Status and Ecology of the Nilgiri Wood Pigeon in the Western Ghats

Thesis submitted to the
Bharathiar University, Coimbatore
for the award of
Doctor of Philosophy
in
Zoology

by

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COIMBATORE - 641 108

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CERTIFICATE

This is to certify that the thesis, entitled "**Status and Ecology of the Nilgiri Wood Pigeon in the Western Ghats**" submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original research work done by **Mr. S. Somasundaram** during the period August 2002 to September 2006 of his study in the Department of Zoology at Sálim Ali Centre for Ornithology and Natural History, under my supervision and guidance and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate in any University.

Signature of the Guide

Countersigned

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DECLARATION

I, **S. Somasundaram** hereby declare that the thesis, entitled "**Status and Ecology of the Nilgiri Wood Pigeon in the Western Ghats**", submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original and independent research work done by me during August 2002 to September 2006 under the Supervision and guidance of **Dr. Lalitha Vijayan**, Department of Zoology, and it has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate in any University.

S. Somasundaram

Signature of the Candidate

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S. Somasundaram

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Chapter 1

Introduction

1.1. General introduction

Human society has a choice with regard to the amount of diversity that will be retained along its development path, and this choice has thus far been made in a random fashion, resulting in unmanaged diversity depletion (Grafton *et al.* 2004). In the case of birds, habitat loss has been identified as one of the main factors for 1025 species, currently threatened in the world (Collar & Andrew 1988, Collar *et al.* 1994, Robinet *et al.* 2003). In the tropical Pacific, more than two thousand species of birds have been exterminated and many others have suffered local or regional extirpations (Dirrickson *et al.* 1998). The endemic species with restricted ranges are clearly at the greatest risk of extinction (Bibby *et al.* 1992, Simberloff 1995, Pimm & Askins 1995, Pimm *et al.* 1995).

The magnitude of the extinction crisis is moving conservation from a reactive management of a threatened species toward the productive management of ecosystems and landscapes. Before recommending specific management strategies, it is necessary to understand the ecology and temporal interactions between habitats (Keller 1989, Whittaker & Knight 1998).

Among the Asian avifauna, 12 % (324) are Globally Threatened, including one Extinct, 41 Critically Endangered, 66 Endangered and 217 Vulnerable (BildLife International 2001). An additional 317 are Near Threatened, close to qualifying as Globally Threatened species. According to BildLife International (2001) about 25 % (664) of the Asian avifauna, are of the global conservation concern.

In the Indian subcontinent, of the 1295 species of birds recorded, 81 % are land birds (Inskipp *et al.* 1996). Of those in India, 75 species are Globally Threatened, two Data Deficient, one Conservation Dependant and 52 Near Threatened (BirdLife International 2001). Coming to Western Ghats, there are 507 species of birds, of which 144 are aquatic including those found also in the coastal habitats (Daniels 1997, Daniels *et al.* 1992). 16

bird species are endemic to the Western Ghats (Ali & Ripley 1987, Stattersfield *et al.* 1998), of which four are Threatened (BirdLife International 2001) which include one Endangered (Nilgiri Laughing Thrush) three Vulnerable (Nilgiri Wood Pigeon, White-bellied Shortwing, Broad-tailed Grassbird) and four Near Threatened (Nilgiri Pipit, Grey-breasted Laughing Thrush, Black-and-Orange Flycatcher, and Nilgiri Flycatcher). Besides these, four Threatened (Spot-billed Pelican, White-backed Vulture, Lesser Adjutant, Kasmir Flycatcher) and three Near Threatened species (Grey-headed Fishing Eagle, Malabar Pied Hornbill, Great Hornbill) occur in this region. Nilgiri Pipit and Nilgiri Flycatcher, considered as Near Threatened by BirdLife International have been included under Vulnerable by Islam and Rahmani (2004).

The ever increasing anthropogenic pressures on the tropical forests have been depicted by Prabhakar and Gadgil (1994) on a landscape scale in the Nilgiri Biosphere Reserve. Studies in the Kerala part of the Western Ghats indicated the decline in forest cover, especially the evergreen forests (Prasad 1998, Prasad *et al.* 1998a, b). A general evaluation on the impacts of disturbances on the bird communities shows that the status of many endemics cannot be assessed without conducting detailed studies on individual species (Vijayan *et al.* 1999). Under varying conditions, the generalist species are capable of adapting to the changes to a certain extent, while the specialists are unable to do so and hence, may migrate or gradually disappear.

Conservation of the species requires a comprehensive picture on the status and distribution, ecological requirements for feeding, breeding and other activities. Ecological studies on most of the endemics have not yet been conducted and hence, such information is not available for any management programmes. Moreover, human impacts on the habitats of most species are also not understood. Hence, the present study was conducted on an endemic, endangered species of the Western Ghats which is considered as Globally Threatened, the Nilgiri Wood Pigeon *Columba elphinstonii,* addressing mainly its biological and ecological requirements.

1.2. Literature Review

Basic biology of many species of birds was studied in various parts of the world (Lack 1966, 1968, Cockrem 1995, Gwinner 1996, Hahn *et al.* 1997) and the breeding seasons were recorded in detail (Lack 1968, Gwinner 1996, Murton & Westwood 1977). The reproductive effort is considered to be related to resource variability and, reproductive output to environmental stability (Cody 1971). Various environmental factors affecting breeding seasonality have been investigated and found that the factors related to climate such as temperature and rainfall do play a vital role (Sharp 2006). Photoperiods play a major role in the temperate region where it is more pronounced (Gwinner 1996, Gwinner, & Scheuerlein 1998). Importance in the abundance food such as insects (Martin 1986, 1987, 1992) and fruits (Caterall *et al.* 1982) has already been reported. In certain cases, insect was not a limiting factor (Rotenberry 1980, Rosenberg *et al.* 1982), but formed part of the habitat suitability (Alatalo 1981), showing the importance of habitat for the survival of the species (Cody 1985). Predation on eggs and nestlings in passerines and the factors affecting them are reported by Thiollay (1988). The nest defense by parents with the risks and rewards as a survival strategy is reviewed by Montgomerie and Weatherhead (1988). Alatalo *et al.* (1988) reported the impact of time allocation of the sexes on the survival rate of the young. Mate choice and various related aspects have been worked out in several species of birds (Bateson 1983).

Although basic information on the breeding, feeding and habitats of most species of birds in India are available (Baker 1934, Ali & Ripley 1987), detailed ecology is known only for about 60 species. The following are a few to mention: Baya (Ali & Ambedkar 1957, Mathew 1976), Jungle Babbler (Gaston 1978 a, b, Andrews & Naik 1966, 1970), Vultures (Grubh 1974), Indian Peafowl (Trivedi & Johnsingh 1996, Veeramani & Sathyanarayana 1999.), Bulbuls (Vijayan 1975, 1980), Black-and-orange Flycatcher (Khan 1977, 1978 a, b), House Sparrow (Mathew 1986, Naik & Mistry 1980), Drongos (Vijayan 1984, 1986, Shukkur & Joseph 1980), Barbets (Yahya 1980, 1989), Laughing Thrushes (Islam 1985), Ring Dove (Rana 1975, Alagarajan 1991), Crow-Pheasant (Natarajan 1991), Great Pied Hornbill (Kannan 1994), Norcondam Hornbill (Hussain 1984), Malabar Grey Hornbill (Mudappa 2000, Maheswaran 2002), Great, Wreathed and

Oriental Pied Hornbills (Datta & Rawat 2003), Spotted Munia (Gokula 2001a), White-browed Fantail (Gokula 2001b), Bay-backed Shrike (Gokula 2001c), Paradise Flycatcher (Gokula & Vijayan 2003), Nicobar Megapode (Sivakumar 2000), Purple Sunbird (Kumar *et al.* 1999a), and Woodpeckers (Santharam 1995). Breeding seasonality and breeding requirements of birds in various regions are discussed by Gaston and Vijayan (1986), Price and Jamdar (1990) and Sundaramoorthy (1991).

Study on the ecology of frugivorous birds was restricted mainly to Hornbills (Hussain 1984, Kannan 1994, Mudappa 2000, Maheswaran 2002, Datta & Rawat 2003), Bulbuls (Vijayan 1975) and Barbets (Yahya 1989). In the case of Pigeons, studies are scanty in Indian subcontinent, except the occasional notes of Rana (1975) and Alagarajan (1991) on the Ring Dove and, Kumar and Ramachandran (1990), Javed and Yahya (1991) and Nirmala (2002) on the Laughing Dove.

1.3. Endemic birds of the Western Ghats

Species which have restricted distributional ranges have more chances of becoming endangered or extinct (Lee *et al.* 2005). Such endemics are mostly forest dwellers. Although there are 16 endemic birds in the Western Ghats, detailed ecology of only three species, namely the Black-and-Orange Flycatcher (Khan 1977, 1978), Grey-breasted Laughing Thrush, and Nilgiri Laughing Thrush (Islam 1985) have been documented. It may be noted that the last two species were not studied in detail. Apart from these, Vijayan and Gokula (2000) have estimated the population of the Nilgiri Laughing Thrush in the Upper Nilgiris. Habitat utilization and breeding biology of the Malabar Grey Hornbill were reported by Mudappa (2000) and Maheswaran (2002). Breeding biology of the Blue-winged (Malabar) Parakeet was recorded by Gokula and Venkatraman (2003). Status and habitat preference of the White bellied Shortwing in Kerala and Tamil Nadu part of the Western Ghats were studied by Robin and Sukumar (2002). Non-breeding ecology of the Nilgiri Flycatcher was documented by Ranjini (2003), while it's breeding by Somasundaram and Vijayan (*commu*). However, the remaining endemics, especially those rare and facing threats, are not studied (BirdLife International 2001).

The Nilgiri Wood Pigeon *Columba elphinstonii* was recorded as one of the rare species of the world by Mountfort (1988). However, it was categorized as Near Threatened by Collar *et al.* (1994) and Stattersfield *et al.* (1998). An account of it in the Red Data Book of the Birds of Asia (BirdLife International 2001) shows that in spite of its wider distribution, the sightings are very few in the recent times and the threats are high because of hunting pressure and, destruction, degradation and disturbance of the evergreen forests (Prasad 1998, Prasad *et al* 1998a, b, Vijayan *et al.* 1999, BirdLife International 2001). There were only some occasional sightings of the Nilgiri Wood Pigeon (BirdLife International 2001). Zacharias and Gaston (1999) conducted a survey in the Kerala part of Western Ghats focusing mainly on the endemic, disjunct and globally uncommon birds and, reported that Nilgiri Wood Pigeon was uncommon in most of the places.

It may be noted that the pigeons and doves are declining the world over, due to habitat loss and hunting pressure (Crome 1975a, b, Rivera - Millan 1990, Wiley & Wiley 1979, Recher & Date 1988, Date *et al.* 1996). To determine the factors that contribute to the continued decline of a species, it is imperative to understand as much ecology of the species as possible (Cousin 2004). Moreover, habitat quality is very vital for the conservation of endemics, particularly for the endangered species (Raman 2001b, Vijayan & Gokula 2000). Since there was no detailed information on the status, ecology and behaviour of the Nilgiri Wood Pigeon, the present study was undertaken with the following specific objectives.

1.4. Objectives

1. Determine the current status of the Endemic and Threatened Nilgiri Wood Pigeon in the Western Ghats
2. Document the ecology of the Nilgiri Wood Pigeon and,
3. Identify the key factors affecting their survival.

Chapter 2

Study area and study species

2.1. Western Ghats

The Western Ghats is almost an unbroken chain of hills running parallel along the west coast of the Indian Peninsula for almost 1,600 km from near Kanyakumari (8° N) at the southern end to the River Tapti in the north (21° N). The long chain of hills is interrupted by the 30 km wide Palghat Gap at around 11° N, and a few other small gaps along its length. This unique biogeographic province (Mani 1974, Rodgers & Panwar 1988) has pronounced north-south, east-west elevation gradients, which have profound consequences on the distribution of plants and animals. The major soil types found in the Western Ghats are red soil, laterite, black and humid (Subramanyan & Nayar 1974, Nair & Daniel 1986). The Western Ghats is further divided into Northern Western Ghats (Surat to Goa), Central Western Ghats (Goa to Nilgiris) and Southern Western Ghats (south of the Palghat Gap); (Fig. 2.1).

2.2. Climate

The climate of the Western Ghats varies depending on the altitudes and slopes. The western slopes of the Ghats are subject to direct influence of rain-bearing winds of the south-west monsoon. They receive 2,000 to 7,500 mm of rainfall. The temperature gradient is related mostly to increase in altitude. However, it is not uniform throughout the Ghats because of the variability in relief from south to north. In general, the mean temperature of the coldest month varies from 23°C at sea level to 12°C at 2300 m (Pascal 1988, Daniels 1992).

2.3. Biodiversity richness

Four major forests and 23 floristic types have been distinguished in the Western Ghats, based on the ecological factors and floristic composition, (Champion & Seth 1968). These types are closely correlated with the temperature and rainfall regimes.

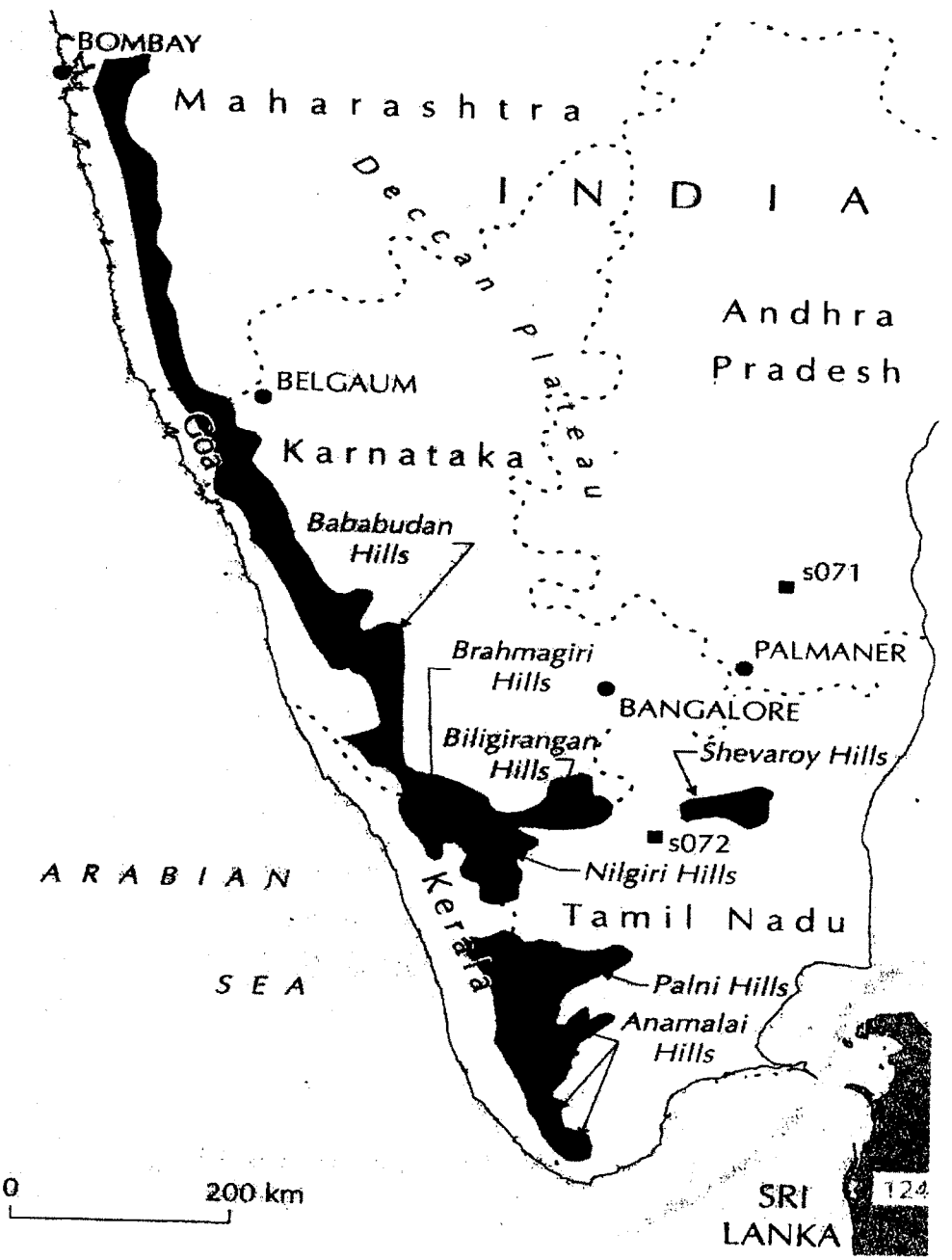


Figure 2.1 Study areas of the Nilgiri Wood Pigeon - Western Ghats (Stattersfield *et al.* 1998)

2.4. Vegetation types

The vegetation of the Western Ghats is classified into seven major types, namely 1). montane wet temperate grasslands, 2) montane wet temperate (shola) forests, 3) tropical wet evergreen forests, 4) tropical semi-evergreen forests, 5) tropical moist deciduous forests, 6) dry deciduous forests, and 7) scrub forests (Champion & Seth 1968). Of these, shola forests, tropical wet evergreen and tropical semi-evergreen forests are the key habitats of the Nilgiri Wood Pigeon.

2.5. Floral diversity

A compilation of the flora of the Western Ghats shows that it has 4000 species of flowering plants, around 320 Pteridophytes, 200 Bryophytes, 300 Algae and 800 Lichens (Daniels 2002). Apart from these, 600 species of fungi were also reported (Pascal 1988). 56 genera of flowering plants are considered endemic to the Western Ghats. The validity of endemism at generic and higher taxonomic levels is however subject to systematic revisions. It is interesting to note that nearly 38 % of all species of flowering plants in the Western Ghats are endemic. Further, 63 % of India's evergreen woody plants are endemic to the Western Ghats. Nearly 650 species of plants in the Western Ghats are trees (Nair & Daniel 1986).

2.6. Faunal diversity

A review of the literature on the fauna of the Western Ghats has reported 5626 species/subspecies, out of which 439 are endemic. Information on the invertebrates of the Western Ghats is confined mainly to insects with about 4056 species, out of the 4623 invertebrates recorded. Diptera, Lepidoptera and Hymenoptera are represented more in the known list with 1800, 710, and 492 species respectively (Lakshminarayana et al. 2002). Kumar *et al.* (1999b) reported 330 species of butterflies, including 37 endemics.

Among the 209 species of freshwater fishes, and the 133 species of amphibians known from the Western Ghats, 120 species of the former and 106 species of the latter are endemic (Lakshminarayana *et al.* 2002).

The reptile fauna of the Western Ghats consists of 163 species, of which 89 are endemic to the area. Snakes constitute more than 50% of them, and endemism is especially high in the

family Uropeltidae with 33 species. Turtles and tortoises are represented by one species each and the lizards and snakes 36 and 51 species respectively (Lakshminarayana et al. 2002) A species of crocodile *Crocodylus palustris* also is reported from the Western Ghats (Kumar *et al.* 1999b).

The Western Ghats has around 508 species of birds out of which 144 are aquatic including those which are found in the coastal habitats (Daniels 1997). 16 species have been considered endemic and restricted to the Western Ghats (Ali & Ripley 1987).

Mammals in the Western Ghats are represented by 125 species, including 11 insectivores, 41 bats, and 27 rodents (including the porcupine) (Kumar *et al.* 1999b).14 species are endemic to the Western Ghats.

2.7. Conservation issues

The Western Ghats is recognized as one of the eight 'hottest hot spots' of biological diversity in the world (Myers *et al.* 2000) and among the 200 globally most important ecoregions (Olson & Dinerstein 1998). Among the global biodiversity hotspots, the Western Ghats and Sri Lanka rank third in terms of the number of endemic vertebrates/unit area (species/100 km^2, Myers *et al.* 2000). The region has also been recognized as an Endemic Bird Area with 16 species of restricted-range birds of the world, and eight Threatened and seven Near Threatened species (Stattersfield *et al.* 1998, BirdLife International 2001). Loss of forest cover in the Western Ghats during the last two decades is 25.6 %, and Menon and Bawa (1997) estimated that between 1920 and 1990 forest cover declined by 40 %, resulting in a four-fold increase in the number of fragments and, 83 % reduction in the size of forest patches. In the Kerala part of the Western Ghats, loss of forest cover was estimated at 0.28 % per year amounting to 47 % of reduction in the evergreen forest during 30 years (Prasad 1998). This is not surprising given that this region is one of the hotspots with the highest human population density (Cincotta *et al.* 2000). It is also reported that there has been a loss of 50 % of shola forest since 1850 (Sukumar *et al.* 1995, Robin & Sukumar 2002). Such changes threaten the flora and fauna at both species as well as community level.

2.8. Intensive Study Area

Systematic survey to estimate the status of the Nilgiri Wood Pigeon was conducted from Goa (15° 25' N; 74° 07' E) to Tirunelveli (08° 23' N; 77° 35'); more intensively in the semi-evergreen, evergreen and montane shola forests and grasslands of the Nilgiris, Palni, and Anamalai hills. Subsequently, a good population of the Nilgiri Wood Pigeon was observed at Kukkal in the Upper Palni Hills where intensive study was conducted from April 2002 to June 2004.

2.8.1. Upper Palni Hills – Kukkal

The Palni Hills (10°1' N to 10°26' N; 77°14' E to 77°52' E) got their English name from the town Palani, which lies just north of them, the native appellation of which is Varahagiri or Boar Hills (Anon 1908). Palni Hills come under Dindigul District with the revenue taluks of Palani, Kodaikanal and Bathalakundu. The north and east of Palni Hills are bounded by Dindigul district, west by Periyakualm taluk of Theni District, and the north-east by Udumalpet taluk of Coimbatore District. While all these are all in Tamil Nadu, the south-west of Palni Hills is bounded by Iddukki District of Kerala. Kodaikanal is a sanitarium in the Upper Palni Hills. There are about 2.25 lakhs people living in the Upper Palni Hills (www.tamilnadu/ dindigul/maps.com).

The Palni Hills are the south-eastern offshoot of the Western Ghats in Tamil Nadu, with altitude ranging from 300 m to nearly 2600 m above msl. (Sustainable Development Programme 1992). It is one of the highly fragmented and populated areas in the Western Ghats. It covers 12600.48 km², out of which 2130.04 km² is forest with different types of vegetation, namely evergreen, semi-evergreen, moist deciduous, dry-deciduous, dry evergreen, shola forests and grasslands. Dry deciduous forest (816.92 km^2) covers the maximum and, shola (6.58 km^2) the minimum (Amarnath *et al.* 2003). The Palni Hills is in the catchments of the rivers, namely Kodaganaru, Palar, Kuthiraiyar, Porandalar, Varadhamanathi, Manjalar and Aruthanathi, which drain into two major rivers; Vaigai and Cauveri. Nine dams were constructed in these rivers mainly for irrigation and drinking water for Dindigul, Madurai and Theni districts (Table 2.1). The Palni Hills consists of two well-marked topographic divisions, namely Upper Palnis and Lower Palnis with the elevation

ranging between 1500-2450 m and 300 -1500 m respectively. The Lower Palnis consists of slopes with (c.1683 sq. km) more tropical moist vegetation.

Table 2.1 Vegetative cover in the Palni Hills

Vegetation type	Area in Km^2
Evergreen	285.86
Semi-evergreen	110.48
Moist deciduous	626.89
Dry deciduous	816.92
Shola	6.58
Grassland	283.30
Total Area	2130.04

Source: Amarnath *et al.* 2003.

The Upper Palnis is an undulating plateau known as Kodaikanal plateau, which stretches from the outskirts of Kodaikanal town to the Kerala state on the west. It includes the eastern slopes of the Western Ghats running southwards. The highest peak, Vandaravu in the Upper Palnis occurs near the Tamil Nadu - Kerala border (2554 m msl). The Upper Palni plateau, extending to 385 sq km with an average altitude of 2200 m, consists of undulating slopes of grasslands (16627 ha) interspersed with forests, locally called Sholas (2337 ha), with subtropical or temperate vegetation. It comprises three valleys, namely Parrappar-Devanakarai Valley with the Perumal peak 2205 m, Gundar Valley with Observatory 2343 m, Karumankadu 2439 m in the east and, Vembadi with Vembadi peak 2506 m and Upper Amaravathi Valley with Vandaravu peak 2506 m in the west. On the north of the Kodaikanal plateau, two great valleys pierce the hills and penetrate southwards as far as the Vilpatti and Poomparai. Of these, the Poomparai valley is the most striking with its parallel sides almost cut up with cultivation.

Intensive study on the Nilgiri Wood Pigeon was conducted in the largest shola, located at Kukkal in Poomparai Reserve Forest, Kodaikanal taluk (Figure 2.2). Seasonal studies were conducted in Pambar shola situated near Kodaikanal town. Kukkal is 35 km north-west of

Kodaikanal town while Pambar shola is near the Doordarsan Broadcasting Station at Kodaikanal town. Elevation of both the places is above 1850 m. These areas are now considered as Important Bird Areas in India (Islam & Rahmani 2004) and Asia (Chan *et al* 2004).

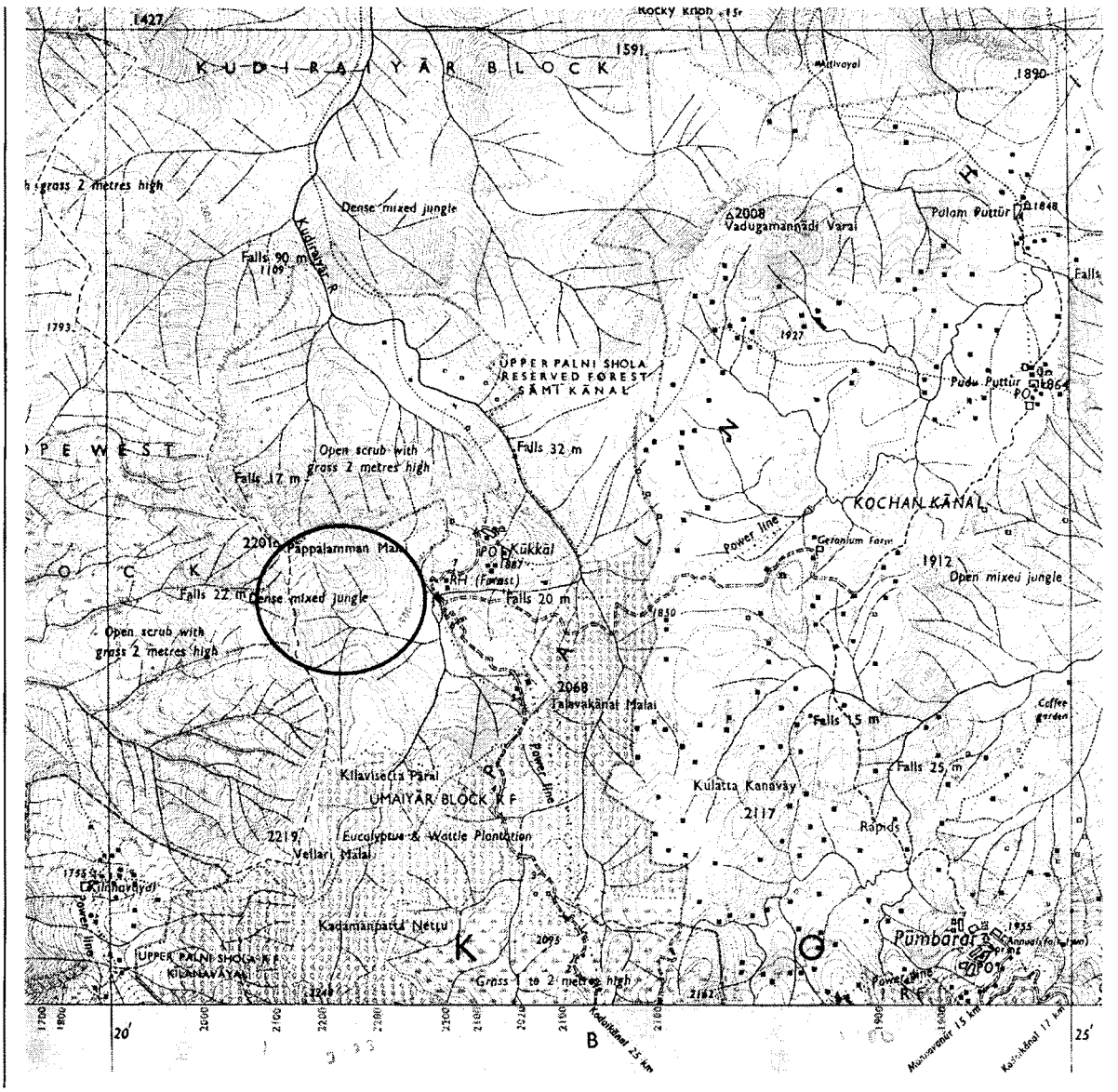


Figure 2.2 Palni Hills - showing study location: Kukkal shola

Plate 1 Habitat of the Nilgiri Wood Pigeon

Undisturbed shola & grasslands at Eravikulam

Kukkal shola

Disturbed shola & plantations

2.8.2. Conservation issues in the Palni Hills

The Palni Hills had a large area of evergreen forests but currently most of them are fragmented to smaller patches which might be due to the large number of orchards and commercial plantations and lack of protected areas (Amarnath *et al.* 2003).

Coupled with the destruction of forests and large scale introduction of commercial species, came the invasion of weeds such as *Ageratina adenophora* and *Lantana camera*. These have, irretrievably altered the floristic face of the Palni Hills. The primary vegetation now is confined to isolated pockets such as Kukkal (330 ha) and Mathikettan (100 ha) sholas both of which are listed as Nature Reserves. Wattle, Eucalyptus and Pine are the major plantations which alone accounted for 23,037 ha in 1986-87. Expansion of agriculture, requirements of local people for timber and fuel wood, and cattle grazing also made a telling effect on the natural vegetation.

It may be noted that the National Remote Sensing Agency, Hyderabad has reported a loss of 25 % of the forest cover in the Palni Hills between 1972 and1980. The impact of such a loss of forests on the watershed and biodiversity has already been reported by Mathew (1990).

Major problems specific to Kukkal are collection of fire wood and lichen, cattle grazing, and wood cutting while the major problem for Pambar is disposal of a large quantity of plastics as a result of the increased tourism.

2.8.3. Physical features

2.8.3.1. Climate

The Kodaikanal taluk (Kukkal) falls in the tropical zone, but it enjoys a sub-tropical to temperate climate.

2.8.3.2. Temperature

The minimum temperature of Kodaikkanal town varies between 8 °C and 13° C and the maximum between 17° C and 22° C. The average annual mean maximum and minimum

temperature for the last 10 years was 19°C and 8°C respectively. Monthly average of the maximum was (22.6°C) in March –April and the minimum (8.3°C) in December during the intensive study (Fig. 2.3).

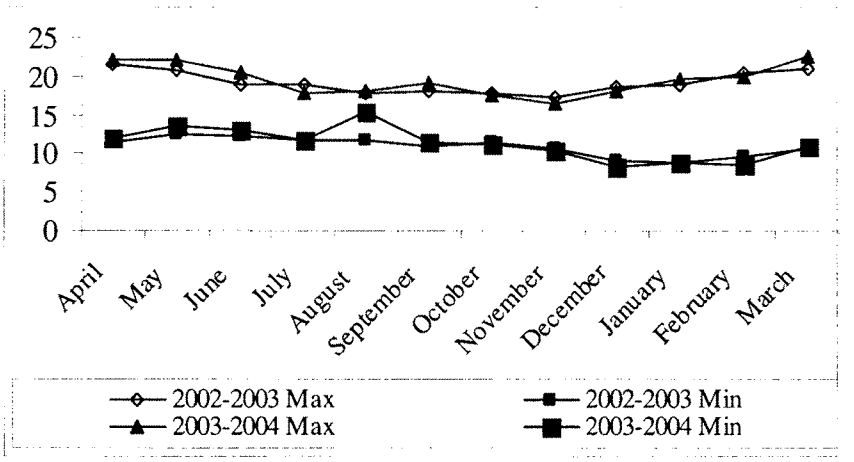


Figure 2.3 Monthly mean maximum-minimum temperature in the Palni Hills during April 2002 to March 2004.

2.8.3.3. Relative humidity

The mean humidity of the area was 77.5 % during 2002 – 2003 while it was slightly less (74 %) during 2003 – 2004. Annual average varied from 51 % to 89 % during 2002 -2003 while it was 49% to 89 % during 2003 -2004 (Fig. 2.4).

2.8.3.4. Rainfall

The Palni Hills receives both the south-west and north-east monsoons but the maximum rainfall was from the latter. The total rainfall was the highest in October (Fig 2.5), while the number of rainy days was the highest in September and October (Fig. 2.6). A minimum of 2.5.mm rain in a day is considered as rainy day. Winter (December – February) had comparatively less rain.

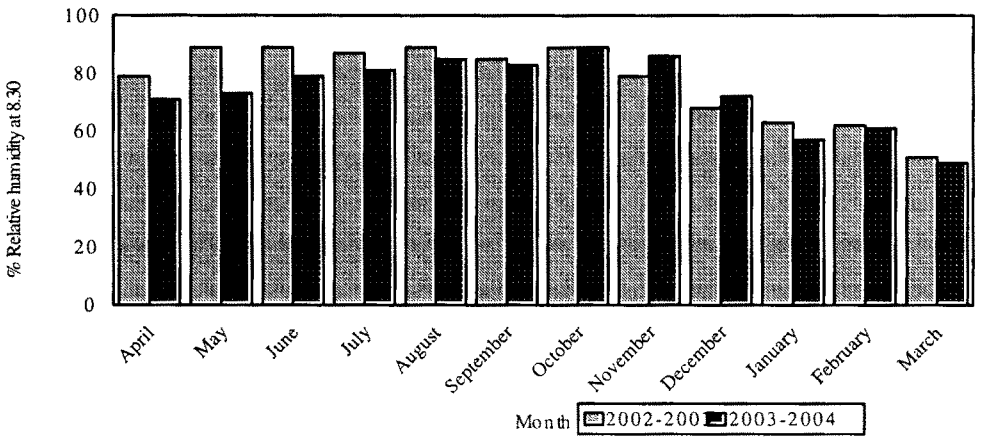


Figure 2.4 Mean monthly relative humidity at Kukkal from April 2002 to March 2004.

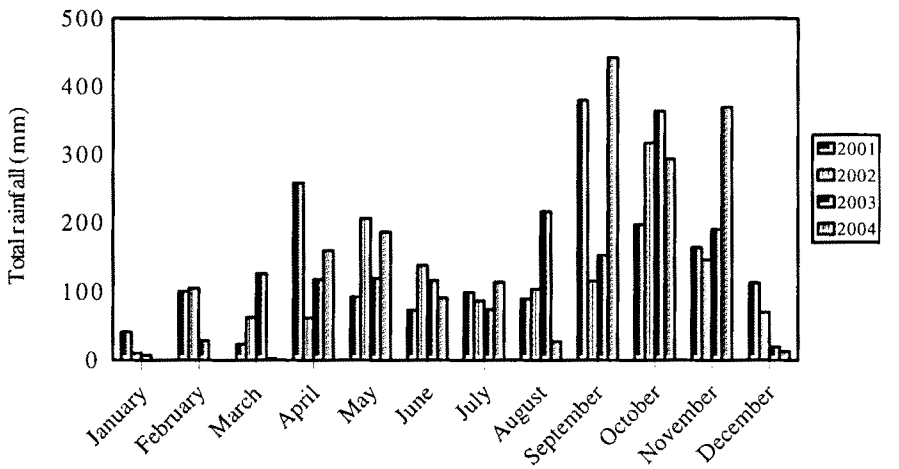


Figure 2.5 Variation in the monthly rainfall in the intensive study area

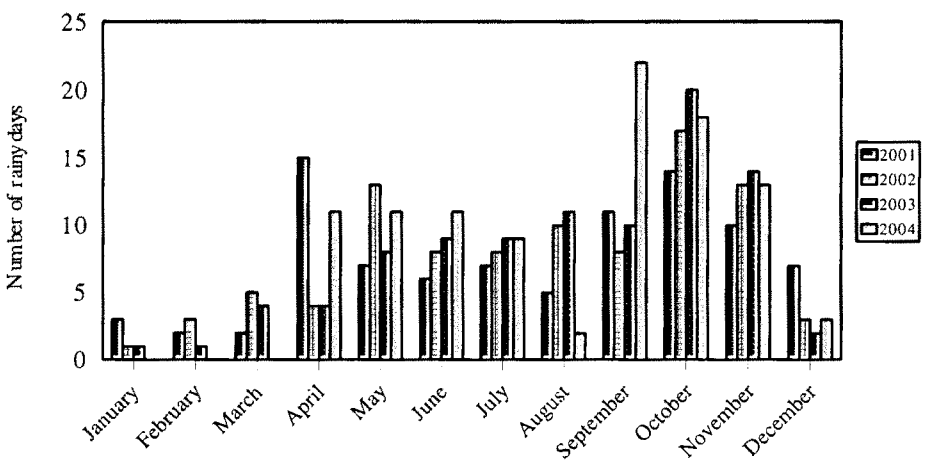


Figure 2.6 Number of rainy days in various months the intensive study area

2.8.3.5. Geomorphology and soil

The Western Ghats was formed in Archean age, represented by gneiss and granites. The Palni Hills consists of plutonic rocks. The rocks are entirely charnockites, bluish granite, through broad bands of feldspars and quartz cross the gneissic foliations. The out slopes of the hills were washed mainly by rain because of rarity of vegetation. The soil found in slopes is brown and loamy, and is rich in organic matter while it is clayey in the valley. The thickness of the topsoil varied from a few millimeters to 90 cm. The soil is rich in iron and aluminum oxides and the porous thickness was measured up to 1m (Amarnath *et al.* 2003).

2.8.4. Vegetation

The natural vegetation in the Kukkal area is the southern montane wet temperate forest, commonly known as "Shola". This specialized forest is distributed all over the rolling hills, especially in sheltered folds in the hills either at the head of the streams or on the converging slopes. These are usually confined to sites where there is good atmospheric moisture (Khan 1977, Nair *et al.* 2001). The Shola forests exhibit high bio-diversity. 75 species of Threatened plants (34 families) were recorded in the Palni Hills (Matthew 1996). A recent study shows 60 new species of plants and 82 species of orchids (Amarnath *et al.* 2003).

There are vast stretches of grasslands in the Palni Hills. However in many places exotics such as *Acacia*, *Eucalyptus* and *Pine* have been planted. Other exotic species such as *Cytisus, Ulex, Eupatorium*, and *Rubus* became naturalized in the areas especially along the roadside.

The importance of vegetation studies for a better understanding of bird ecology was highlighted by MacArthur and MacArthur (1961). The species of trees, their diversity, density, and the vegetation complexity, and resource exploitation pattern have a direct impact on the wildlife (Willson 1974, Maratha & Louis 1988, Bland 1998). A number of earlier studies have established correlation between vegetation and birds, mainly the frugivorous species (Corlett 1998). In India, Vijayan (1975), Balasubramaninan and Bole (1993), Ganesh (1996), Balasubramanian (1996), Kannan and James (1999), Mudappa (2000), Maheswaran (2002), Nirmala (2002), Jayson and Mathew (2003), and Datta and

Rawat (2003) focused on bird-plant interactions in different parts of the country. All these studies were conducted mainly on the low elevation evergreen and dry deciduous habitats, and hence, it may be for the first time that such an attempt was made in the high elevation montane forests of the Western Ghats.

2.8.4.1. Methods

Vegetation was studied in the shola forest of Kukkal, where the bird census was done. 12 plots of 30 × 30 m each were laid randomly in a 20 ha plot for the tree species. In each plot, name of the species and the number of individuals were recorded. 10 sub-plots of 10 x 10m each were laid for the shrubs. All the individuals with a GBH between 10 cm and 30 cm were considered as shrubs or tree saplings and, those above 30 cm as trees following Chandrashekara and Ramakrishnan (1994), and Aravind *et al.* (2005). A few prominent trees were marked for measuring height classes. 10 plots of 1 x 1m each were laid randomly inside the 30 x 30 m quadrats and the percentage cover of herbs was visually estimated.

The relative values of density, dominance and frequency were determined for each species. Density refers to the number of individuals per unit area, dominance to the basal area or crown cover per unit area, and frequency to the fraction of sample plots containing the species. Importance Value Index gives an idea of the sociological structure of a species in its totality in the community but does not indicate its position separately with regard to other aspects such as frequency and density. The data were analyzed using standard analytical and statistical methods with software packages (Excel, SPSS 10.5 and Vedas):

$$\text{Density per plot} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats examined}}$$

$$\text{Relative density} = \frac{\text{No. of individuals of a species in all quadrats}}{\text{No. of individuals of a species of all species in all quadrats}} \times 100$$

$$\text{Frequency (\%)} = \frac{\text{No. of quadrats in which the species occur}}{\text{Total number of quadrats examined}} \times 100$$

$$\text{Relative Frequency \%} = \frac{\text{No. of occurrences of a species}}{\text{No. of occurrences of all species}} \times 100$$

Importance Value Index (IVI) = Relative density + relative dominance + relative frequency

Species Diversity was calculated using Shannan – Wiener (1949) index

$$H' = - \sum pi \log_e pi$$

Where

pi = ni/N

ni = number of individuals of the i^{th} species and

N = total number of individuals of all the species in that sample area

greater the value of H', greater the diversity

2.8.4.2. Results

Plant community was studied in 1.08 ha of montane wet temperate (shola) forest. 97 species of plants were identified, out of which 63 were trees, 19 shrubs, and 15 stragglers (Appendix I). 18 tree species were endemic, of which *Beilschmiedia wightii* (74 trees / ha) was the most dominant followed by *Rhododendron nilagiricum* (67 / ha). Among shrubs, *Psychotria nilgiriensis* (208 / ha), followed by *Ardisia rhomboidea* (35 / ha) were the dominant endemics.

Vegetation profile of montane wet temperate forest was dominated by trees with 2.5 to 7.5 m height (Fig. 2.7). The dominant trees were *Phoebe paniculata, Symplocos foliosa, Neolitsea zeylanica,* and *Maesa indica.* The dominant shrub species were *Psychotria nilgiriensis var. astephana,* and *Lasianthus acuminatus.* The dominant stragglers (lianas) were *Ventilago bomaniensis, Piper mullesua,* and *Ampelocissus araneosa.*

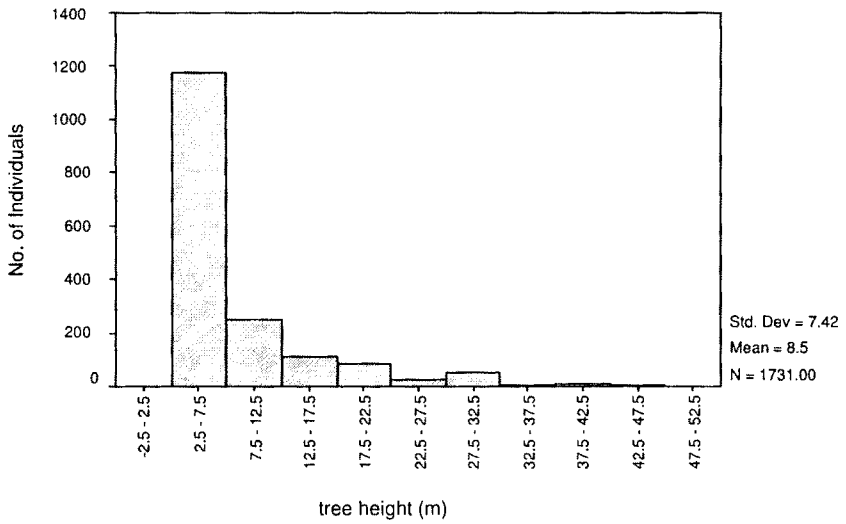


Figure 2.7 Distribution of trees with varying height classes at Kukkal

Species richness and diversity (H') were more in trees than in shrubs and lianas. In all, 1734 trees of 63 species, 402 shrubs of 19 species and 143 lianas of 15 species were recorded in the sampled area (Table 2.2.). Edges of the shola and openings inside were covered mainly by *Maesa indica.*

Table. 2.2. Species richness, diversity and equitability of plants at Kukkal

Growth forms	Species richness	Diversity	Equitability
Tree	63	3.15	0.76
Shrub	19	1.31	0.44
Liana	15	2.14	0.79

2.8.5. Fauna

2.8.5.1. Insects

Insects are the predominant diet of most tropical birds and their importance in the ecology of some of the birds was reported earlier (Vijayan 1975, 1984, Khan 1978, Islam 1985, Nirmala 2002). Islam (1985) and Thomas *et al.* (1995) studied the insect community of the

Palni Hills, the former as a part of the Laughing Thrush ecology and the latter focusing on the altitudinal gradient of insect diversity.

Standard methods such as sweeping, beating and visual count in 1 km transect and ground quadrats were adopted following Southwood (1978).

Eight insects orders were recorded during the study; Lepidoptera, Diptera, Orthoptera, Dictyoptera, Isoptera, Hymenoptera, Hemiptera and Coleoptera. The Lepidopterans were predominant (55.2 %) followed by Coleopterans (13.8 %) and Dipterans (10.3 %) (Fig. 2.8). Arachnids were also seen in all the months. The list of Lepidoptera (butterflies) with their status in the intensive study area is given in appendix 2.

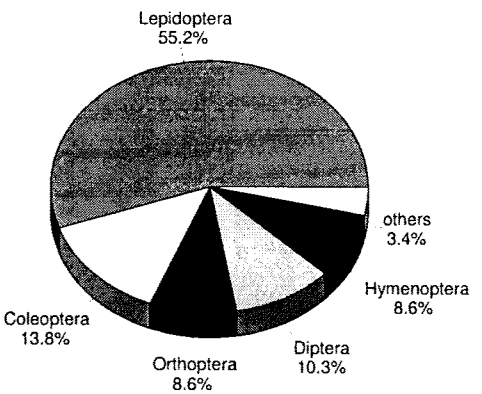


Figure 2.8 Comparative abundance of major insect groups in the study area

2.8.5.2. Molluscs

Ground invertebrates were estimated using quadrat method. Ten quadrats of 1 x 1m each were examined every month. Ground invertebrates were abundant during the south-west monsoon. Snails were observed in all the months, but were more abundant during the monsoons (Fig. 2.9). Coleopteran grubs and earthworms were found mainly during the south-west monsoon.

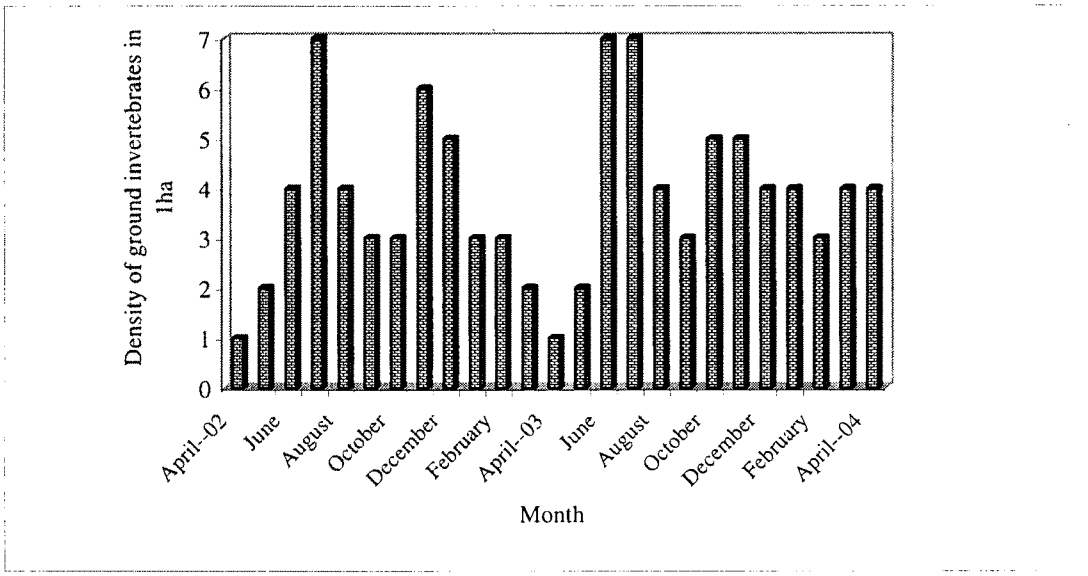


Figure 2.9 Monthly variations in the abundance of ground invertebrates in Kukkal.

2.8.5.3. Herpetofauna

No especial effort was taken to record the herpetofauna of the study area. However *Buffo malanostictus* and tree frogs were sighted. Among the reptiles, Uropeltids and *Salea anamallayana* were frequently seen. Bamboo Pit Viper, Rat Snake and a few other species were also sighted (but could not be identified).

2.8.5.4. Birds

The montane wet temperate forests have high endemism and many habitat specialists (Vijayan & Gokula 2000). Species richness and abundance were more in these forests than in the grasslands and plantations in the Nilgiris (Vijayan & Gokula. 2006). The Black-and–Orange Flycatcher *Ficedula nigrorufa*, Nilgiri Flycatcher *Eumyias albicaudata*, Grey-breasted Laughing thrush *Garrulax jerdoni*, White-bellied Shortwing *Brachypteryx major* and Nilgiri Wood Pigeon *Columba elphinstonii* are endemics in the high altitude montane wet temperate forests in the southern Western Ghats, while Crimson-backed Sunbird *Nectarinia minima* another endemic occur in both high and mid elevation forests (Somasundaram & Vijayan. *2004*). Important studies on the birds of Palni Hills are by Islam (1985), Shahabuddin (1997), Balachandaran (1999), Somasundaram and Vijayan (2004), and Balachandaran and Rahmani (2005).

2.8.5.4.1. Methods

Bird population was estimated by using Variable width circular – plot method (Ralph & Scott 1981, Bibby *et al* .1992). Stations were not closer than 100 m to the next station. Census began half an hour after sunrise when the bird activity was at the peak (Buckland *et al.* 1993). The duration of census in each plot was ten minutes. Careful scanning for birds was carried out while approaching and leaving the point to spot any undetected birds and theses birds were separately noted. All the birds seen, heard, or flying under the canopy were recorded (Buckland *et al.* 1993, Raman 2001a).

Species diversity (H') was calculated by using Shannon - Weiner index (1949) as given earlier in the chapter.

2.8.5.4.2. Results

Ninety six species of birds were recorded during the two years of study, which include seven winter and three local migrants, and six birds of prey (Appendix 3). Pied Thrush and Orange-headed Ground Thrush were recorded only once. Of the seven endemic bird species recorded, the Crimson-backed Sunbird was observed only during the non-breeding season, (June to August). 29 species of breeding birds were observed in the intensive study area (Appendix 3). The highest species diversity (3.29) was in December-January and lowest (2.42) in June-July (Fig.2.10). Six species of frugivores occur in the study area. Among the Columbids, Nilgiri Wood Pigeon, Spotted Dove, and Emerald Dove were seen. Black Bulbul, White-cheeked Barbet, and Eurasian Black Bird were the major species sharing the food resources with the Nilgiri Wood Pigeon (details in Chapter 4).

2.8.5.6. Mammals

No systematic study was done on the mammalian fauna of Kukkal. However, the rare species recorded in the course of study were Nilgiri Tahr, Nilgiri Langur, Nilgiri Marten and Leopard.

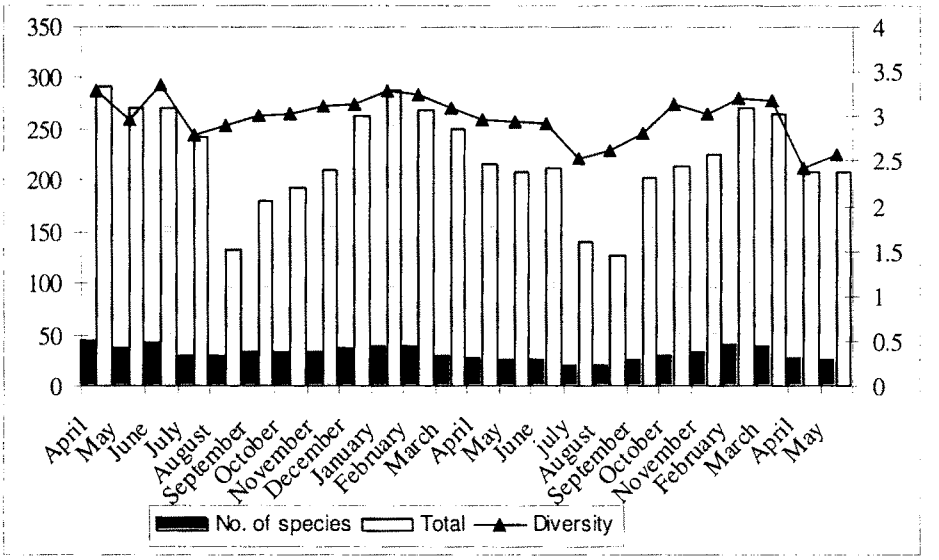


Figure 2.10 Details of the bird community in the intensive study area during 2002 to 2004

2.9. Study species: Nilgiri Wood Pigeon *Columba elphinstonii*

Nilgiri Wood Pigeon belongs to the Family Columbidae (Order: Columbiformes) which has 316 species. The smaller species are commonly known as doves, but generally the size of pigeons and doves overlap. The pigeons and doves are the only extant family within the Order Columbiformes. Recent DNA studies have shown that Columbids have no close living relatives. The Columbids occur throughout the world with exception of extreme climatic conditions.

Pigeons have small heads, short necks, stout bodies with short legs, sleek plumage and, have a fleshy or waxy protuberance at the base of the bill. They reside in trees or on the ground and feed on seeds, fruit, nuts and insects. Pigeons are noted for their cooing call. They build loose, almost flat nests made of twigs, bark, straw, and weeds; the female lays one or two tan or white eggs (Gibbs *et al.* 2001).

Pigeons vary enormously in size, from the sparrow-sized Ground Doves of the Americas and Fruit Dove of New Guinea to the huge terrestrial fowl-like Goura Crowned Pigeons, also of New Guinea. Plumage colour pattern also displays a great deal of variety from dull

uniform brown to different bright colours. Some of the tropical pigeons are amongst the most colourful of all the birds (Goodwin 1983).

All the pigeons are predominantly granivorous or frugivorous, although leaves, flowers and buds are often eaten by some and occasionally by many species (Oliveira *et al.* 2002). Some are known to eat invertebrates such as worms, small snails and insect larvae, during breeding (Ali & Ripley 1987). Although a great number of Columbids are associated with forest, woodland and other tree dominated environments, a few species have successfully exploited many habitats including sea-cliffs, the high altitudes of Himalayas near the snowlines and open treeless semi-deserts of Central Australia (Gibbs *et al.* 2001).

The success of the family in occupying much of the globe and often being very abundant is perhaps surprising, as the pigeons are much sought-after by many predators, including humans, and lack many defensive mechanism, except remain unobserved or escape by swift flight. Many species are able to cope with heavy predation during their breeding. Pigeons invest very little effort for nest building and usually construct a flimsy platform which often looks like no more than a natural accumulation of twigs on a horizontal branch. If the egg is preyed upon, a new nest can be constructed within a few days. Pigeons have not evolved cryptically coloured eggs (Goodwin 1983). They normally lay one or two conspicuous whitish eggs, which can often be seen below through the nest, so they rely on tight sitting and a relatively short incubation period to hatch their young before being discovered (Ali & Ripley 1987). The young are born helpless but the small number of the young ones in the nest allows them to grow rapidly on crop-milk, a protein rich secretion that help avoid the need for supplementing the diet with invertebrates. The fledglings are barely half the size of the adult. At this stage, they fledge which may help to reduce their period of vulnerability (Goodwin 1983).

The family Columbidae are divided into five sub-families: Columbinae (typical seed eating pigeons: 187 species); Otidiphabinae (Pheasant Pigeon: 1 species); Treroninae (fruit doves: 124 species), Gourinae (crowned pigeons: 3 species), Didunculinae (Tooth-billed Pigeon: 1 species). The 316 species of pigeons and doves are divided into 42 genera (Gibbs *et al.*

Plate 2 Nilgiri Wood Pigeon *Columba elphinstonii*

Photo by S. Somasundaram

Photo by P.K. Uthaman

2001). 61 species of Columbids are Threatened and 34 Near-Threatened and 11 have already become extinct in the world (BirdLife International 2001). The Passenger Pigeon (Martha), once common throughout the United States, became extinct since 1914. In Asia, two species, namely Silvery Wood-Pigeon *Columba argentin* and Negros Fruit Dove *Ptilinopus arcanus* disappeared in the last decade. Both of them were frugivores and forest dwellers.

Columba is the largest genus of the family Columbidae with 54 species having the widest distribution. It is a very diverse taxa, but typically plumaged in soft greys and browns often with white markings especially on the head and neck. It has iridescent greens and purples on the neck and breast (Goodwin 1983). Members of Columba are strong fliers, often gregarious, arboreal frugivores or semi-terrestrial granivores, and their sexual dimorphism is relatively slight or moderate.

Today, about a third of all pigeons known are, to a greater or lesser degree, in danger of extinction in the absence of efforts to conserve them. Additionally, many distinctive races not listed by Collar *et al.* (1994) are equally endangered. Of the large bird families in the world, few contain such a high proportion of endangered species (Gibbs *et al.* 2001).

In India, 29 species of Columbids are found, of which three are listed as Threatened. In the Western Ghats, 12 species are reported, of which one, the Nilgiri Wood Pigeon *Columba elphinstonii,* is endemic and also Threatened (Ali & Ripley 1987, BirdLife International 2001).

The Nilgiri Wood Pigeon is a large bodied frugivorus forest bird found in the evergreen and southern montane wet temperate (shola) forests in the Western Ghats. It has grey head with a conspicuous black-and-white "chessboard" of white tipped feathers on the hindneck. Its body is reddish brown with a glistening metallic green above and below, with white chin and throat and milk grey in the remaining portion (Plate 2). Bill is black and the legs are pinkish. Both the sexes are alike (Ali & Ripley 1987, Grimett *et al.* 1998). Juveniles have poorly developed "chessboard" on the hind neck. The Nilgiri Wood Pigeon is separated

from other species either by the un-banded tail or by the uniform grey under parts lacking chestnut on undertail-coverts (Ali & Ripley 1987). The Green Imperial Pigeon, Mountain Imperial Pigeon and Spotted Dove are Columbids with almost similar appearance found along with the Nilgiri Wood Pigeon.

Chapter 3

Status, distribution and habitat use of the Nilgiri Wood Pigeon

3.1. Introduction

The distribution and abundance of birds is one of the central themes of research in avian biology (MacArthur 1972, Cody 1985). For any bird species, habitat varies in quality from place to place; that is in the benefits in terms of survival and reproduction that it confers on its occupants (Newton 1988). Habitat use, in particular, has drawn the attention of researchers because of its relevance to conservation management (Martin & Finch 1995, Sherry & Holmes 1996, Kilgo *et al.* 2002, Kwit *et al.* 2004). Habitat loss has been identified as one of the main factors affecting the survival of the 1025 Globally Threatened bird species (Collar & Andrew 1988, Collar *et al.* 1994), especially those dwelling forest and island (Robinet *et al.* 2003). Among the 61 species of Threatened Columbids, 31 are frugivores (BirdLife International 2001) believed to prefer specific plants.

The Nilgiri Wood Pigeon is one of the 16 bird species endemic to the Western Ghats and is also Globally Threatened (Ali & Ripley 1987, Stattersfield *et al.* 1998). It is restricted to the moist evergreen biotope at an altitude of 500 to 2450 m above msl, from Anamalai Hills to Maharashtra (Baker1934, Ali & Ripley 1968–1998, Zacharias & Gaston 1999). The present survey was conducted to: a) determine the status of the Nilgiri Wood Pigeon in its known range, b) assess their status in relation to altitude and forest type and, c) evaluate the impact of disturbance on the species.

3.2. Method

Standard method, namely variable width line transects method (Bibby *et al.* 1992) has been adopted to assess the abundance. Also, unpublished reports on the sightings were gathered from bird-watchers and experts. Habitat quality was assessed with respect to different grades of disturbance in the areas surveyed.

The location of the species recorded earlier and the other probable locations were marked on maps. Existing roads and footpaths in evergreen and shola forests were used as transects. Presence of the Nilgiri Wood Pigeon was recorded based on direct sightings and calls in the area.

Population of the Nilgiri Wood Pigeon at Kukkal was monitored from April 2002 to April 2004. Point count method was used to estimate the general bird community in the intensive study area. The frequency of sighting or calling of the Nilgiri Wood Pigeon was noted and tabulated separately for each month.

3.3. Data analysis

The data were analysed in the following ways:

1. Encounter rate of the Nilgiri Wood Pigeon in different habitats.
   Encounter rate = Number of birds sighted / Area surveyed
2. Relationship between elevation and encounter rate by using Correlation.
3. Spearman Rank Correlation test for food availability and number of the Nilgiri Wood Pigeon observed.
4. Mann-Whitney Ų test for comparing nests site characters between the Nilgiri Wood Pigeon and Mountain Imperial Pigeon.
5. Relationship between environmental factors and number of the Nilgiri Wood Pigeon by Stepwise Regression and Correlation.
6. Impact of habitat alteration was determined by using Hills equation.

3.4. Results

3.4.1. Earlier sightings of the Nilgiri Wood Pigeon

Locality records of the Nilgiri Wood Pigeon were marked on a map based on published information (Fig 3.1). The sightings were classified (BirdLife International 2001) into three categories, namely historical (before 1950), recent past (1950 -1979) and recent (1980 – 2004).

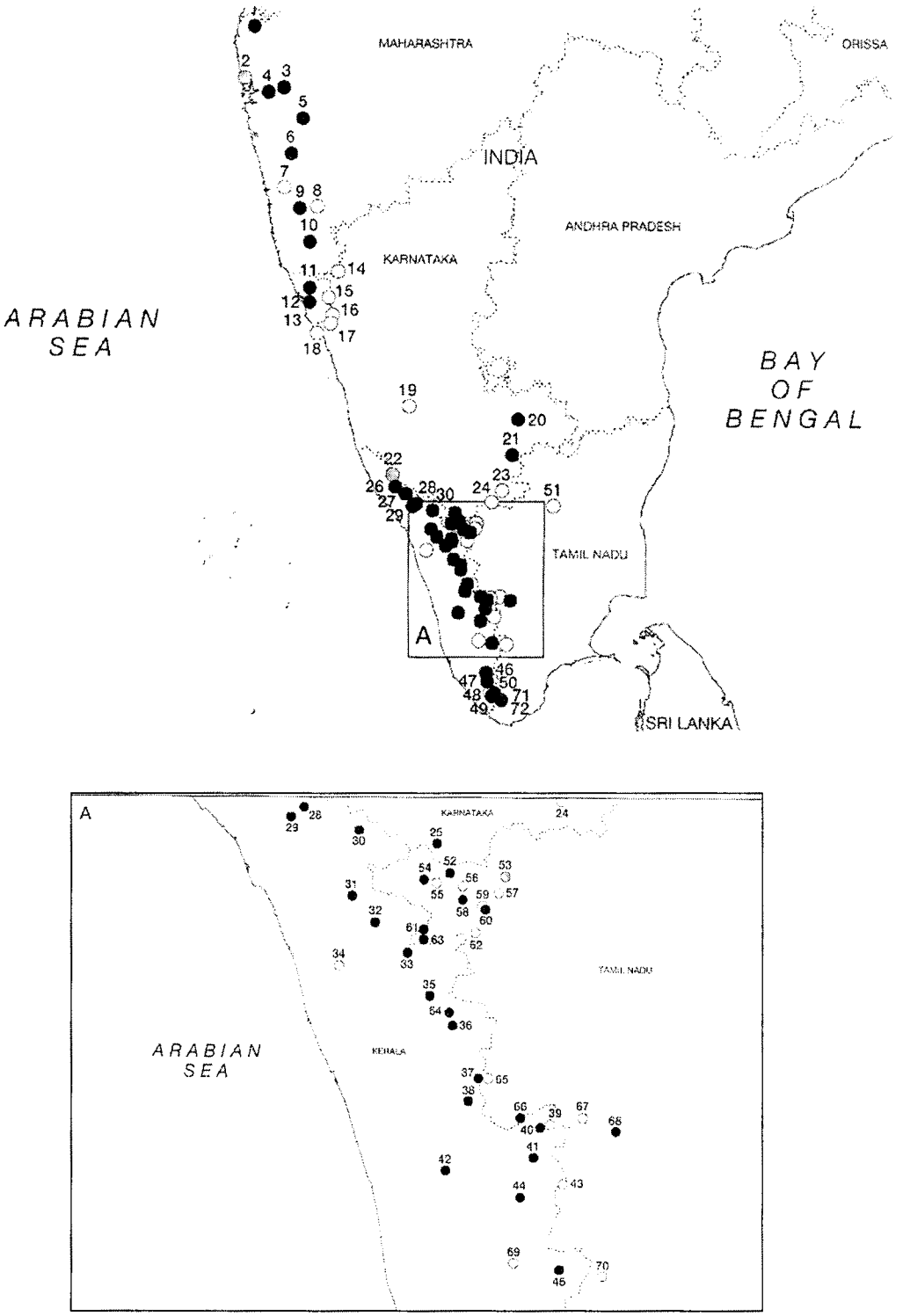


Figure 3.1 Records of the Nilgiri Wood Pigeon at various locations in the Western Ghats (BirdLife International 2001)

The Nilgiri Wood Pigeon was reported at 72 locations out of which the highest was (25 locations) in Kerala and lowest (3 locations) in Goa (Table 3.1.). In Tamil Nadu, they were at 20 locations.

Table 3.1 Records of the Nilgiri Wood Pigeon in various states

S. No.	State	Location	Reference
1	Maharashtra	Amboli	BLI 2001
2	Maharashtra	Borivli National Park	BLI 2001
3	Maharashtra	Bhimashankar	BLI 2001
4	Maharashtra	Matheran	BLI 2001
5	Maharashtra	Pune	BLI 2001
6	Maharashtra	Mahabaleshwar	BLI 2001
7	Maharashtra	Durga Vadi	BLI 2001
8	Maharashtra	Satara	BLI 2001
9	Maharashtra	Chandoli	BLI 2001
10	Maharashtra	Radhanagari	BLI 2001
11	Goa	Bondla Wildlife Sanctuary	BLI 2001, Santharam 2003
12	Goa	Bhagwan Mahavir National Park	BLI 2001
13	Goa	Canacona	BLI 2001
14	Karnataka	Belgaum	BLI 2001
15	Karnataka	Castle Rock	BLI 2001
16	Karnataka	Kumbharwada	BLI 2001
17	Karnataka	Anshi	BLI 2001
18	Karnataka	Karwar	BLI 2001
19	Karnataka	Kemmanugundi	BLI 2001, Thejaswi 2004
20	Karnataka	Nandi hills	BLI 2001
21	Karnataka	Bannerghatta National Park	BLI 2001
22	Karnataka	Brahmagiri	BLI 2001
23	Karnataka	Devarbetta hill	BLI 2001

24	Karnataka	Bellaji	BLI 2001
25	Karnataka	Bandipur National Park	BLI 2001
26	Kerala	Konnakad	BLI 2001
27	Kerala	Thirunelli	BLI 2001
28	Kerala	Aralam Wildlife Sanctuary	BLI 2001
29	Kerala	Periya ghats	BLI 2001
30	Kerala	Wynaad district	BLI 2001
31	Kerala	Wynaad ghats	BLI 2001
32	Kerala	Nilambur	BLI 2001
33	Kerala	Silent Valley National Park	BLI 2001
34	Kerala	Malappuram	BLI 2001
35	Kerala	Dhoni	BLI 2001
36	Kerala	Palghat	BLI 2001
37	Kerala	Nelliampathy hills	BLI 2001
38	Kerala	Parambikulam Wildlife Sanctuary	BLI 2001
39	Kerala	Maraiyur	BLI 2001
40	Kerala	Eravikulam National Park	BLI 2001
41	Kerala	Munnar	BLI 2001
42	Kerala	Thattakkad Bird Sanctuary	BLI 2001
43	Kerala	Santhanpara	BLI 2001
44	Kerala	Idukki Wildlife Sanctuary	BLI 2001
45	Kerala	Periyar Sanctuary	BLI 2001
46	Kerala	Tenmalai	BLI 2001
47	Kerala	Shendurney Wildlife Sanctuary	BLI 2001
48	Kerala	Mynall	BLI 2001
49	Kerala	Agastiamalai	BLI 2001
50	Kerala	Peppara Wildlife Sanctuary	BLI 2001
51	Kerala	Shevaroy hills	BLI 2001
52	Tamil Nadu	Mudumalai Wildlife Sanctuary	BLI 2001

53	Tamil Nadu	Kodanad	BLI 2001
54	Tamil Nadu	Gudalur	BLI 2001
55	Tamil Nadu	Naduvattam	BLI 2001
56	Tamil Nadu	Kalhatti	BLI 2001
57	Tamil Nadu	Kotagiri	BLI 2001
58	Tamil Nadu	Udagamandalam	BLI 2001
59	Tamil Nadu	Wellington	BLI 2001
60	Tamil Nadu	Coonoor	BLI 2001
61	Tamil Nadu	Avalanche	BLI 2001
62	Tamil Nadu	Kundah river	BLI 2001
63	Tamil Nadu	Upper Bhavani	BLI 2001
64	Tamil Nadu	Siruvani hills	BLI 2001
65	Tamil Nadu	Grass hills	BLI 2001
66	Tamil Nadu	Anaimalai hills	BLI 2001
67	Tamil Nadu	Kukkal	BLI 2001
68	Tamil Nadu	Kodaikanal	BLI 2001
69	Tamil Nadu	Pirmed	BLI 2001
70	Tamil Nadu	High Wavy mountains	BLI 2001
71	Tamil Nadu	Muthukuzhi	BLI 2001
72	Tamil Nadu	Ashambu hills	BLI 2001

3.4.2. Records from the present survey

Nineteen locations in four states were surveyed, out of which the Nilgiri Wood Pigeon was recorded at 13 locations (Table 3. 2). The highest bird density was in Kukkal (2.8) and nil in Goa, Belgaum and Chinnar.

Table 3.2 Status of the Nilgiri Wood Pigeon at the sites surveyed.

State	Locality	Season of survey	Altitude	Forest type	Density/ 1 ha
Goa	Catigao WS	Non breeding	200	Evergreen + Moist deciduous	0
	Bondla WS	Non breeding	350	Moist deciduous	0
	Bhagwan Mahavir NP	Non breeding	350	Evergreen + Moist deciduous	0
	Canacona	Non breeding	400	Moist deciduous	0
Karnataka	Belgaum	Non breeding	300	Moist deciduous	
	Castle Rock	Non breeding	700	Evergreen	0.1
Kerala	Munnar	Non breeding	2000	Shola	0.67
	Mannavan shola	Non breeding	1750	Shola	1.1
	Eravikulam NP	Non breeding	2000	Shola	0.5
	Mathikettan shola	Non breeding	1000	Evergreen	0.02
	Chinnar WS	Non breeding	700	Moist deciduous	0
	Silent Valley NP	Non breeding, breeding	1000	Evergreen	2.2
	Siruvani	Breeding	900	Evergreen	0.2
Tamil Nadu	Upper Bhavani	Breeding	2200	Shola	0.1
	Mukurthi NP	Breeding	2200	Shola	0.1
	Thai Shola	Breeding	2100	Shola	2.5
	Korakundha	Breeding	2200	Shola	0.02
	Upper Palnis	Breeding	2000	Shola	2.8
	Lower Palnis	Breeding	1200	Evergreen	0.1

3.4.3. Habitat - wise distribution

Different types of habitats were surveyed concentrating on the evergreen, shola and moist deciduous forests. The encounter rate was calculated habitat - wise. The shola forest had the maximum encounters (2.77 birds/ 10 ha) followed by evergreen forest (0.88 bird/10 ha) and plantation (0.07 birds/ 10ha) (Table3.3.). The Nilgiri Wood Pigeon was not sighted in the moist deciduous forests during this survey.

Table 3.3 Distribution of the Nilgiri Wood Pigeon in various habitats of the Western Ghats.

Habitat type	No. of area surveyed	No. of sightings	Density/ 10ha
Shola	166	46	2.77
Evergreen	158.5	14	0.88
Moist deciduous	178.5	0	0.00
Plantation	297.5	2	0.07

3.4.4. Altitude-wise distribution

The Nilgiri Wood Pigeon was sighted at different elevations confirming the earlier records. However, in the recent survey it was recorded in the evergreen forests only above 650 m elevation. Most of the records were at an elevation from 1000 m to 2200 m (Table 3.4). Sighting frequency increased with altitude and the correlation between their occurrence and altitude was statistically significant (R^2 =0.13, $p < 0.05$). The maximum sighting was at an elevation from 2000 to 2250 m (Fig. 3.2.).

3.4.5. Status of the Nilgiri Wood Pigeon in the Silent Valley National Park

In all, 20 ha evergreen forest in different locations, including Sirendhry, Kunthipuzha, Punnamala, Arugampara, Kattumudi, Poochapara, Chempatty, Neelikal, Walakad and Sispara in Silent Valley National park was selected for assessing the status of the Nilgiri Wood Pigeon. Highest density (0.7 birds/ ha; Fig 3.3) was at Walakad and there were no birds at Arugampara and Poochapara. Their density varies also with the season; the highest in the heavy monsoon (1.2 birds / ha) and the lowest in summer (0.2 birds/ ha; Fig.3.4).

Table 3.4 Distribution of the Nilgiri Wood Pigeon in different altitudes

Altitude (m)	No. of area surveyed (ha)	No. of sightings	Density/ 10 ha
0-500	135	0	0.00
500-750	30	1	0.33
750-1000	70	13	1.86
1000-1250	94	1	0.11
1250-1500	0	0	0.00
1500-1750	30	3	1.00
1750-2000	438	33	0.75
2000-2250	48	10	2.08

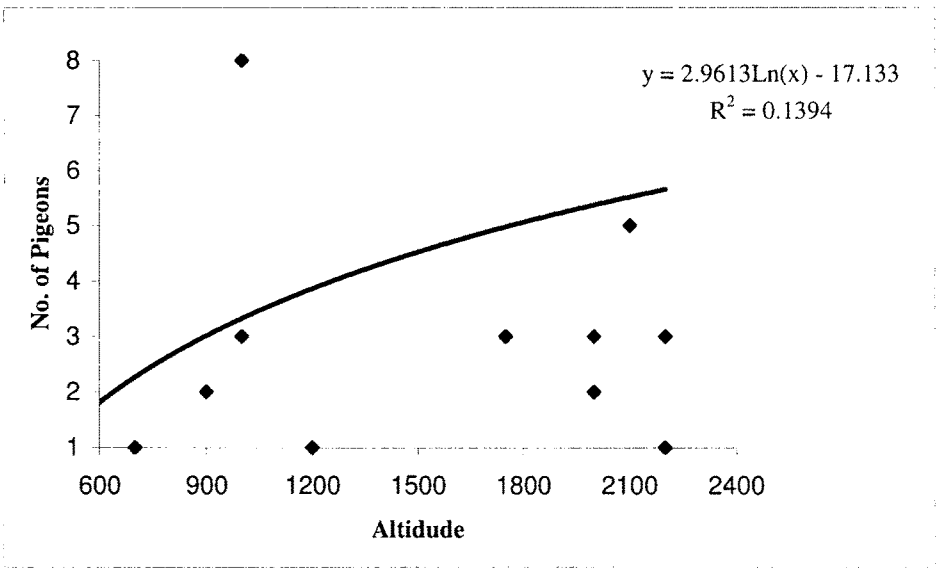


Figure 3.2 Relation between sightings of the Nilgiri Wood Pigeon and altitude.

3.4.6. Population of the Nilgiri Wood Pigeon at Kukkal, Upper Palni Hills

Regular observations of the Nilgiri Wood Pigeon at Kukkal in the Upper Palni Hills showed a definite trend of increase in its population during January to June (Fig. 3.5), coinciding with its breeding season. The maximum population was in May 2004 and minimum in September 2002.

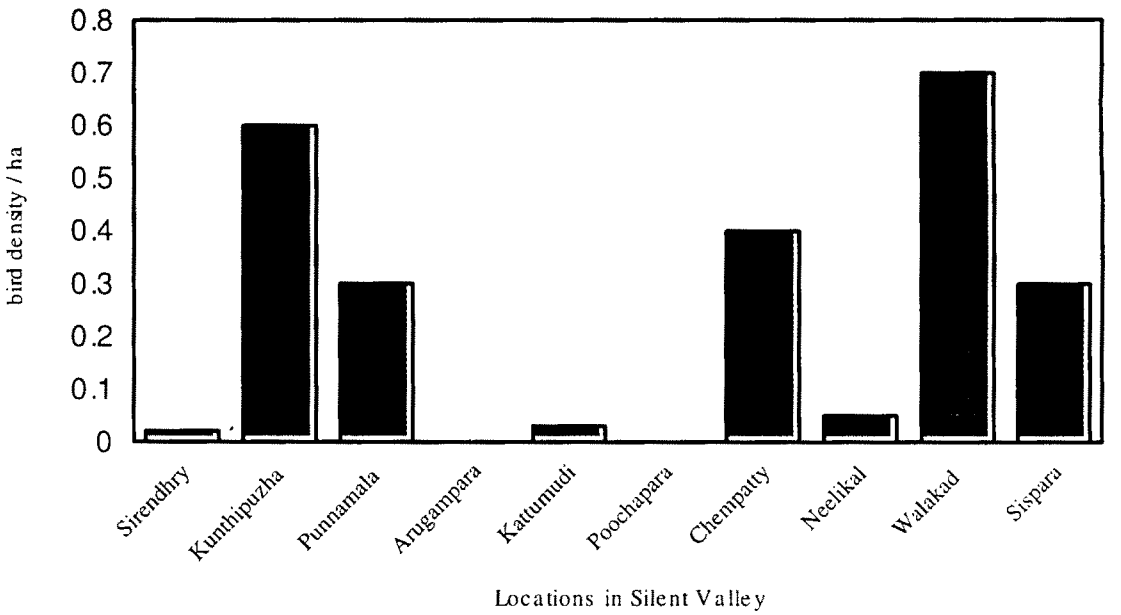


Figure 3.3 Sighting frequencies of the Nilgiri Wood Pigeon at various locations in the Silent Valley National Park.

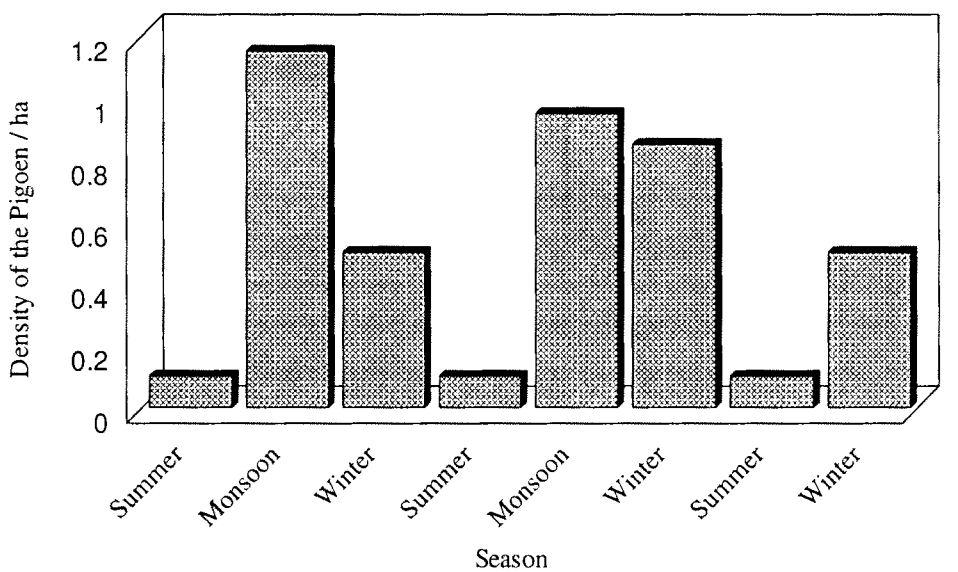


Figure 3.4 Sighting frequencies of the Nilgiri Wood Pigeon during different seasons in the Silent Valley National Park.

Various abiotic and biotic factors such as food availability, temperature, humidity, rainfall and duration of bright sunlight hour appear to be affecting the population of the Nilgiri

Wood Pigeon. Its density in the area had a significant positive correlation with abundance of fruits (Spearman Rank Correlation; $F = 5.78$, $p < 0.05$) (details on phenology in Chapter 4). Among the environmental factors, maximum temperature and duration of sunlight had positive linear relationship with the density of the Nilgiri Wood Pigeon (Fig. 3.6; Fig. 3.7.). Step-wise regression analysis also showed that duration of sunlight ($t = 3.04$, $p<0.05$) and temperature ($t = 2.61$; $p< 0.05$) were the significant factors.

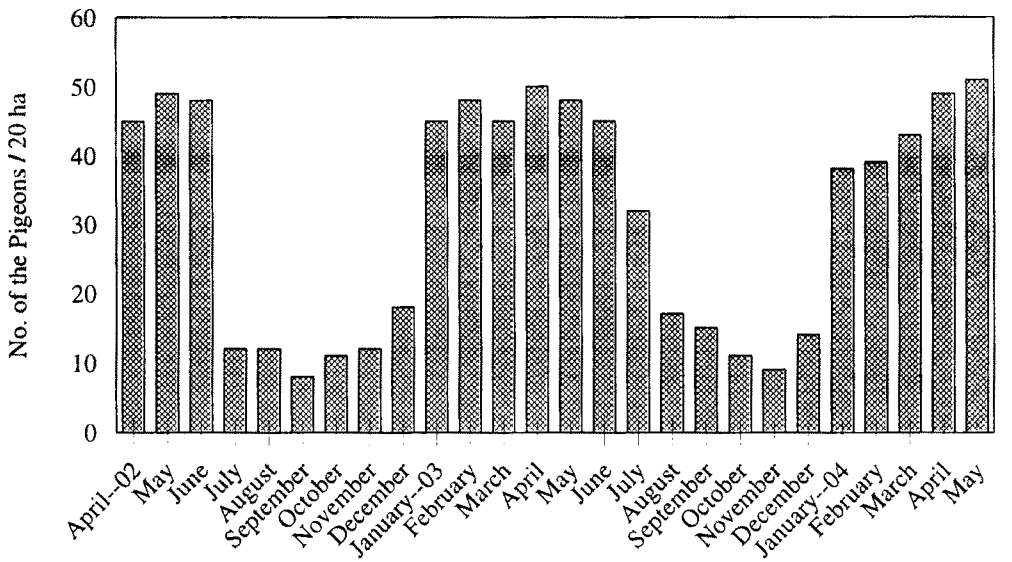


Figure 3.5 Population of the Nilgiri Wood Pigeon in the intensive study area.

It may be noted that the fluctuation of the population of the Nilgiri Wood Pigeon in Kukkal and Silent Valley appears to be related to the breeding season. They breed during spring – summer (January – June) and avoid it by the onset of heavy monsoon; October in Kukkal and June in Silent Valley. And, they breed mainly in the shola forests and not in the evergreen forests. This explains the increase in population in Silent Valley (evergreen forests) during heavy monsoon (June – December); the non breeding season for the area. The birds would have moved into the area after breeding in shola forests. In Kukkal (shola forests), there is a decrease in the population from July to December, after the major breeding season. It may be noted that the peak monsoon in Silent Valley is in June while in Kukkal it is October. The former gets both the south-west and north-east monsoons, while

the latter mainly the north-east. It also shows that there is a regular movement of the Nilgiri Wood Pigeon from evergreen forests to shola forests for breeding. In the evergreen forests also they breed, but only rarely. One of the other possible reasons for the low breeding in and the movement from the evergreen forests is the competition with the co-existing species, the Mountain Imperial Pigeon for nest sites. Comparison of nest site characters of the two species shows similar nesting requirements in the evergreen forests ($Z = -1.6$; $p = 0.1$).

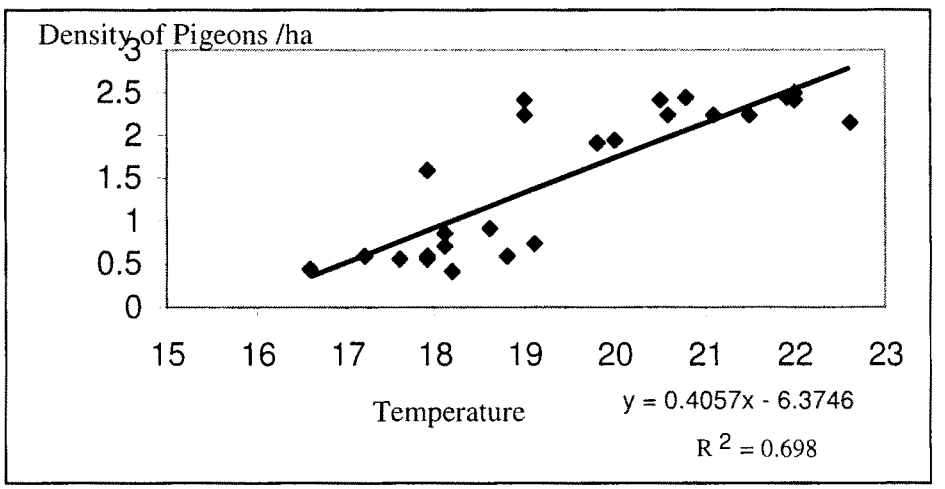


Figure 3.6 Relationship between density of the Nilgiri Wood Pigeon and monthly mean maximum temperature at Kukkal

3.4.7. Habitat use of the Nilgiri Wood Pigeon at Kukkal

The Nilgiri Wood Pigeon was monitored in both natural and modified habitats. 10 ha plots were selected in each modified habitats, namely Wattle, Pine, and Eucalyptus and, the census was conducted fortnightly in every month throughout the study period. Among the plantations, the Nilgiri Wood Pigeon was sighted more in wattle than in eucalyptus and pine. Most such sightings were in plantations nearer to shola forests (Fig. 3.8). No nests were observed in any plantation during the two-year study. The pair loss in plantations was estimated by using Hill equation comparing with natural shola forest and it showed that maximum pair loss was in pine (100) followed by eucalyptus (97 %) and wattle (92%).

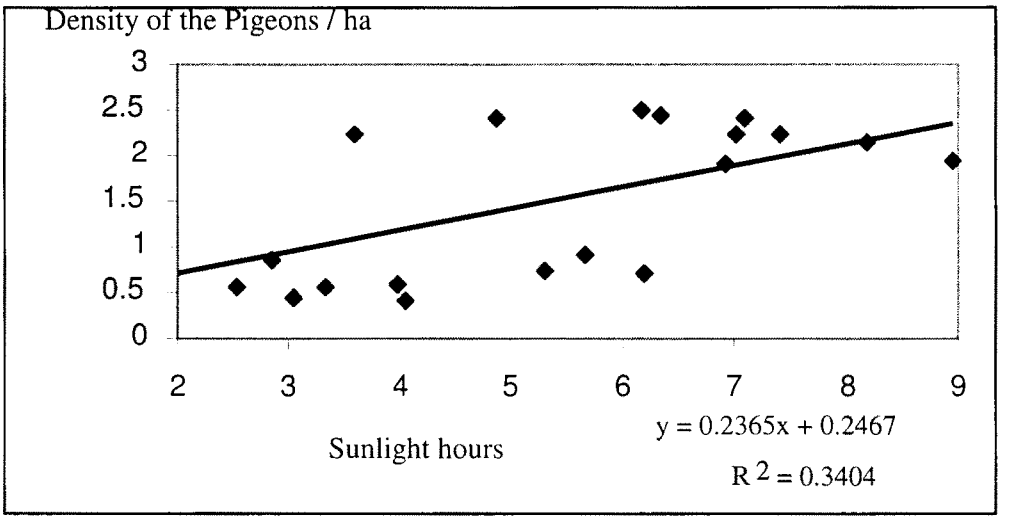


Figure 3.7 Relationship between the density of the Nilgiri Wood Pigeon and the duration of mean bright sunlight hours at Kukkal

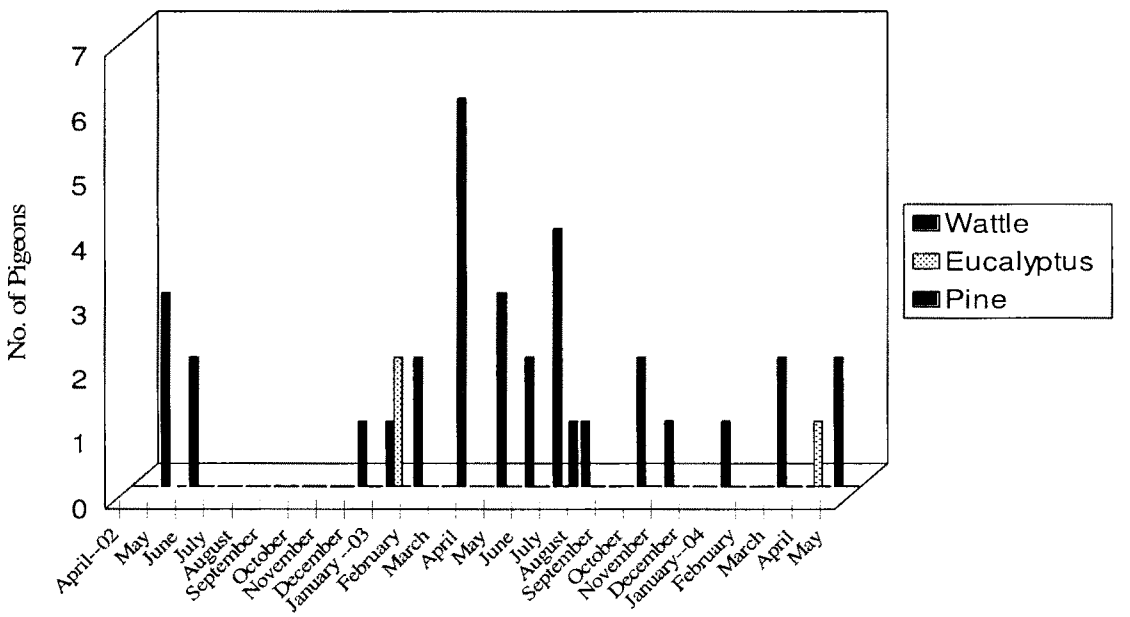


Figure 3.8 Frequency of sightings of the Nilgiri Wood Pigeon in plantations

3.5. Discussion

The Nilgiri Wood Pigeon has been recorded throughout the Western Ghats (Ali & Ripley 1987) but its distribution in the northern Western Ghats showed most of them as historical records with only one or two recent sightings (BirdLife International 2001). One of the reasons for the same is the increased human pressure and rapid conversion of natural forests. Also, the forests in the region are at lower elevation.

The Nilgiri Wood Pigeon has been frequently sighted in various protected areas of Goa, but not any during my survey conducted between December – January. However, during November to March 1999 they were recorded in Goa specifically at Dudh Sagar, Colem-Madgaum railway, Tamdi Surla (Holt 1999). However, in the present survey conducted during the same period in the same localities could not yield any.

In Karnataka, historical records show their sightings at Belgaum and Castle Rock, but during the present survey only one bird was recorded in Castle Rock. Most of the forest areas are degraded in the Belgaum area.

In Kerala, most of the sightings of the Nilgiri Wood Pigeon were confined to mid-elevation moist forests. The population was at low density in most areas, and at high density only in a few patches of evergreen or semi-evergreen forests as observed by Prasad *et al.* (1998a, b). In the Silent Valley National Park, it was reported as uncommon during 1973-1997 (Zacharias and Gaston 1999). However, during the present survey in winter (December) at least one bird was sighted or heard at every 300 m. In the same area, it may be noted that (April) only 0.2 birds per 10 ha was observed during the breeding season. It is interesting that during the same period, 2.25 birds per 10 ha were recorded in the shola forest. This indicates a clear local movement of this species between the shola and evergreen forests as mentioned earlier. Nests in the lower altitudes in the Silent Valley National Park were still sparse. Muthikulam reserve forest was surveyed in February and only two birds were recorded. In Munnar area, most of the natural habitats were converted into tea plantation. A few remnant shola patches among the estates and a few large patches in the Sevanmalai

support the Nilgiri Wood Pigeon. In Eravikulam National Park, a few larger shola patches had this pigeon singly or in pairs.

The Nilgiri Wood Pigeon was recorded at a wide altitudinal range from 50 m to above 2000 m (Ali & Ripley 1987). It was seen in large numbers in the lower and middle altitudes during the non breeding season and in shola forests during the breeding season. However, size of the shola patches also might play an important role in the density of this species as seen in the Upper Nilgiris. Various other factors such as availability of food (Fairbank 1877, Davison 1883, Baker & Inglis 1930, Whistler & Kinnear 1931–1937, Primrose 1939, Lainer 1999), nest site and climatic condition (Ali & Ripley 1987) determine the movement pattern of pigeons. In the intensive study area, the number of the Nilgiri Wood Pigeon had significant correlation with food availability (refer chapter iv). The maximum temperature and the duration of bright sunlight hours influenced not only the phenological pattern of fruiting trees but also the movement of birds and their breeding.

The habitat-wise distribution of the Nilgiri Wood Pigeon showed that it breeds in the high altitude sholas and moves to the low and mid elevation evergreen forests during non-breeding season. The results corroborate the findings of Williams (1937), Prasad *et al.* (1998a) and Vijayan *et al.* (1999).

The encounter rate of the Nilgiri Wood Pigeon was high in the shola forest in the present study as well as in the historical records of Sykes (1832) and Blyth (1845). There were no sightings in moist deciduous forest except those reported by Goodwin (1983). Subramanya *et al.* (1994) reported the occurrence of this species in Coffee plantation. It was recorded in eucalyptus plantations only in the Nilgiris, but it was absent in tea and acacia plantations (Khan 1980). Ali and Whistler (1942–1943), Ali and Ripley (1987) reported that its favourite habitat was cardamom plantation and tall shade trees. In the present study, it was not recorded in the cardamom and pine plantations.

In Kukkal, the intensive study area, the population of the Nilgiri Wood Pigeon showed a seasonal pattern, similar to the pattern observed in the Nilgiris (Primrose 1939). The Nilgiri

Wood Pigeon was considered as a resident bird by Hume (1876). However, various authors listed it as an "erratic visitor, possibly resident" (Davison 1883 Fairbank 1877, Lainer 1999). Primrose (1939) reported that in the Nilgiris, a few pairs are residents and breed in suitable Sholas in the vicinity, but the remainders leave these parts in November. Thus it could be inferred that availability of suitable habitats and climatic condition and, availability of or competition for nest-site could be the limiting factors influencing the population and movement pattern of the Nilgiri Wood Pigeon.

More detailed study using colour marking or telemetry, is required to asses the specific movement pattern and the reason for the same. However, the present study clearly shows the movement pattern of the species and that site-based conservation management strategies are essential for its long-term conservation. Moreover, adequate number of sites should be protected for the Nilgiri Wood Pigeon to cover its entire range of movement following the seasonal patterns of fruiting and for its successful breeding.

3.6. Summary

Status and Distribution of the Nilgiri Wood Pigeon were studied in various parts of the Western Ghats and the habitat use at Kukkal in the Upper Palni Hills from April 2002 to April 2004. Summary and salient findings are:

- Surveys were conducted in Silent Valley, Siruvani, Munnar, Eravikulam National Park, and Chinnar Wildlife Sanctuary in Kerala; Upper Nilgiris and Upper Palni Hills in Tamil Nadu; Castle rock and Belgaum in Karnataka; Catigao Wildlife Sanctuary, Bhagwan Mahavir National Park and Bondla Wildlife Sanctuary in Goa.

- The Nilgiri Wood Pigeon was recorded in the Silent Valley National Park, Siruvani, Castle rock, Mathikettan shola, Eravikulam National Park, Mannavan shola, Mukurthi National Pak, Thai shola and most of the sholas in the Upper Palni Hills.

- The species was not recorded in Goa during our survey.

- Preferred habitat of the Nilgiri Wood Pigeon was shola forests followed by evergreen forest, the former mainly during breeding.

- The maximum number of birds (51) was recorded in May 2004 and minimum (8) in September 2002 in the Kukkal forest in Palni Hills showing a regular movement pattern which was influenced mainly by the availability of food and suitable climate.

- Thirty two breeding pairs were observed in 40 ha of the intensive study area during the breeding season.

- The Nilgiri Wood Pigeon was observed only rarely in the plantations, that too those nearer to the shola or evergreen forests; but it does not nest in the plantations.

- Detailed studies with marking/ telemetry are required to determine the specific movement pattern of the Nilgiri Wood Pigeon.

- Adequate number of sites should be protected to cover its entire range of movement and site-based conservation management strategies are essential for the long term conservation of the Nilgiri Wood Pigeon.

Chapter 4

Foraging ecology of the Nilgiri Wood Pigeon

4.1. Introduction

The study of foraging ecology must begin with an understanding of food resources and it encompasses all behaviours that go with obtaining food. Food is often considered to be the most important factor influencing the production of offspring (Lack 1968, Martin 1987, 1992).

The relationship between bird and food abundance has been relatively well studied in the tropics, particularly in frugivores (Levey 1988, Loiselle & Blake 1991). Most tropical rain forest trees produce fruits that are consumed by animals and rely on frugivores for their seed dispersal (Frankie *et al.* 1974, Howe 1986). Concomitantly, a large proportion of the vertebrates in tropical forests are frugivorous (Terborgh 1986a, b). Very few avian frugivores are exclusive fruit eaters and a large number of them have a mixed diet of fruits and insects (Howe 1986). Only 17 families of birds such as the Oilbirds (*Steatornis caripensis*) and Quetzals (*Pharomachrus mocinno*) in the Neotropics (Snow 1980, Wheelwright 1983, Howe 1986) and Fruit Pigeons (*Ducula spp*) in South-East Asia (Wheelwright 1988) can be considered as strictly frugivorous, yet species from at least 44 families include fruits in their diet (Snow 1981, Jordano 1992, Ganesh 1996, Corlett 1998, Balasubramanian & Maheswaran 2003). The numerical strength of this guild of consumers highlights the importance of investigating their ecology, and quantification of fruit abundance as an important component of such studies. Although a variety of methods have been employed to provide estimates of fruit abundance, calibration of these methods has largely been neglected (Blake *et al.* 1990).

Seasonality and species diversity of fruits and frugivores are considerably influenced by location, climate, composition of plants and bird communities (Howe & Westley 1986, Fleming *et al.* 1987). Fruit availability has been shown to vary greatly over time in all major blocks of rain forests of South- East Asia (Medway 1972, Raemaekers *et al.* 1980, Leighton

& Leighton 1983) and it could affect the bird diversity (Fogden 1972). Fruit scarcity might restrict the breeding season and breeding success in at least certain bird species (Howe 1986, Ganesh 1996, Renton & Salinas- Melgoza 2004).

Apart from the abundance of resources, diet choice may also depend on fruit traits - morphological or nutritive value (Herrera 1984, Gautier-Hion *et al.* 1985). Janson (1983) classified two thirds of the plant species in a Neotropical forest as bird and mammal dispersed species based on their morphology. The richness of tropical forest plant communities is well known (Richards 1996, Whitemore 1997). A majority of fruits in the tropical rainforest are fleshy, and a large variety of fruits are available throughout the year, often in superabundance (Terborgh 1986b).

Seasonality in the tropics is not as pronounced as in the temperate regions. This apparent 'aseasonality' does not however imply a plentiful or uniform availability of resources as studies have shown peaks and trough in resource availability even in tropical forests (van Schaik *et al.* 1993, Richards 1996). Plant parts such as leaves, flowers, fruits, and seeds are some of the most commonly and widely used resources in tropical forests. The availability of these resources is often not well defined or predictable, and exhibits tremendous inter-annual and inter-site variations (Frankie *et al.* 1974, Leighton & Leighton 1983). While many species are strictly seasonal in flowering and fruiting, some are aseasonal, and by being available even during the periods of low resource availability, serve as keystone resources; eg. Ficus (Mckey 1975, Terborgh 1986a). Among the seasonal species, a few could be sub-annual, annual, or supra-annual and also those that exhibit synchronous or staggered phenophases (Chapman *et al.* 1999).

Variations in flowering and fruiting can be influenced by abiotic and biotic factors. Irradiance peaks and minimum temperature of previous dry season trigger leaf flush and flowering in tropical forests (van Schaik *et al.* 1993, Chapman *et al.* 1999). Therefore, peak in leaf flush and flowering are usually observed at the end of the dry season followed by peak in fruit production in the subsequent wet seasons (vanSchaik *et al.* 1993). Canopy openness and rainfall may also influence local phenological patterns. In addition to these

abiotic factors, biotic factors may determine staggered or clustered phenological activity of many plant species (vanSchaik *et al.* 1993, Poulin *et al.* 1999). Many studies suggest synchrony in phenological activity as an adaptation to reduce predation through predator satiation, whereas staggered phenological activity may be a plant strategy to avoid competition for pollinators and seed dispersers (Wheelwright and Janson 1985). It has also been suggested that phenological patterns may be determined by the optimal time for ripening of fruit (Terborgh 1986a, Gautier-Hion 1990).

The periodicity or unpredictability in resource abundance, in turn, plays a major role in determining food choice, movement patterns, and interactions in tropical bird communities (Kannan & James 1999). Animals exhibit some ecological flexibility and behavioural adaptations to cope with the fluctuations in resource availability. Phenological variation is known to stimulate resource tracking by many animal species, particularly nectarivores and frugivores (Fleming 1992, Leighton & Leighton 1983). Periods of low resource availability trigger some species to migrate to sites with better conditions, while others may temporarily switch their dietary habits (vanSchaik *et al.* 1993). Although intricate plant-animal interactions are common in all habitats including tropical forests, there are a few evidences to show obligate mutualisms or one to one dependencies (Herrera 1984), particularly between vertebrates and plants.

Phenological patterns can be described as the periodic variations in the flowering and fruiting patterns of a species. It could be defined as variations in (a) the number of species in flower or fruit, (b) the proportion of plants bearing flowers or fruits, and (c) the abundance of flowers or fruits over time (Blake *et al.* 1990). Monitoring plant phenology is imperative for the description of temporal variation in resource availability for frugivores. As the Nilgiri Wood Pigeon is a frugivorous bird, information on the pattern of availability of fruit resource would give a better insight into the response of this species to phenological changes and the vagaries of food abundance.

Most of the tropical forest tree fruits contain poor mineral and essential nutrients (McDiarmid *et al.* 1977, Jordano 1984), and many avian species depend on mineral intake

from natural or anthropogenic sources to supplement mineral-deficient diets (MacClean 1974, Graveland 1996, Perrins 1996). However, congregations of birds at mineral sites, sometimes called mineral licks, are rare and it is not a universal characteristic among any family of birds. Among birds, mineral use is notable among a few species of pigeons and doves (Ali & Ripley 1987, Jarvis & Passmore 1992). The most plausible hypothesis proposed to explain the use of mineral sites are to:(1) provide grit for grinding food in the stomach, (2) serve as a mineral supplement, (3) buffer acidic or alkaline foods in gizzard (Bechtold 1996), (4) detoxify secondary plant compounds such as alkaloids and tannins (Diamond 1998) and, (5) replace electrolytes lost during daily diuresis (Adam & Des Lauriers 1998).

March and Sadleir (1975) found high levels of serum calcium during ovulation and production of crop milk in pigeons. Both male and female adults regurgitate crop milk, a curd like substance, to feed their young ones for about one week after hatching and then in decreasing amounts until fledging (March & Sadleir 1975, Griminger 1983). Crop milk contains 0.5 mg calcium g^{-1} and March and Sadleir (1975) estimated that Band-tailed Pigeons needed 10mg day^{-1} of calcium to maintain calcium equilibrium while feeding young ones. It is reported that mineral sites were used to supplement calcium deficient diet (Sanders & Jarvis 2000). Jarvis and Passmore (1992) hypothesised that in the Pacific North-West, the diet of Band - tailed Pigeon during the breeding season, principally berries of red elder (*Sambucus racemosa var. arborescens*) and cascara (*Rhamnus purshiana*), are deficient in calcium, and that these birds seek mineral sites to supplement dietary calcium. Braun (1994) reported, based on literature, that calcium intake by adults is extremely important during nesting cycle, especially during feeding nestlings. The calcium deficiency hypothesis, however, has not been tested (Sanders & Jarvis 2000). In India not much information is available about the compensatory supplement food of pigeons but; Ali and Ripley (1987) reported Green Pigeons feeding on mineral lick sites. Other frugivores like Hornbills, fed on supplementary foods such as reptiles, invertebrates as reported by Mudappa (2000), Kannan and James (1999), and Maheswaran (2002).

Information on the basic ecology of most of the Columbidae family in tropics also is very limited, especially on food and feeding (Recher & Date 1988). In India, no such studies were conducted in Columbids. Food is the major factor to determine the habitat use (Kwit *et al.* 2004). However, food shortage can act globally by limiting the level of population and the reproductive success of a number of tropical birds (eg. Martin 1987, Thiollay 1989, Robinet *et al.*2003).

In the case of the Nilgiri Wood Pigeon an endemic, endangered species of the Western Ghats, no detailed information about the food and feeding habits is available for evolving a long-term conservation programme. However, stomach contents of the Nilgiri Wood Pigeon showed fruits and snails; the former was mainly *Randia dumetorum* (Ali & Ripley 1987). The present chapter deals with the food and feeding habits and the phenological pattern of the major food plants of the Nilgiri Wood Pigeon and, the factors affecting their phenology.

4.2. Method

Foraging ecology of the Nilgiri Wood Pigeon was studied by both direct and indirect methods. In the direct method, the bird was observed by using focal animal sampling /or scan sampling method (Altmann 1974) and, the availability of food was assessed by *direct observation* method (Blake *et al.* 1990). For the indirect method, faecal pellets were collected in the resting, roosting and nesting places and were examined.

4.2.1. Indirect method

Although direct observation of feeding is widely used to assess pigeon diets, it is subject to observational bias (Snow & Snow 1988, Rosenberg & Cooper 1990). Like many other pigeons, the Nilgiri Wood Pigeon is also very shy, and feeding observations have to be made from a distance, usually through twigs and foliage. Ralph *et al.* (1985) suggest that faecal samples are a less biased method to assess diet, and the faecal samples can be obtained without disturbing the birds (Oliveira *et al.* 2002).

Faecal samples of the Nilgiri Wood Pigeon were collected mainly from nesting and feeding sites. Plant food items were often unidentifiable macroscopically, so microhistological

methods were used based on plant epidermal resistance to herbivore digestion (Chapuis 1979). Prior to analysis, every faecal sample was mixed in water and cleaned by the addition of two drops of sodium hydrochloride. From this mixture a few drops were placed in a glass slide and viewed under the microscope. Epidermal tissues were identified by comparison with a reference collection of leaves, flowers, fruits and seeds of dominant trees and shrubs of Kukkal shola.

4.2.2. Direct method

Foraging activity was recorded throughout the day for every five minutes with one minute interval to cover four full days in a month to an average 50 hrs of observation per month. This was continued till the bird was visible. During each foraging observations, the following details were recorded: a) foraging method, b) foraging substrate, c) foraging height, and d) other behaviour, if any.

4.2.2.1. Foraging method

Foraging method was classified into:

Gleaning: To pick food items from nearby substrate, including the ground, that can be reached without full extension of legs or neck; no acrobatic movements are involved.

Leaping: To launch into the air to reach a food item too far for a "reach "but too close for a "sally". This differs from "sally" in that the upward thrust seems to come mostly from leg movements rather than wing movements.

Others: Includes the other methods which were less frequently used methods such as "sally" and "hang down".

4.2.2. 2. Foraging substrate

The location of the food item taken by the bird was considered as foraging substrate and, it was further classified into:

Trunk/main branches: Trunk and main branches of the tree, supporting the canopy. Mostly this area had large amount of epiphytes.

Twigs: Small branches < 3 cm in diameter to which leaves were attached

Ground: It included forest floor.

4.2.2. 3. Foraging height

Foraging location of the birds was divided into eight height classes with vegetation strata, namely 0 m (ground), 0 - 2 m, 2.1 – 4 m (shrubs), 4.1 – 6 m, 6.1- 8 m (sub-canopy), 8.1-10 m10.1-12 m (canopy), and >12 m (above canopy). Markings indicating the height classes were made on trees for reference.

4.2.2. 4. Horizontal stratification

The canopy was divided into nine categories based on the horizontal structure of the tree canopy (Nirmala 2002), namely centre edge, middle edge, edge - edge in the upper canopy; centre middle, middle-middle, edge middle in middle canopy and, lower centre, lower middle, and lower edge in the lower canopy (Figure 4.1.).

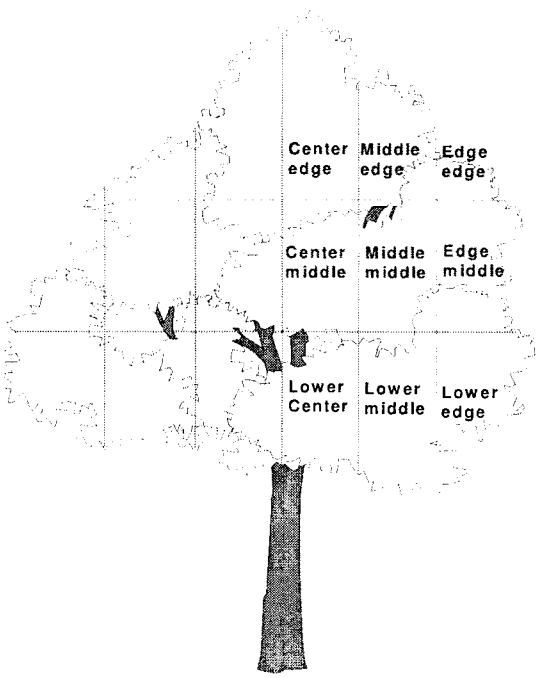


Figure 4.1 Horizontal structure of the tree canopy

4.2.3. Feeding behaviour

Feeding behaviours recorded include, species of tree where feeding occurred, the features and size of the fruits, number of fruits ingested, duration of visit, number of birds feeding at

the time, and food handling technique (engulf or bite), percentage of fruit cover on the particular tree.

4.2.4. Availability of food

4.2.4.1. Plant phenology

In order to investigate the availability of food resources in the study area, phenology of the food plants and fruiting rates of the trees were studied.

A six hectare plot encompassing the bird census area was laid for the phonological studies. Trees used by the Nilgiri Wood Pigeon were recorded from the first six months observations. They accounted for 23 species. 10 individuals from each were selected and phonological events recorded every fortnight following Frankie *et al.* (1974), Guy *et al.* (1979), Wheelwright (1988) and Maheswaran (2002).

The phenological events were divided into vegetative and reproductive phases. Assigning the values ranging from 0-100 % for each phase, an approximate proportion of flowers, fruits and young leaves were recorded (Prasad & Hegde 1986). Fruits were classified as ripe or unripe (Guy *et al.* 1979).

4.2.4.2. Fruit colour

The fruit colours were noted in the ripe condition. The fruit colours were classified into eight broad categories, namely black, blue, brown, red, green, yellow, orange and white following Willson and Thompson (1982), Balasubramanian (1990), Kannan and James (1999), Ganesh and Davidar (2001), Balasubramanian and Maheswaran (2003).

4.2.4.3. Fruit type, size and weight

Fruit character can influence the choice of fruit selection by birds (Ganesh 1996). The fruit type was classified into the following categories, namely berry, capsule, carpel, drupe and syconium. Ten fruits of each species were taken and the length and diameter measured using

vernier calliper. The average weight of ten fresh fruits was measured with the help of Pesola spring balance.

4.2.4.4. Abundance of ground invertebrates

Abundance of ground invertebrates was calculated by using ground quadrat. Ten quadrats of 1 x1m each were placed and the litter was removed. The number of invertebrates and the size class of each was noted. Sampling was done at an interval of 15 days in the intensive study area and the relative abundance of invertebrate was calculated. Their abundance with the ground foraging of the Nilgiri Wood Pigeon was tested in different seasons.

4.3. Data analysis

1. Pearson correlation test was used to find the relationship between the abundance of ground invertebrates and the frequency of ground feeding by the Nilgiri Wood Pigeon in the study area.
2. The Analysis of Variance (ANOVA) was used to compare foraging methods of the Nilgiri Wood Pigeon in different seasons.
3. Student t test was performed to find out the significance in the difference on foraging height of the Nilgiri Wood Pigeon.
4. Regression analysis was employed to determine the relationship between fruiting phenology and environmental factors.
5. Niche breadth of Nilgiri Wood Pigeon on each foraging dimension such as height, method and substrate was calculated using the Shannon - Wiener index (Shannon & Wiener 1949).
6. $H' = -\Sigma\ p_i \ln p_i$ (Where H' = diversity and p_i = the proportion of observation in subset i) as done by Recher (1985).
7. These values were then converted to a standardized range using the formula:
   J' =H' / H max (Where J' = niche breadth or specialization and H max = the H' value obtained when the observations are distributed equally across all subsets of the foraging dimension). J' values range between one and zero, with foraging

specialization increasing as J' falls. It is used as an index of foraging specialization by Crome (1978) and Gokula and Vijayan (2000).

4.4. Results

4.4.1. Food

In all, 1520 foraging observations were made during the two years study. The Nilgiri Wood Pigeon was primarily a frugivore even though it fed on leaf buds, flowers, ground invertebrates such as snails and coleopteran grub and soil. On an average 47.10 % of the total time was spent for foraging in all the seasons; and comparatively more in summer (57 %) than in other seasons (more details in Chapter 5). The food of the Nilgiri Wood Pigeon include 34 species (Fig 4.2., Appendix III) belonging to 26 families of plants with fruits and flower, leaf buds (four species) and three taxa of ground invertebrates. Nine species were fed on more than 47 % in all the seasons and a few were common in both in pre- breeding and breeding seasons. Lauraceae contributed the maximum species (14). Myrsinaceae, Myrtaceae, Rosaceae and Rubiaceae contributed equally; three species each. Eight species from other families were also used occasionally.

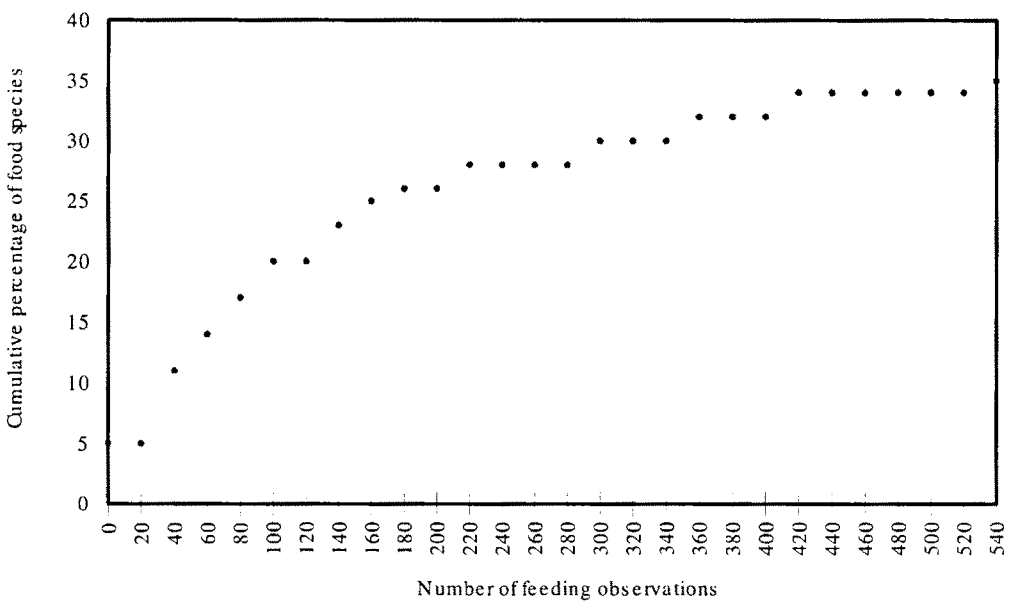


Figure 4.2 Food species and frequency of feeding of the Nilgiri Wood Pigeon.

4.4.1.1. Indirect method

One hundred thirty four faecal samples of the Nilgiri Wood Pigeon were collected during the two years study and analysed. 30 samples contained only soil particles, 95 contained only seeds and the remaining plant matters such as tender shoots and flower buds and, shell of snails. 11 species of seeds were identified from the faecal samples. Maximum samples contained seeds of *Viburnum cylindricum* (17) followed by *Ilex wightiana* (12), *Casearia zeylanica*, *Olea glandulifera, Beilschmiedia wightii* and *Daphniphyllum neilgherrense* (Table 4.1.). Seeds found intact in the faecal pellets were considered to be fit for dispersal (Table 4.1). Fruits were identified by seeds as well as by epicarp or skin present in the faecal matter. Seeds up to 35mm in size were intact and hence dispersible, whereas those of 50 to 125 mm were slightly damaged and hence, considered as non-dispersible.

Table 4.1 Food species of the Nilgiri Wood Pigeon identified from the faecal samples

Species	% of occurrence	%dispersible
Viburnum cylindricum	17.89	25
Ilex wightiana	12.63	100
Casearia zeylanica	9.47	0
Olea glandulifera	11.58	0
Daphniphyllum neilgherrense	9.47	0
Ficus arnottiana (Miq) Miq	8.42	100
Beilschmiedia wightii	6.32	25
Syzygium densiflorum	5.26	0
Syzygium jambolanum	9.47	0
Syzygium tamilnadensis	5.26	0
Maesa indica	4.21	75

4.4.1. 2. Direct method

The Nilgiri Wood Pigeon, based on the direct feeding observations, consumed more than 70 % fruits, followed by soil, invertebrates and buds (Fig. 4.3). Fruit was the major food in all the seasons. Apart from the fruits, they were found feeding on soil during summer and on

soil and flower buds during winter. Invertebrates also consumed in sizable quantity during the monsoons (Table. 4.2.).The food composition was checked between the seasons within a year and between the same seasons in the subsequent years. It shows that there was no significant difference (F = 0.5, p = 0.50).

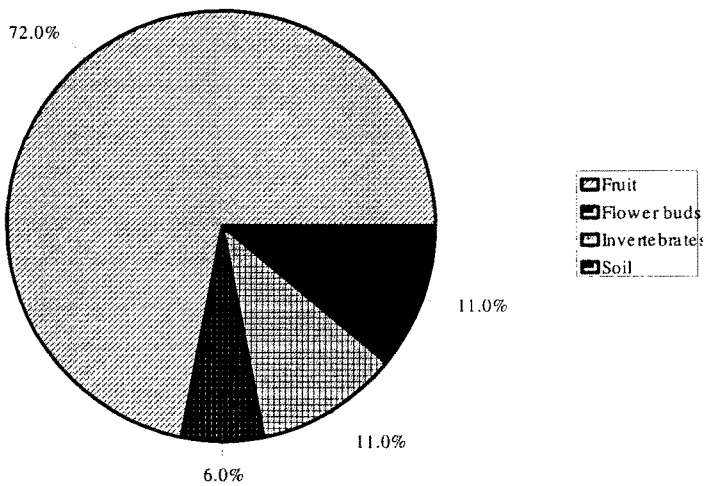


Figure 4.3 Food compositions of the Nilgiri Wood Pigeon

Table 4.2 Seasonal variation in the diet of the Nilgiri Wood Pigeon

Food item/Season	Summer	South-west monsoon	North-east monsoon	Winter	Total
Fruit	71.5	72.5	70.0	70.0	71.0
Flower buds	4.5	1.5	7.0	12.5	6.38
Invertebrates	9.0	18.5	14.5	3.5	11.38
Soil	15.0	7.5	8.5	14.0	11.25
Total No. of observations	350	430	361	379	1520

Note: Figures in percent

4.4. 2. Foraging pattern of the Nilgiri Wood Pigeon

The Nilgiri Wood Pigeon started foraging from 0500 hr and continued up to 1800hrs with a major peak during the forenoon and sub - peak in the afternoon (Fig. 4.4.). The major peak was between 0800 and 0859 in all the seasons, except in the winter, and the sub - peak in the evening during 1700 - 1759 hr. In all the seasons, feeding was low or absent in the afternoon. In the north – east monsoon and winter, the peak was observed a little later based on the environmental conditions. In summer, active feeding was observed after even 18.30 hr.

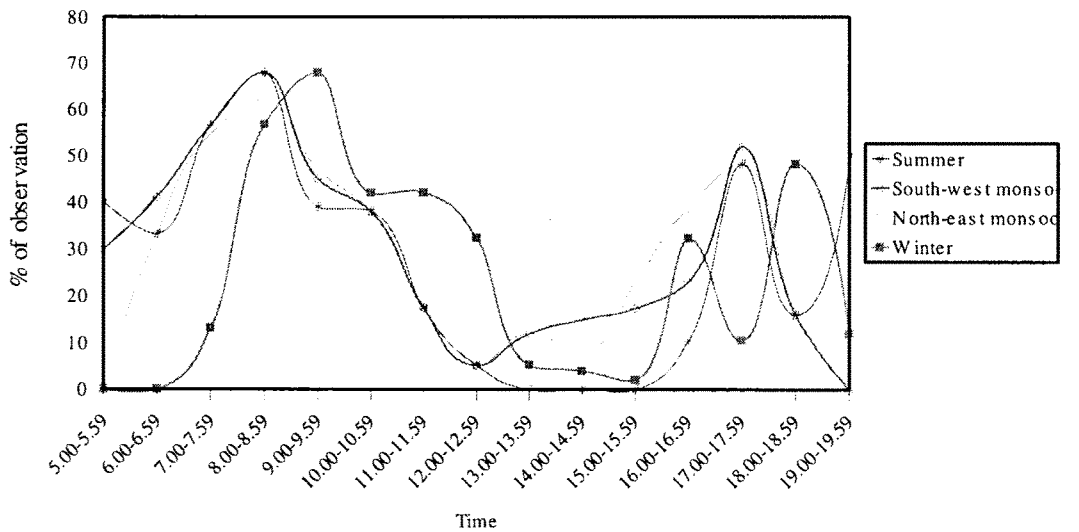


Figure 4.4 Foraging patterns of the Nilgiri Wood Pigeon in various seasons.

4.4.3. Fruit colour

The Nilgiri Wood Pigeon predominantly used black fruits (59%) followed by red (27%); the other colours were used less frequently (Fig. 4.5.). 26 species of trees had black fruits while

12 had red fruits. Preference to colour correlated with their availability in the intensive study area ($r = 0.97$; $p < 0.01$).

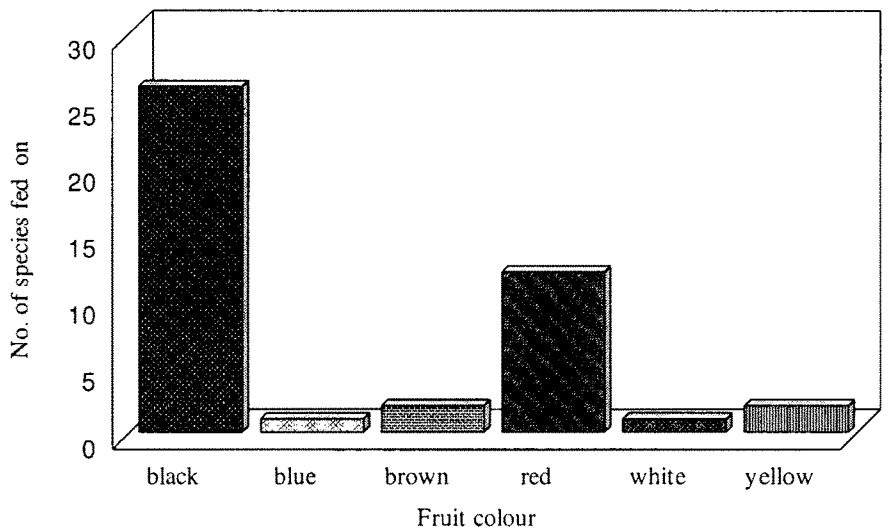


Figure 4.5 Preference of the Nilgiri Wood Pigeon for fruits of varying colours.

4.4.4. Fruit type

Fruit consumed by the Nilgiri Wood Pigeon included mainly berries and drupes (Fig. 4.6.). The former was preferred more than the others.

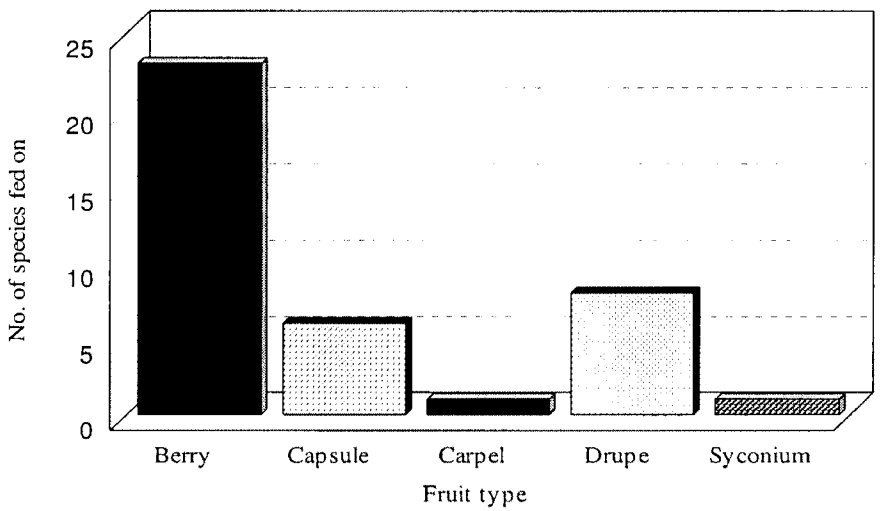


Figure 4.6 Preference of the Nilgiri Wood Pigeon for different types of fruits.

4.4.5. Fruit size

The Nilgiri Wood Pigeon consumed fruits of various sizes (0.04 - 70 mm). The most preferred size category was 10-20 mm (14.16± 2.77). The frequency of fruits of the size above 40 mm was very low in the diet (Fig. 4.7.).

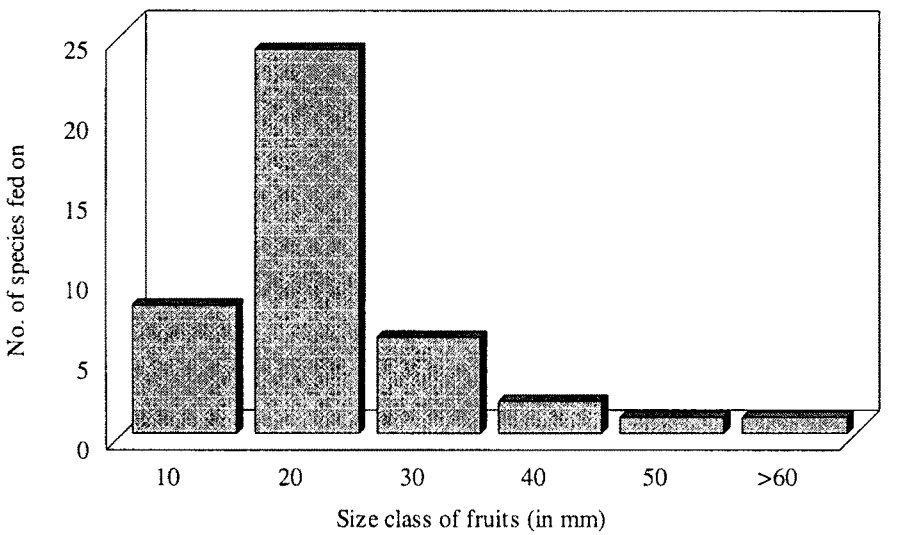


Figure 4.7 Size class distributions of fruits in the diet of the Nilgiri Wood Pigeon

4.4.6. Fruit weight

The Nilgiri Wood Pigeon consumed fruits weighing from 0.14 to 30 gm. The mean weight was 3.10 ± 4.00 gm. The frequency of fruit consumption by the Nilgiri Wood Pigeon showed (Fig 4.8.) that most of the preferred fruits fell under the size class of 0.1 to 4gm.

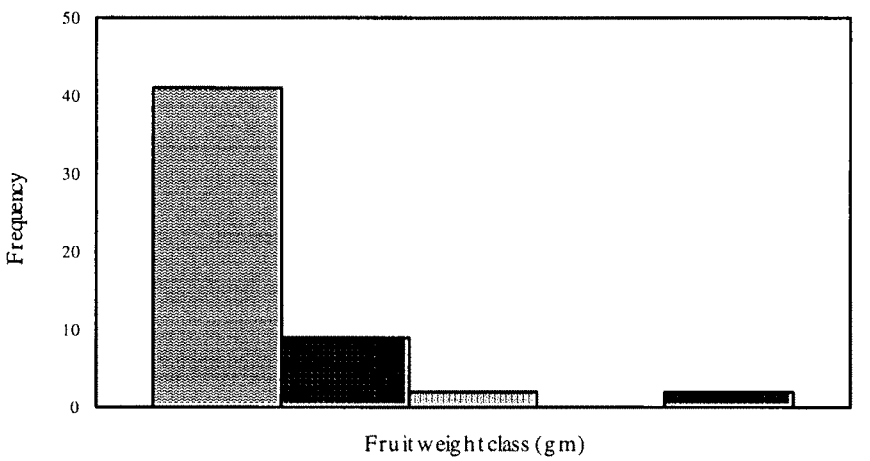


Figure 4.8 Weight class distributions of fruits in the diet of the Nilgiri Wood Pigeon

4.4.7. Foraging height or vertical strata

Vertical foraging locations of the Nilgiri Wood Pigeon were categorised into 12 (Fig. 4.9). Middle and upper canopy height classes were predominantly used. Shrubs and sub-canopy were the least used. The maximum foraging took place in the upper canopy from 6 to10 m and above 10 m (Fig. 4.9.). The overall mean height utilized by the Nilgiri Wood Pigeon was 4.08 $\pm$ 2.71 m. ANOVA showed that foraging height of the Nilgiri Wood Pigeon varied significantly between the seasons ($F = 15.85$; $p<0.001$).

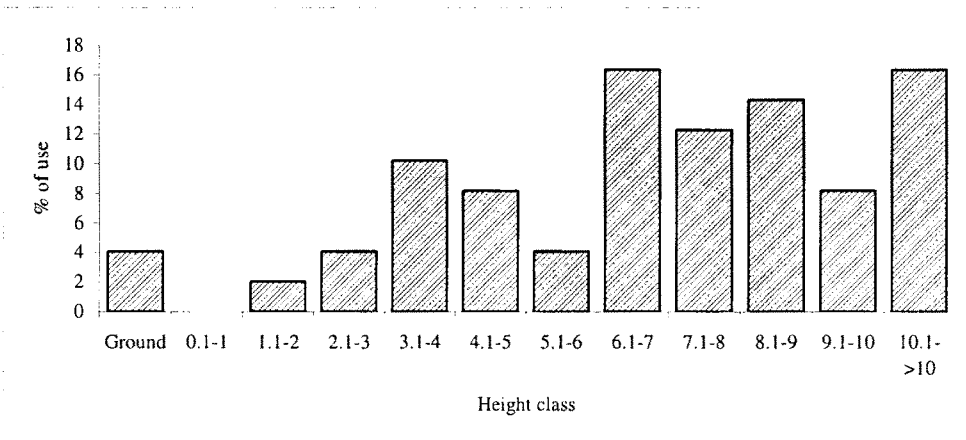


Figure 4.9 Foraging height classes of the Nilgiri Wood Pigeon

4.4.8. Foraging substrate

The Nilgiri Wood Pigeon is basically a canopy frugivore. However, occasionally, flocks of birds came, settled on the ground and started feeding on the fallen fruits, snails and soil. The major feeding site was twig (64.95 %) followed by ground (27.85 %) (Fig. 4.10 to 4.14). Foraging on the ground was the maximum during winter followed by south-west monsoon. However, the level of use was not significantly different among the seasons (ANOVA; $F = 2.95$, $p < 0.05$). There was no record of feeding at the main branches and trunks, as most of the feeding was at the twigs where a large number of fruits were present.

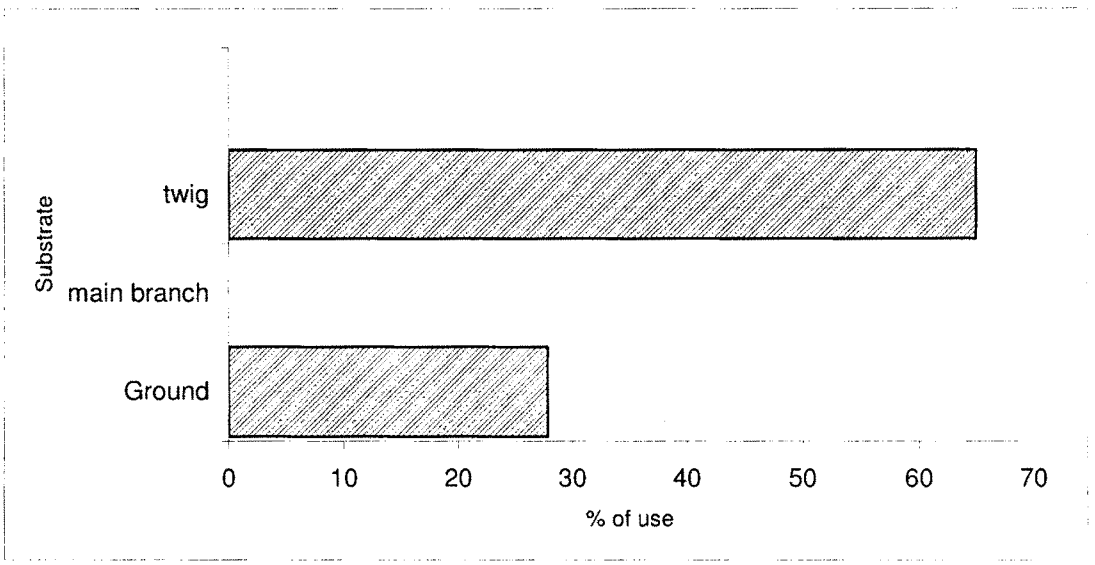


Figure 4.10 Overall substrate utilisation by the Nilgiri Wood Pigeon

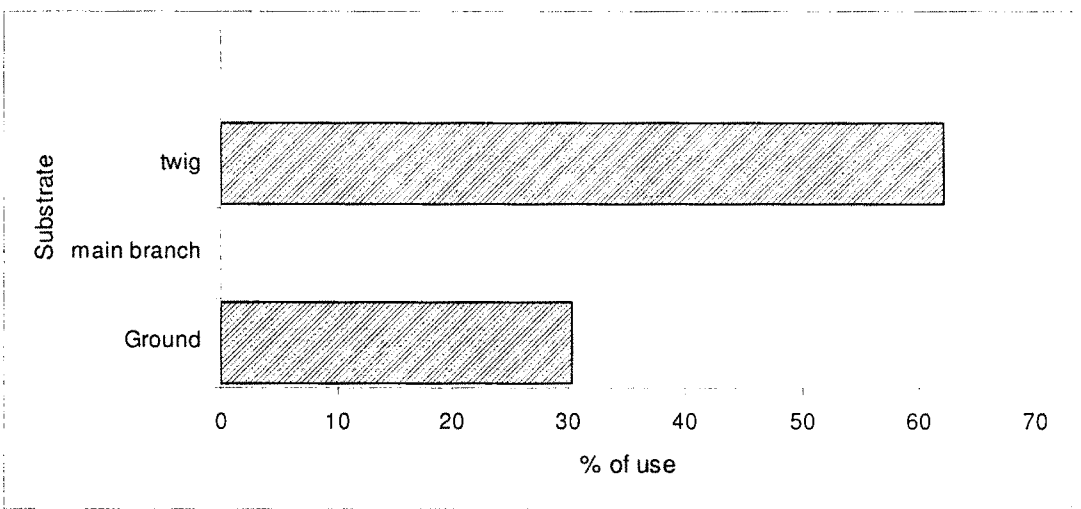


Figure 4.11 Substrate utilisation by the Nilgiri Wood Pigeon during summer

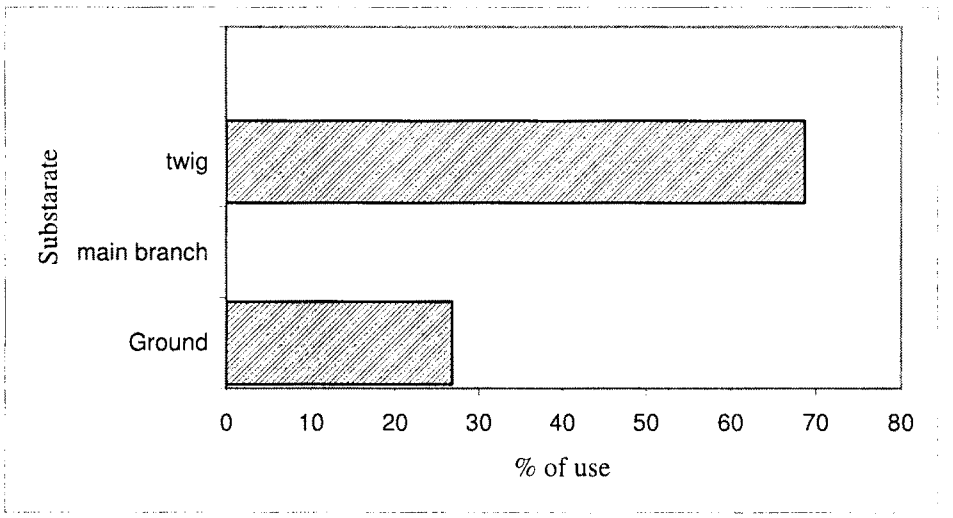


Figure 4.12 Substrate utilisation by the Nilgiri Wood Pigeon during south-west monsoon

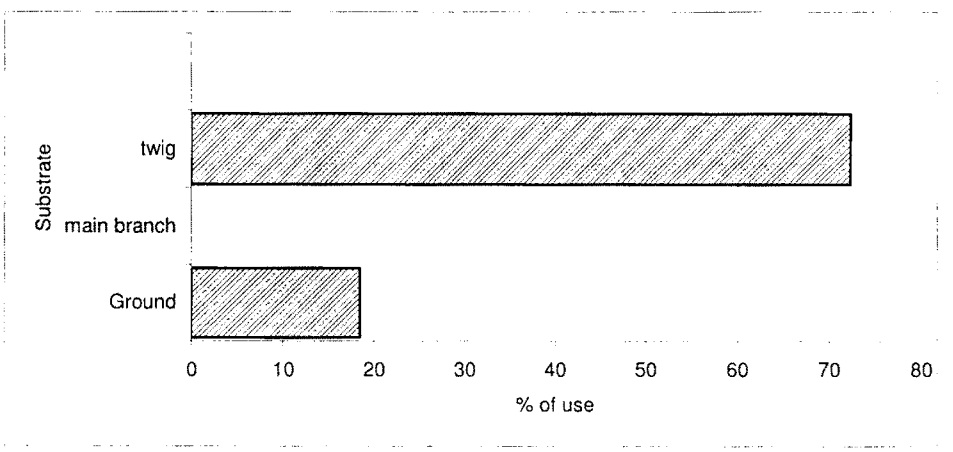


Figure 4.13 Substrate utilisations of the Nilgiri Wood Pigeon during north-east monsoon

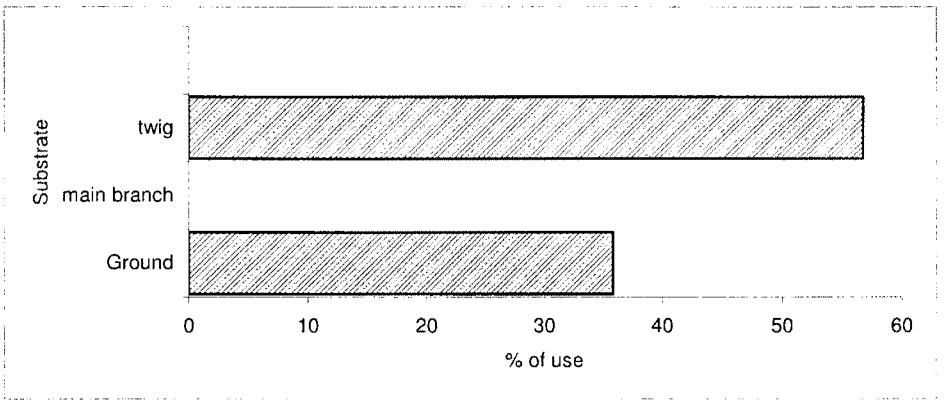


Figure 4.14 Substrate utilisations by the Nilgiri Wood Pigeon during winter

4.4.9. Horizontal strata of feeding

Even though many trees had fruits all over, the Nilgiri Wood Pigeon preferred mostly the edge. Usually they settle in the upper canopy and after a few minutes, slowly move towards the edge and start feeding. Hence, foraging was recorded mainly on the edges (76 %). The birds preferred upper edges of canopy (39 %) followed by middle edge (28 %; Fig. 4.15). The pattern was the same in all the seasons.

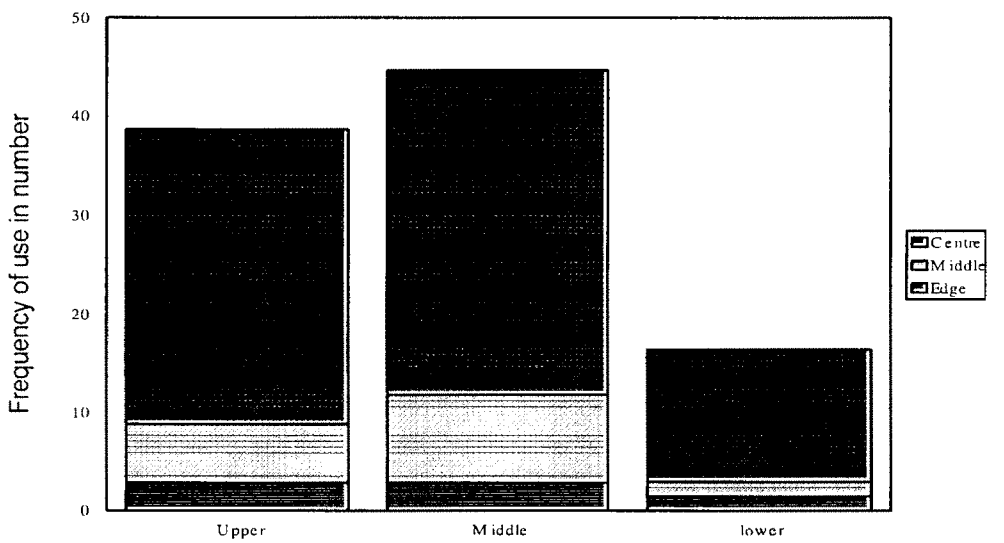


Figure 4.15 Horizontal foraging strata of the Nilgiri Wood Pigeon in Kukkal

4.4.10. Foraging method

The Nilgiri Wood Pigeon used largely two foraging methods, namely gleaning and leaping. The former was more common, the frequency varying from 68 % in winter to 84% in the south-west monsoon (Fig 4.16). No significant difference was observed between the seasons with in the year and between the years.

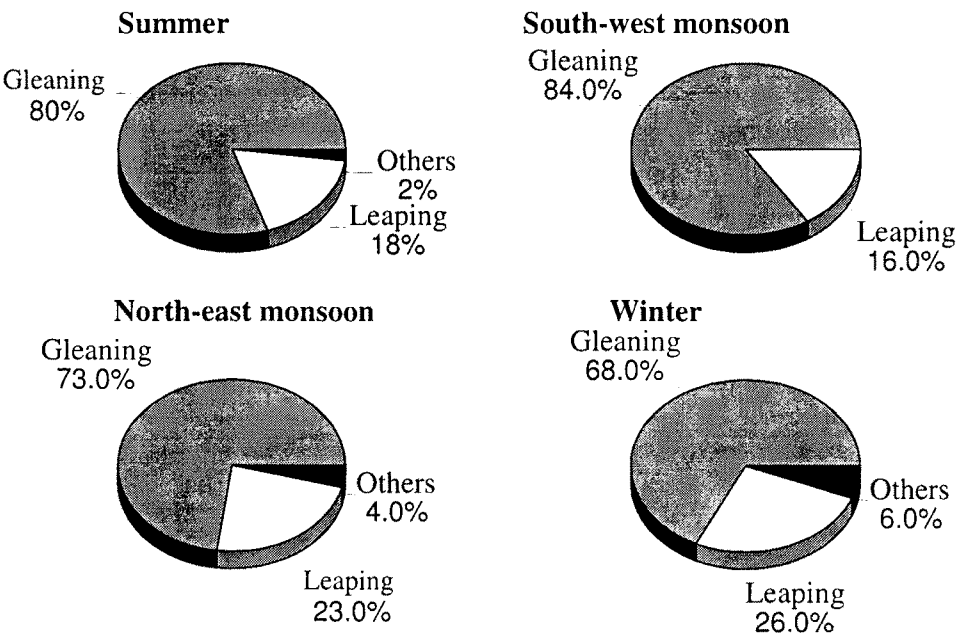


Figure 4.16 Frequency of foraging methods of the Nilgiri Wood Pigeon in various seasons

4.4.11. Food handling technique

Observation on the food-handling techniques of the Nilgiri Wood Pigeon was difficult in the field, as they foraged mostly in the top closed canopy. It could be recorded only in 25 % of feeding observations during the two-year study. They mostly engulfed the fruit and rarely did they take it bit by bit. If the fruit size was large, the bird used the later method, but most of the fruits could be swallowed as whole. It may be noted that size of the most preferred fruits were also small.

4.4.12. Fruiting phenology of food plants

Phenology of 23 species of trees was observed during the two- year field study from April 2002 to May 2004. Fruiting was at the peak in July 2003 and least in June 2002 (Fig. 4.17). During the peak period, fruits of 85 individuals of six species were consumed by the Nilgiri Wood Pigeon. *Syzygium tamilnadensis, Ilex wightiana* and *Beilschmiedia wightii* fruited only once during the two years of study. In August, only Trichillia *connoroides* were in fruit, whereas in December only *Olea glandulifera,* and *Measa indica* had fruits, the latter was about 10 % only. The number of fruiting species appeared to have no correlation with rainfall ($r = 0.26$, $p = 0.2$) while the fruit abundance did show a correlation ($r = 0.40$, $p < 0.05$). Out of the 23 species, fruits of only eight species were fed largely in different seasons.

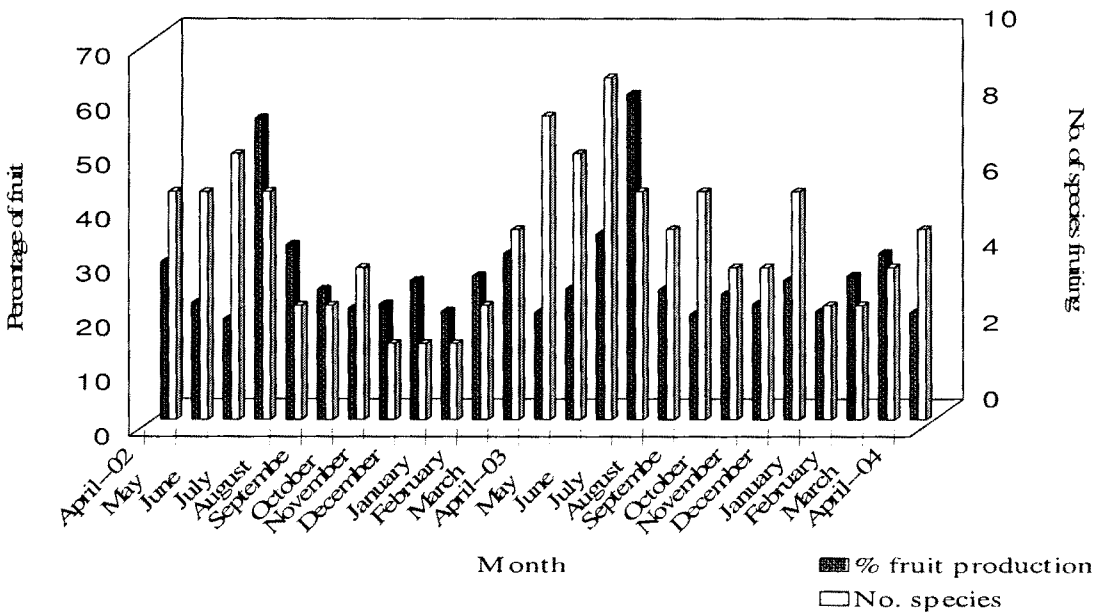


Figure 4.17 Fruiting patterns of tree species in the Upper Palni Hills during April 2002 to April 2004.

Phenological details of the species more commonly used by the Nilgiri Wood Pigeon are given below.

4.4.12. 1. *Olea glandulifera* (plate 3).

Flowering of *Olea glandulifera* was in the drier months of summer (April-May). Fruiting commenced from the middle of June and fully ripe fruits were available from December to February (Fig 4.18). There was no much variation in the pattern of phenology between the years. Fruit was black and was found more at the edges of branches. It may be noted that the pre-breeding activities of the Nilgiri Wood Pigeon coincided with the peak availability of ripe fruits during December –February. Again, the diet of the bird consisted mainly of the fruits of *Olea glandulifera* during the period.

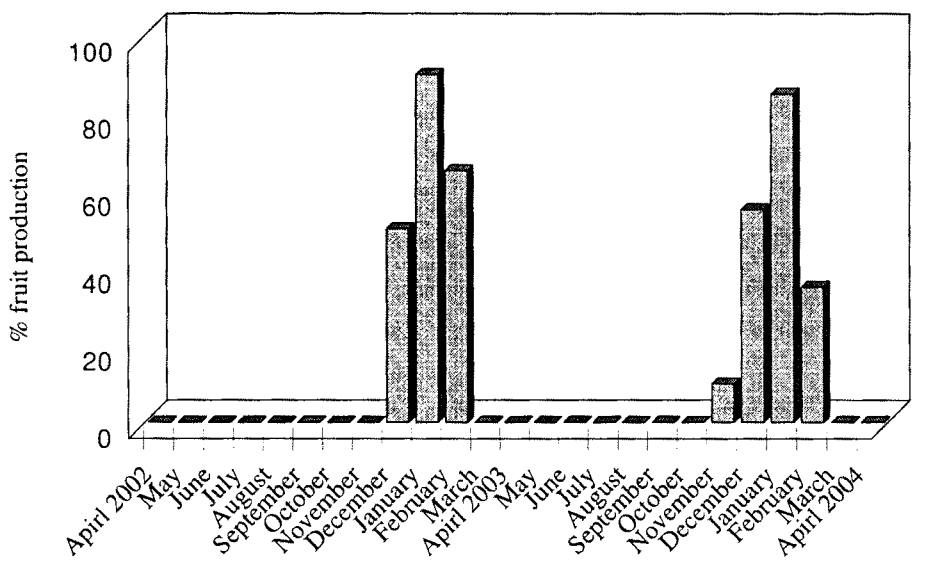


Figure 4.18 Fruiting phenology of *Olea glandulifera* at Kukkal during the study

4.4.12. 2. *Viburnum cylindricum*

Viburnum cylindricum was one of the common species in the intensive study area and was abundant in the edges and openings in the shola. Flowering was from August to October and December to January. Fruits were seen in most of the months except in winter and hence, formed the staple food of the Nilgiri Wood Pigeon, especially when the other trees were not

Plate 3 Some important food plants of the Nilgiri Wood Pigeon

Olea glandulifera

Syzygium jambolanum

Trichillia connoroides

in fruit. Peak fruiting was observed from March to July (Fig. 4.19). Fruit was red and globose.

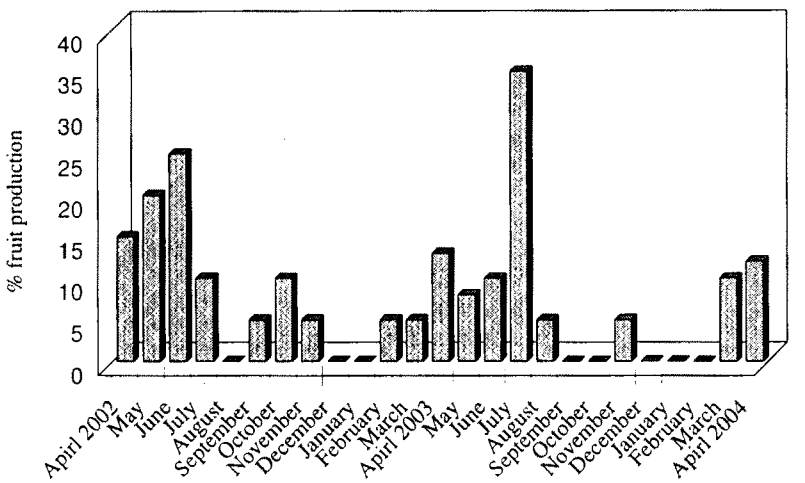


Figure 4.19 Fruiting phenology of *Viburnum cylindricum* at Kukkal during the study

4.4.12. 3. *Trichillia connoroides*

It is interesting to note that phenology of *Trichillia connoroides* varies individually. Some of the trees flowered from March to May, while some from July to August. In the former, fruits started appearing from the end May with the onset of monsoon and ripe from the end of June (Fig. 4.20). By July, there was a peak of ripe fruits. Those in flower during July to August were in fruits in September, but they ripe only by the next June. It is quite interesting to note that some of those trees in flower during March to May and in fruit during June – July, also had flower during July. However, the fruits of these get ripe only by next June. The adaptive significance of the differential phenological regime of individuals of the species is not very clear.

4.4.12. 4. *Syzygium jambolanum* (plate 3).

Syzygium jambolanum flowers from January to March and begins fruiting from April. Ripe fruits appear from the end of May reaching a peak in June (Fig 4.21). Fruit is a black berry. It is an important food item of the Nilgiri Wood Pigeon in the post-breeding and pre-moulting period.

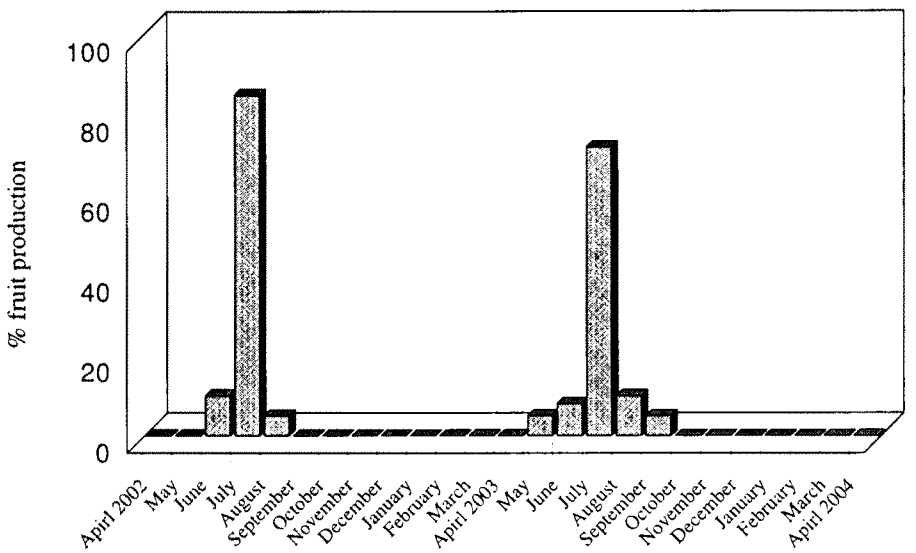


Figure 4.20 Fruiting phenology of *Trichillia connoroides* at Kukkal during the study

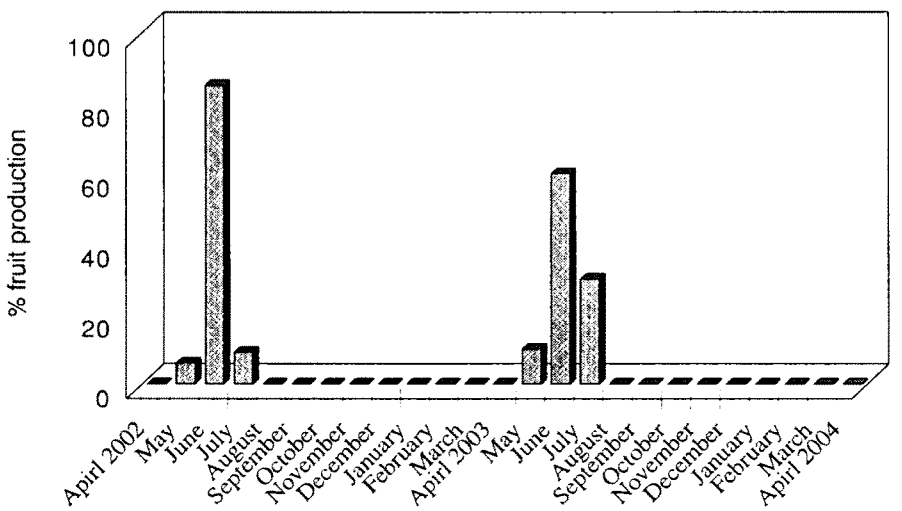


Figure 4.21 Fruiting phenology of *Syzygium jambolanum* at Kukkal during the study

4.4.12. 5. *Maesa indica*

Maesa indica had flower and fruit throughout the year. Peak fruiting was during June to July (Fig. 4.22). Fruit is a white berry. These trees were present in the edges and the openings inside the shola. Nilgiri Wood Pigeon occasionally consumed this berry.

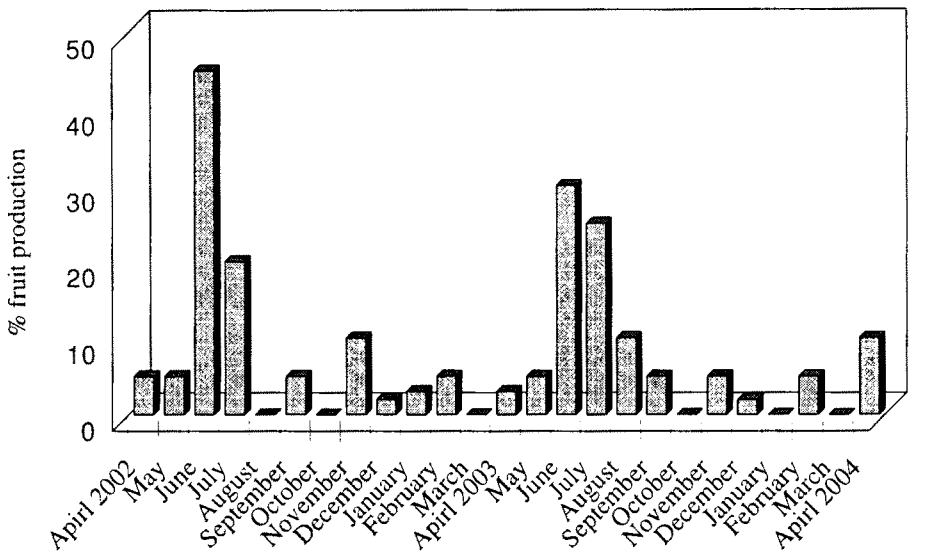


Figure 4.22 Fruiting phenology of *Maesa indica* at Kukkal during the study

4.4.12. 6. *Daphniphyllum neilgherrense*

Flowering of *Daphniphyllum neilgherrense* was from December to February and fruiting from January to May with a peak in April (Fig. 4.23) which was the peak breeding season of the Nilgiri Wood Pigeon. Fruit is a red drupe. A large number of the Nilgiri Wood Pigeon fed on this fruit during the peak fruiting.

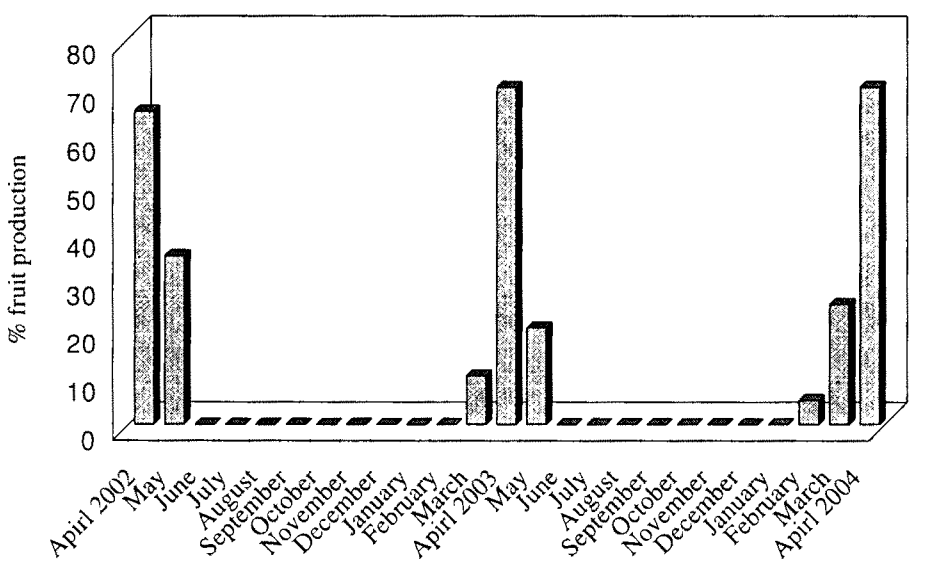


Figure 4.23 Fruiting phenology of *Daphniphyllum neilgherrense at* Kukkal during the study

4.4.12. 7. *Casearia zeylanica*

Flowering of the *Casearia zeylanica* was in the drier months from March to May. Fruits began appearing from the end of May and started ripening by June. Peak period of ripe fruits was in July – August in 2002 and it extended up to September (Fig 4.24). The fruit was red covered with yellow capsule.

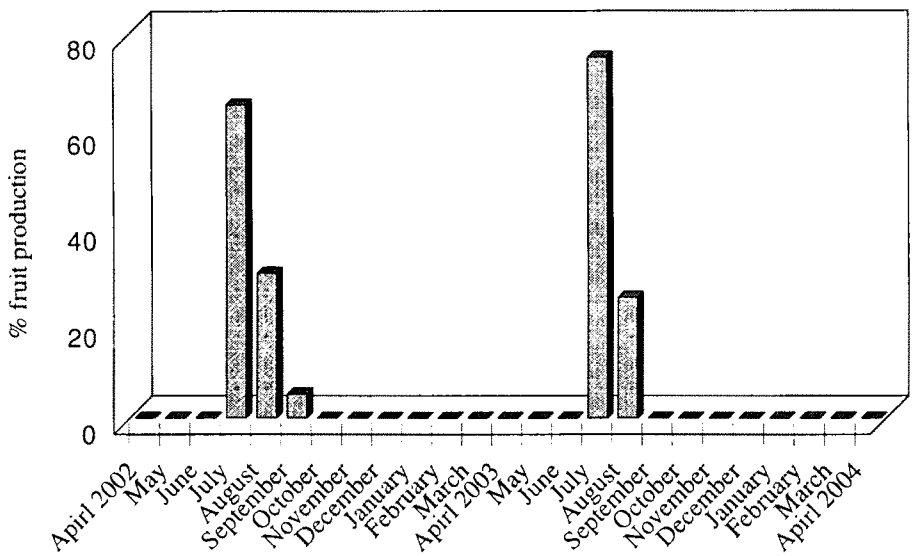


Figure 4.24 Fruiting phenology of Casearia *zeylanica at* Kukkal during the study

4.4.12. 8. *Ilex wightiana*

Ilex wightiana flowers from December to January. Fruits appear from April and ripe from the end of June. The peak of ripe fruits was in July (Fig 4. 25). However, it may be noted that flowering and fruiting was observed only during 2002. Fruit is a red berry. Whole seeds were seen in the faecal samples of the Nilgiri Wood Pigeon.

4.4.12. 9. *Beilschmiedia wightii*

Beilschmiedia wightii flowers in March and April and ripe fruits appear from June and present up to five months (June- October 2003) with a peak during July (Fig. 4.26). Fruit is a black berry.

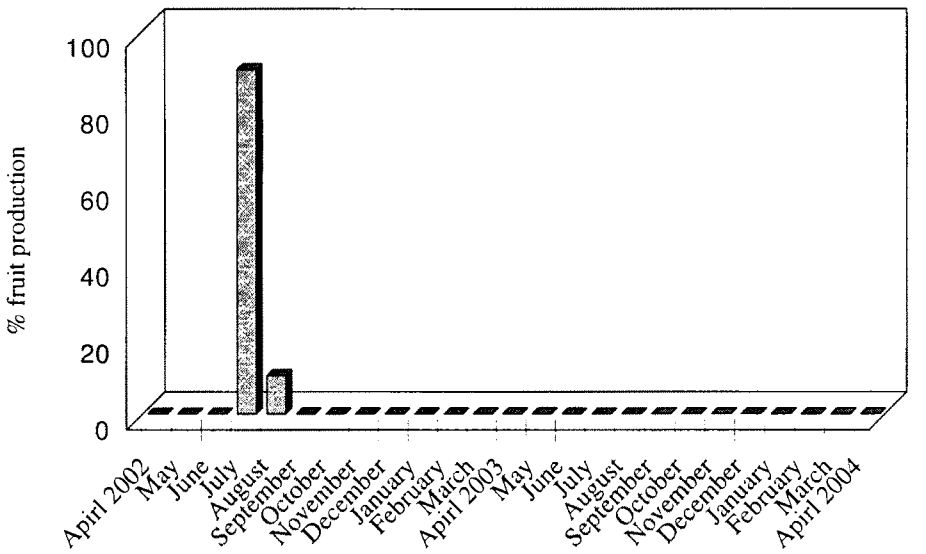


Figure 4.25 Fruiting phenology of *Ilex wightiana* at Kukkal during the study

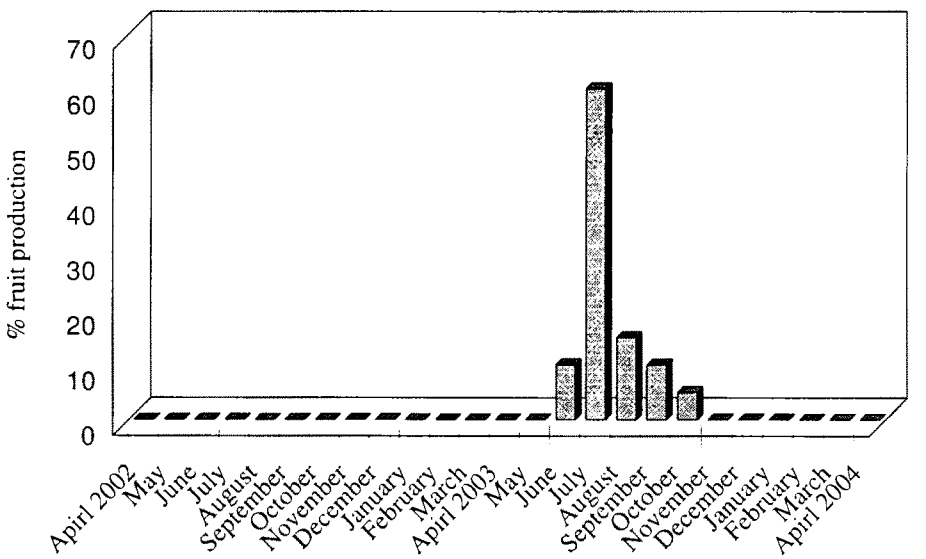


Figure 4.26 Fruiting phenology of *Beilschmiedia wightii* at Kukkal during the study

4.4.12. 10. Factors affecting fruiting phenology

The peak fruit abundance had a significant linear correlation with rainfall ($r = 0.40$, $p < 0.05$), while there was no correlation between the fruit abundance and number of species in fruit ($r = 0.22$, $p = 0.2$) and, fruit abundance and the number of rainy days ($r = 0.16$, $p =$

0.44). Maximum number of species was in fruit only when the number of rainy days was less than six days. Total fruit production did not correlate with the monthly mean maximum temperature, while the number of species in fruit had a significant correlation ($r = 0.39$, $p < 0.05$). Minimum temperature and number of species fruiting also showed similar trend ($r = 0.58$, $p < 0.01$). Total fruit production and relative humidity had no correlation, whereas the number of species in fruit significantly correlated with humidity ($r = 0.32$ $p = 0.05$).

4.4.12. 11. Factors affecting individual species phenology

Olea glandulifera, Viburnum cylindricum, Trichillia connoroides, Syzygium jambolanum, Maesa indica, Daphniphyllum neilgherrense, Casearia zeylanica, Ilex wightiana and *Beilschmiedia wightii* are the preferred food plants of the Nilgiri Wood Pigeon. Phenology of these species were studied in detail and tested with environmental factors such as rainfall, temperature and humidity. *Olea glandulifera* had significant correlation with relative humidity ($r = 0$ .48, $p < 0.05$), minimum temperature ($r = 0.77$, $p < 0.001$), total rainfall (0.59, $p < 0.05$), and number of rainy days ($r = 0.57$, $p< 0.05$). Fruiting phenology had significant correlation with relative humidity and minimum temperature in the case of *Viburnum cylindricum* ($r = 0.34$, $p < 0.05$; $r = 0.58$, $p < 0.05$ respectively), *Trichillia connoroides* ($r = 0.45$, $p <0.05$; $r = 0.62$, $p< 0.01$ respectively) and *Syzygium jambolanum* ($r = 0.37$, $p< 0.05$; $r = 0.59$, $p < 0.05$ respectively). Similarly, Fruiting phenology had significant correlation with relative humidity and maximum temperature in *Daphniphyllum neilgherrense* ($r = 0.34$, $p < 0.05$; $r = 0.79$, $p< 0.05$ respectively) and *Casearia zeylanica* ($r = 0.34$, $p < 0.05$; $r = 0.38$, $p < 0.05$ respectively). *Beilschmiedia wightii* had significant correlation with relative humidity, minimum temperature and number of rainy days ($r = 0.36$, $p < 0.05$; $r = 0.38$, $p < 0.05$, $r = 0.37$, $p < 0.05$ respectively), whereas *Maesa indica* had significant correlation only with minimum temperature ($r = 0.49$, $p < 0.05$). Fruiting of *Ilex wightiana* did not correlate with any environmental factors.

4.4.13. Abundance of ground invertebrate

Nilgiri Wood Pigeon fed on ground invertebrates during the south-west monsoon (June - August), when the young fledged out and the adults underwent moulting. Ground invertebrates were also abundant during this period (Fig. 4.27). There is a significant

correlation between the frequency of feeding on the ground and the abundance of ground invertebrates (Pearson correlation r = 0.65, $p < 0.01$). A great portion of invertebrate diet component was snails (84 %). Very rarely did they feed on the coleopteran grub.

4.4.14. Association with other birds during feeding

4.4.14. 1. Intraspecific

The Nilgiri Wood Pigeon foraged mostly in flocks, the size of which varied from four to 40, depending upon the fruit abundance of the particular tree. While foraging, one bird from the flock kept watching around and did not involve in feeding, as if acting as a sentinel. On the approach of predator or an alarm call by the Grey-breasted Laughing thrush or any other species, the sentinel gets alerted and all the pigeons fly off and settle in closed canopy. If there is no threat for 5 to 10 minutes, the role of sentinel is exchanged with another bird from the flock, making way for it to feed. This behaviour was more frequent at the ground feeding sites. The males were very vocal during the breeding season. Their feeding calls like "" ku-uu, ku kuu"" were audible up to a distance of five metres. During this period (April- May), they flocked in large numbers where the fruits were abundant. Fight between two individuals was observed only once and that happened when the fruit was in abundance; whether the individuals were from the same flock or different flocks are not known.

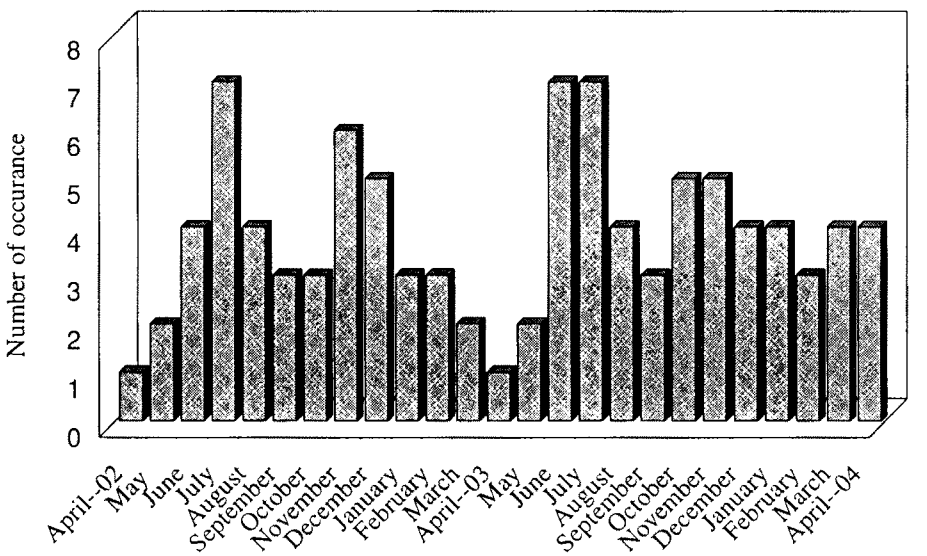


Figure 4.27 Abundance of ground invertebrates in the study area

4.4.14. 2. Interspecific

The Nilgiri Wood Pigeon foraged very rarely with other species in the same tree. Black bulbul, White-cheeked Barbet, Yellow-browed bulbul, Grey-breasted Laughing Thrush, and Eurasian Black Bird were some of the frugivores present in the study area (Appendix 1). The White-cheeked Barbet has some association (Fig. 4.28) feeding on the same tree (Table 4.3).

Table 4.3 Frequency of occurrence of the Nilgiri Wood Pigeon with other birds while foraging.

Species	% occurrence with Nilgiri Wood Pigeon
Black Bulbul	8.42
Yellow - browed Bulbul	4.28
Eurasian Black bird	3.16
White - cheeked Barbet	11.05
Grey - breasted Laughing thrush	0.00
Oriental White - eye	0.00

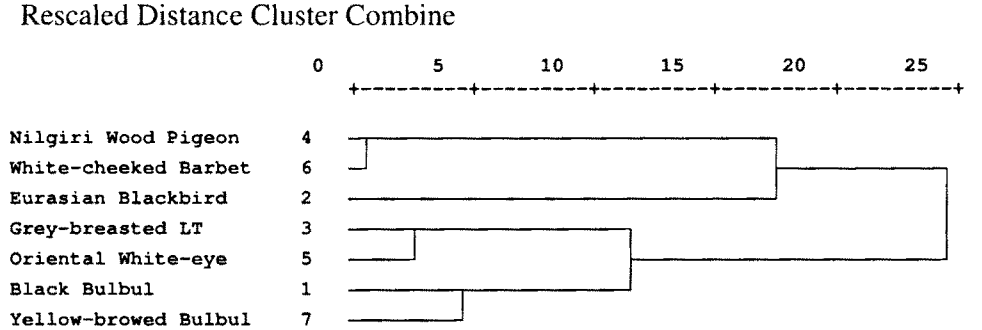


Figure 4.28 Cluster dendrogram showing interspecific relationships between the frugivores present in Kukkal based on multivariate analyses of foraging method, substrate and height use.

Niche breadth of the Nilgiri Wood Pigeon was calculated based on the three dimensions such as foraging substrate, method and height. The Nilgiri Wood Pigeon had more specialization on foraging method (0.19) followed by substrate (0.30). The mean value of J' in the three dimensions was 0.42. J' values range between one and zero, with foraging specialization increasing as J' value falls.

4.5. Discussion

The Nilgiri Wood Pigeon is largely a frugivorous bird, and the animal component (invertebrates) in the diet was negligibly small in quantity. It used 34 species of plants for fruits, buds and flowers, and three taxa of invertebrates. Such diverse diet has been reported in various species of pigeons elsewhere (Neff 1947,Crome 1975a, McEwen 1978, Oliveira & Jones 1995, Zino & Zino 1986,Snow & Snow 1988, Pearson & Climo 1993, Bancroft & Bowman 1994, Brooke & Jones 1995, Powlesland *et al.* 1997, Hernandez *et al.* 1999, Martín *et al.* 2000, Oliveira *et al.* 2002).

Faecal analysis, a more dependable evidence for the food (McEwen 1978), shows that Nilgiri Wood Pigeon feeds on fruits of different size, leaf buds, flower, snail, coleopteran grub and soil. 85 samples showed that the Nilgiri Wood Pigeon acted as a seed predator for many plants as the seeds were crushed. A sizeable number of intact seeds were also obtained, suggesting that they also act as a disperser for a large number of species. It contains muscular gizzards adapted for grinding food, and long narrow guts, unlike in some genera (example ; *Ptilinopus,* and *Ducula;* Goodwin 1983). However, in the pellets of the Nilgiri Wood Pigeon, intact seeds were noticed as in the pellets of the Maderia Laurel Pigeon *Columba trocaz* (Oliveira *et al.* 2002).

Direct observation of feeding, widely used to assess pigeon diets elsewhere (Snow & Snow 1988, Rosenberg & Cooper 1990, Oliveira *et al.* 2002), showed that the diet of the Nilgiri Wood Pigeon contained principally fruits while the other items were less frequent as secondary diet as observed in several tropical frugivores (Kannan & James 1999). Recent

studies on the nutritional value of fruits and frugivorous birds indicate that most of the birds are unable to subsist on an exclusive diet of fruits (Herrera 1984), as fruits are less in protein content. Hence, the frugivores were moving on to mixed diet with invertebrates (Levey & Karasov 1992). The proportion of invertebrate diet may vary depending upon the energy requirements of a species such as breeding and moulting (Kannan & James 1999). In summer, most of the rain forest birds start breeding and once the breeding is over they undergo moulting and hence, during this period they need protein rich food such as invertebrates. In the case of Nilgiri Wood Pigeon also it was the same. Pigeon diets contain soil and grit (Griminger 1983, Ali & Ripely 1987, Jarvis & Passmore 1992, Sanders & Jarvis 2000, Dhondt & Hochachka 2001). Frequency of feeding on soil was high in the breeding season, when they require more calcium for eggshell and crop milk production (Griminger 1983, March & Sadleir 1975, Sanders & Jarvis 2000). The present observations on the diet of the Nilgiri Wood Pigeon confirm the earlier findings on the pigeons.

Nutrient intake would be better balanced, if the birds fed on several fruit species than on a single one, since a mixed diet could increase the possibility of extracting specific nutrients (Jordano 1992).

Fruiting trees and frugivory relationship explained various attributes such as fruit colour, weight, accessibility, nutrition and seed size (Willson 1986, Balasubramanian 1990). The colours of fruits serve to advertise them to birds, having good colour vision. The colour preference of the Nilgiri Wood Pigeon shows that they preferred black fruits the most followed by red. It may be noted that many bird-fruits of the south Indian forests are black (Balasubramanian & Maheswaran 2003). Such preference was reported in South Africa (Knight & Siegfried 1983), Costa Rica and Peru (Wheelwright & Janson 1985), and Panama (Howe & Smallwood 1982). While in French Guiana, birds prefer Purple-black (Charles-Dominique *et al.* 1981). In the case of Pacific Pigeon, the preference was for red followed by Black (McConkey *et al.* 2004). Balasubramanian (1990) reported red as the major fruit colour in Point Calimere. Vijayan (1975) observed Bulbuls preferring red and yellow fruits and Maheswaran (2002) showed that Malabar Grey Hornbill used mostly purple fruits. Most of the bird's choice is purple-black and red. Thus it seems to be

universal and correlates with their good discrimination of red wavelengths (Gautier –Hion *et al.* 1985). Various authors suggested that fruit colour and size were interrelated, small size fruits are purple black and red.

The Nilgiri Wood Pigeon consumed mainly berries as recorded in most of the South Indian forest frugivores (Balasubramanian & Maheswaran 2003). It may be noted that berry was more abundant than drupe.

The size of fruits preferred by the Nilgiri Wood Pigeon varied, but most of them were about 10-20 mm. Fruit size selection apparently is depended mainly on the throat size (Sabatier 1983, Gautier –Hion *et al.* 1985). Hence, most of the small to medium size fruits were fed by the Nilgiri Wood Pigeon as in the Pacific Pigeons (Meehan *et al.* 2002, McConkey *et al.* 2004).

The Nilgiri Wood Pigeon fed on fruits that fell mainly under the weight class of 0.01- 4 gm. However, the mean weight was 3.1 $\pm$ 4 gm. The mean weight of fruits at Kukkal was 1.10 $\pm$ 0.50 gm. The fruit weight in Palni Hills was similar to that reported in the evergreen forest by Ganesh (1996).

The vertical strata of feeding varied according to the abundance of fruit. However, the Nilgiri Wood Pigeon preferred the upper canopy as the rain forest Pigeons of Australia (Crome 1975a, b). The Nilgiri Wood Pigeon fed mostly on the edges of the tree canopy mainly because of the availability of fruits and, foliage cover to avoid predators. It may be noted that tropical forest trees contained fruits along the small axes (twigs).During food scarcity, flocks of birds fed on the wind fallen fruits and snails as noted by Ali & Ripely (1987). Apart from this, the ground stratum was used to feed on invertebrates or soil to compensate nutritional and calcium requirement during the breeding seasons. This is especially for the development of gonad, egg shell (Kannan & James 1999) and production of crop milk in pigeons (March & Sadleir 1975, Griminger 1983, Sanders & Jarvis 2000). Soil feeding was reported in various species (MacClean 1974, Graveland 1996, Perrins 1996). Band –tailed Pigeon used grits throughout the year (Neff 1947), which it obtained at

roadsides and some mineral sites (March & Sadleir 1975, Sanders & Jarvis 2000) and, the phenomenon was similar in the Nilgiri Wood Pigeon also, but the level of usage differed between seasons, probably depending on the requirement of calcium.

Foraging method is important in determining the size of food (Remsen & Robinson 1990, Reacher *et al.* 2002). The Nilgiri Wood Pigeon preferred gleaning method as in many other tropical species (Innis 1989, Recher *et al.* 1995). Ford *et al.* (1986) found that more than 50 % species of birds in Australia used gleaning as the predominant method, as it involved least energy expenditure (Moermond & Denslow1983, Remsen & Parkerii 1984).

Food handling technique has important implications for plant - frugivore interaction (Howe & Smallwood 1982, Moermondt & Denslow 1983, Levey 1987). Engulfing and biting were observed in the Nilgiri Wood Pigeon as in many frugivorous birds (Remsen & Robinson 1990). However, it depended mainly on the fruit and seed size as reported earlier by various authors (Levey 1987, Symes & Perrin 2003).

Plant phenological studies are fundamental to understand the forest as a resource base for dependent species, populations and communities. Tropical plant communities display conspicuous seasonal pattern in vegetative and reproductive phenophses at both community and species levels (Frankie *et al.* 1974, Williams – Linera 2003). Hence, emphasis was given to the phenological studies at Kukkal, the intensive study area. Ripe fruits were present round the year with a peak in July in both the years, after the onset of south- west monsoon. Similar pattern was reported in many tropical forests (Sun *et al.* 1997, Kannan & James 1999, Griz & Machado 2001, Kimura 2003, Bleher *et al.* 2003, Sundarapandian *et al.* 2005). After the heavy rains, the number of species fruiting decreased so also the total fruit production. In the drier months, the fruit abundance was mainly due to *Olea glandulifera* and *Daphniphyllum neilgherrense* which served as keystone species of the Nilgiri Wood Pigeon. Rainfall had a significant positive correlation with fruiting at Kukkal, as reported for several other tropical forests (Murali and Sukumar 1993, Ganesh 1996, Kannan and James 1999, Sundarapandian *et al.* 2005). Total monthly rainfall and the number of rainy days, when considered together, had only a weak correlation with number of species fruiting,

whereas total fruit production had a significant relation. In the case of dry forests, total rainfall and number of rainy days stimulated fruiting (Balasubramanian 1990, Nirmala 2002, Murali & Sukumar 1993, Sundarapandian *et al.* 2005), whereas in the case of montane forest, as in Kukkal, fruiting was close to the onset of rainfall or at the onset of early rainy season (Ganesh 1996, Sun *et al.* 1996, Griz & Machado 2001, Kimura *et al.*2001). These phenomena could be attributed to enhance dispersal, escape predation and avoid pathogen infection (Prasad & Hegde 1986, Sundarapandian *et al.* 2005).

Total number of species in fruit at Kukkal significantly correlated with both maximum and minimum temperatures. However in the wet evergreen forests of the Southern Western Ghats, correlation was only with minimum temperature (Ganesh 1996). The number of species in fruit had significant correlation with the relative humidity. But total fruit production had only a weak correlation as in the evergreen forests in the Southern Western Ghats, reported by Ganesh (1996).

A universal tendency for tropical forests to fluctuate seasonally in fruit production with abundance peaks and period of scarcity has been established in South-East Asia (Leighton & Leighton 1983, Kannan & James 1999, Maheswaran 2002). Fruiting plants that provide critical resource for frugivores during the period of scarcity are called keystone plant resources (Leighton & Leighton 1983, Terborgh 1986a, b). They are of great ecological significance, because they appear to set the carrying capacity of the frugivores (Terborgh 1986a, b). In most of the tropical forests, Moraceae family, *Ficus* spp act as keystone species (Maheswaran 2002, Kannan & James 1999), whereas in the montane forest only a single species of *Ficus* (*Ficus macrocarpa),* was present and, its fruiting did not coincide with the lean season. Its place is taken were by *Olea glandulifera* (Oleaceae) and *Trichillia connoroides* (Meliaceae) which act as keystone species in the montane shola forest. Meliaceae was identified as a keystone resource for Hornbills in a Bornean lowland rainforests (Leighton & Leighton 1983, White 1994). Lauraceae and Daphniphyllaceae are lipid rich fruits and these species act as an important food item in breeding season for various frugivores in India (Kannan & James 1999, Maheswaran 2002). In most of the

Lauraceae family, fruiting was observed from April to June, which coincided with the breeding of birds (Powlesland *et al.* 1997).

Frugivores that rely on these keystone resources may be vulnerable to change in fruit supply resulting from the influence of climatic change on plant phenology (Foster 1982, Corlett & LaFrankie 1998), increased deforestation and fragmentation (Bleher *et al.* 2003).

Frugivorous birds move and migrate, tracking fruit resources (Leighton & Leighton 1983, Levey 1988, van Schaik *et al.*1993). In temperate region, migratory frugivorous birds which have finished breeding in the north arrive when fruits are abundant (Herrera 1984). In subtropical and tropical regions, where most of the temperate migrants over winter, fruiting occurs during this period. However, these migrants also move locally tracking food resources (Loiselle & Blake 1991). Local movement of resident frugivorous birds with in their habitats has already been reported (Levey, 1988, Leighton & Leighton, 1983, Loiselle & Blake, 1991, van Schaik *et al.*, 1993, Vijayan *et al.* 1999), although the destinations, seasonality and periodicity have not been clarified for the most part. In South-East Asia, a tropical montane area has been noticed as a destination for migratory frugivorous birds (Corlett 1998). Leighton and Leighton (1983) reported that the number of inhabiting hornbills and pigeons decreased with decreasing number of fruiting species in a lowland forest of Borneo. They suggested montane regions as one of the destinations of the disappearing birds. During the prolonged periods of dryness and food scarcity, Columbiforms might easily disperse to neighbouring forests in the ecotone of the dry and moist zones (Rivera- Millan 1992). Wells (1985) noted that in the Greater Sunda regions, frugivorous birds including temperate migrants, often flocked in montane regions, and suggested that fruit resource conditions might be more comfortable in the montane regions. However, no provable study has been reported associating a seasonal change in fruiting conditions with seasonal dynamics of frugivorous birds in montane regions of South-East Asia (Corlett 1998).

The resource use pattern suggests that the Nilgiri Wood Pigeon which live in a limited area and habitat are flexible and exploit each food resource as available. This flexibility in diet

was demonstrated by the strong seasonal changes in niche breadth. The optimal foraging theory predicts "less energy spent with maximum gain"(Goldstein 1990). Hence, selection of foraging method is important for long - term survival of a species. Niche breadth of the Nilgiri Wood Pigeon narrows with their diets in response to a high availability of fruits and they broaden their diet to include other plant parts when fruits are scarce. These observations suggests that diet of the Nilgiri Wood Pigeon is quite flexible, adapted to exploit the available resources as in Maderia Laurel Pigeon (Oliveira *et al.* 2002). Such evolutionary adaptations make the species more successful, although it is a habitat specialist. The flexibility is shown with in the given restricted habitat.

The Nilgiri Wood Pigeon during low fruit abundance in the study area, moved out to other areas where the fruits were abundant. Frequency of their sightings had significant correlation with fruit abundance. Fruit eating birds generally have to deal with strong spatiotemporal patterns that will affect the way they use their habitat (Herrera 1984) and suitable changes in resources such as berry density may promote changes in habitat use (Cody 1985). Seasonal patterns were observed in the diet of Maderia Laurel Pigeon; when total abundance of fruits in the forest decreased, birds shifted from trees to the ground and shrub layers (Oliveira *et al.* 2002). Innis (1989) showed that foraging habits of pigeons in subtropical forests in Australia were largely opportunistic; the birds used whatever fruits were available. Crome (1975) identified the same pattern for several Australian Columbid species.

Usually the Nilgiri Wood Pigeon forage in flocks which varied from 6 to 24 individuals and sometimes the number may go up to 45. Such flocking for feeding was reported in other tropical pigeons (Recher & Date 1988), as flocking would reduce predators. While feeding on soil, it prefers to peck mostly around the dilapidated buildings closer to the forest edges and cuttings on the sides of the road, where the forest is divided into fragments. Preference to the premises of dilapidated buildings for ground feeding, may be because of the probable high content of calcium in the soil.

The findings of the present study on the Nilgiri Wood Pigeon give an understanding of the relationship between this endemic threatened species and its relict forest habitat.

Conservation of the species depends on preserving all habitat types required to meet their resource needs throughout the year. Habitat loss and degradation are the major threats to the species. Moreover, the knowledge emanated from the study that pigeons use many flowering plants which occur more abundantly on the edges of the forest can be used to redefine the conservation value of these areas. Illegal hunting and lack of awareness on this species are other threats to the species as in the other pigeons (Crome 1975, Oliveira *et al.* 2002).

4.6. Summary

- In total, 1520 hrs of foraging observations were made.
- The Nilgiri Wood Pigeon fed on fruits of 34 species belonging to 26 families, flower and leaf buds of four species, and three taxa of ground invertebrates.
- In the 134 faecal samples analysed, 13 species of seeds were identified.
- Seventy percent of the diet of the Nilgiri Wood Pigeon was fruits of 10-20 mm in size and 3.1 + 4 gm in weight.
- The Nilgiri Wood Pigeon showed a definite preference to black berries.
- Nine species of plants were used more often, (47% of observations), in all the seasons.
- Fruits of the members of the family Lauraceae were the most preferred.
- *Trichillia connoroides* and *Olea glanuilifera* are the keystone species for the Nilgiri Wood Pigeon.

- The principal feeding technique was gleaning (76.25 %) and there was no significant difference in feeding method among the seasons with in the year or between the years.

- Feeding was mainly from twigs at the edges on the upper and middle canopy (> 6m)

- Nilgiri Wood Pigeon fed on ground invertebrates during monsoon which had significant correlation with the abundance of ground invertebrates.

- Frequency of feeding on fruits correlated significantly with fruit abundance.

- Fruit abundance had a significant correlation with the rainfall.

Chapter 5

Activity budget and pattern

5.1. Introduction

Activity budgets reflect a combination of factors including individual physical condition, social structure and environmental conditions. The amount of time allocated to various behaviours is therefore critical in understanding species ecological needs and pressures acting upon the individuals (Muzaffar 2004). Verner (1965, 1972) suggested that every species has an optimal activity budget specifically adapted to local environmental conditions. The ability to vary time and energy budgets is a "potent means of coping with a changing environment and retaining some degree of adaptation to it" (Pianka 1974). Reproductive activities (Verner 1965), food availability (Boxall & Lein 1989), ambient temperature (Verbeek 1964, 1972), day length (Gibb 1956), and habitat (Eberhardt *et al.* 1989) can vary temporally and all have been found to influence avian activity budgets. The degree to which activity budgets are influenced by daily and seasonal changes in the environment can provide important insight into the mechanisms by which an animal adapts to its environment (Engel & Young 1992).

Evolutionarily, animals have adjusted the seasonal regulation of life history stages to the seasonality of environments in which they live. Lack (1968) argued that selection favours individuals that rear their offspring during the season when productivity is maximized or mortality is minimized. It was confirmed in both theoretical and empirical studies (Price *et al.* 1988, Hau 2000). The control of reproduction is well documented for animals living at temperate, seasonal latitudes (Murton & Westwood 1977, Ball 1993, Wingfield & Hahn 1994). In contrast, the timing processes of animals inhabiting environments with only slight seasonal fluctuations such as the tropics are poorly understood (Dittami & Gwinner 1990, Levin & Wingfield 1992, Heidemann & Bronson 1994, Wikelski *et al.* 2000). The two most critical features in the seasonality of an environment are the amplitude of the seasonal fluctuations and the precision with which these fluctuations occur each year (Colwell, 1974, Wingfield *et al.* 1993). In general, there exists a decline from high to low latitudes both in

the amplitude of seasonal fluctuations and in their year-to-year precision. Consequently, life history states in animals from higher latitudes are controlled by rather rigid seasonal processes. In contrast, animals of lower latitudes need a more flexible physiological control of life history states to cope with seasonal variability (Wingfield *et al.* 1993).

Behaviour is one of the tools with which an animal exploits its environment. Through behaviour the animal moves in an organized and directed way and manipulates objects in the environment to suit its fundamental requirements (Kushlan & Jacobsen 1990, Wikelski *et al.* 2000)). Most behaviours are directed toward an organism's own welfare (Gill 1994).

The animals select particular habitats for specific types of activity (Palomares & Delibes 1992) and hence, when evaluating habitat use of an animal, the time of the day and the activity being performed by it should be considered. Therefore, the activity budget and pattern of a species are important for conservation (Robinet *et al.* 2003). The following section deals with important behaviour and activity budget pattern of the Nilgiri Wood Pigeon.

5.2. Method

The activity and time budget of the Nilgiri Wood Pigeon were studied by direct observation using Focal Animal Sampling and, or Scan Sampling Methods (Altmann 1974). Individual birds were followed as long as possible. Each bird was observed continually for five minutes followed by one-minute break. The following details were recorded: time of the day; foliage density (%) at the location of activity; activities such as feeding, preening, resting, calling, sunning and bathing. All the behaviours were classified into four major categories namely foraging, breeding, maintenance, and resting. Activity data were collected for 800 contact hours, 100 h for each season for four seasons in two years. The time spent by the bird for each activity in all the seasons in the daylight hours was recorded. Average of the observations on each activity for a particular hour of the day was calculated and compiled for a season and activity budgets were prepared for the bird.

5.3. Data analysis

1. The Analysis of Variance (ANOVA) was used to compare the activity budget of the Nilgiri Wood Pigeon in different seasons.
2. Pearson correlation was used to compare the activities of the Nilgiri Wood Pigeon in different seasons with environmental factors.

5.4. Results

The Nilgiri Wood Pigeon performed various behaviours that were broadly categorized into four major heads, namely foraging, resting, maintenance and breeding. The foraging behaviour includes food searching and feeding while maintenance behaviour includes various activities such as bathing, drying, oiling, preening, head scratching, sunning and calling. Resting is considered as a period when the bird does not do any of the activities mentioned under maintenance. The breeding behaviour includes pair formation, territory maintenance, nest building, nest defense and feeding chicks.

5.4.1. Activity budget

The Nilgiri Wood Pigeon spent more time for foraging (47.1 %) followed by maintenance (30.1 %) and resting (16 %; Fig. 5.1.). The total activity budget of the Nilgiri Wood Pigeon between the years had no significant difference. In summer, they spent 58 % time for foraging followed by maintenance 21%. (Fig 5.2) The time spent for foraging during both the monsoons was almost the same, 47 % (Fig.5.3; 5.4). It came down to 34.5 % during winter (Fig 5.5). The pre-breeding activities such as pair formation, calling, display were seen during winter and breeding activities such as nest building, egg laying, incubation and chick rearing were in summer. Details of foraging and breeding behaviour and their relationship with environmental factors are explained in the Chapters 4 and 6 respectively. The Nilgiri Wood Pigeon spent more than 25 % time for maintenance activities in all the seasons, except in summer.

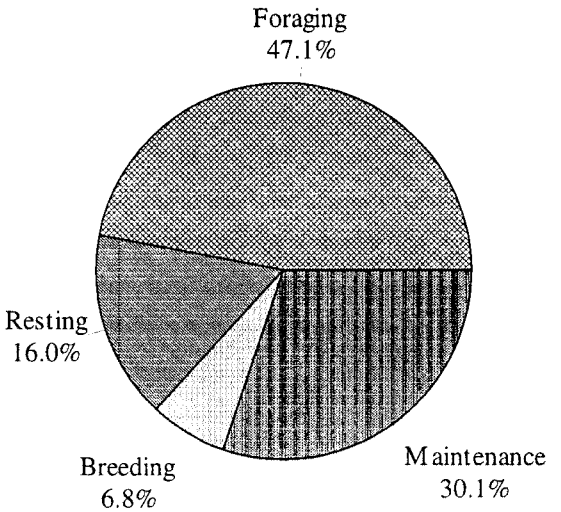


Figure 5.1 Total activity budget of the Nilgiri Wood Pigeon

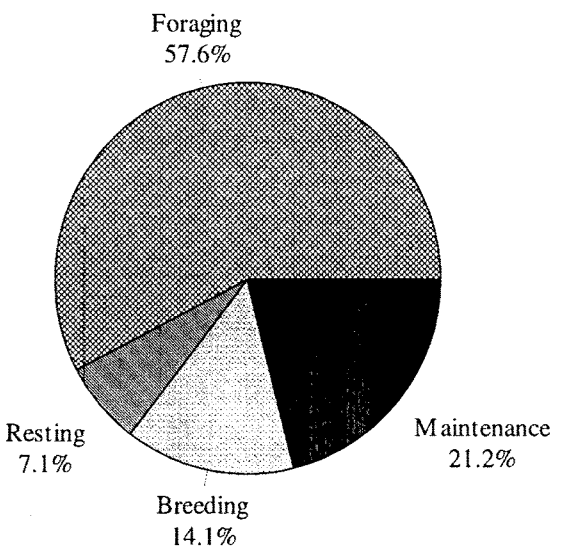


Figure 5.2 Activity budget of the Nilgiri Wood Pigeon during summer

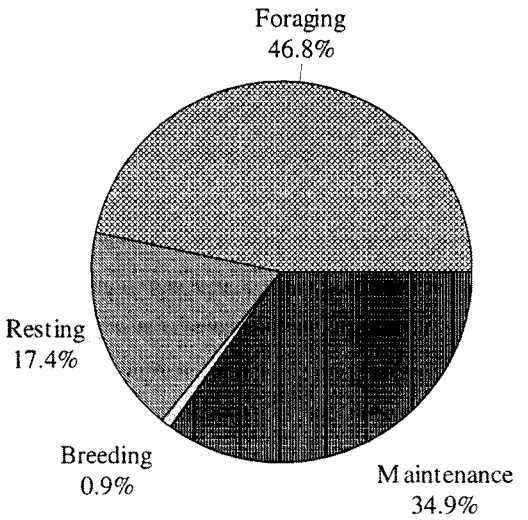


Figure 5.3 Activity budgets of the Nilgiri Wood Pigeon during south-west monsoon

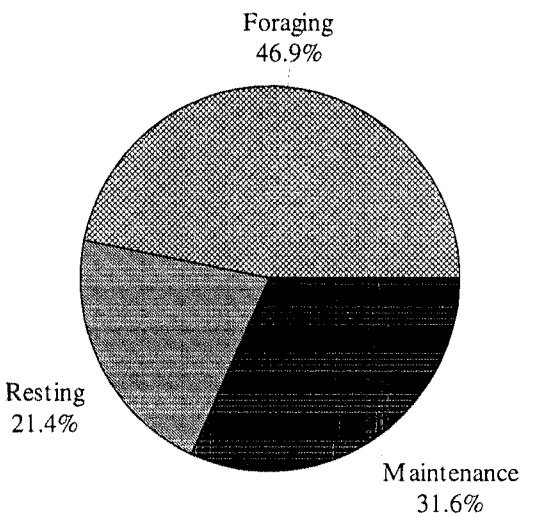


Figure 5.4 Activity budgets of the Nilgiri Wood Pigeon during north-east monsoon

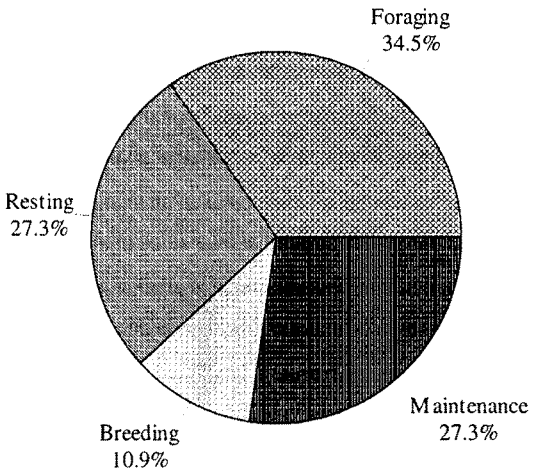


Figure 5.5 Activity budgets of the Nilgiri Wood Pigeon during winter

5.4.2. Daily activity pattern

The major daily activities of the Nilgiri Wood Pigeon were foraging, flight maintenance, resting and breeding, the last one only during the particular season. Activity started at 0500 h and continued up to 1959 h. The foraging activity of the Nilgiri Wood Pigeon showed a bimodal pattern with a major peak in the morning and another minor peak in the evening and the breeding activity also followed the same trend. Maintenance pattern showed a uni model pattern with a peak in the afternoon. In summer and south-west monsoon, feeding started slightly earlier and the peak was attained at 0800-0859 h (Fig 5.6; 5.7), whereas in winter and north-east monsoon, activity began at 0600 h and reached peak at 0900-0959 h (Fig 5.9; 5.8). The birds fed more in the morning hours and resting was less during this period in all the seasons. During the north-east monsoon and winter (September to January) light was available only after 0600 h which explains the slight delay in starting the activities. The activity pattern did not vary in all seasons. The major difference among the summer, south-west monsoon, north-east monsoon and winter was in the territorial activity. The peak feeding was in the late morning during cloudy days. The canopy cover was recorded in all localities and it was found that the Nilgiri Wood Pigeon preferred locations with above 75 % canopy cover for all activities, other than sunning.

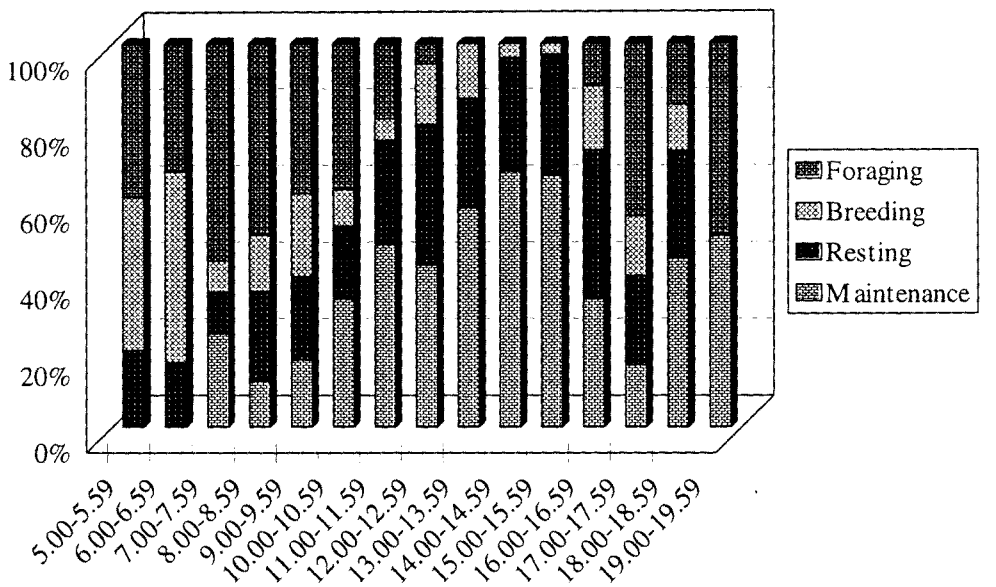


Figure 5.6 Activity patterns of the Nilgiri Wood Pigeon during summer

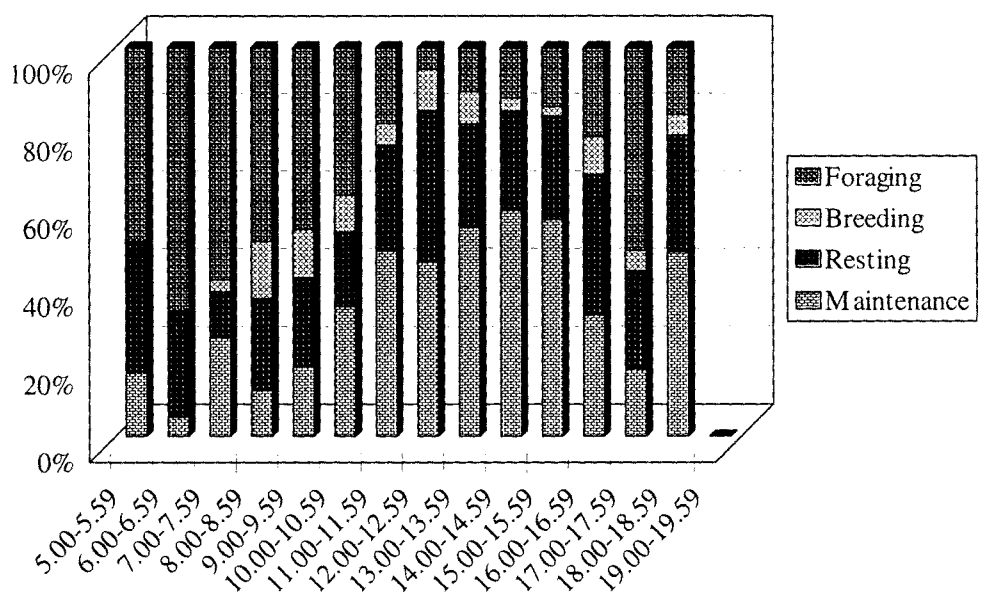


Figure 5.7 Activity pattern of the Nilgiri Wood Pigeon during south-west monsoon

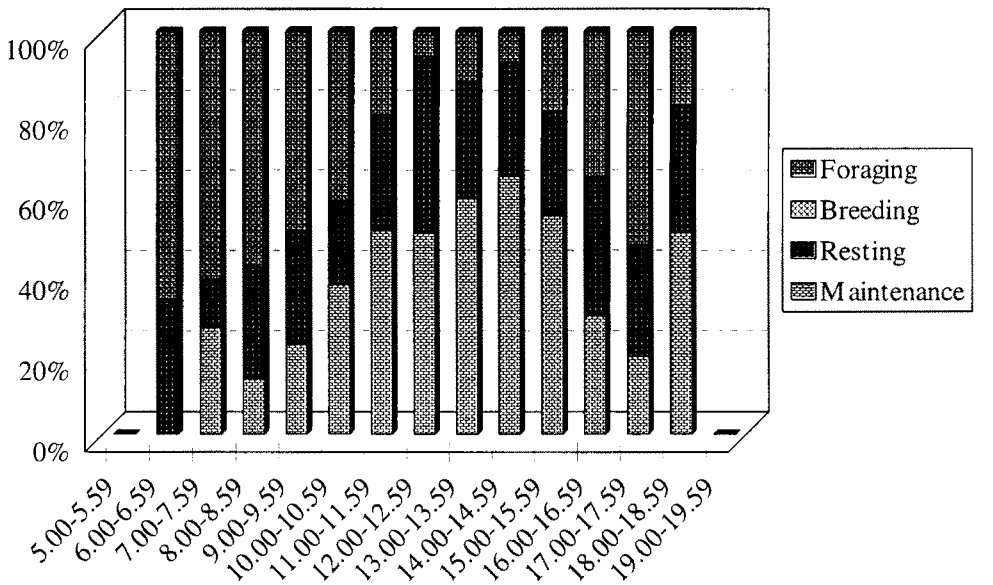


Figure 5.8 Activity pattern of the Nilgiri Wood Pigeon during north-east monsoon

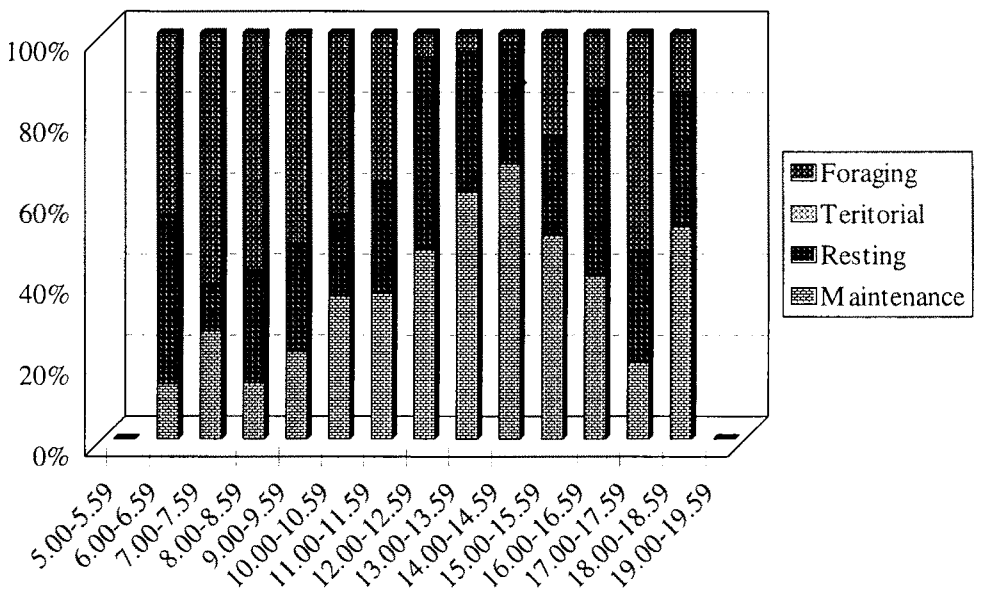


Figure 5.9 Activity pattern of the Nilgiri Wood Pigeon during winter

Some of the major interesting behaviours of the Nilgiri Wood Pigeon observed during the period are given below.

5.4.3 Various behaviours of the Nilgiri Wood Pigeon

5.4.3.1 Bathing

Foliage-bathing was observed in the Nilgiri Wood Pigeon. Once the rain starts, the bird tries to avoid the rain by moving with in the canopy. When it is little wet, it moves to a place (with in the canopy) where more water drips from the foliage. After a while, they returned to the more concealed area of the canopy. It was observed mostly between 1500 and 1700 hrs. While bathing only one bird was observed. Such type of bathing was reported in hornbills (Campbell and Lack 1985).

5.4.3.2 Drying

After bathing, the bird returns to the closed canopy and begins to dry itself. Mostly the bird shakes the body, flutters the wing, fans the tail and, fluffs the body feathers. This is repeated for ten to twenty minutes.

5.4.3.3 Preening

Preening is one of the important activities for feather maintenance. Once the feeding is completed and the crop is full, the bird sits on the closed canopy of trees and begins preening elaborately. Preening starts from the left wing. The bill is inserted at the base of the first primary and keeping the feather in between the mandibles pulls up to tip of the feather. It then goes to the second primary and repeats the same. Once the primaries are over, it goes to the secondaries. On completion of the preening of the primaries and scondaries of the left wing, it moves on to the right wing. On completing the wings, it moves on to the tail feathers and the body feathers. Preening mostly is in the late morning and afternoon and, before roosting.

Oiling and head scratching are recorded during long bouts of preening, For oiling, the bird reaches with its bill the oil gland at the rump in the dorsal caudal tract at the bottom of the

tail feathers. The secretion is collected with mandibles and applied to the feathers while preening.

5.4.3.4 Head scratching

The bird raises the leg up to the wing, while bringing the neck and head downwards. It then cleans the head, face and neck by scratching with the toes. It occurred mostly at the end of ground foraging or at the end of preening and extended only for a few seconds. However, it was observed very rarely.

5.4.3.5 Sunning

The bird comes out and sits on the edges of the forest and wattle plantation during early morning, especially during winter and misty days. It slightly raises the wings and perches on the top of the canopy. Sunning and preening are observed together in many occasions.

5.4.3.6 Call

Three distinct types of calls were recorded.

a) Non breeding call: sounds like 'who do, who do' repeating for five to eight times during the non breeding season as reported by Ali and Reply (1987). A single call lasts for 10 to 23 seconds. Interval between one call and the next ranges between 15 and 30 seconds, calling interval being more in the afternoon than in the morning.

b) Breeding call: sounds like Langur "Poopo po, Popoo po, ..." for five or six times loudly. While calling, the bird's body shrinks up and down and the call is from the base of the throat. It is audible up to about 300 m. It is heard from the end of January to June, during the breeding period. Afterwards, the non-breeding calls start. However, during the breeding season, some non breeding calls also are heard.

c) Feeding call: call sounds like " ku-uu, ku kuu" uttered repeatedly during feeding and could be heard only for five meters. On sighting the observer (intruder), it stops the call and watches for a few minutes and again starts feeding. It is silent for another half an hour. Feeding call is slightly louder during the breeding season. Thejaswi (2004) has also reported this kind of call.

5.4.3.7 Drinking

The bird was observed drinking, during the present study, only from the tree holes where rainwater was present. However, it is reported that the Nilgiri Wood Pigeon normally drinks water in the streams and water pools (Ali & Ripley 1987). In the present study period, it was noticed that the bird came to the streams for feeding on the snails and did not drink water.

5.4.3.8 Feather fluffing

The bird fluffs up the feathers giving the appearance of a ball and sits idle. Subsequently, at times it starts preening. This is common during misty days in winter and also during rainy days once the crop is full.

5.5. Discussion

Various behaviours of the Nilgiri Wood Pigeon, such as feeding, maintenance, and breeding were studied for two years. Activity budget of the Nilgiri Wood Pigeon showed that, it spent more time for feeding followed by resting in all the seasons, a trend similar to all the tropical frugivores (Crome 1975a, Recher & Date 1988, Salinas - Melgoza & Renton 2005). It has been reported that through behaviour the animal moves in an organized and directed way and manipulates objects in the environment to suit its fundamental requirements (Huntingford 1984).

Breeding behaviours of the Nilgiri Wood Pigeon, such as calling, nest building, pair formation were observed only in the late winter and during summer while in the other seasons they were absent. It was noted that when the Nilgiri Wood Pigeon started breeding activities, the mean monthly temperature was high while the total rainfall was less, as reported in many other frugivorous pigeons (Crome 1975a, b, Recher & Date 1988).

Except the breeding season (summer and south – west monsoon in Kukkal), the Nilgiri Wood Pigeon spent 20 % of the total time for resting. During the breeding season it required more energy and fed more. It is in line with the findings on many species reported earlier (Gibson 1978, Powlesland 1981).

The Maintenance activities in Nilgiri Wood Pigeon varied from 21 % to 35% of the total time; it was less in summer and high in south-west monsoon. During the south-west monsoon, fruit availability was more and the time required for foraging was comparatively less than in other seasons and hence, the birds could spent more time for maintenance.

The Nilgiri Wood Pigeon showed the typical pattern of daily activity of diurnal tropical birds, with peaks of activity in the morning and the late afternoon. This may be for avoiding high-metabolic activities (flight and foraging) when the temperature is the highest (Powlesland 1981, Robinet *et al.* 2003). They spent 47 % time for foraging, and the foraging activity had two peaks; one major peak in the morning and the other minor peak in the evening, as observed in other birds (Morton 1967, Gilardi & Munn 1998). The limited time spent on foraging was also consistent with the abundant food supply, which allowed the birds to stop feeding for several hours in the middle of the day. This type of bimodal pattern of feeding is common in many bird species (Boxall & Lein 1989, Engel & Young 1992) and is apparently adaptive for accumulating overnight energy reserves immediately before roosting and then replenishing depleted reserves the following morning (Murton & Westwood 1977).

The Nilgiri Wood Pigeon spent comparatively more time on social activities, such as vocalizations and agnostic interactions in the early and late hours of the day. In the mid days they preferred to rest and other flight maintenance activities as reported in the Red-eyed Dove, Ring-necked Dove and Laughing Dove (Kopij 2003).

The Nilgiri Wood Pigeon started their activity before 0600 h during summer, whereas it was only after 0630 h during winter and monsoon. These findings indicate a relation with sunlight as reported in many other species (Gwinner & Scheuerlein 1998). Light intensity varied seasonally according to the variations in cloud cover that were associated with the alteration between dry and rainy seasons (Gwinner & Scheuerlein 1998).

The Nilgiri Wood Pigeon wakes up before sunrise and roosts after sunset as many tropical birds (Ettingear & King 1980, Mugaas & King 1981). Active feeding at the top canopy was after the sunset during summer on many occasions. They seem to be avoiding the top canopy of the trees during summer, probably to avoid the bright sunlight.

5.6. Summary

- The major daily activities of the Nilgiri Wood Pigeon were foraging and maintenance.
- It spent maximum time for foraging (47 %) followed by flight maintenance (30 %).
- The time spent for foraging in both the monsoons was almost same (47%).
- The foraging activity of the Nilgiri Wood Pigeon showed a bimodal pattern with a major peak in the morning and minor peak in the evening.
- The maintenance activities showed a uni model pattern with a peak in the afternoon which coincided with maximum temperature.
- Breeding behaviour was seen in summer, south-west monsoon and winter.
- The pre-nesting activities such as pair formation, calling, display were noted during late winter.
- The localities used for all activities, other than for sunning, had above 75 % canopy cover.

Chapter 6

Breeding biology of the Nilgiri Wood Pigeon

6.1 Introduction

The most important aspect of an animal's life is the act of leaving offspring to succeeding generations (Perrins & Birkhead 1983) and contributing to its gene pool. Successful reproduction is a key for population recovery and stability of a species (Pimm *et al.* 1995, Perrins 1996). The success of an individual in breeding is determined by two important features such as time at which it breeds (breeding season) and fecundity (Lack. 1968). Most of the habitats worldwide exhibit temporal fluctuations in both abiotic and biotic conditions. Animals living in the variable environment breed only when the conditions are suitable for the production of viable offspring (Wingfield 1993). Reproduction is closely tied with favorable environmental conditions, as they have high metabolic rate and specialized dietary needs for raising offspring. Pigeons are symmetrical with environmental conditions because they do feed chicks with crop milk (Dawson *et al.* 2001, Dawson 2002).

Decline of a species is mainly by the poor reproductive success, particularly as a result of high rate of nest predation (Robinson 1992, Roth & Jhonson 1993, Hoover *et al.* 1995). Identification of habitat features associated with nest, nest – sites, nesting success and calculation of probability of success, are needed to develop a long-term strategy reversing a decline in population (Martin 1992). Competition for nest sites and nest predation exerts great influence on avian natural history traits including nest-site selection, clutch size, and nesting period (Martin 1995, Yanes & Suarez 1997, Brightsmith 2005 a, b).

One of the main determinants of breeding success in birds is predation (Martin 1995). It is estimated that about 30 % of nests are lost due to predation throughout the world (Martin & Clobert 1996, Batáry & Báldi 2004). Nest predation is usually higher in open – nesting birds compared to hole-nesting (Martin & Li 1992). As predation is a powerful selective pressure, birds evolve various anti-predator strategies, which may reduce nest losses.

A variety of factors can potentially influence nest and nest-site selection, including the availability of song perches, floristic composition, moisture regimes, amount and kind of feeding strata, amount of food, structure of plant community and risks of nest predation (Martin 1993 a). Nest site selection is a key component of habitat selection by birds (Hilden 1965), with important consequences for survival and reproduction of individuals (Cody 1985). Nest predation is often considered as a strong selective force in the evolution of nesting and dispersal strategies (Newton 1998, Martin 1992, 1995, Hakkarainen *et al.* 1998). Further, nest predation is known to influence life history traits such as fecundity and development rates (Martn 1995, 1996, Bosque & Bosque 1995, Julliard *et al.* 1997).

Food is often considered to be one of the most important factors influencing the production of offspring (Lack 1968, Martin 1987, 1992, Dias & Blondel 1996). The seasonality in breeding, moulting and movements in birds are often correlated with availability of primary food resources. Breeding of a species often coincided with peak availability of food resources needed to nourish the young and, also the adults to satisfy the energy demands for breeding (Stiles 1985, Ralph *et al.* 1995). Most birds breed and moult throughout the year in the tropics, but some are restricted to during certain times of the year based on the foraging niche of the species (Stiles 1980, Poulin *et al.* 1992, Ralph *et al.* 1995). Altitudinal bird migrations are also found to be in response to fluctuating food supplies and occur predominantly among nectarivores and frugivores (Loiselle & Blake 1991). In general, these birds have limited food choice and are highly mobile to locate new sources of flowers or fruits.

Vegetation structure at a habitat scale or location within a landscape may be more important than nest site characters such as concealment in reducing nest predation (Leimgruber *et al.* 1994, Donovan *et al.* 1997, Burhans & Thompson 1998) or parasitism (Morse & Robinson 1998). Furthermore, nest predation or brood parasitism may be related to landscape composition and structure (Robinson *et al.* 1995, Donovan *et al.* 1999, Thompson & Burhans 2004). Finally geographic location and abiotic and biotic characteristic at multiple scales can directly have impact on population growth (Thompson & Burhans 2004).

It is commonly assumed that the nest concealment plays an important role in the reduction of predation risk. However, not all studies support this assumption (Martin & Li 1992). It is also generally accepted that visually oriented predators or brood parasites can more easily find a nest than by observing parents (Gill 1994). Invisibility, inaccessibility and unapproachability of the nest contribute to its safety (Skutch 1976) and thus both intra and especially inter-specific differences in the nest safety could diversify the behaviour of parents (Bossema 1979).

Studies also show that shrub-nesting birds preferentially select nest sites with higher shrub densities to reduce the risk of predation (Joern & Jackson 1983, Martin 1993b). The relationship between density of shrubs and risk of predation may be more important in more open habitats where shrubs form discrete patches (Martin 1993b, Filliater *et al.* 1994).

The persistent nature of nest predation and the influence of nest sites on predation risk indicate that nest sites are important habitat components and that the nesting season can be critical period for maintenance of bird population. Conservation of species depends on knowing their breeding biology and identifying and conserving the habitat features that affect breeding productivity and survival (Martin 1993 a).

The reproductive strategy of Columbids is characterised by special traits and behaviours such as crop milk production, rapid growth, early maturity, multiple brood and extended breeding season (Blockstein & Westmoreland 1993). These factors allow them to respond rapidly to environmental fluctuations and offset low survival through increased recruitment rate (Bancroft *et al.* 2000, Rivera-Milán 2001, Rivera-Milán & Schaffner 2002, Rivera-Milán *et al.* 2003). Yet, some species of Columbids become endangered or extinct because they cannot survive the adverse deterministic and stochastic processes upsetting their population (Bucher 1992, Lind 1994, Rivera-Milán *et al.* 2003).

Information on breeding biology and habitat requirements of the Columbids are scanty. Only species such as Band-tailed Pigeon *Columba fasciata*, (Burger *et al.* 1989), White - crowned

Pigeon *Columba leucocephala* (Bancroft *et al.* 2000), and Morning Dove *Zenaida macroura* (Pace *et al.* 1952, Hass1980, Westmoreland & Best 1987) were well studied. Columbids in the tropical Old World were studied by Goodwin (1983). Rufous Turtle Dove *Streptopelia orientalis* (Wada 1994), African Green Pigeon *Treron* spp. (Cowles & Goodwin 1959), Pink-headed Fruit-dove *Ptilinopus porphyreus* (Balen & Nijman 2004), Turtle Dove *Streptopelia tranquebarica* (Browne *et al.* 2005), and White- winged Dove *Zenaida asiatica* (Small *et al.* 2005) were also studied. However, information on most of the Indian Columbids is scanty. Breeding biology of the Ring Dove *Columba palumbus* was studied by Rana (1975), and Laughing Dove *Streptopelia senegalensis* by Alagarrajan (1991) and Nirmala (2002). In the case of Nilgiri Wood Pigeon, only incidental information on the breeding is available (Terry 1887, Baker 1934, Subramanya *et. al.* 1994, Thejaswi 2004). This chapter deals with the breeding season of the Nilgiri Wood Pigeon and the factors affecting it, the nest-site characters (habitat features), details of nesting cycle and factors influencing breeding success.

6.2. Methods

Breeding biology of the Nilgiri Wood Pigeon was studied in Kukkal in the Palni Hills from April 2002 to August 2004. 40 ha shola, 10 ha each of wattle, pine and eucalyptus plantations, five ha shola regeneration plot, and 4.5 ha of a shola fragment were selected and the nest searching was conducted daily, spending 40 hrs in a month. An average 100 hrs were spent in a month inside the shola forests for detailed observation during the breeding season. Occasional observations were made in the evergreen forests and coffee plantations in the Silent Valley area, while the Thai shola was surveyed during the breeding season. Nests were located by observing birds carrying nest materials or food to the nestlings. A circular plot (15 m radius; about 0.07 ha) centred on the nest site was laid for every nest and all the nest details were recorded following the established methods (Titus & Mosher 1981, Hullsieg & Becker 1990, Bechard *et al.* 1990). Variables were set at three levels – nest, nest-substrate and nest- patch with the following details:

(1) Nest: height from the forest floor, position in the canopy, supporting branch thickness (cm), shade over the nest, concealment;

(2) Nest substrate: tree species, height, GBH (Girth at Breast Height), size (small, medium and large), cover over the nest (in %), climber species, climber cover on the nesting tree (in %);

(3) Nest patch : canopy cover and ground cover (visually estimated in %), number of trees, number of shrubs, distance to nearest tree, distance to trek path or road and distance to water; disturbances such as grazing, firewood collection, cattle dung, fire, foot path, logging and pole cutting in the surrounding of nesting area.

The size classes of nest tree were described on the basis of GBH: up to 15 cm as small, 16-45 cm medium, and above 45 cm large.

Nest concealment: it was estimated by viewing the nest at a distance of 2 m, 5 m, 7 m and 10 m in each of the four cardinal directions (Martin & Roper 1988). Based on the number of points where the nest was not seen, the concealment was evaluated as low (1-4 points), medium (5-8 points), high (9-12 points) and very high (13-16 points).

6.2.1. Random site

The 10 ha plot established for nest searching was divided into 100 grids (20 × 50 m). Grids were plotted on an enlarged topographic map of the study area and numbered and 20 grids were selected as random sites by lot system. To test nest-site selection, except for the nest measurements, all nest patch variables were recorded with one tree at the centre of the 15 m radius plot as done for the nest and, these were compared with similar measurements recorded at nest sites.

6.2.2. Nest Monitoring

Nest found during construction or early incubation was visited regularly at an interval of two days. Temporal variation in survival rates was estimated in four days blocks: eg early incubation (days 0-4) vs. late incubation (days 10-15) or early nestling (days 16-24) vs. late nestling (days 25-31) periods (Manly 1986). Exposure time (nest days) was calculated

using the last observed active date and first observed inactive date for nests with known fate (Manolis *et al.* 2000).

Nest survival rate was estimated using Mayfield's method (Mayfield 1975) as modified by Johanson (1979), which is given below:

From exposure time (e) and number of nest losses observed (I),
Estimated daily survival rates (DSR=1-I/e)
For incubation (I=15 days),
For nestling (I =16 days),
For nesting period (32 days).

The nearest tree to the nesting tree was tagged and numbered. The growth of the nestling was monitored in most of the nests whenever possible. Detailed observations at nests were made from a hide placed eight to ten meters away from the nesting tree.

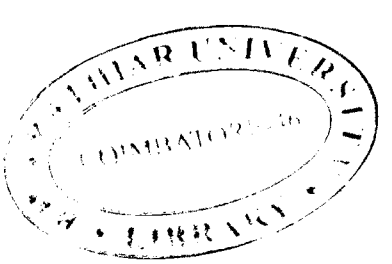
6.3. Data analysis

1. Pearson Correlation was used to compare the nest abundance of the Nilgiri Wood Pigeon in different months with environmental factors and food availability.

2. Regression analysis was employed to develop a model of the relationship between environmental factors and breeding season.

3. The Mann Whitney U test was used to compare nest-site characters of the Nilgiri Wood Pigeon with random site characters and, also for comparison between successful and unsuccessful nests.

4. Principal Component Analysis was used to identify the patterns of covariation among the nest-site parameters. It reduced a large number of covarying variables into a smaller number of orthogonal components that accounted for the nest site data.



5. Discriminant Function Analysis was done to find out the important factors which discriminate the nest site from the random site.

6. Lvlev's Index of Selectivity (Lvlev 1961) test was carried out to understand the species-specific utilization of nesting trees.
   Lvlev's Index of Selectivity = U – A / U + A where "U" denotes percent utilisation of species and "A" denotes percent availability of corresponding species. Selectivity values of Levlevs range between -1 and +1, where – indicates avoidance while + indicates preference.

6.4. Results

6.4.1. Breeding season

Breeding season in this study is considered as the period from pair formation up to fledging. It extents from January to September (Fig. 6.1). Pair formation was in peak during February. Nest building and egg lying continued up to July with a peak in March-April (15 nests). In 2003, the peak nesting was in March, whereas in 2002 and 2004 it was in April (Fig.6.2). Chicks emerged mostly at the onset of the south-west monsoon (June). Only a few nests were active during July to September. Clutch size of the Nilgiri Wood Pigeon was one.

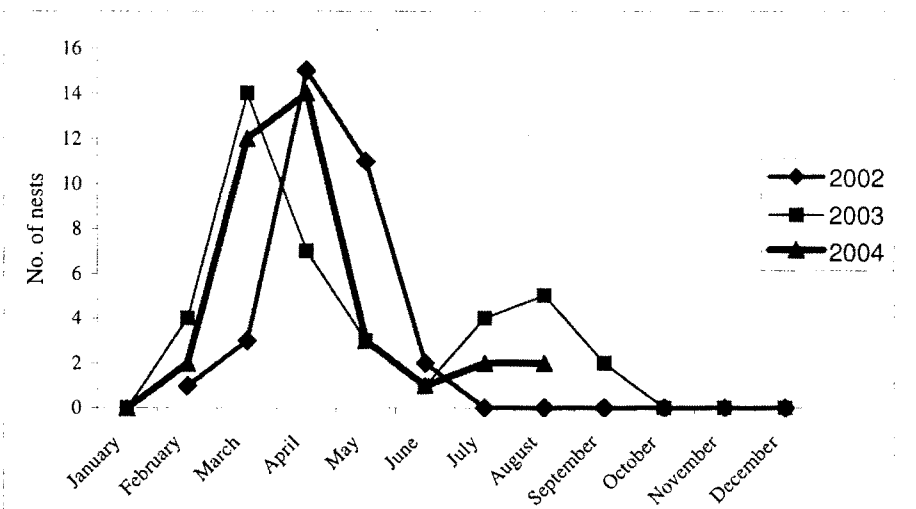


Figure 6.1 Number of nests of the Nilgiri Wood Pigeon at Kukkal during 2002 to2004.

Breeding phases	A-02	M	J	J	A	S	O	N	D	J-03	F	M	A	M	J	J	A	S	O	N	D	J-04	F	M	A
Pair formation										*	*	*										*	*	*	
Nest building	*	*									*	*	*	*	*	*							*	*	*
Incubation	*	*	*									*	*	*	*	*	*							*	*
Nestling		*	*	*									*	*	*	*	*	*							*
Fledgling			*	*											*	*	*	*							

* - peak activity

Figure 6. 2 Chronology of breeding of the Nilgiri Wood Pigeon

6.4.2. Factors affecting breeding season

6.4.2.1. Environmental factors

It appears there was no much correlation between the number of nests of the Nilgiri Wood Pigeon with the number of rainy days (Fig.6.3) and total rainfall (Fig.6.4). Temperature variation was not high between months but the Nilgiri Wood Pigeon preferred nesting in the comparatively hotter months (Fig.6.4). The breeding activity had a week correlation with temperature (Fig. 6.5.). Humidity in the study area had little variation between breeding and non-breeding seasons.

6.4.2.2. Food availability

The food abundance was comparatively low during the incubation period but when the chicks emerged out the fruit availability was more. The maximum fruit availability was in June and July which coincided with maximum emergence of chicks. The total fruit production and the number of nests had positive correlation (Fig. 6.6.). Lauraceae trees contributed maximum food in June and July.

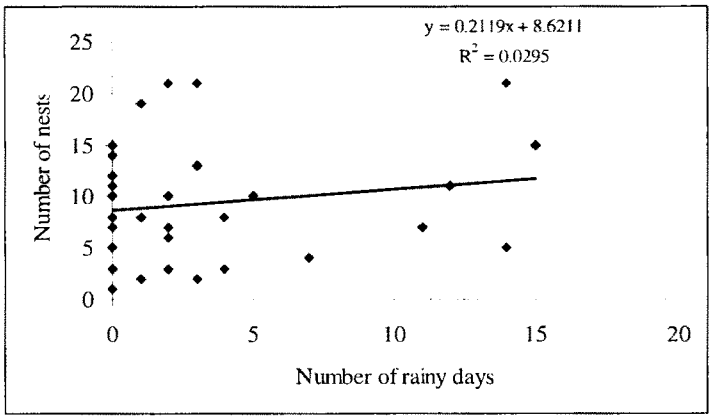


Figure 6.3 Relationship of number of nests of the Nilgiri Wood Pigeon and number of rainy days at Kukkal during 2002 to 2004

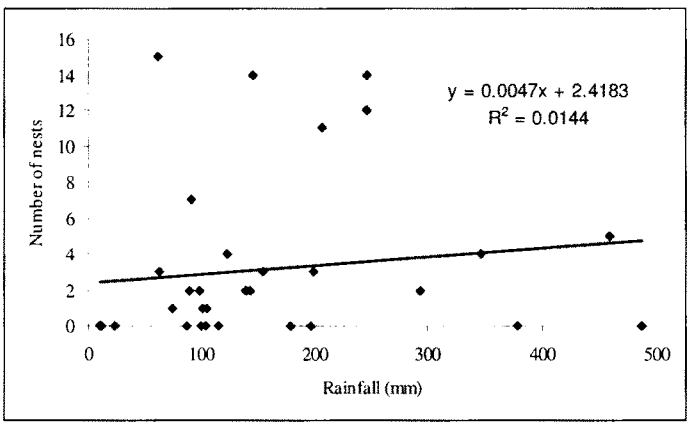


Figure 6.4 Relationship of number of nests of the Nilgiri Wood Pigeon and total monthly rainfall in Kukkal during 2002 to 2004

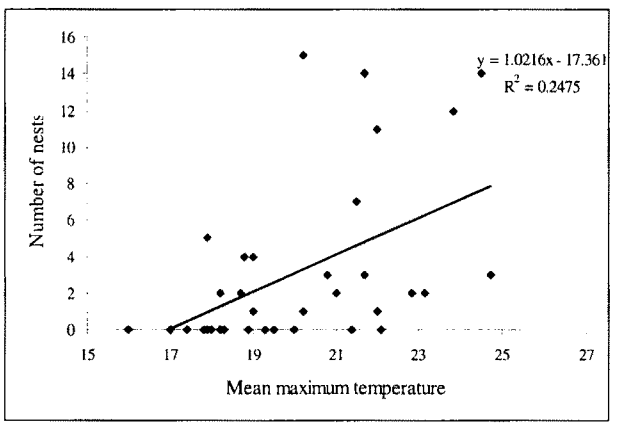


Figure 6.5 Relationship of number of nests of the Nilgiri Wood Pigeon and mean maximum temperature at Kukkal during 2002 to 2004

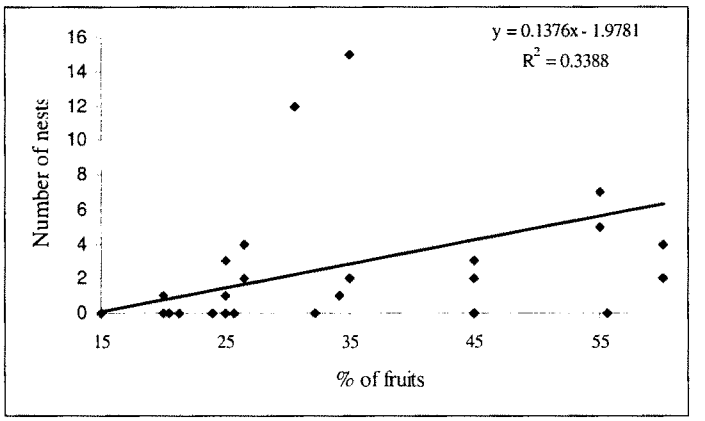


Figure 6.6 Relationship of number of nests of the Nilgiri Wood Pigeon and fruit abundance at Kukkal during 2002 to 2004.

Apart from the fruiting pattern of trees, phenology of nesting trees can also influence the breeding of birds. During the first year of study, 90 % of the nests were on *Ventilago bomaiensis* liana on trees. The Nilgiri Wood Pigeon had its nest building, egglaying and incubation during the same period when young tender shoots of this species were abundant. It is found that there is a positive correlation of nesting with abundance of tender leaves of *Ventilago bomaiensis* (Fig. 6.7).

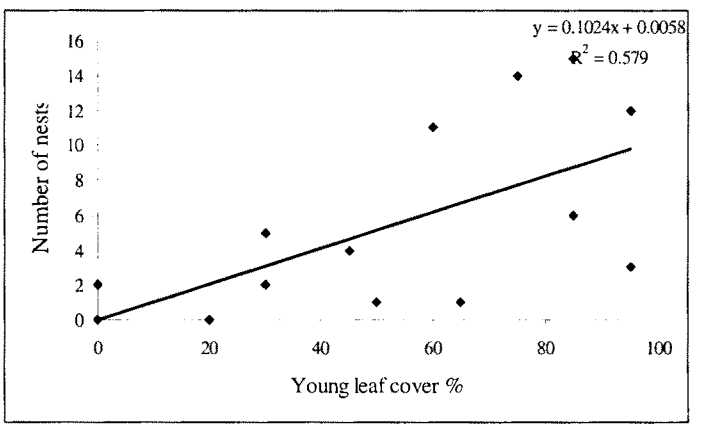


Figure 6.7 Relationship of number of nests and phenology of the *Ventilago* sp. at Kukkal during 2002 to2004.

6.4.3. Breeding biology

One hundred and eight nests were observed during the three breeding seasons from 2001 to 2004, out of which 106 were in the montane wet temperate forest, and two in the evergreen forest. No nests were observed in plantations such as wattle, pine, and eucalyptus in the higher altitude and coffee in the mid- altitude. Nests were observed in a loose colony.

6.4.4. Nest-site

The nests were on indigenous trees covered with thorny climbers such as *Ventilago* (80.58 %), *Rubus ellipticus* (14.56 %) and *Piper mullesua* (2.91 %). Only two nests were without the cover of climber but both had thick canopy cover. Nests were placed between four and eight meters above ground on medium sized trees nearby streams or any other small openings.

Nest – site variables of 103 nests at Kukkal were analysed. Mean nest height was 5.82 $\pm$ 2.76m, while mean nest tree height and GBH were 8.16 $\pm$ 4.0 m and 18.65 $\pm$ 17.93 cm respectively (Table 6.1.). Canopy cover was 79.7 $\pm$ 15.1 % and the ground cover 51.11% which was significantly differed from the random site ($U = 1065$, $P < 0.005$). The nest concealment was high in 35 % followed by medium in 29 % of nests. Seven parameters were significantly different between nest sites and random sites (Table 6.2); canopy cover and ground cover were of higher significance.

Table 6.1 Nest variables of the Nilgiri Wood Pigeon

Variables	Mean	(+)SD
Nest height (m)	5.82	2.76
Shade over the nest (%)	86.45	15.74
Nest concealment	high	*****
Nest tree height (m)	8.16	4.00
GBH of nest tree (cm)	18.65	17.93
Canopy cover (%)	79.70	15.12

Plate 4 Nest and chicks of the Nilgiri Wood Pigeon

Nest – a view from below

Chick in the nest

Fledgling

Table 6.2 Comparison of the variables of the nest-sites with random sites

Parameter	Nest-site (mean ± SD)	Random site (mean ± SD)	U
Canopy cover (%)	81.00 ± 15.63	73.18 ± 12.90	1065**
No. of trees	11.24 ± 5.89	16.39 ± 6.49	570*
No. of shrubs	32.21 ± 14.31	30.24 ± 11.96	1596
Ground cover (%)	58.71 ± 20.04	47.05 ± 16.62	1019**
Distance to trek path (m)	96.21 ± 365.18	327.19 ± 644.21	698*
Distance to water (m)	106.57 ± 163.12	357.18 ± 250.06	434*
Distance to human settlement (m)	892.28 ± 898.78	1194.06 ±1030.37	772*

* Significant at p value <0.05 level

** Significant at p value < 0.01 level

The first three principal components accounted for 57.18 % of the total variance (Table 6.3.). The first component was closely associated with nest tree height and nest height. The second component was associated with shade over the nest and nest tree canopy and total canopy cover and, the third component was closely associated with nest tree GBH. The Discriminant Function Analysis (stepwise) gave out two variables such as distance to water (0.69) and tree canopy (0.35), which discriminated the nest-site from random site.

The characters of successful and unsuccessful nests were compared to find out the factors influencing the breeding success of the Nilgiri Wood Pigeon. Thickness of branch supporting the nest and climber cover of the nest tree significantly differed between successful and unsuccessful nests (Table 6.4.). Nest site parameters, namely canopy cover, number of trees and ground cover also significantly differed among sites. The disturbance factor, namely distance to trek path had significant negative influence on the nesting success. Discriminant Function Analysis (stepwise) shows three variables as the key factors,

namely thickness of branch supporting the nest (0.74), canopy cover (0.54) and number of trees at the site (0.42).

Table 6.3 Factor loading of nest-site variables in the first three principal components

Variable	PC - 1	PC - 2	PC – 3
Distance to human settlement	-0.621	0.393	0.385
Distance to road (m)	0.348	0.0686	-0.219
Distance to water (m)	0.633	-0.177	0.229
Ground cover	0.0660	0.633	-0.261
Nest height (m)	0.902	0.0354	0.231
Nest tree GBH (cm)	-0.109	0.299	0.602
Nest tree height (m)	0.908	0.0962	0.237
Number of shrubs	-0.257	0.265	-0.406
Number of trees	0.636	-0.130	-0.165
Shade over the nest	0.277	0.830	0.0464
Thickness of supporting branch	-0.218	0.503	0.506
Tree canopy cover	0.237	0.793	-0.118
Climber cover	-0.175	0.621	-0.106
Canopy cover	0.396	0.760	-0.181
Eigen value	3.40	3.31	1.30
% Variance	24.29	23.64	9.25
% accumulated variance	24.29	47.93	57.18

6.4.5. Nesting trees

Nests were found only on trees in the shola forests. 103 nests were recorded on 102 trees. *Turpinia nepalensis* was the most common nesting tree species (22.55 %) followed by *Viburnum cylindricum* (11.76 %), *Phoebe paniculata* (9.80 %) and *Neolitsea zeylanica* (8.82 %; Table 6.5). The other trees were less frequently used. All the trees had liana cover at varying levels. Lvlev's Index for selectivity test was done to examine the species-specific

utilization and it showed none of the species was particularly preferred (Table 6.5). The '0' values denote neither preference nor avoidance.

Table 6.4 Comparison between the successful and unsuccessful nests of the Nilgiri Wood Pigeon.

Parameter	Successful nest (m + SD)	Unsuccessful nest (m + SD)	Z
Nest height (m)	7.01± 3.41	6.91 ± 2.64	-0.87
Thickness of supp. branch (cm)	14.88 + 5.36	10.06 ± 3.51	- 2.59**
Shade over the nest (%)	89.94± 7.14	86.66 ± 5.94	-1.19
Nest tree height (m)	9.87 ± 5.22	9.83 ± 3.51	-0.17
GBH of nest tree (cm)	17.27 ± 18.23	17.17 ± 4.72	-0.26
Nest tree canopy cover (%)	82.72 ± 9.55	77.77 ± 10.74	-1.49
Climber cover (%)	79.33 ± 14.58	56.44 ± 32.22	- 2.13*
Canopy cover (%)	86.28 ± 8.01	76.27 ± 10.51	- 2.45*
No. of trees	7.83 ± 6.76	18.61 ± 6.34	- 2.96**
No. of shrubs	21.56 ± 21.61	27.61 ± 9.50	-1.08
Ground cover (%)	66.11 ± 22.40	52.78 ± 17.59	- 2.16*
Distance to trek path (m)	244.83 + 477.75	25.66 ±19.12	- 3.07**
Distance to water (m)	155.61 + 206.69	105.38 ± 126.43	-0.24
Distance to human settlement (m)	868.36 + 840.70	301.22 + 598.09	-1.85

* Significant at p value <0.05 level

** Significant at p value < 0.01 level

6.4.6. Nest and nest building

The nest was a platform as in many other pigeons. The materials were dry twigs of about 7-8 cm length. Nest building was in the morning between 0700 and 0930 hrs. Both sexes

involved in nest building which continued for 4-5 days (n= 9) to complete. The nest was made only with twigs.

Table 6.5 Frequency of tree species used for nesting.

Nest tree species	% of use	Preference index
Antidesma menasu	0.98	-0.50
Beilschmiedia wightii	2.94	-0.92
Celastrus paniculatus	0.98	0.00
Chinonanthus zeylanica	0.98	-0.60
Cryptocarya stocksii	0.98	**0.00**
Debragassia velutina	0.98	-0.82
Glochidion velutinum	1.96	-0.73
Gomphandra coriacea	2.94	-0.45
Litsea wightiana	0.98	-0.67
Maesa indica	2.94	-0.98
Mahonia leschenaultii	2.94	-0.45
Neolitsea scrobiculata	3.92	-0.47
Neolitsea zeylanica	**8.82**	-0.89
Nothopodytes nimmoniana	2.94	-0.93
Olea glandulifera	6.86	-0.62
Phoebe paniculata	**9.80**	-0.89
Psychotria nilgiriensis	1.96	-0.95
Symplocos foliosa	4.90	-0.94
Syzygium densiflorum	4.90	-0.67
Tarenna asiatica	0.98	-0.67
Turpinia nepalensis	**22.55**	-0.53
Vaccinium leschenaultii	0.98	-0.96
Viburnum cylindricum	**11.76**	-0.64

6.4.7. Egg, egg – laying and incubation

The Nilgiri Wood Pigeon laid eggs in the morning between 0630 and 0900 hrs. Only one egg was laid, which was pure white. The average size of nine eggs is 38.4 x 28.8mm (Baker 1934). Incubation started immediately after laying and continued until hatching. Only one bird was present at the nest most of the times, and very rarely both.

The average incubation period was 15.89 $\pm$ 2.3 days (N=23) ranging from 14 to 18 days. The incubating birds never made any call or movement for three to five hours (n = 6 nests). Hatching success was 44.32%.

6.4.8. Nestling and brooding

The nestling of the Nilgiri Wood Pigeon was yellowish with black bill. The eyeballs were fully covered. Immediately after hatching, the parent at the nest fed the chick with crop milk. After three days, the colour of the chick changed into metallic black with a brown tinge and the neck checkerboard started appearing. The chick started moving from the nest after fourteen days and began perching on nearby dense bushes. The tail growth was observed on the ninth day. Both the sexes shared brooding and feeding with crop milk.

6.4.8.1. Frequency of feeding the nestling

Both the parents fed the nestlings. Feeding behaviour was observed in16 nests. A few nests could be observed only in the first few days, as they failed subsequently. Frequency of feeding crop milk decreased with the increasing age of the chick. However, in some cases it continued up to the 14^{th} day. The feeding rate of chicks slowly decreased with increasing age (Fig. 6.8.). The invertebrate diet of the chicks included soft-bodied molluscs. Grubs were also added subsequently. Once the chicks left the nest, it was difficult to observe the food consumed, because of the thick canopy cover.

6.4.8.2. Nestling period and nesting success

The average nestling period was 16.83 + 1.19 days with a range of 15-19 days, (N =12). The total fledging and nesting success was 36.84 % and 13.72 % respectively. Maximum nesting success (16%) was recorded in 2002 and minimum (12%) in 2004 (Table 6.7).

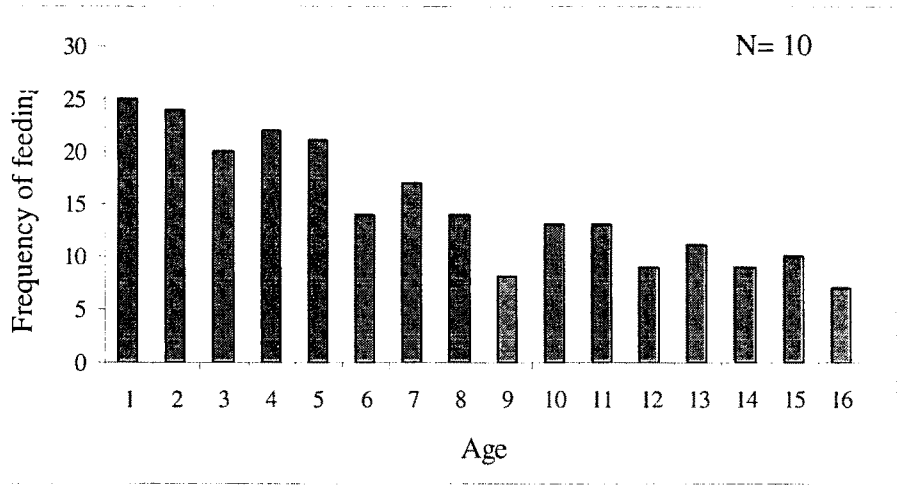


Figure 6.8 Feeding frequencies of the chicks of the Nilgiri Wood Pigeon.

Two nests were preyed upon by Large-billed Crow (*Carvus macrorhynchos*) and eggs from four nests were collected by the local people. One unhatched egg was noticed and 79.41 %(81) nests were preyed upon by unknown predators. The nest survival rate was calculated by May Field method and the daily survival rate was 0.48. Most of the nests failed in the late incubation and early nestling period (Fig 6.9).

Table 6.7 Summary of nesting of the Nilgiri Wood Pigeon at Kukkal

Year	2002	2003	2004	Total
Total number of eggs	31	37	34	102
Hatching success %	81 (25)	22 (8)	15 (5)	37.25 (38)
Fledging success %	20 (5)	62.5 (5)	80 (4)	36.84 (14)
Total nesting success %	16.1 (5)	13.5 (5)	11.8 (4)	13.72 (14)

Note: Figures in parentheses are number of chicks

6.5. Discussion

The Nilgiri Wood Pigeon nested in the shola forests but not in plantations (Somasundaram and Vijayan 2006); while other activities were observed even in the plantations (see habitat use Chapter 3 pp.). Nests were in loose colonies. The clutch size was one as in many other

Columbids in the world (Ali & Ripley 1987, Gibbs *et al.* 2001). Number of nests was higher in the drier months (March – May) and decreased with rainfall, which again is similar to that in most of the tropical birds (Lack 1968, Poulin *et al.* 1992, Padmanabhan & Yom- Tov 2000,). Relation between numbers of rainy days and number of nests was negative. Most of the years, the Nilgiri Wood Pigeon completed all the breeding activities before the onset of rainfall, whereas in 2003, it bred up to September possibly because of the less rainfall in the area. There was no significant relation between breeding seasonality and the relative humidity and temperature, probably because these parameters did not vary much throughout the year in their breeding habitats; the montane wet temperate forest ecosystem (Khan 1977, Nair & Khanduri 2001).

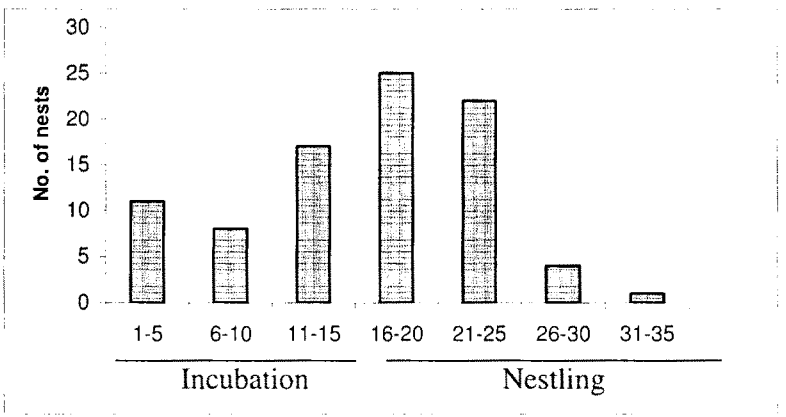


Figure 6.9 Rate of failure of nests during different periods of nesting.

Food is a crucial factor for breeding birds (Lack 1968), and the breeding activity tends to coincide with food abundance. This was found true in the case of the Nilgiri Wood Pigeon as the maximum fruit availability and number of chicks emerged from the nest had a strong correlation, as reported in many other species (Lack 1968) and in various tropical frugivorous birds (Guevara de Lampe *et al.* 1992, Poulin *et al.* 1992), including Columbids (Cramp 1972, Powlesland *et al.* 1997, Bancroft *et al.* 2000). In the case of the Nilgiri Wood Pigeon nesting activity coincided particularly with the abundance of Lauraceae fruits. Such association with particular fruits was reported in Torres Strait Pigeon *Ducula spilorrhoa* (Crome 1975a) and Resplendent Quetzals *Pharomachrus moicnno* (Wheelwright 1983).

The comparatively low abundance of fruits in the pre-nestling period appeared to be adequate to meet the requirements of the breeding birds, as the phenomenon was the same during both the years. Fruit abundance during the fledgling period appeared to be more critical; as the time of emergence of maximum chicks coincided with the peak abundance of ripe fruits. It may also be noted that Columbids are capable of multiple brooding and crop-milk production and they have a diverse frugivorous or granivorous diet and hence, complete synchronization of nesting events with foraging resource is not necessary to enhance their reproductive success (Rivera-Milán 1996, Westmoreland & Best 1987).

Vegetation structure around the nest and nest plant can also influence the breeding success of the birds (Martin & Roper 1988, Martin & Geupel 1993). In the present case more than 90 % of nests were on trees covered with the climber *Ventilago bomaiensis*. The nesting of the Nilgiri Wood Pigeon had positive correlation with abundance of young tender shoots of *Ventilago*. It is interesting to note that the bird is well camouflaged with colour of the young tender shoots which may save the incubating bird from aerial predators. While sitting quietly and motionless on egg or nestling, the Columbids appeared to rely on the concealment provided by their plumage colouration and the vegetation cover (Murton & Westwood 1977, Westmoreland & Best 1987, Martin 1992, Rivera-Milán 1996).

Nilgiri Wood Pigeon move in flocks of 6 to 40 birds depending mainly on the fruit availability in a particular area (Ali & Ripley 1987). Pair formation took place in the post winter season (December –January).

Nests were constructed on trees covered with thorny climbers such as *Ventilago*, *Rubus ellipticus* and *Piper mullesua*. Nests with greater thorny climber cover gave better concealment and also more chances to escape from the predation by macaques and squirrels and also the aerial predators. Nests were placed between four and eight meter height in medium sized trees nearer to the streams or any other small openings as observed in other tropical pigeons (Crome 1975a, Rivera - Milan *et al.* 2003).

Canopy cover and number of trees in the nesting area were significantly different from the random site. Principal Component Analysis helped to identify the important factors in nest site data (Manly 1986). The nesting height on a particular tree and, canopy cover over the nest play major roles in selection of nest site.

Larger trees with closed canopy were preferred by the Nilgiri Wood Pigeon, as they gave high concealment to the nests. Similar results were reported by Walsberg (1985), Rivera-Milán (1996) and Matsuoka *et al.* (1997). Distance to water and to trek path, tree canopy cover, and tree height differ significantly between the nesting and random-sites. Nest tree height and canopy cover help the nest from both aerial and ground predators.

Nests located away from human settlement and trek path were less affected by humans and were highly successful. Moreover, comparison of the nest site characteristics between the successful and unsuccessful nests showed that successful nests were away from the human settlement and activities. These observations support the human-disturbance hypothesis (Batáry & Báldi 2004).

Nests were placed nearby streams probably to get more mollusks. Nearness to stream or water may also be to have open space for easy escape from predators as reported by Vijayan (1985) in Drongos and Gokula (2001b) in Fantail Flycatcher. This may also be because of the abundance of the preferred fruiting trees.

Thickness of the branches supporting the nest and climber cover were the most important factors determining the success of the nest of the Nilgiri Wood Pigeon , as in many Columbids which needed to find sites with adequate horizontal support and concealment against predators to increase the probability of nesting success (Martin 1992, Rivera-Milán 1996).

Number of shrubs within the nest patch is a good indicator of the complexity of the vegetation structure, but this was not significantly different between unsuccessful and successful nests of the Nilgiri Wood Pigeon, as reported in Blue Jays (Tarvin &Smith 1995).

Nesting was seen only in shola forests and not in plantations. *Turpinia nepalensis* had the maximum number of nests followed by *Viburnum cylindricum* while the other trees had only a few nests. These two species had the highest density in the intensive study area. However, when analysed statistically (Lvlev's index), it was found that there was no possible preference for the abundant species. The same phenomenon was reported in the case of Bolle's Laurel Pigeon (Hernandez *et al.* 1999). Use of abundant species at a location may reduce the nest predation, because the predator's search time would increase and the foraging efficiency decrease as suggested by Martin and Roper (1988), Martin (1992, 1993b) and Hernández *et al.* (1999).

Nilgiri Wood Pigeon built new nests every year. In three cases, the same tree was used in the successive years, but the nesting site varied in each year. It is interesting to note that the Scaly –naped Pigeon used other birds' nests as substrate which was not seen among any other species of Columbids (Rivera-Milán 1996, Sayre & Silvy 1993).

The Nilgiri Wood Pigeon has lower reproductive capacity compared to other Columbids (Perrins 1996, Blockstein & Westmoreland 1993), as its clutch size is only one. The hatching, fledging and nesting success was 37.25 %, 36.84 %, and 13.72 % respectively. Predation on eggs and nestlings was the major cause (79.41 %) of failure in the Nilgiri Wood Pigeon while in other pigeons, it accounted for 89% in Scaly-naped Pigeon, 81 %, in Zenaida Dove, 92 % in Common Ground Dove, 68% in Mourning Dove, 67 % in White-winged Dove, 88 % in Bolle's Laurel Pigeon, and 88 % in White-tailed Laurel Pigeon (Rivera-Milán 1996, Hernández *et al.* 1999).

The present study clearly indicates that the Nilgiri Wood Pigeon requires undisturbed montane wet temperate forest (shola forest) for breeding. It may be noted that there has been a loss of 50 % of shola forest since 1850 in the Nilgiris because of habitat alterations (Sukumar *et al.* 1995). The situation is still worse in the Palni Hills where the loss of shola forests in the 1980s is estimated at 25%. Further, the shola forests constitute only 0.3% of the vegetative cover of the Palni Hills (Amarnath *et al.* 2003).

6.6. Summary

- In all, during the two years of study, 108 nests of the Nilgiri Wood Pigeon were observed; 103 in Kukkal, three in Thai Shola (Nilgiris), and one each in Silent Valley National Park and Siruvani (Muthikulam Reserve Forest).

- The Nilgiri Wood Pigeon nests mainly in shola forest; of the 108 nests 106 were in the shola forest, and two in evergreen forest.

- They do not nest in the plantations of wattle, pine, and eucalyptus in the higher altitude and coffee in the mid altitude.

- They nest in loose colony, nesting on nearby trees.

- Breeding season is from February to September with a peak in March – April.

- Nest is a platform of twigs placed between four and eight metres above ground in medium sized trees nearby a stream or any small openings.

- The most preferred nesting plants are *Turpinia nepalensis*, followed by Viburnum *cylindricum, Phoebe paniculata*, and *Neolitsea zeylanica.*

- Nest site depends on canopy cover, nest concealment, distance to water, distance to trek path, tree canopy cover, tree height, and ground cover. Among these, nest height, canopy cover and number of trees at the site were more important for selection of the site.

- Clutch size of the Nilgiri Wood Pigeon is one.

- Incubation and nestling periods are 14-18 and 15 -19 days respectively.

- Both the parents took part in nest-building and caring chicks.

- Nesting success varied from 16 % to 12 % respectively for 2002 and 2004. Total success for three years was 14 from 102 eggs (13.72 %).

- Productivity was very low (one chick for 7 pairs).

- Predation, both natural and human (egg collection by local people) was high. Nests nearer to the forest edge were more vulnerable to human predation.

- Thickness of branch supporting the nest, climber cover on the nest tree and, distance to trek path significantly influenced the nesting success.

- The inherent low fecundity and productivity of the Nilgiri Wood Pigeon coupled with its absolute dependence on the shola forests for nesting make it imperative to take prudent actions to conserve the remaining forests for the survival of this endangered, endemic specialist.

Chapter 7

Summary and conclusions

The Nilgiri Wood Pigeon is a Globally Threatened species and endemic to the Western Ghats in India. In Asia 323 bird species (about 12 %) face extinction; and an additional 317 are Near Threatened. In the Indian subcontinent, of the 1295 species of birds, 75 are Globally Threatened, two Data Deficient, one Conservation Dependent and 52 Near Threatened (BirdLife International 2001). 16 species are endemic to the Western Ghats, of which four each are Threatened and Near Threatened. Species, which have restricted range of distribution, have more chances of getting endangered or extinct. A study on the impacts of disturbances on the bird communities conducted by Vijayan *et al.* (1999) shows that the status of many endemics cannot be assessed without conducting detailed studies on individual species.

In the case of the Nilgiri Wood Pigeon, except some occasional sightings, no detailed information was available on the ecology and biology which are very vital for the conservation of endemics, particularly the endangered species. Hence, a detailed ecological study was carried out on this species with the following specific objectives:

a) Determine the current status of the endemic, endangered Nilgiri Wood Pigeon.
b) Study the ecology of the Nilgiri Wood Pigeon, and
c) Identify the key factors affecting the survival of the species

The field work was conducted during 2002 to 2004 with surveys of important locations of previous sightings of this species from Goa to the southern tip of the Western Ghats and, intensive ecological studies were undertaken at Kukkal (10°1- 26' N; 77°14 - 52' E), one of the Important Bird Areas in India, in the Upper Palni Hills elevation of which ranges between 1500 and 2450 m. The area had a moderate climate with mean temperatures ranging from 12 to 23° C in summer while the winter temperatures ranged from 8.3 to 17.3° C. The annual rainfall averages 165 cm. The vegetation at Kukkal is predominantly montane

wet temperate forest, popularly known as shola forest and a variety of plantations. Totally 1734 trees of 63 species, 402 individuals of 19 species of shrubs, and 143 lianas of 15 species were recorded in 1.08 ha of shola forest sampled. Tree species richness and diversity (H') were more than those of the shrub species. The dominant trees are *Phoebe paniculata, Symplocos foliosa, Neolitsea zeylanica,* and *Maesa indica* and the dominant shrub species are *Psychotria nilgiriensis var. astephana,* and *Lasianthus acuminatus.* 23 species of trees were with fruits during the study period with a peak fruiting in June-July.

There are 72 locations with sighting records of the Nilgiri Wood Pigeon in its distribution range. Surveys were conducted in 20 probable locations in the Nilgiris and Anamalai Hills in the Kerala and Tamil Nadu and a few sites in Karnataka and Goa. Nilgiri Wood Pigeon was recorded in the Silent Valley National Park, Siruvani, Castle rock, Mathikettan shola, Eravikulam National Park, Mannavan shola, Mukurthi National Park, Thai shola and most of the sholas in the Upper Palni Hills. The species was not recorded in Goa during our survey.

Preferred habitat of the Nilgiri Wood Pigeon was montane wet temperate forest followed by tropical wet evergreen forest. In the 158.5 ha of evergreen forest and 166 ha of shola forest surveyed in four states, 17 and 41 Nilgiri Wood Pigeon were found in the respective habitats. Sighting frequency increased with size of the forest patch, encounter rates being 0.24 birds/ ha in shola and 0.10 bird/ ha in the evergreen forest. The Nilgiri Wood Pigeon was recorded in evergreen forests > 650m in elevation with maximum numbers > 1800m. In the intensive study area, the maximum number of birds (51) was recorded in May 2004 and minimum (8) in September 2002. During the breeding season, 32 breeding pairs were observed in 40 ha of the intensive study area. The Nilgiri Wood Pigeon was very rarely recorded in the plantations, that too only on their edges near the shola.

The foraging ecology of the Nilgiri Wood Pigeon was studied by direct method using focal animal or scan sampling and, food by direct observation and fecal analysis. In total, 1520 foraging observations were made. The Pigeon fed on the fruits of 34 species of 26 families of plants, four species of flower and leaf buds and three taxa of ground invertebrates. Nine

species of plants were used more often, 47%; while 12 species were used very rarely. Fruits of the family Lauraceae were the most preferred. In the 134 faecal samples, 13 species of seeds were identified; 70% the diet was fruits, ranging from 0.04 to 70mm, mainly 10 - 20mm. The Nilgiri Wood Pigeon fed on ground invertebrates during monsoon, which had significant correlation with their abundance ($r = 0.65$, $p < 0.01$). The fruit abundance and the frequency of sightings of the Nilgiri Wood Pigeon correlated significantly ($r = 0.49$, $p < 0.01$). The principal feeding technique was gleaning (76.25 %) followed by leaping (20.75 %). There was no significant difference in the method within the season and between seasons. Mostly, the species foraged in small flocks of its own and only rarely did they share with other species on the same tree.

Phonological events of 10 individuals each of the 23 species of trees used by the Nilgiri Wood Pigeon were studied in a six hectare plot encompassing the bird census area. Values ranging from 0-100 % for each phase (such as flowers, fruits and young leaves) were recorded for each individual every fortnight. Ripe fruits were available round the year. The number of species in fruit and the fruit abundance generally kept increasing from February and attain a peak in June – July. The number of species appears to have no correlation with rainfall ($r = 0.26$, $p = 0.2$) while the fruit abundance did show a correlation ($r = 0.40$, $p < 0.05$). In the drier months, the fruit abundance was mainly due to *Olea glandulifera* and *Daphniphyllum neilgherrense* which serve as keystone species of the Nilgiri Wood Pigeon.

Activity pattern was studied by direct observation. The Nilgiri Wood Pigeon spent maximum time for foraging (47 %) followed by maintenance (30 %). Resting (16%) and breeding behaviour were low (6.8 %); the latter was seen during summer, south-west monsoon and winter. During late winter, the pre-nesting activities such as pair-formation, calling and display were noted.

The Nilgiri Wood Pigeon has three distinct calls, namely breeding, non-breeding and feeding calls. Breeding call was heard from February onwards and the frequency was more in the early breeding season. It made both non-breeding and breeding calls during the late breeding season.

Peak breeding of the Nilgiri Wood Pigeon was during March to April, although the breeding season extended from February to September. The emergence of large number of chicks coincides with the high abundance of ripe fruits in June – July. It completes its breeding before the onset of heavy monsoon which is October at Kukkal.

The Nilgiri Wood Pigeon nested inside the forest, mainly in shola forest, on trees located close to any stream or openings but away from human settlement. During the two years of study, 108 nests were observed; 103 at Kukkal, three at Thai Shola (Nilgiris), one each in the Silent Valley National Park and Siruvani (Muthikulam Reserve Forest). Of the 108 nests, 106 were in the shola forest, and two in evergreen forest. No nests were observed in wattle, pine, eucalyptus and coffee plantations. Nests were observed in loose colonies.

Nest was a platform of twigs placed between four and eight meter in medium sized trees near the streams or any other small openings. *Turpinia nepalensis* had the maximum number of nests (22.55 %) followed by *Viburnum cylindricum* (11.76 %), *Phoebe paniculata* (9.80 %) and *Neolitsea zeylanica* (8.82 %). Canopy cover at the nest-site was 81% and nest concealment was high in 35% nests. Distance to water, distance to trek path, tree canopy cover, tree height, nest concealment and ground cover were the important factors in nest-site selection as these differed significantly between the nesting and random sites. The principal component analysis of the nest-site characteristics showed that the first component was closely associated with nest tree height and nest height.

The clutch size was only one. Both the parents took part in nest-building and feeding chicks. Incubation period was 14-18 days (15.89 $\pm$ 2.3; N= 23) and nestling period 15-19 days (16.89 $\pm$ 4.4; N =12). Nesting success was 14.43 %; productivity was very low (one chick for 7 pairs), mainly because of predation, natural and human (mainly egg collection by local people). Nests nearer to the forest edge had more chances of human predation. Thickness of nesting branch and climber cover on the nest tree and, distance to trek path significantly influenced the nesting success.

The study shows the restricted distribution of the Nilgiri Wood Pigeon; its low population density, movement pattern between the evergreen and shola forests, altitudinal and habitat restrictions, specific nesting and breeding requirements, low fecundity and productivity; along with the loss of its critical habitats, the shola forests. It is only prudent to protect its habitat in its entire range of movement and take site-based conservation management strategies for the long- term conservation of this Globally Threatened endemic bird from extinction.

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Appendix - I

Dominant tree, shrub and liana species recorded in Kukkal shola forest

Trees

Ardisia rhomboidea
*Beilschmiedia wightii**
Caesalpinia sepiaria
*Casearia wynandensis**
*Casearia zeylanica**
*Cassine glauca**
Celastrus paniculatus
Celtis tetrandra
Chinonanthus zeylanica
Cinnamomum malabthrum
Cinnamomum perrottetii
Cinnamomum wightii
*Coffea Arabica**
Cryptocarya neilgherrensis
*Daphniphyllum neilgreneses**
Debragassia velutina
Demosis lawii
*Elaeocarpus glandulosus**
Erythroxylum acuminatum
Euonymus crenulatus
*Eurya nitida**
*Ficus arnottiana (Miq) Miq.**
Gaultheria fragrantissima
Glochidion velutinum
Gomphandra coriacea
Grewia disperma
Ilex wightiana
Isonandra perrotettiana
*Litsea floribunda**
Litsea glabrata
Litsea insigns
Litsea wightiana
*Maesa indica**
*Mahonia leschenaultia**
Michelia nilagirica
*Myrsine wightiana**
Neolitsea fischeri
*Neolitsea scrobiculata**
Neolitsea zeylanica
Nothopodytes nimmoniana
*Olea glandulifera**
*Persea macrantha**
*Phoebe paniculata**
Photinia integrifolia
Piper mullesua
Prunus ceylanica
Psychotria nilgiriensis
Rhododendron nilagiricum
Rubus ellipticus
*Symplocos cochinchinses**

Symplocos foliosa
Symplocos pendula
*Syzygium densiflorum**
*Syzygium jambolanum**
*Syzygium tamilnadensis**
Tarenna asiatica
Toddalia asiatica
*Trichillia connoroides**
*Turpinia nepalensis**
*Vaccinium leschenaultia**
Ventilago bomaiensis
*Viburnum cylindricum**
Xantolis tomentosa

Shrubs

Apodytes dimidiate
Berberis tinctoria
Chasalia curviflora
Coffea Arabica
Crotalaria Formosa
Dodonaea viscose
Hedyotis leschenualtii
Hypericum javanicum
Justicia diffusa var. hydyotidif
Lasianthus acuminatus
Mussaenda hirsutissima
Psychotria nilgiriensis
Rubus ellipticus
Rubus racemosus
Rubus rugosus
Sarcoccoco salinga
Strobilanthus foliosa
Strobilanthus luridus
Tarenna asiatica

Lianas

Cissampelos corymbosa
Demosis lawii
Derris canarensis
Desmos lawii
Elaeagnus kologa
Gardneria ovata
Grewia disperma
Jasminum brevilobum
Mussaenda hirsutissima
Osyris quadripartita Salzm
Piper agyrophyllum
Piper mullesua
Rosa leschenaultiana
Toddalia asiatica
Ventilago bomaiensis

*- Fruits used by Nilgiri Wood Pigeon

Appendix II

List of Butterflies observed at Kukkal

Tawny Coster	*Acraea violae*	Acraeidae
Glassy Blue Tiger	*Parantica aglea aglea*	Danaidae
Nilgiri Blue Tiger	*Tirumala limniace leopardus*	Danaidae
Striped Tiger	*Danaus genutia genutia*	Danaidae
Brown Awl	*Badamia exclamationis*	Hesperiidae
Common Spotted Flat	*Celaenorrhinus leucocera*	Hesperiidae
Fulvous pied Flat	*Pseudocoladenia dan dan*	Hesperiidae
Malabar Flat	*Celaenorrhinus ambareesa*	Hesperiidae
Blue Admiral	*Kaniska canace viridis*	Nymphalidae
Blue Pansy	*Precis orithya*	Nymphalidae
Common Leopard	*Phalanta phalantha phalantha*	Nymphalidae
Common Map	*Cyrestis thyodamas indica*	Nymphalidae
Common Sailer	*Neptis hylas varmona*	Nymphalidae
Common Sergeant	*Athyma perius perius*	Nymphalidae
Great Eggfly	*Hypolimnas bolina jacintha*	Nymphalidae
Indian Fritillary	*Argyreus hyperbius hybrida*	Nymphalidae
Indian Red Admiral	*Vanessa indica pholoe*	Nymphalidae
Lemon Pansy	*Precis lemonias lemonias`*	Nymphalidae
Rustic	*Cupha erymanthis maja*	Nymphalidae
Yellow Pansy	*Precis hierta hierta*	Nymphalidae
Common Blue Bottle	*Graphium sarpedon teredon*	Papilionidae
Common Mormon	*Papilio polytes stichius*	Papilionidae
Red Helen	*Papilio helenus daksha*	Papilionidae
Southern Birdwing	*Troides minos*	Papilionidae
Common Emigrant	*Catopsilia crocale*	Pieridae
Common Grass Yellow	*Eurema hecabe simulata*	Pieridae
Common Gull	*Cepora nerissa nerissa*	Pieridae

Common Jezebel	*Delias eucharis*	Pieridae
Three Spot Grass Yellow	*Eurema blanda silhetana*	Pieridae
Common Evening Brown	*Melanitis leda leda*	Satyridae
Common Four Ring	*Ypthima huebneri*	Satyridae
Red –disc Bushbrown	*Mycalesis oculus*	Satyridae

Appendix III

List of birds observed in the Palni Hills, Western Ghats

(Grimett *et al.* 1998)

Asian Brown Flycatcher	*Muscicapa dauurica*
Asian Fairy-Bluebird	*Irena puella*
Asian Koel	*Eudynamys scolopacea*
Asian Palm-Swift	*Cypsiurus balasiensis*
Asian Paradise-Flycatcher	*Terpsiphone paradise*
Ashy-crowned Sparrow-Lark	*Eremopterix grisea*
Ashy Prinia	*Prinia socialis*
Bar-winged Flycatcher shrike	*Hemipus picatus*
Besra	*Accipiter virgatus*
Black – and –Orange Flycatcher * ◊ ♦	*Ficedula nigrorufa*
Black Bulbul ♦	*Hypsipetes leucocephalus*
Black Drongo	*Dicrurus macrocercus*
Black Eagle	*Ictinaetus malayensis*
Black-hooded Oriole	*Oriolus xanthornus*
Black-lored Tit	*Parus xanthogenys*
Black-naped Monarch-Flycatcher	*Hypothymis azurea*
Blue-winged Leafbird	*Chloropsis cochinchinensis*
Blyth's Reed-Warbler	*Acrocephalus dumetorum*
Brahminy Starling	*Sturnus pagodarum*
Broad-tailed Grassbird	*Schoenicola platyura*
Bronzed Drongo	*Dicrurus aeneus*
Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*
Brown-cheeked Fulvetta ♦	*Alcippe poioicephala*
Chestnut-headed Bee-eater	*Merops leschenaultia*
Common Hawk Cuckoo	*Hierococcyx varius*
Common Hoopoe ♦	*Upupa epops*
Common Iora	*Aegithina tiphia*

Common Moorhen	*Gallinula chloropus*
Common Tailorbird	*Orthotomus sutorius*
Coppersmith Barbet	*Megalaima haemacephala*
Crested Serpent Eagle ♦	*Spilornis cheela*
Crimson-backed Sunbird	*Nectarinia minima*
Emerald Dove	*Chalcophaps indica*
Eurasian Blackbird ♦	*Turdus merula*
Eurasian Golden Oriole	*Oriolus oriolus*
Golden-fronted Leafbird	*Chloropsis aurifrons*
Great Tit ♦	*Parus major*
Greater Coucal	*Centropus sinensis*
Greater Flameback	*Chrysocolaptes lucidus*
Greater Racket-tailed Drongo	*Dicrurus paradiseus*
Grey-headed Bulbul	*Pycnonotus priocephalus*
Grey Junglefowl ♦	*Gallus sonneratii*
Grey-breasted Laughingthrush * ◊ ♦	*Garrulax jerdoni*
Grey-headed Canary Flycatcher ♦	*Culicicapa ceylonensis*
Heart-spotted Woodpecker	*Hemicircus canente*
Hill Myna	*Gracula religiosa*
House Crow ♦	*Corvus splendens*
House Sparrow	*Passer domesticus*
House Swift ♦	*Apus affinis*
Indian Blue Robin	*Luscinia brunnea*
Indian Peafowl	*Pavo cristatus*
Indian Pond Heron	*Ardeola grayii*
Indian Robin	*Saxicoloides fulicata*
Indian Scimitar Babbler ♦	*Pomatorhinus horsfieldii*
Jungle Babbler ♦	*Turdoides striatus*
Jungle Myna	*Acridotheres fuscus*
Kashmir Flycatcher	*Ficedula subrubra*
Large-billed Crow ♦	*Corvus macrorhynchos*

Large-billed Leaf Warbler	*Phylloscopus magnirostris*
Little Egret	*Egretta garzetta*
Little Grebe	*Tachybaptus ruficollis*
Long-tailed Shrike ♦	*Lanius schach*
Loten's Sunbird	*Nectarinia lotenia*
Malabar Grey Hornbill * ◊	*Ocyceros griseus*
Malabar Parakeet *	*Psittacula columboides*
Malabar Trogon	*Harpactes fasciatus*
Malabar Whistling Thrush ♦	*Myophonus horsfieldii*
Mountain Imperial Pigeon	*Ducula badia*
Nilgiri Flycatcher * ◊ ♦	*Eumyias albicaudata*
Nilgiri Pipit * ◊ ♦	*Anthus nilghiriensis*
Nilgiri Wood Pigeon * # ♦	*Columba elphinstonii*
Orange-headed Thrush	*Zoothera citrine*
Oriental Honey-buzzard	*Pernis ptilorhyncus*
Oriental Magpie Robin ♦	*Copsychus saularis*
Oriental White-eye ♦	*Zosterops palpebrosus*
Paddyfield Pipit ♦	*Anthus rufulus*
Pacific Swallow ♦	*Hirundo tahitica*
Peregrine Falcon	*Falco peregrinus*
Pied Bushchat ♦	*Saxicola caprata*
Pied Thrush	*Zoothera wardii*
Plain Flowerpecker	*Dicaeum concolor*
Puff-throated Babbler	*Pellorneum ruficeps*
Purple-rumped Sunbird	*Nectarinia zeylonica*
Red-rumped Swallow	*Hirundo daurica*
Red Spurfowl	*Galloperdix spadicea*
Red-vented Bulbul ♦	*Pycnonotus cafer*
Red-wattled Lapwing	*Vanellus indicus*
Red-whiskered Bulbul ♦	*Pycnonotus jocosus*
Rufous Babbler *	*Turdoides subrufus*

Rufous Treepie	*Dendrocitta vagabunda*
Rusty-tailed Flycatcher	*Muscicapa ruficauda*
Scaly-breasted Munia	*Lonchura punctulata*
Scarlet Minivet	*Pericrocotus flammeus*
Shikra	*Accipiter badius*
Slaty-Blue Flycatcher	*Ficedula tricolor*
Spotted Dove ♦	*Streptopelia chinensis*
Thick-billed Flowerpecker	*Dicaeum agile*
Tickell's Blue Flycatcher	*Cyornis tickelliae*
Velvet-fronted Nuthatch	*Sitta frontalis*
Vernal Hanging Parrot	*Loriculus vernalis*
White-bellied Blue Flycatcher *	*Cyornis pallipes*
White-bellied Shortwing * # ♦	*Brachypteryx major*
White-bellied Treepie *	*Dendrocitta leucogastra*
White-breasted Waterhen ♦	*Amaurornis phoenicurus*
White-browed Bulbul	*Pycnonotus luteolus*
White-browed Wagtail	*Motacilla maderaspatensis*
White-cheeked Barbet ♦	*Megalaima viridis*
White-rumped Munia	*Lonchura striata*
White-throated Kingfisher ♦	*Halcyon smyrnensis*
Yellow-billed Babbler	*Turdoides affinis*
Yellow-browed Bulbul ♦	*Iole indica*

*- endemic; ◊ - Near Threatened; # -Threatened; ♦ - breeding observed in Kukkal