimilis* from Karnataka, India. *Indian birds* 1: 118-119.

Verzhutskii, B. and Ramanujam, M.E. 2002. On the prey of collared scops owl (*Otus bakkamoena*) at Aruville, Pondichery. *Zoo's Print* 17: 939-940.

Vighnarajan, G. 1990. Shendurney Wildlife Sanctuary, Management Plan 1990-'91 to 1999-2000. Kerala Forest Department 90 p.

Webb, T.J., Noble, D. and Freckleton, R.P. 2007. Abundance-occupancy dynamics in a human dominated environment: linking interspecific and intraspecific trends in British farmland and woodland birds. *J. Anim. Ecol.* 76: 123-134.

Wemmer, Chris and Derrickson, Kim C. 1994. Duetting in the great horned owl, *Bubo nipalensis* Hodgson (Strigiformes: Strigidae) *J. Bombay nat. Hist. Soc.* 91: 141-142.

Williams, Robert S.R. 1998. Uneven sex ratio of the long-eared owl *Asio otus* in northern India. *J. Bombay nat. Hist. Soc.* 95: 343-344.

Zarri, A.A. and Rahmani, A.R. 2005. Annotated avifauna of the Upper Nilgiris, Western Ghats, Tamil Nadu, India. *ENVIS Newsletter* 10(1).

Zuberogoitia, I. and Campos, L. F. 1998. Censusing owls in large areas: a comparison between methods *Ardeola* 45: 47-53.

Microhabitat preference of owls:

Sl. No.	Species Name	Micro habitat	Perch height	Status of substrate	Total tree height	Species of tree	DBH of tree	Canopy cover	Remarks

Notes:

Call play back behaviour:

Sl. No.	Species Name	Latency to Response	Mode of response (V or C)	Type of call	Duration of call	Sex of owl (if possible)	Distance to the bird	Light intensity	Remarks