THE EFFECT OF FORESTRY PRACTICES ON BIRD SPECIES DIVERSITY IN SATPURA HILL RANGES.

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CERTIFICATE

I have great pleasure in forwarding the thesis of **Prachi Mehta**, titled **"The Effect of Forestry Practices on Bird Species Diversity in Satpura Hill Ranges"** for acceptance for the degree of **Doctor of Philosophy** in **Wildlife Science**. The thesis embodies original findings and interpretations of facts. This research was carried out by Prachi Mehta under my supervision, and has not been submitted in part or full to any other University/Institution for the award of any degree.

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THE EFFECT OF FORESTRY PRACTICES ON BIRD DIVERSITY IN SATPURA HILL RANGES.

SUMMARY

The major cause of concern amongst tropical nations is the increasing rate of logging of forests for timber. Annually, 45,000 km ^{2} of forests are logged for timber in the tropical countries. Apart from being utilised for industrial and domestic purpose, timber from countries like Malaysia and Philippines is exported to other countries as well. In India, 23 million m^3 of forests are cleared for timber annually. The present deforestation rate is expected to rise up to 39 million m^3 in coming years. Studies have documented the effect of timber logging on plant and animal communities in tropical rain forests of South- east Asia, Central America and Central and West Africa. Although, logging is one of the major land-use practice in India, its effect has not been studied and there is practically no information available on the effect of logging in the dry deciduous forests in the country and elsewhere.

The largest zone of dry deciduous teak forests in the country is located along the Satpura Hill ranges in Central India. Apart from being one of the oldest hill ranges in the country, Satpura Mountain houses 4 important Protected Areas (PA) in contiguity. In Madhya Pradesh, a cluster of three PAs namely Bori Wildlife Sanctuary, Pachmari Wildlife Sanctuary and Satpura National Park forms a compact unit of 1400 km^2. A large tract of 2000 km^2 of reserved forests connects these three PAs to another one in Maharashtra, known as Melghat Tiger Reserve. The forests of Satpuras were logged under different silvicultural regimes for over a century. Timber logging in the Protected Areas was discontinued in 1991 following the Forest Conservation Act (1980), while it is still operational in the reserved forests. The objective of this study was to evaluate the impact of past and present silvicultural practices on bird communities in Satpura Hills. Two study sites were chosen for this purpose. During November 1992 to June 1994, the effect of different silvicultural practices on bird community was studied in Bori Wildlife Sanctuary. From

October 1994 to June 1996, the study was conducted in reserved forests adjacent to Melghat Tiger Reserve where selective logging was going on.

The data on bird abundance was collected on 1 km. long variable width line transect, monitored 4 times in summer and 5 times in winter. The information collected on these transects was used to calculate bird species richness, diversity, similarity and density. Vegetation data was collected on the same transect at every 50 m point in 10 m radius plot. Number and species of trees and shrubs were recorded in these plots. Canopy cover was measured using an ocular tube and ground cover was measured in 1m x 1m grid in each sampling point in 4 directions. Foliage height diversity was measured in 8 height classes in both the seasons. 20 individuals of fleshy and non-fleshy fruit trees were tagged and monitored every month for availability of fruits, flowers and leaves. Landscape heterogeneity was assessed subjectively in 10 categories for each transect. These methods were common for Bori and Melghat with some modification in sampling intensity and stratification.

In Bori Wildlife Sanctuary, forests were logged under following 4 systems: Coppice With Reserve (CWR), Selection Cum Improvement (SCI), General Teak Felling System (GTFS) and Special Teak Felling System (STFS). Three compartments selected in each system represented logging age of 7 years, 20 years and 40 years. In addition to this, a preservation plot was also selected in the STFS site. In Melghat, three sites were selected where logging was going on. Chunkhedi in east, Jarida in north and Dharni in west Melghat forest division were chosen for the study. In each site, a compartment that was to be logged next year was selected so that data could be collected before, during and after logging. Along with this site, compartments that were logged 1 year ago and 20 years ago were also chosen as control sites.

The assemblage of bird community was governed by vegetation structure and floristic in Bori Wildlife Sanctuary. In the SCI and STFS systems, the bird species richness and diversity was higher in the old logged forests than in their younger sites, whereas in the 7 yr sites of CWR and GTFS richness was almost equal to or higher than that of their older logged forests. The

reason for this was that the older logged site in GTFS was structurally not as complex as its younger site so it could not support more bird species. Similarly, in the preservation plot granivores and understorey insectivores were not represented in response to the lower structural complexity and smaller size of the plot. The abundance of fruit dependent species such as parakeets, mynas, orioles, barbets and hornbills was related to availability of the resource and not to the age of the site. The number of woodpeckers, tits, nuthatches, flycatchers, and owls were higher in the older logged sites but they were represented in the younger sites also. Overall, bird species composition was not largely influenced by the logging age in Bori Sanctuary.

In Melghat, maximum timber extraction was in Dharni range. Here density of trees and shrub and canopy cover had declined following logging. Chunkhedi and Jarida had lower extraction rate and as a result did not show significant difference in vegetation structure after logging. The bird community response to logging was almost similar in all three sites. Although during logging, the bird species richness, diversity and density declined in all three currently logged sites, it reached the pre - logging level after logging. However, the composition of the community had changed following logging. Forest specialists such as some understorey insectivores, trunk/bark feeders (woodpeckers, nuthatches and tits) and some flycatchers declined in numbers, whereas generalists such as robins, sparrows, and doves increased in numbers after logging. Species that were more mobile, less specialised and abundant in number were resilient to logging. Large bodied and less mobile species such as the Lesser Goldenbacked Woodpecker, Grey Junglefowl, Red Spurfowl, Large Green Barbet declined after logging. However, some changes in community composition was seen in the control sites as well. Apart from logging disturbance, changes in bird community could be caused due to annual or seasonal variations.

In Melghat, logging did not affect the bird community severely because the intensity of logging and damage to the structure was lower than that reported from the rain forests studies. Consequently, recovery of birds was also rapid in these sites as by the end of the logging season many species were

beginning to return to the site. The decline in specialist species was primarily due to disturbance caused during felling and not as much due to the felling process. The availability of unlogged forests within and near the logged sites proved to be vital as they provided the necessary refuge for the bird communities. The management recommendation from this study suggests enumeration of all trees, shrubs and climbers in the site prior to logging that could help in obtaining a vegetation profile for the area. A complete inventory of flora and fauna of the site prior to and after logging would help in understanding the response of various species to logging and these features could be incorporated in the felling rules. Felling of smaller trees should be avoided as it depletes the growing stock. Reserving 5 large compartments as preservation plot is very essential for conserving biological diversity in areas where logging is going on. After logging the site should be protected from fire and grazing and frequent thinning of coupes should be avoided.

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Abbreviations

CL - Currently Logged site

CWR – Coppice With Reserve

GTFS - General Teak felling System

PP- Preservation Plot

SCA – Satpura Conservation Area

SCI - Selection Cum Improvement

STFS - Special Teak Felling System

1 yr- 1 year logged site

6 yr - 6 year logged site

7 yr – 7 year logged site

20 yr – 20 year logged site

40 yr – 40 year logged site

60 yr – 60 year logged site

80 yr – 80 year logged site

CHAPTER 1

INTRODUCTION

1.1 Tropical forests and commercial logging

Tropical forests cover almost 8 million km^2 of the humid tropics and account for 42 percent of the world's total forest area. Two third of world's flora and fauna inhabit the tropical forests. The high species richness in tropical forests is attributed to its structurally complexity (Terborgh 1992) Tropical forests are not only genetically rich but also ecologically fragile (Myers 1992). Destruction of tropical forests contributes to climatic change by releasing stored carbon into the atmosphere, and often results in serious soil degradation (Ravindranathan and Hall 1994).

Seventy-six nations including India, located entirely or partly within the tropical latitudes are characterized by rapidly growing populations, low per capita incomes and agrarian economies. Globally, tropical rain forests are undergoing rapid rate of change with over half of natural forests in tropics having already disappeared during this century (Dudley et al., 1995). The proximate causes that results in large-scale disappearance of tropical forests are the clearing of land for agriculture activities and commercial forestry operations. One of the principal commercial products of tropical nations is timber and fuelwood. Commercial logging and fuel wood collection attributes to 40 percent of deforestation rate (Jepma 1995, Pearce and Brown 1995). Commercial logging alone leads to 45, 000 km^2 of deforestation annually in the world, of which 30,000 km^2 forests are cleared in South-East Asia alone (Myers 1992).

Apart from depleting the forest cover, logging activity results in soil erosion, and accelerated sedimentation that ultimately results in eutrophication of lakes and water bodies (Johns et al., 1996; Whitman et al., 1997). In the logged forests, ground temperature and humidity levels get altered. Following logging, the habitat changes, vegetation regeneration gets affected and weed infiltration takes place in opened areas (Food and agriculture organization

conservation guide 1992, also see section 1.7). In spite of having such detrimental impacts, consumption and production of timber continues the world over. Between 1960 and 1987 production of timber increased four fold in the tropical countries. The export of wood has also increased three and half times the original level during this period. Presently, Malaysia and Indonesia are the largest exporters of tropical timber wood (Johns 1997). For tropical nations, a forest provides wood for lumber and paper, construction, fuel and is also an important source of foreign exchange. The benefits from logging are reaped by both exporting as well as the importing countries (OTA 1984).

Increasing demand for wood for both commercial and domestic requirements is contributing to large-scale deforestation. Alternatives to wood, such as aluminum, plastic, steel or concrete are not renewable and use considerable amount of energy for production (Salwasser et al., 1993). Wood being a renewable source needs to be used judiciously. If the demand for timber is to be met without depleting the resources in tropical forests, alternatives to intensive and damaging logging practices need to be practiced. An idea central to sustainable logging is to enhance the potential of the forests to produce marketable timber by minimizing the ecological loss (Poore 1989). This does not suggest that timber logging should be allowed in all the forested areas. Distinction has to be made between areas that needs complete protection and the areas where regulated forestry operations could be permitted. Commercial logging in primary forests should be stopped. It is also very important to maintain the basic structural elements of natural forests in logged sites. Commercial logging must demonstrate a commitment to sustainable development and biodiversity conservation. Provision of sufficient forests for preservation, cyclic use of plantations and selective felling in secondary forests could result in reducing the negative impacts of logging (Poore 1989, Johns 1997).

1.2 Biodiversity conservation in India

India occupies 2.45 per cent of world's geographical area and has 1 per cent of world's forest area. Sixteen per cent of world's human population and

15 per cent of livestock population resides in India (Forest Survey of India 1996). The country's forest cover is rapidly decreasing due to deforestation as forests (including semi-arid and degraded forests) cover about 23 per cent of India compared to 40 percent a century ago (World Resource Institute 1995). India's forest resources suffer under the needs of a growing population. In India, fuel wood energy is used in 73 per cent rural households and 32 per cent in urban houses. Annually, 7 million m^3 of timber is required for construction and industrial purpose in urban India (FSI 1996). Forest Survey of India report (1996) estimated the demand for industrial wood alone to rise up to 39 million m^3 by the year 2006. Forests are also used for livestock fodder and grazing which depletes soil nutrients and vegetation regeneration (Lamb 1990).

The Indian subcontinent comes under the influence of three biogeographic realms, Palaearctic, Afrotropical and Indomalayan, which render the country one of the biologically richest tracts in the world (Mani 1974, Gadgil 1990). India is considered one of the twelve "megabiodiversity" nations (World Resource Institute 1995) It is home to about 317 species of mammals, 1200 species of birds, and 16,000 of plants. Of these, about 39 species of mammals, 170 of birds, and 1,331 species of plants are threatened (World Resource Institute 1995). To protect these, India has established 75 national parks and 423 Sanctuaries covering 4 percent of its land area (World Resource Institute 1995).

In India, forests have been cleared primarily for agriculture purpose and various forestry practices such as commercial tree harvesting and plantations for over a century (Marcot 1991). What is the effect of such practices on the country's biodiversity? There could be loss of species in some areas while an increase in number of species in other areas. The older concept of existence of maximum diversity under equilibrium condition has taken a back seat as studies have reported higher diversity in non - equilibrium conditions (Connell and Slayter 1977; Connell 1978, Schemske & Brokaw 1981, Hansen et al., 1991). As Hutton (1995) suggests, this is not a simple assessment problem as it is indeed difficult to define equilibrium and non-equilibrium conditions and explain why we see such patterns. Generalists species having wide spread

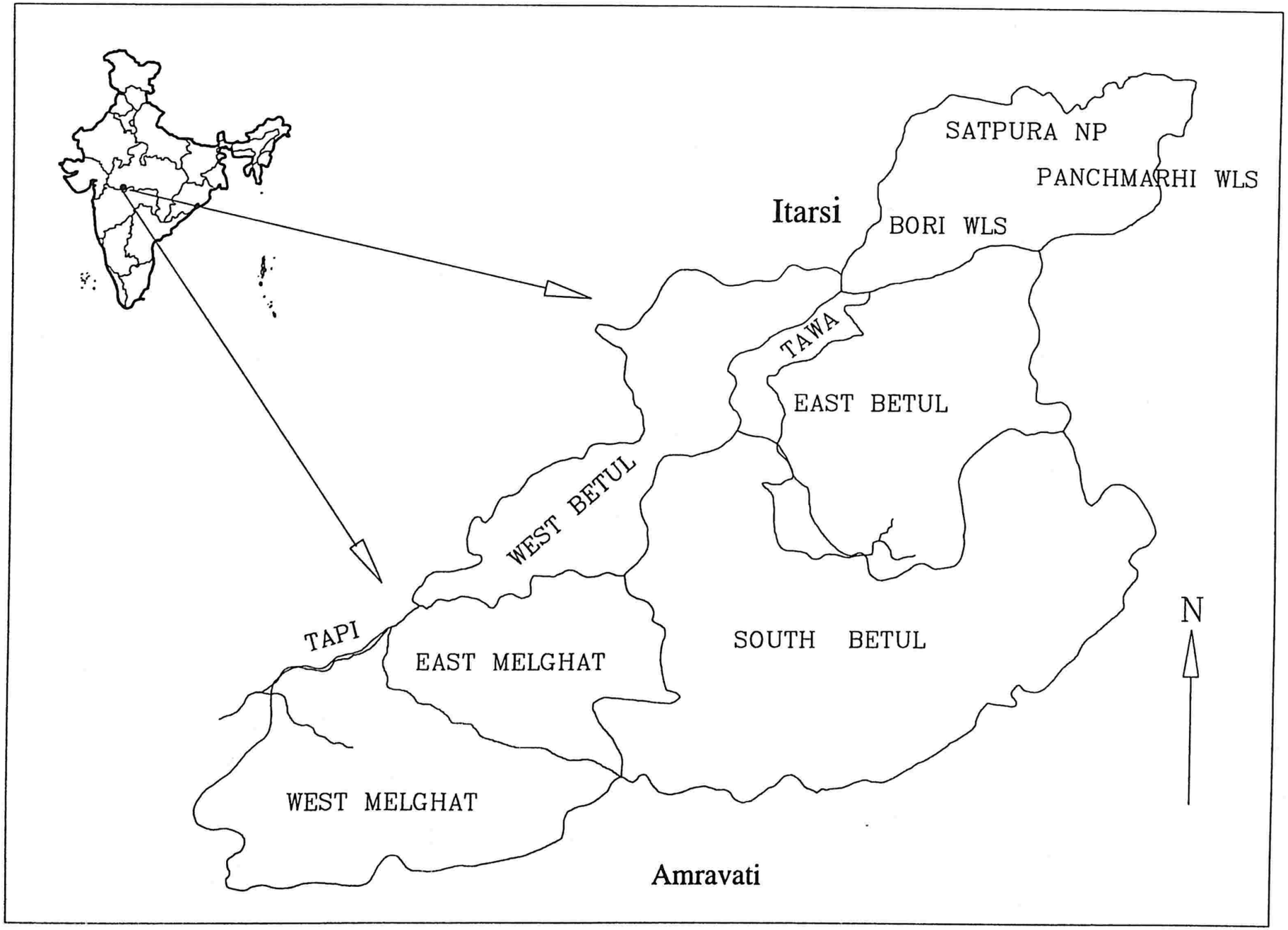
occurrence tend to dominate the disturbed sites while occurrence of specialists species tend to be low. Such findings need quantification of the state of disturbance, as well as the location, extent and degree to which the disturbance is tolerated by species.

A few studies have assessed the ecological impact of some common land use practices. In India, shifting cultivation remains one of the common agriculture practices of North-Eastern hill states. The impact of shifting cultivation in Meghalaya in North-East India on vegetation regeneration (Ramakrishnan 1983), and Mizoram avifauna have (Shankar Raman 1995) been well documented. Logging and plantations are continuing in most forested areas by either the forest department or by private agencies all over the country but very few workers have studied the ecological impact of such practices. Daniel (1989) studied the bird diversity in plantations and natural forests in Uttar Kannada district in the Western Ghats. Nair (1991) compared the effect of selective logging on plant regeneration in the tropical rain forests of Assam, Western Ghats and Andaman Islands. Datta (in prep.) studied the response of arboreal mammals to selective logging in Western Arunachal Pradesh. Kakati (1997) studied the impact of fragmentation (one of the causes stated was illicit logging) on Hoolock Gibbon in the reserved forests of Assam. A large number of studies have been carried out outside the country on the effects logging practices in South-East Asia, Central and South America and Africa (see section 1.7). In India and elsewhere, major studies on selective logging have been carried out in tropical rain forests. No study so far has documented the effect of selective logging on biodiversity of tropical dry deciduous forests.

1. 3 Objectives of the Study

This study was initiated to understand the effect of logging in the Satpura hills in Central India. Satpura hills are one of the oldest hill ranges in the country and the forests fall primarily in the dry deciduous forest zone. In Central India, the largest contiguous forested tract spread across four protected areas is in the Satpura hills. The Satpura Conservation Area (SCA)

Figure 1. : Map of Satpura Conservation Area



comprises of Bori Wildlife Sanctuary, Pachmarhi Wildlife Sanctuary and Satpura National Park in Madhya Pradesh, and Melghat Tiger Reserve in Maharashtra. The total area of the SCA, including the connecting tract of Betul Reserved Forest is around 7,000 km^2. The Satpura Conservation Area is not an officially recognized entity with any legal status but rather an ecologically important tract in Central India, which has been given a separate name because of its conservation value (Kulkarni 1988).

The Central Indian forests of Satpura have a century old history of forestry operations, mainly in the form of timber logging and plantations that has resulted in transforming the landscapes in the area. Forestry operations were continued in the SCA area up till 1986, after which a ban was declared under the Forest Conservation Act 1980 to stop commercial felling in Protected Areas. Today, commercial timber logging and plantations are carried out only in the reserved forests adjoining the Protected Areas and not inside the area. Silvicultural practices are designed according to the condition of the forest stand. In a typical forestry operation, the number of species extractable, the timber yield, and revenue generated often takes priority over species diversity and biodiversity conservation. Though forestry operations have been going on in the country for over a century, very few studies have evaluated the effect of this major land-use practice on the floral and faunal diversity. In wake of varied demands made on the country's forests, a more judicious approach is required to choose between what to extract and what to protect (Sawarkar 1990).

To assess both, the past and the current forestry practices, two study sites were chosen in the Satpura Hills. During the first two years (1992 to 1994), the study was carried out in Bori Wildlife Sanctuary in Madhya Pradesh, where logging operations had already ceased 6 years ago. From 1994 to 1996, the study was carried out in the reserved forests contiguous with Melghat Tiger Reserve in Maharashtra State, where selective logging was going on.

Objective

The main objective of this study was to evaluate the impact of past and present silvicultural systems on bird communities in the forests of Satpura Hills and to make recommendations for minimizing deleterious effects of logging as practiced at present in the Satpura Hills.

The study appeared to be challenging as it involved different forest types, their distinct bird communities and different silvicultural practices. The details of different systems are given in the Chapter 2 and 3. This study would help to establish the response of bird communities to different logging practices in the Central Indian dry deciduous forests. It could then be determined which species would be sensitive and which would be resilient to logging activity. These features could be emphasized in the recommendation given at the end of the study. Since the demand for timber is unlikely to decline, the felling of reserved forests will continue in future (Poore 1985). Prior to logging, a study conducted in the reserved forests to be felled would help in highlighting the sensitive species for which provisions should be made while designing the felling rules. A point to be stressed here is, that the recommendations given in this study are site specific. If they are to be applied to other sites they should be applicable only to similar sites, with caution, and only after adequate study.

1.4 The importance of conserving bird diversity in tropical forests

I chose to study bird communities for the following reasons:

Considerable work has already been done on bird diversity and therefore substantial amount of information is already available on this subject. Since the pioneering work of MacArthur (1964), a lot of work has been carried out on bird - habitat relationships (Orians 1969, Karr and Roth 1971, Pearson 1975, Karr 1976, James and Wamer 1982, Stiles 1985, Morris 1990, Johns 1991, Probst et al., 1992). This makes it easier to interpret the patterns between bird - habitat relationship observed in this study. Another equally important aspect is that birds are relatively easy to locate and easy to identify by trained observer. This makes it easier to obtain sufficient number of observation so that valid inferences can be drawn.

Forest birds play an important role in tropical forest ecosystems. Birds participate in various biological interactions as herbivores, predators, competitors and prey for other groups of animals (Otvos 1979, Stiles 1985). Herbivores consume nectar and fleshy fruit parts and serve as pollinators or seed dispersal agents for plants (Stiles 1978). As predators, forest birds play an important role in controlling insect folivores (see Otvos 1979 for detailed review).

Tropical forest birds are perhaps more acutely threatened than the birds of any other ecosystem (Diamond 1985). Currently prevalent landuse practices in the form of logging, plantations, and cultivation are resulting in an alarming rate of habitat destruction depleting the available resources in the forests. About 65 per cent of forest birds in the world are facing great threat from developmental activities. As per the IUCN Red Data Book (1994), India is one of the top five countries in the world facing major threat to biodiversity. There are about 170 species of birds in the country bearing a status between threatened to in danger of extinction. This fact also reflects relatively higher bird species richness and ecological fragility of ecosystems in India. Thus, it becomes very important to study the consequences of forest dependent activities on bird diversity in the forests.

As this study deals with the forest management, it is essential to review the background of traditional forest management practices in the country and more specifically, in the Satpura hills. This would give an idea how, over so many years, the landscape has changed owing to different silvicultural systems.

1.5 History of Forest management in India

India's history of forest management is linked to its civilization history. Archeological evidence from the Indus Valley civilization shows that people were using the forests as well as protecting them (Dwivedi 1980). In the ancient Indian scriptures like Ramayana and Mahabharata, forests have always been a central theme. These scriptures mention kadamba (*Anthocepahllus kadamba*) van, Ashoka (*Saraca indica*) van and

dandakaranya (forested area) . The peepal tree (*Ficus religiosa*) derives its religious significance after Buddha, who attained enlightenment while meditating under this tree. During Ashoka's rule, the forests were reserved as 'abhayaranya' equivalent to a present-day Sanctuary. 'Shukraniti' a well known work during 320-400 AD describes forest management, plantations of fruiting and flowering trees and the importance of preserving the forests. Akbar was the only king in the Mughal dynasty who realized the importance of plantations along the roadside and canals and maintaining the Reserved forests. Most other Mughal kings systematically destroyed the forests as they were used by the dacoits and rebels as hiding grounds but at the same time, some of the forests were preserved as hunting reserves by these Kings (Dwivedi 1980, Pande and Pande 1991, Malhotra 1992, Palit 1993).

Forests were of free access to the local owners and rulers before the British took over. The locals used the forests for slash and burn agriculture, timber logging and export of big timber to countries such as Persia and Arabia. Local inhabitants and rulers managed the forests as they liked and wanted. Only certain tree species were reserved against felling as they were considered to be the prerogative of the rulers. Tipu Sultan, a ruler in Southern India had reserved teak and sandalwood as the 'royal species' that were not allowed to be felled. This reservation did not result in protecting the forests as eventually these forests were leased out to timber merchants who wiped off most of the forests. (Malhotra 1992).

At that time of British rule, Central Provinces was a large state that included parts of Maharashtra, Madhya Pradesh, and Gujarat. Several tribes among whom the Gonds were the most powerful inhabited the Central Indian Highlands and valleys. Gonds defeated the local Rajput rulers in several areas and formed smaller kingdoms. By the 16 Th century, Mughal rulers overpowered this region. They tried to encourage the clearance of forests for agriculture extension. Such a policy not only helped them in winning over the tribals but also helped in controlling the dacoits and rebels. By the 17th Century, Marathas had taken over the Central India. The policy of clearing forests for cultivation was kept alive till internal feuds among the Marathas created dispute among

them. The British took over control from Marathas by the 18th century (Guha and Gadgil 1989, Rangarajan 1996). Initially the British viewed forests as an impediment to agricultural expansion (Gadgil and Guha 1992). Tree felling and wasteful form of extraction were greatly intensified during the early British occupation (Guha and Gadgil 1989, Gadgil and Guha 1992, Rangarajan 1996). The British required timber for military expansion and for export of teak to England so tree felling process expedited during the British Rule. However, it was soon realized that timber supply was not unlimited and a check had to be maintained on such overexploitation. In 1806, the teak forests in Malabar region were the very first to be declared as reserved forests in the country. In 1856, when organized forestry operation began in the country, Dietrich Brandis was appointed as India's first Inspector General of Forests (Stebbing 1982). Brandis appointed forest officers for each state to formulate the forestry working.

The forests of Central India remained largely unexplored up till 1860. It was only after Forsyth's exploration in 1889 that the value of Central Indian forests was revealed. By the end of the 19 Th century, the Central Indian forests were maintained under improvement felling and strict fire protection. As a result, within a few years some of the finest natural teak and miscellaneous forest in the country were seen in Central India (Rao 1961, Guha 1983).

1.6 Introduction to Satpura Hill ranges

1.6.1 Physical Geography

Satpura Hills traverse the width of the country in an West-East direction and are considered as the dividing line between the North and the Deccan Biogeographic zones of peninsular India (Rodgers and Panwar 1988) Seeing the hilly and undulating terrain of Satpura hills, Captain J. Forsyth (1889) christened the hills as the 'highlands of Central India'. Satpuras are located to south of the Vindhyan uplands and in the catchment of Narmada and Tapti rivers. One of the oldest ranges in the country, the Satpuras begin in Western India from the Rajpipla Hills, continue through the Mahadeo hills to the Maikal range in Central India. Dhupgarh, the highest peak of Satpuras at 1,350 m is

located in the Mahadeo hills. Satpuras appear to have been affected by tectonic disturbances as outpourings of lava resulting in trap formations are commonly seen here. The Satpura range shows a series of steep scarps towards the North at 600 to 900 m elevations. In the Western Satpuras, the lowest elevation is seen at 360 m near Khandwa-Burhanpur area. The Eastern Satpura range culminates near Rajmahal Hills at the base of the Bengal basin (Wadia 1978)

The Satpura forests show contiguous network of forests with that of Harda divisions in the west while to the south are forests of Betul division that leads to the Melghat forests and Western Satpuras. The Western Satpuras are contiguous with the Dang and Panchmahal hills in Gujarat and Dhule and Jalgaon hills in Maharashtra. (Sawarkar and Panwar 1990).

1.6. 2 Biological values of Satpuras

1.6.2.1 The forests

The revised classification of Champion and Seth (1968) categorizes Satpura forests as Group 5A Tropical Dry Deciduous Forests, sub group Dry Deciduous Teak Forests. Rodger's and Panwar's (1988) biogeographic classification places Satpura hills in the 6E Deccan Biogeographic zone. This zone is the most extensive zone and over 50% of the country's forests are contained in this zone. The Northern half of this zone has forests dominated by *Tectona grandis, Acacia catechu, Diospyros melanoxylon, Terminalia tomentosa, Albizzia lebbek, and Anogeissus latifolia.* Towards the southern half , the forests are relatively more dry with species such as *Tectona grandis, Boswellia serrata, Butea monosperma, Lannea coromandelica, and Lagerstroemia parviflora.* While the forests in Satpuras are chiefly dry deciduous considerable variations in the forest types are seen due to varying altitude and topography. There is a gradient of moist forests in the east to very dry teak forest in the West in Bori (Sawarkar and Panwar 1990). A detailed description of these forests is given in Chapter 2 and 3.

1.6.2.2 Birdlife in Satpura Hills

The central Indian forests did not attract much attention from ornithologists for a long time. Most of the past records are published as checklists maintained by officers who were posted in these forests. Osmaston (1921) published a detailed list of 135 species from Pachmarhi. He mentions recording the Wedgetailed Pigeon in Pachmarhi. None of the other studies reports this species from Satpuras. Bates (1927) published his list of birds in Pachmarhi. He added 9 more species to Osmaston's list and has given a detailed description of bird breeding activity between April to late June. D'Abreau (1931) recorded 409 species over 20 years of observations on bird life in Central Provinces that included a large area outside the Satpura Hills. He mentions a few species not recorded by earlier workers: this includes the Himalayan Yellowbacked Sunbird, European Hoopoe, Malabar Grey Hornbill, and Black Eagle. In 1939, Ali carried out a detailed survey in a larger portion of Central India that included the Northern and Eastern parts of Satpura range. Within 6 months, Ali documented 278 species. In 1931, Heweston surveyed the Betul area and documented 158 species. Most of these were mentioned in the earlier lists and were commonly seen in present day Bori Sanctuary. Wright (1942) recorded 193 species from Berar area that constitutes the plains of Satpura. In 1955, Heweston complied his observation of 30 years (from 1926-1955) from all over the state and recorded 308 species. In his previous survey He had mentioned the Nilgiri Blackbird (*Turdus merula simillimus*) that finds mention in Osmaston's list (1921) also. This is actually the Blackcapped Blackbird (*T.m.nigropileus*) which is commonly seen in Satpura Hills. It was recognized as a sub-species as late as 1960s (Ali and Ripley 1983). Heweston's list was the very first to mention the presence of Red Jungle fowl in Central Indian region. I did not observe Red Junglefowl in Bori, although it is more common in adjacent Pachmarhi Sanctuary . Forsyth (1989) mentions its occurrence in Central Indian forests.

Another very interesting aspect of the avifauna of Satpura hills was highlighted by Ali (1949) when he recorded some Eastern Himalayan species distributed in the Satpura Hills. Ali has mentioned 13 genera of birds whose

representative species are found in the Eastern Himalayas, South-East Asia and Western Ghats. They are not found elsewhere in India.

Table 1.1 The Genera and representative species listed by Ali (1950) that shows discontinuous distribution from Eastern Himalayas and Western Ghats in India.

Genus	Representative Species
Trochalopteron	Laughing Thrushes
Garrulax	Laughing Thrushes
Oreocincla	Mountain Thrushes
Irena	Fairy Bluebird
Aracnothera	Spider Hunter
Hemicircus	The Heart-spotted Woodpecker
Dryocopus	The Great Black Woodpecker
Vivia	The Speckled Piculet
Alcemerops	The Blue-bearded Bee Eater
Dichoceros	The Great Indian Hornbill
Lynocornis	The Great Eared Nightjar
Batrachostomus	Frogmouths
Tephrodornis	The Large Wood -Shrike

Ali explains that these birds probably used the Satpura range as 'ornithogeographical highway ' to enter the Western Ghat forest from the Himalayas using the connecting Satpura mountains. This supported Hora's "Satpura hypothesis" (1949) which proposes a lost mountainous connection between the Assam Himalayas in the east and the Western Ghats in the west. Hora's Satpura hypothesis was based on his finding south-east Asian and Himalayan species of fishes in the mountains of peninsular India. Hora's claim was substantiated by Roonwal (1949, on mammals belonging to family Viverridae, Mustelidae, and Hemitragus), Biswas (1949, on floral affinities) and recently by Swan (1993, on Herpetofauna). All the above mentioned studies reported various species of Himalayan and Malayan origin to have reached the peninsular India through the Satpura hills. While many biologists accepted it, some did not. Abdualali (1949) advocated Eastern Ghats as a possible

some did not. Abdualali (1949) advocated Eastern Ghats as a possible dispersal pathway for northern forms. Many birds (e.g. *Arachnothera longirostris*, *Stachyris rufifrons*, *S.ruficeps* and *Cyornis poligenys*) occur in the Eastern Ghats as well as in disjunct areas in the Western Ghats and the North-east. Mani (1974) points out that there is no geological evidence to support such continuous mountain link as suggested by Hora. Ripley et al. (1987) discards the possibility of such connection suggesting that continuous distribution of humid forests rather than mountains on the Indian plains is more plausible explanation for this peculiar distribution. Randhawa (1945) and Ripley (1949) supported this theory. Of the species mentioned by Ali, I have observed the Blue-bearded Bee-eater in Bori, and Sawarkar (1988) mentions the occurrence of the Heart-spotted Woodpecker and the Great Black Woodpecker from Melghat Tiger Reserve. The latter two species are inhabitants of evergreen forests, and their occurrence in the dry deciduous forests of Satpuras is indeed intriguing.

1.7 Previous studies on the impact of selective logging:

1.7.1 Impact of selective logging on canopy opening

Logging is known to have considerable effect on the forest microclimate. Due to logging, subcanopy levels of the forest are exposed to increased levels of radiation, increased temperature (Scultz 1960, in Johns 1997, Crome et al., 1992), and decreased humidity (Johns 1985). However, this depends largely on the level of canopy opening created by logging.

Crome et al., (1992) reported 22 per cent loss in canopy in selectively logged rain forests of Australia. Uhl and Vieria (1989) reported about 80 per cent canopy opening in Belem- Brasilia forests in Brazilian Amazon. Although the extraction rate was not more than 10 to 12 trees per ha, 26 per cent of tree mortality due to felling led to major canopy opening. Another study by Uhl et al., (1991) in Tailadia in eastern Amazonia reported extraction rate of 2 to 3 trees per ha. and corresponding lower canopy opening of 8 per cent. Verissimo et al., (1992) studied logging impacts on Paragominas in Eastern Amazon. The extraction rate was six trees per ha and 27 trees were damaged

per tree felled. As a result, 68 per cent canopy loss was reported. Thiollay (1992) reported extraction rate of 4 to 8 trees per ha in French Guianan rainforests and due to felling damage the total loss in canopy cover was about 45 per cent. Johns et al., (1996) compared two sites with varying degrees of damage in Eastern Amazonian rainforests. The site where precautions were taken to reduce the damage had 10 per cent canopy loss and the site where precautions were over looked had canopy loss of over 19 per cent, although both the sites had similar rate of tree extraction. This indicates that the degree of canopy opening is governed not only by the extraction rate but also by the damage caused during extraction per se.

1.7.2 Impact of selective logging on tree diversity, regeneration, and phenology

Johns (1983), Thiollay (1992), Baker and Lacki (1997) found that abundance of different families of trees before and after logging varied. Tree species diversity and richness reduced not only due to removal of trees but also due to damage to other tree species in Malaysian rain forests (Johns 1983). However, Uhl et al., (1991) found opposite results. In eastern Brazilian rainforests, the tree diversity had increased after logging. This was due to an increase in light reaching the ground that allowed pioneer species to be established in the logged site which were absent prior to logging.

Initial regeneration was found to be rapid following logging in some studies. Saulei and Lamb' s study (1991) in logged forests of Papua New Guinea found that initial regeneration appears to originate from seed stored in the top soil and from the vegetative regrowth. This is largely dependent on the extent to which the topsoil is disturbed after felling. In Papua New Guinea, the floristic recovery was more of pioneer species than the primary species. Thiollay's (1992) study indicated that after logging, softwood species that were fast growing and could tolerate increased light radiation had replaced the climax species in the logged site.

In the evergreen forests of Kerala and Assam in India, Nair (1991) found poor regeneration after selective logging. Nair attributed increased insolation,

logging-associated damage to seedlings and saplings and competition from colonizers as important factors contributing to poor regeneration in the felled area. In Assam, poor regeneration was attributed to high intensity of felling, and increased weed growth. In his Andaman study, Nair (1991) found that the silviculture system known as Canopy Lifting System was beneficial for regeneration of Dipterocarpus saplings as the Dipterocarp seedlings are partially shade tolerant. Elkunchwar et al., (1997) had carried out plant regeneration study in logged forests of Andaman islands and found results similar to that of Nair's. Chandransubhas (1990) found that intensive logging in the evergreen forests of Uttara Kannada in South India resulted in severe damage to other standing trees and very poor regeneration. Datta (unpublished) found lower levels of regeneration, reduced tree density and basal area in selectively logged forests of Arunchal Pradesh in North- East India. It therefore appears that regeneration in logged areas is dependent upon the intensity of felling, and precautions observed prior to and after logging to curtail the damage associated with logging.

Rainfall affects the pattern of fruiting and flowering in an area. Apart from rainfall, local microclimatic features are also responsible for leaf and fruit production. Johns (1983) reported lower fruiting and flowering from logged forests in Brazil, whereas in Malaysian rain forests, fruiting and leaf production was higher or equal to the unlogged forests. Peres (1994) reported increase in fruiting, especially in *Ficus* species in the disturbed areas. Changes in phenological patterns due to selective logging has not been established in studies up till now.

1.7.3 Impact of selective logging on bird species richness, and bird species diversity

Silvicultural practices can not be categorically described as beneficial or detrimental to birds. A certain silvicultural practice may change the habitat enough to decrease the population of some species, while it may benefit other species. Effect of clear cutting on bird communities has been documented by a number of studies (Franzeb 1977, Titterington et al., 1979, Crawford et al., 1981, Neimi and Hanowski 1984; Warkentein et al., 1995). These studies

report a decline in most forest specialists and an increase in generalist species from the clear felled sites Effect of selective logging on bird communities is documented in Southeast Asia in Sabha and Tekam reserves (Johns 1983, Wilson and Johns 1982, Wong 1985), Amazonian rainforests (Thiollay 1992, Johns 1991, Lamb 1991) and Australian rainforests of Queensland (Crome et al., 1992).

Webb et al. (1977) studied the effect of varying intensity of selective logging in hardwood forests of Adirondack Mountains, New York. The study indicated that bird species richness increased with increasing intensity of logging. 11 species remained unaffected by logging, 7 species had increased in abundance and 8 species had declined immediately after logging. The species that declined were forest specialists and could not tolerate canopy openings. Johns (1983, 1986) found a significant decline in species richness in the logged forests in Malaysian rain forests. A marked decline in bird diversity and richness after logging was reported by studies in Malaysian and French Guianan forests (Wong 1985, John 1991, Thiollay 1992). Crome (1991) found no difference in number of species after logging, as felling did not change the structure of the site to a greater extent in Queensland, Australia. Taylor and Haseler (1995) studied the effect of partial logging systems on bird community in dry eucalyptus forests of Tasmania, Australia. The study found higher abundance and richness of birds in mature unlogged forests and least in the logged forests. Baker and Lacki (1997) investigated impact of various silvicultural practices on birds in Oak-Hickory forests, Kentucky. Their study found increased bird diversity in two Age Harvest system plots and unharvested plots.

1.7.4 Species affected by selective logging

All the above-mentioned studies reported a decline in forest specialist species that included terrestrial insectivores, and understorey and fallen fruit eaters (Bowerbird, Oven- birds, Cowbirds). Most Malaysian Hornbills were able to persist in selectively logged forests because the logged sites were large tracts of forests and felling did not target at the hornbill food and nesting trees (Johns

1987). Among the insectivores, bark and twig feeders, foliage gleaners, ground insectivores and some flycatchers are reported to be sensitive to logging (Johns 1983, Wong 1985, Thiollay 1992). Raptors declined in Thiollay's study (1992) and increased in John's study (1983, and other studies in Johns 1997). The cause of increase was due to availability of open areas and improved visibility in the rain forests. The species that increased after logging were small and medium sized frugivores like bulbuls, mynas, pigeons and smaller sized hornbills. Woodpeckers and secondary growth insectivores such as beeeaters, rollers, drongos, nectarivores, and granivores also increased in some studies (Johns 1983, 1991). However, within the same genus, response to forest disturbance depends on the species and the site. Trogons declined after felling in Malaysian forests (Johns 1983) but increased in Amazonian rainforests (Johns 1991). Larger species of Hornbills declined in Malaysian logged forests whereas smaller hornbills survived (Johns 1983b, 1987, 1988).

1.7.5 Rate of recovery of birds in selectively logged forests

After logging, the vegetation structure is altered and there is a corresponding change in the bird community composition. Wilson and Johns (1982) reported that recolonizing is possible and rapid if the logged site does not deteriorate further after logging. Once vegetation regrowth begins, some bird species are able to recolonise the logged areas. Webb et al. (1977) found that of the 8 species that had declined following logging, 3 returned within 15 months of logging. Johns (1989) found that after twelve years, high proportion of avifauna had reappeared in the logged site, barring some understorey flycatchers. Thiollay (1992) found very slow recovery rate of avifauna even after 10 years of logging as removal of large seed trees had resulted in loss of soil nutrients and food resources. Wong (1985) reported poor recovery of understorey birds after 25 years although the plant recovery was well advanced. The reason was that the logged site was isolated and absence of a source population in close by areas made the avifaunal recovery slower than those areas where the primary forests were nearer. Presence of unlogged forests in close proximity to the logged site has proved to accelerate the recovery of bird species in other

studies as well (Johns 1983, Recher et al., 1987, Taylor and Haseler 1995, Backer and Lacki 1997). Apart from the extent of removal of trees, the ecological requirements of species and availability of refuge areas nearby determines the time taken for recolonization of species in an area.

1.8 Hypotheses

Based on results from the cited studies, I expected the following outcome from my study, which I put forward as hypotheses:

1. Long rotation cycles give sufficient time for recovery of the vegetation and therefore of the bird communities .

Several studies have reported higher bird species richness in the old logged sites (Johns 1983, Mannan and Meslow 1984, Thiollay 1992, Taylor and Haseler 1995). Among the forest species, woodpeckers (Conner et al., 1975), nuthatches, some flycatchers, (Manna and Meslow 1984), large sized hornbills (Johns 1983) and owls are usually associated with old logged site (Probst et al., 1992). Long rotation cycles are required to retain higher bird species richness in an area. I expect total species richness to be higher in the older logged sites in each silvicultural system.

2. Bird species diversity is higher in areas having greater vertical and horizontal diversity.

Bird species diversity is reported to increase with both vertical (MaCArthur and MacArthur 1961, MacArthur and Wilson 1967, Karr and Roth 1971, Willson 1974, Terbogh 1977) and horizontal indices of habitat heterogeneity (Roth 1976, Schemske and Brokaw 1986). Daniels (1989) found a weak correlation between structural complexity and bird species diversity. Daniels reported higher bird diversity in disturbed forests as such areas had a mosaic of structural and floristic elements. Areas with greater habitat diversity will offer wider foraging opportunities and results in formation of heterogeneous edge habitat (Terbogh 1977, Price 1975, Schemske and Brokaw 1986) that can support more number of bird species.

Following two hypotheses will be tested primarily on results obtained from Melghat study as I had the opportunity to compare the 'pre' and 'post ' logging situation in Melghat. The hypotheses are based on the results from studies mentioned in section 1.7.

3. Selective logging results in an overall decline in bird species richness, diversity, tree density and basal area.

4. Immediately after logging, the abundance of generalist species increases and that of the specialists declines.

1.9 The design of this thesis

The thesis has four Chapters, including this Chapter on Introduction. The four different silvicultural practices in Bori were practiced according to the different forest types. Though forestry practices had stopped before 1992, evaluating post-logged areas would give an idea about which system results in least modification to the habitat. Chapter 2 focuses on the Bori study, describing the study sites and the main results, and discussing the important patterns observed. To compare the immediate effect of logging, it was necessary to study an area prior to logging and immediately after logging. This was possible in Reserved forests adjacent to Melghat, where selective logging was going on since 1993. I studied the logged sites before it was logged, while it was being logged and after logging. The description of the study sites, the results obtained and the discussions on the patterns seen in Melghat are included in Chapter 3. In Chapter 4, the main results are used to test the above mentioned hypotheses. As an outcome of this study, further suggestions for forest management are included in this Chapter.

CHAPTER 2

The effect of different logging practices on bird communities in Bori Wildlife Sanctuary.

2.1 Introduction

Bori Sanctuary is located on the northwestern slope of the Satpura Hills in Hoshangabad district of Madhya Pradesh. There is an interesting history describing how Bori Forests were brought under protection. Prior to 1862, the tribal chiefs had all the rights over these forests and they allowed their subjects to use forests for lopping, cultivating and grazing purposes. The forests of Bori belonged to a Korku chief, Thakur Bhupatsingh Jagirdar. Gangopadhyaya (1985) writes that in 1859, the British seized these forests from the chief when the chief demanded the payment for the fowls that were purchased from him by a British officer! By 1863, the British took over the administration of Bori forests. Brandis (1897) writes that at that time the forests were in extremely neglected condition with over half of the forests burnt and cleared by the *dahiya* (slash and burn) cultivators and about 1,10,00 cft. Of half burnt wood was found from this area. Believing that if protection is given to these forests it will be naturally regenerated, Colonel Pearson ordered removal of villages and cattle from Bori Valley. Brandis (1897) gives credit to Colonel Pearson for introducing fire protection measures in Bori Forests. Pearson experimented dry burning for the first time in Bori forests to protect them from further fires. His experiment was successful as was evident from the filling up of blank areas with seedlings, and subsequently increased growth of large trees and bamboo (Gangopadhyay 1985).

Till 1889, there was no felling in the Sanctuary. From 1889 to 1895, mature teak and *Ougeinia oogenesis were* felled. In 1909, Brander prepared a working plan that excluded the good quality teak forests and prescribed selective felling in the Western portion of the Sanctuary. From 1928 onwards, Sodhi's working plan introduced heavy canopy opening that brought in bamboo, grass and weed in the opened up area. However, one important modification suggested by Sodhi was to treat the teak and non-teak forests

under different system of management. Up till 1986, these systems were followed with periodic changes in felling cycle period in the Sanctuary.

Bori Sanctuary was selected for the initial phase of the study to evaluate the past forestry practices in the area. Bori forests were maintained under various types of silvicultural practices for over a century. Since past ten years no commercial logging is permitted in the Sanctuary. Thus, we investigated the response of bird communities in the previously logged sites to understand the changes in alpha and beta diversity scales. The study was carried out between November 1992 - June 1994, excluding the rainy season (July to October).

Review of other studies on the impact of logging practices on bird diversity has indicated that diversity is not necessarily correlated with age of the forest (section 1.7). Species diversity is examined at several scales, the most popular being alpha and beta diversity. Alpha diversity is point diversity or diversity of a homogenous habitat. This is the smallest scale of measuring diversity and describes within-habitat diversity. Second component of diversity is Beta diversity. Beta diversity measures the rate of species turnover between habitat types. This is the between habitat diversity (Wiens 1989, Cody 1983). This chapter deals with description of species diversity at both these scales. Diversity can be influenced by several factors. Vegetation complexity plays a major role in determining the avifaunal response to the site. What factors limit the abundance of a species in an area? The most common approach to answer this is to quantify the key resources (Sager et al 1969; Daniels 1989; Hell 1996) and relate them to bird diversity measures.

2. 2 Location of Bori Wildlife Sanctuary

Bori Sanctuary is shaped like an elongated boat, with one end raised in the East. There are continuous chains of steep cliffs on the eastern side and the other sides have irregular chain of hills. The Sanctuary lies between 22° 19' 28" and 22°30'18" and between 77°56'40" and 78°20'40". The Mahadeo Hill Ranges runs in the northern boundary of the Sanctuary. Tawa River in the

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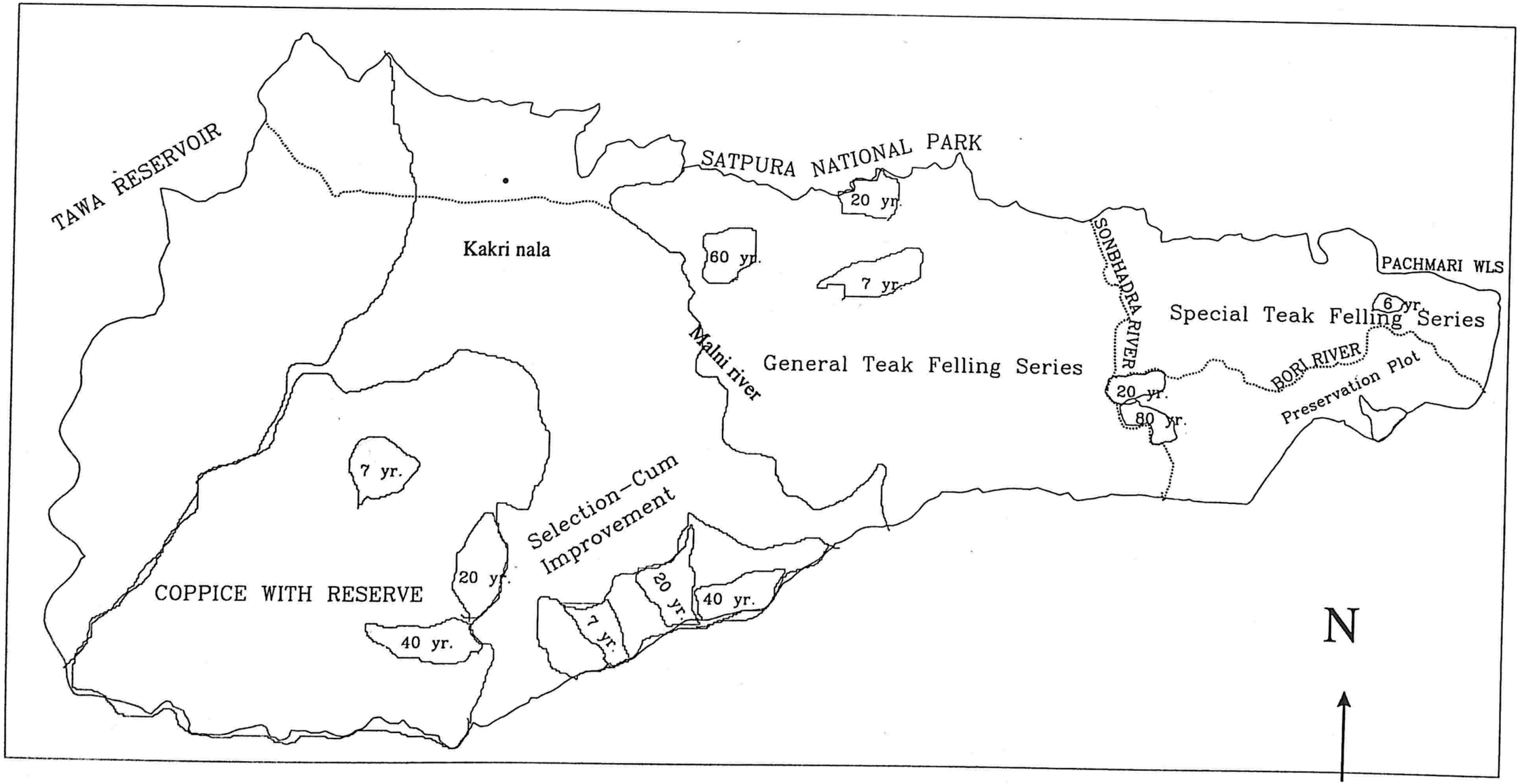
Figure 2. 1 Map of Bori Wildlife Sanctuary



west and steep Hills of Pachmarhi in the east serve as natural boundaries for the Sanctuary. The forest vegetation is contiguous with Betul forests in the south and forests of Chindwara district in the east. The total area of Bori is 483 km2. The Sanctuary lies in the catchment area of the Narmada River. The Satpura Range in this part of the Sanctuary displays a gradient of gentle rolling slopes in the West to steep scarps in the East. The lowest altitude recorded is in the East at 375 m.a.s.l. Belkhandhar peak along the Mahadeo hills is the highest point at 1,045 m.a.s.l in the West (Gupta 1988, Sawarkar 1990).

Under Wildlife (Protection Act) of 1972, about 1427 km^2 of forests were notified as Bori Wildlife Sanctuary in 1975. In 1977, Pachmarhi Wildlife Sanctuary was carved out of Bori Sanctuary with an area of 418 km^2 and in 1981, Satpura National park was created out of the Northern part of the Bori Sanctuary and western side of Pachmarhi Sanctuary with an area of 524 km^2 (Gangopadhyay 1985). This whole area together forms the compact unit of Satpura Conservation Area (SCA).

2.3 Geology, rock and soil

The Bori valley lies along the northern edge of the Satpura range and south of the Vindhyan range. Narmada River valley is situated between these two hill ranges. The tributaries of Narmada namely, Tawa and Denwa flow in to the valley from West to East, which is also the general direction of river flow in the area. Deccan traps, sandstone and occasionally conglomerates are the main rock formations in the Sanctuary. Trap formations are seen as intrusions generally from east to west direction. Limestone is frequently found in the northern boundary of the forests. Bijori rocks made up of sandstone and large quantities of clay are seen around the southern part of the Sanctuary. The underlying rock type is basaltic (Sawarkar 1990).

Among the soils, alluvium is seen along the banks of rivers. Alluvium is considered richest in nutrients. A partly disintegrated trap gives rises to clayey soil that drain poorly and supports poor tree growth. However, finer decomposition of trap gives rise to better quality soil that can support better

quality teak forests. Conglomerate derived black, shallow soils support mixed type of forests. Sandstone derived soil do not support good quality teak forests as the soil is sandy and poor in nutrients. Soil pH seems to be another important factor in determining the type of forests it can support. Best quality teak forests grow on neutral soils. Most rocks except the Conglomerates yields neutral to mildly acidic soils that can support good quality teak forests (Gangopadhyay 1985).

2.4 Climate

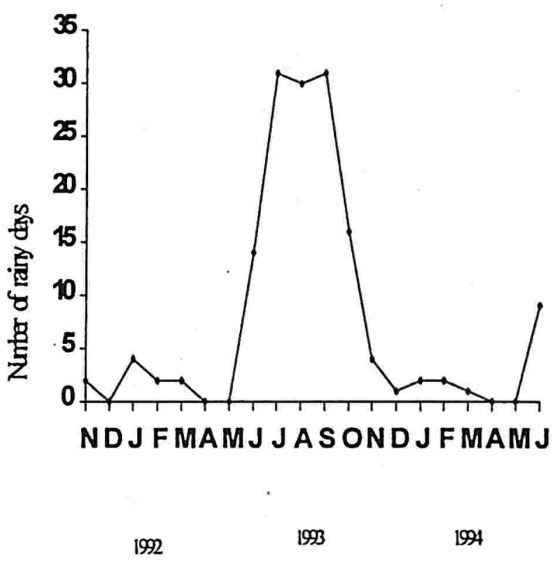
Three distinct seasons are defined as Summer (March to mid June); Monsoon (mid June to September) and winter (October to February). For the entire study period, I had recorded minimum and maximum temperature on a daily basis. The following records are a daily average for the two seasons.

Table 2.0 Average temperature (° c) for Bori from 1992- 1994.

Season	Minimum ° c	Maximum ° c
Winter 1994	7.5	19.0
Summer 1995	23.4	35.5
Winter 1995	9.7	20.6
Summer 1996	24.5	37.5

Rainfall : Period between June to September are always wet months, constituting a distinct monsoon season. The rainfall data was collected from October to June, and the information ion rainfall from July to September is obtained from the weather station at Churna. The sanctuary received winter rains from October to February. December was usually the dry month. A few showers were recorded in March also.

Figure 2.2 Number of rainy days per month between October 1992 to June 1994.



The average rainfall is 2000 mm per year in the Sanctuary since 1988. The western part of the Sanctuary receives less rainfall (up to 1600 mm) , while the eastern part receives over 2000 mm rainfall (Gangopadhyay 1985).

2.5 Drainage

Tawa and Denwa are two main rivers flowing in the Sanctuary. Rivers such as Koti and Malni in the western side of the Sanctuary drain into Tawa, whereas Sonbhadra and Bori are tributaries of Denwa. Most of these rivers dry up during summer. In 1967, a dam was constructed on the Tawa reservoir, a little downstream of the confluence of the Denwa with Tawa. An area of 5000 ha in the Western portion of the Sanctuary was submerged under the backwaters of Tawa Dam. The filling up of backwater has created an artificial lake near Banglapura ghat (Gangopadhyay 1985). During the rainy season this reservoir fills up and water is retained up till the month of March-April. This has attracted a number of ducks and waders in the reservoir (pers observ) that were not present earlier.

2. 6 Vegetation

According to Champion and Seth's classification, Bori forests are classified under following forest types:

The major forest type is **3 B/C1 South Indian Moist teak bearing forest.** These forests are dominated by teak on trap along with *Terminalia tomentosa, Lagerstroemia parviflora, Schleichera oleosa* and *Dalbergia latifolia*. Bamboo (*Dendrocalamus strictus*) is presents everywhere. Two sub types are recognized as given:

(i) 3B /C1 (B) Moist teak forests: Eastern half of the Sanctuary comprises of these forests. Here, the rainfall range is between 1600 to 2500 mm on deep loamy soils that supports good quality teak with dense undergrowth. Associate canopy species of teak are *Terminalia tomentosa, Adina cordifolia, Pterocarpus marsupium, Anogeissus latifolia and Diospyros melanoxylon.* Understorey is mainly of *Helicteres isora, Phoenix acualis*, and *Lantana camara*. The grass species commonly seen here are *Themeda quadivalvis, Dichanthium annulatum. Milletia auriculata, Bauhinia vahlii, Butea superba* are frequently seen climbers in this forests.

(ii) 3 B/C1(C) Semi Moist teak Forests: The forests from Sonbhadra river in the East up to Kakri nallah in the West comes under this sub-type. The rainfall is less than 1600 mm, with moderately deep loamy soil, higher percentage of teak and moderate undergrowth. Better quality teak forests are found along the riverbeds on alluvium soil in this area. In the eastern side of the Sanctuary, along the confluence of Sonbhadra and Bori River, superior growth of teak is seen. In the western and southern side of Sonbhadra, teak was of relatively inferior quality. Other drier tree species association was seen along with teak in canopy *are Butea monosperma, Adina cordifolia, Buchananina lanzan, Aegel marmelos* with undergrowth of grass species such as *Heteropogon contortus, Eulailopsis binata, Ischammum laxum.* Bori forests can be classified primarily in moist deciduous forests that includes the moist and semi moist deciduous forests of Eastern Bori and dry deciduous forests that include the

forests in the Western and Southern part of the Sanctuary (Gangopadhyay 1985).

2.7 Fauna

Captain Forsyth (1889) describes large sized gaurs (*Bos gaurus*) and sambar (*Cervus unicolor*) in this area. The sloth bear (Melursus *ursinus*) is most frequently encountered and most feared carnivore in the Sanctuary. tigers (*Panthera tig*ris), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), Hyena (*Hyena hyena*) are present in the forests, the latter three more frequently encountered than the tigers (pers.observ). Chowsingha (*Tetraceros quadricornis*), barking deer (*Muntiacus muntjak*), cheetal (*Axis axis*) and nilgai (*Boselaphus tragocamelus*) are commonly seen in the Sanctuary. The Indian giant squirrel's Central Indian sub – species, *Ratufa indica centralis* inhabits the forests of the Bori Sanctuary. Its range in Madhya Pradesh is sporadic, as it is dependent on moister, mature continuous forests. The flying squirrel (*Peturista peturista*) is also common in these forests. Small Indian civet (*Viverricula indica*), porcupine (*Hystrix indica*), otter (*Lutra lutra*), are among the smaller mammals seen here (pers. observ).

2.8 People

The Sanctuary has 16 forest village with a population of about 3500 people. Most villages are located along the southern and western portion of the Sanctuary. In 1859, at the time of British administration, Korkus who were the original inhabitants of the forests were made to evict the villages. A few settlements were allowed to stay inside, as they were required to carry out forestry operations. Later, more labour was required and more people were brought in from outside. Main tribes in this area apart from Korkus, are Gonds and Thathiyas. These people are skilled in carrying out forestry operations and other labour intensive work such as road laying, fire fighting and construction of wells and bunds. Thathiyas are considered much lower in the social hierarchy and are engaged in cattle herding for the rich Gaolis (Gangopadhyay 1985).

2.9 Pervious studies in Bori Wildlife Sanctuary

Rodgers and Hall (1988) carried out an assessment of floral diversity of the Preservation plot in the eastern portion of Bori. Datta (1993) studied the Indian giant squirrel feeding ecology in the Sanctuary. Pai (1993) compared the bird community in disturbed and undisturbed riparian areas and documented 214 species.

Since the present study deals with evaluating the impact of logging, the next section outlines the salient feature of four silvicultural practices operational in the area.

2.10 Past working in the Sanctuary

The teak and non-teak areas were managed under different system since 1928. Non-teak forests and poor quality forests were managed under Coppice with Reserve (CWR) system and better quality miscellaneous forests were managed under Selection cum Improvement (SCI) system. The better quality teak forests were worked under Special Teak Working Circle (STFS) and slightly inferior quality teak forests were managed under General Teak Working Circle (GTFS). Coppice and Selection systems were practiced in the dry deciduous forests and the General teak and Special teak were practiced in the moist and semi-moist deciduous forests.

The present working plan: Gangopadhyay's plan (1985-1995).

Gangopadhyay (1985) wrote the working plan for a period of ten years from 1985-1995. Following the ban, felling had stopped in 1989 in the Sanctuary. However, the working circles were maintained as they were in the earlier plans. Each felling system had its own sets of felling rules, described in the next section. Some felling rules that were common to all the systems are given below:

2.11 Felling rules

Before felling begins, systematic marking of the boundary line is carried out. A compartment is the working unit in the system. Within each compartment,

different areas are demarcated prior to logging on a map (treatment map) in the following manner:

***A area*:** These are areas having greater than 25 ° slope, frosty localities, perennial nallah banks, natural blanks that will be afforded protection from felling. No felling carried out for 20 m on either side of the perennial nallah or riverine patch.

***B area*:** This area represents blank or understocked sites within a compartment. The forest department carries out sampling to estimate the density prior to felling. If seedlings of commercial timber species are less than 625 seedlings per ha, then the area is considered understocked and would be exempted from felling.

***C area*:** These are sites with young pole crop of valuable species such as teak, *Pterocarpus marsupium*, *Dalbergia sisoo, Anogeissus latifolia, and Boswellia serrata*. There will be no felling in such area.

***D area*:** This is the workable area. Where there are adequate seedlings (625/ha), the area is capable of regeneration naturally. Areas where the regeneration is not sufficient, plantations would be carried out after felling. The prescriptions for D area will be different for each silvicultural systems. The rules for retaining the species and number of other trees are listed below:

- Most fruit bearing trees like *Madhuca latifolia, Buchanania lanzan, Embilca officianlis, Ficus religiosa, Cassia fistula, Zizyphus xylopyra* are to be retained.
- Evergreen and semi evergreen species such as *Terminalia arjuna, Careya arborea, Garuga pinnata, Saccopetalum tomentosum, Syzygium cumini*, are to be retained.
- About 5 snags (dead tree) per ha are to be retained.

- Five logs of economically unimportant species such as *Dalbergia paniculata*, or dead fallen logs will be retained per ha for den sites for small animals such as monitor lizard, ratel, shrews etc.

The following section deals with four silvicultural systems, their felling rules, rotation age and their objectives.

2. 12 Coppice with Reserve Forests (CWR)

The non-teak area of this Sanctuary falls under this system of felling. The teak here is of inferior quality. The most dominating species here is saj (*Terminalia tometosa*), *Adina cordifolia, Diospyros melanoxylan, Embelica officinalis, Terminalia bellerica, Zizyphus xylopyra, and Chloroxylon swietenia.*

The objectives of CWR system

This system caters for small timbers, poles and fuel demand for the people in the plains. The teak does not attain higher girth classes (< than 50 cm Gbh is commonly seen) here. However, provision for billets and planks are met with through this system.

Rotation Period and extractable species

The rotation period is 40 years. Extractable species are teak, *Terminalia tomentosa, Anogeissus latifolia, and Adina cordifolia*. Trees in girth class between 50-60 cm and 60-90 cm. are removed

2.13 Selection cum Improvement Felling Series (SCI)

This system was practiced in better quality mixed forests. In the Sanctuary, these forests are found along the southern boundary. Earlier these forests were managed under improvement felling. Geologically, the area shows sandstone formation and as a result supports better quality teak forests than CWR forests. Along with teak there were other tree species such *Adina cordifolia, Anogeissus latifolia, Boswellia serrata, Lannea grandis, Mitragyna parviflora.*

The objectives of SCI

The requirement of this working circle is to improve the depleted stock by way of improvement felling. Improvement is carried out by removing malformed, dead and diseased trees. Not more than 50 percent of harvestable trees are to be felled under this system.

Rotation Period and extractable species

40 years felling cycle was prescribed. Species to be removed are teak, *Terminalia tomentosa, Ougenia oogenesis*. The extractable girth class was 120 cm for teak and for other species between 90 and 105 cm.

2.14 General Teak Felling Series (GTFS)

This working was carried out in the eastern side of the Sanctuary in semi most forests. The forests were of superior quality than CWR and SCI. These forests are along the alluvial soil along Sonbhadra and had tall trees of teak and other species such as *Terminallia bellerica,* and *Adina cordiflora.*

Objective of GTFS system

The system targeted mainly at teak and other large sized timber species. The compartment will undergo major harvesting known as mainfelling and then after every ten years there will be a thinning operation carried out in the compartment. During thinning operations, mature trees interfering in the growth of younger trees would be removed.

Rotation period and extractable species

The prescribed rotation was 60 years. The extractable girth was between 120 and 180 cm. Preference was given to large sized teak trees. Tree removal was not to exceed 50% of the selected trees.

PLATE 1. 7 year old logged site in Coppice With Reserve (CWR) forest.

PLATE 2. 60 year old logged site in General Teak Felling Series (GTFS).

2.15 Special Teak Felling Series (STFS)

Bori forests in the eastern side of the Sanctuary were managed under this system. Forest composition was mesic type with evergreen and semi evergreen species associated with teak. The mode of regeneration was natural as well as by plantations.

Objective of STFS

Removal of over mature teak trees was the main objective of this system. Teak could attain the girth size above 2 m. in this area. This teak was utilized by the furniture industry all over the country. It was popularly known as 'Bori teak'.

Extractable species and rotation period

The rotation cycle was 80 years. Extractable girth was above 180 cm for teak trees and above 120 cm for other species such as *Adina cordifolia*, *Ougenia oogenensis* and *Pterocarpus marsupium*.

2.16 Intensive Study sites

I had selected following three sites in CWR forests

1. Compartment no. 155 (7 yr site): This compartment lies in the southwestern portion of the Sanctuary. Total area of the compartment was 204 ha. This compartment was logged under CWR in the year 1986-87. By the time I began my study, 7 years had already passed since it was logged. The terrain was flat and area was open and scrubby (Plate 1). Mature trees of *Diospyros, Madhuca, Buchanania, and Aegel* were more than that of teak and Saj.

2. Compartment no. 159 (20-yr. site): The area was logged under CWR during 1972-73. The terrain was flat but vegetation was dense. Total area was 225 ha. The tree composition was similar to the 7 yr site but with fairly good representation of large teak trees. Fruiting trees such as *Buchanania lanzan, Madhuca latifolia, Acacia catechu, Randia uliginosa* were more in number here.

3. Compartment no 145 (40 yr site): This was a smaller compartment with an area of 180 ha. Logged 40 years ago, this site had fairly good representation of miscellaneous composition. A dry nallah passed through along the Western boundary of this site.

Three sites were chosen in SCI

1. Compartment no. 139 (7 yr site): This area was logged in 1986-87. Total area was 226 ha. The terrain was mildly hilly. A big nallah marked the eastern boundary of the site. The area was open and had very few teak trees. Tree species such as *Aegel marmelos, Madhuca latifolia, and Diospyros melanoxylon* were more in number here.

2. Compartment no. 123 (20 yr site): This area was logged in 1972-73. Total area was 262 ha. The terrain was flat and vegetation was more dense than the 7 yr site.

3.Compartment no. 124 (40 yr site): This was logged in 1952-53 under improvement felling. The area was flat and had mature teak and *Terminalia* spp., trees. The total area was 268 ha.

Following sites was selected in General teak working circle

1.Compartment no 83 (7 yr site): The terrain was hilly and undulating. Total area was 223ha. Trees such as teak, *Terminalia spp., Madhuca latifolia, Diospyros melanoxylon, Buchanania lanzan* were present here. Undergrowth was that of *Lantana camara.*

2. Compartment no 88 (20 yr site): This site was logged in 1973-74. The area of the site was 245 ha. The terrain was hilly. In this site, *Boswellia serrata, Mitragyna parviflora* and *Stercula urens* were commonly seen.

3. Compartment no 93 (60 yr site): This was relatively flatter area. The total area was 280 ha. This site after being felled 60 years ago had undergone thinning every 10 years. This had resulted in having scarce density of large trees in the area (Plate 2).

PLATE 3. 6 year old logged site in Special Teak Felling Series (STFS). Teak was planted after clearfelling in 1986.

PLATE 4. Preservation plot in Bori. Two strata are visible: tall emergent trees and shrubs. Mid - storey and grass cover were not represented in the plot.

Following sites were selected in Special Teak Working Series

1. Compartment no 6 (6 yr site): This was a hilly area close to Paratha nallah. The area was logged in 1989. Total area of the compartment was 170 ha. After being clearfelled, it was replanted with teak. Three large *Ficus benghalensis* trees were retained at the time of felling. The teak trees were barely 4 m tall. Understorey was mainly of *Ficus hispida* and *Colebrookia oppositifolia*.

2. Compartment no 63 (20 yr site): The total area was 266 ha. This site was along Kabra nalla in the eastern side of the Sanctuary. Plantation of teak was done in patches in this site. The plantation was about 12 m tall and had understroey of *Helicteres isora* and *Wrightia tinctoria* mainly. The miscellaneous composition of the site had been retained as felling must have been distributed all along the site. The site was relatively undisturbed and dense in vegetation.

3. Compartment no. 49 (80 yr site): This site was hilly and was traversed by Bori River and located closer to Bori Village. People used this area and there was a fire during Summer 1993 here. The total area was 200 ha. The tree height was above 20 m but teak was not the dominant species. There were large trees of other species such as *Terminalia tomentosa*, *T. bellerica, Bridelia retusa* and *Saccopetalun tomentosum*. Dense undergrowth of *Lantana camara* was seen in the site.

4. Compartment no. 52 (Preservation Plot): This site was in the moist deciduous forests. This small compartment (38 ha) was chosen for preserving typical mixed forests in the area. For more than 60 years, this area was protected from fire, grazing and logging (Rodgers and Hall 1988). The composition was that of the mesic site a large number of *Ficus glomerta* trees, *Schleichera oleosa, Syzygium cumini, Terminalia bellerica, T. chebula, Semicarpus anacardium, Mangifera indica, Pterocarpus marsupium*, and *Sterospermum personatum*. The height of emergent trees was over 25 m. Most trees had average girth above 120 cm. The understorey comprised of

shade tolerant shrubs of *Colebrookia oppositifolia* about 1 m tall. The plot had no grass cover. Bori River bound the preservation plot on the northeastern side. Since the area was not big enough, I could mark 700 m long transect in the area (Plate 4).

2.17 Methods

Bird transects

Variable width line transect (Verner1985, Emlen 1977) was used for measuring bird abundance. Bird community studies have mainly used different transect methods to assess bird density (fixed width strip transect - Daniels 1989, open width line transect Jonhs 1983, Katti 1988). Variable width line transects, gave reliable density estimates in few studies (Tilghman and Rusch 1981, Anderson and Ohmart 1981, Franzeb 1981).

The assumptions of variable width line transects are as follows (Emlen 1977):

1. All birds on the line are detected.

2. The probability of observing a bird decreases with distances from the transect, or remains constant to a given distance and then declines rapidly.

3. Birds do not move in response to the observer before detection.

4. No bird is counted more than once.

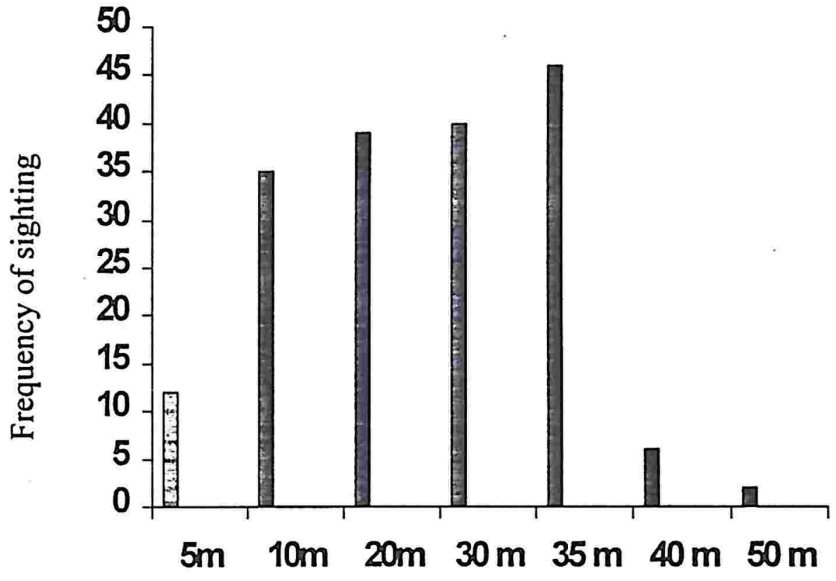
6. The observer identifies the species correctly.

Several of the basic assumptions are difficult to meet in most studies. Birds located on or near the transect may have moved away or escape detection, birds in the canopy may not be detected, and distance estimation may be subjected to error. Double counting is also not avoidable in mobile species such as birds.

For ensuring that most birds are seen, number of effort in the area can be increased. This would also help in recording seasonal movements of the birds. To standardize the number of visits, I monitored the same transect for eight days in summer and winter to determine minimum number of visits required to record maximum species. For summer, totally four visits were required per transect and in winter, five visits were required. This schedule was followed for all the transects in Bori and Melghat. In summer, four visits were made between March to June. Four visits for winter were completed between November to February and the additional fifth visit was completed by walking the transect once more in February.

The second assumption is met with in this study, as the detection rate declined after a certain distance from the transect. I pooled total number of observations in the distance class as 0- 5-m, 5-10 m, 10- 20 m, 20-30 m, 30 - 35 m, 35-40 m, 40-50 m. Maximum observations were within 35 m, after which the detection rate declined. Birds spotted this far were usually bigger species like eagles, vultures or very vocal and mobile species such as the hornbills, mynas or parakeets.

Figure 2.3 Frequency of bird observations at various distances from the transect.



The third assumption about the effect of movement of the observer is not completely ruled out but it could always be minimized by being as inconspicuous and silent as possible. Last two assumptions could be improved through intensive fieldwork and observations.

All transects were of 1 km. length and were marked with red paint and every 50 m. segment was numbered on a nearby tree. This was done to identify the segment where the bird was seen.

Before starting the study, a few transects were walked in the morning and evening to compare maximum sightings for the time of the day (Robbins 1981). Bird observations peaked in an hour after the sunrise in summer and winter. The evening observations were less than those in the morning (16 sightings vs. 29 sightings in the morning). In summer the transects were walked between 06. 00-08.00 hr. and in winters between 08.30- 10.00 hr. The

transects were walked at even pace, noting down following observation at each sighting of birds:

Time, transect segment, species and sex of the bird, number of individuals, the substrate where it was perched, height of substrate, angular or perpendicular distance from the transect line, sighting angle, bird activity, height at which the bird was seen and any other miscellaneous observation regarding the bird.

In variable width line transect, total number of individuals seen on the transect (Emlen 1977, Franzeb 1981) are used instead of clusters. Each transect was walked once a month. This made it possible to collect information on monthly changes in different forest types. I considered each walk on the same transect as a pseudo- replicate as per strata I had one transect.

In Bori Wildlife Sanctuary, the study period was from November 1992- June 1994. The transects were marked in the following sites:

(1) CWR area: 7 yr site, 20 yr site, and 40 yr site.

(2) SCI area : 7 yr site, 20 yr site, and 40 yr site.

(3) GTFS area: 7 yr site, 20 yr site, and 60 yr site.

(4) STFS area : 6 yr site, 20 yr site, 80 yr site, and preservation plot.

Vegetation sampling

The vegetation quantification was done on the same transects where bird abundance was monitored. At every 50 m segment a 10 m radius plot was laid to record the following parameters:

Tree density

Tree species, tree height, and the girth at breast height (GBH) were recorded for each tree measured. Trees > = 30 cm. GBH were considered as large trees and those between 10 - 29 cm were considered as smaller trees. Below 10 cm GBH were poles and saplings. Initially, tree height was measured with a

calibrated pole up till 10 m till I got an idea of the height estimate, after which tree height was measured optically.

Shrub species, shrub height

For estimating shrub abundance, I could not lay a smaller plot due to dense undergrowth of *Lantana camara.* Therefore shrub species, shrub height and shrub numbers, were measured in same plot used for measuring tree density.

Canopy cover

From the center of the 10 m plot, I estimated canopy cover in four direction. I used an ocular tube with a cross wire on one side. From the opposite side of the cross wire the canopy was viewed with the tube held upright. If any foliage coincided with the intersection of the cross wire, it was scored as present. In each direction, two step method was used for estimating the canopy cover. This gave a total of 40 readings per sampling point. Total score divided by 4 gave canopy reading for the sampling point. Adding up these reading over the 20 sampling points was taken as canopy cover value for that particular transect.

The canopy cover was estimated twice in each season. Standard error was calculated to show variations on the canopy cover.

Ground cover

Ground cover was estimated in the same sampling points where the canopy cover was measured. A 1m x 1m iron grid was made to measure the grass cover. The grid was divided in four equal squares by tying a thread across. Each square represented 25% of the grid. The ground cover was measured in four directions from the center of the plot. In each direction the grid was placed on the ground once giving a total of 4 readings per sampling point. A visual estimate of groundcover was made in terms of percent grass, soil, leaf litter, weeds, or rocks that the grid covered. The average ground cover was estimated by dividing the scores by 4. Adding all sampling point gave total ground cover for each transects. The ground cover was measured twice in each season.

Foliage height diversity

At the center of every 50m sampling point, the presence or absence of leaf was measured in the following height classes:

0-1, 1-1.5; 1.5-3, 3-5, 5-7, 7-9, 9-11, 11-15, and > than 15m.

Initially, a 5 m tall calibrated bamboo pole was used to estimate the presence of foliage in the given height class. It was imagined that if a pole were held vertically above, then would the leaf present touch the pole at a given height. If it did, then the leaf is considered present at that height. Once visual estimates were fairly accurate, the use of bamboo pole was discontinued. Shannon-Wiener's diversity index was used to calculate the foliage height diversity for the transect.

Landscape heterogeneity

Landscape heterogeneity or horizontal patchiness (Thioally 1990) was quantified on each transect in the following manner: I had 8 structural categories of habitats: Woodland, grassland, forest edge, open scrubland, nallah , rocky barren patch, hill slope, and valley. At every 20 m the habitat in 10 m radius was subjectively evaluated and classified in one of the above mentioned categories. The total number of categories encountered on each transect was added up and horizontal patchiness was calculated using Shannon- Weiner's diversity index.

Phenology of trees

Birds feed on flower nectar and fruits of selected tree species. All the fruiting trees are not used by birds for feeding, as some of the fruits are non-fleshy and hard. To find out if birds use tree species that are logged and those that are retained, I classified tree species as timber trees, fleshy fruit trees and non-fleshy fruit trees.

Timber tree Species (TTPS): are *Tectona grandis* (teak) and *Terminalia tomentosa* (Saj) .

The Non Timber Tree Species (NTTSP) were further classified as:

Fleshy fruit trees: are *Aegel marmelos, Ficus benghalensis, F. religiosa, F. glomerata, Zizyphus xylopyra, Mangifera indica, Syzygium cumini, Saccopetalum tomentosum, Buchanania lanzan, Embelica officinalis, Bridelia retusa, Careya arborea, Randia uliginosa, Cassia fistula, Garuga pinnata, Diospyros melanoxylon, Stereospermum personatum.*

Non-fleshy fruit trees: *Madhuca latifolia, Anogeissus latifolia, Adina cordifolia, Lannea grandis, Mitragyna parviflora, Lagerstroemia coromendelica, Boswellia serrata, Terminalia bellerica, Terminalia chebula, Bombax ceiba, Butea monosperma.*

Only parakeets eat the seeds of teak. Fleshy fruits are fed by all the frugivores. The non-fleshy fruits are not fed by the birds but when these trees flower they attract insectivores and nectarivores. Individuals of all the above mentioned species were selected in a width of 50 m on either side of each transect and marked with paint. A minimum of 10 and a maximum of 20 individuals of each species were marked. For some species such as *Ficus*, it was not possible to get as many as 10 trees. Every month, all the marked trees were visited and present or absence of fruit, flower and availability of young, mature and senescent leaves were also recorded. In fruits, number of old, ripe, and unripe fruits were visually estimated. The numbers were later converted to percentage fruiting and flowering.

2.18 ANALYSIS

The bird data is analyzed for the resident species, as I did not have complete data on winter migrant for 1992 and winter 1994. The Blackheaded and Greyheaded Mynas are local summer migrants and are included in the analysis as these were the most ubiquitous species.

Bird Species Richness

Species richness is the number of species in an area. Species richness provides an instantly simple expression of diversity (Tilman and Pacala 1993). I calculated mean species richness across the pseudo-replicates for transects in each silvicultural practice

Cumulative bird species richness in logged sites

In a community, the rate in detecting new species is related to number of visits to the area. Initially the detection rate increases but then decreases towards an asymptote. This species area curve gives information on the number of species in relation to area (Wiens 1989). I calculated cumulative species richness for each site and compared them within each silvicultural system. Paired t test was used to compare the differences in richness.

Species Diversity in logged sites

The concept of local species diversity is related to vegetation structure was propounded by MaCArthur's study (1961) in North America. Unlike species richness, diversity measures take both abundance and species richness into account. The most widely used measure of diversity is the Shannon-Wiener index (Maguran 1988). The differences between the sites were detected using paired t test (Zar 1984).

Bird density in logged sites

Number of individuals seen per transect in an area was calculated using the strip width 35 m for all transects. This width was kept constant for all the logged sites.

Similarity index: Beta diversity scale

One of the most popular ways of viewing beta diversity is to compare the different communities and their degree of association or similarity, between pairs of sites taking species and their respective abundance into account. I used Morisita-Horn index to calculate similarity in bird species composition between all the 13 logged sites. This index is not influenced greatly by species richness and sample size (Wolda 1981).

Guild classification

Bird species were classified in definite groups based on their feeding resource. A guild as defined by Root (1967) is ' a group of species that exploit the same class of resources in a similar way'. I categorized 11 major guilds based on my observation on their feeding substrate and secondary information about their diets from Ali and Ripley 1983.

Table 2.1 Guild composition for the Satpura conservation Area.

Guilds	Species	No.of species
Obligate frugivores	Yellow Legged Green Pigeon	1
Fruit-insectivore	Grey Hornbill, Malabar Pied Hornbill, barbets, orioles, Blackcapped Blackbird	7
Fruit - seed - Nectar-insectivore	Parakeets, mynas, bulbuls	8
Nectar -insectivore	White Eye, Purple Sunbird, Tickell's Flowerpecker	3
Understorey insectivore	Babblers, ground thrushes, robins, Grey Junglefowl, Peafowl, Red Spurfowl	16
Canopy insectivore	Minivtes, Common iora, Common Wood Shrike, Large Cuckoo Shrike, green bulbuls.	8
Trunk/ bark feeder	Woodpeckers, tits nuthatches, Spotted Grey creeper	11
Sallying insectivore	Flycatchers, drongos, bee eaters	12
Raptors	eagles, owls, shikra, buzzards, kite	18
Granivore	Doves, quails, munias, Yellow Throated Sparrow	10
Omnivores	shrikes, Indian Roller,Indian Tree pie, Jungle Crow	10

Multivariate Analysis

Data from the four silvicultural systems and two plantations were subjected to cluster analysis. This was done to find out which sites have similar tree species and bird species composition. For this purpose I used hierarchical cluster analysis. Cluster analysis classifies sites according to their species (trees or bird) composition (Pielou 1984). I used hierarchical agglomerative classification. This method arranges separated groups in descending order of similarity. Agglomerative clustering starts from single objects which are combined into larger clusters. I used Ward's method of clustering where between cluster distances are computed as squared Euclidean distance between all pairs of sites . Clusters were formed on similarity values obtained using Morisita - Horn index.

Another multivariate tool used was Principal Component Analysis (PCA). PCA is a most widely used technique of ordination with community ecologists (Pielou 1984; terBraak 1985). This ordination technique relates abundance of species with the values of environmental variable. PCA helps in reducing the dimensionality of the environmental variables and extracting the most important ones. I used Pearson's correlation coefficient to check for the inter-correlation between the variables within a site. With the help of PCA, I could graphically depict the effect of environmental variables on bird species.

2.19 Statistical Tests

Non-parametric tests (Mann-Whitney U test) were used to check for significant differences as data on bird abundance was not normally distributed (K - S test for bird abundance data, $p < 0.08$). Vegetation parameters were normally distributed (K-S test, $p = > 0.05$ for all variables) so i could use one way parametric ANOVA to check for differences and Pearson's correlation coefficient to check for associations between the parameters.

At the broader level, I compared all the parameters within a silvicultural system between the following pairs:

1. The 7 yr and 20 yr site,

2. The 7 yr and 40 yr site

3. The 20 yr and 40 yr site.

Abundance used to compare richness, density, diversity, similarity and guild composition was compared within 35 m width of the transect.

2. 20 RESULTS

217 bird species were recorded during the study period. Of the 77 families of Indian birds (Ripley 1982), 50 have been recorded in Bori. Muscicacapidae was the dominant family with 32 species (14. 7 %) and next dominant family was Accipitridae with 17 species (7. 8 %). Of the 217 total species, 40 species were aquatic and 177 were terrestrial birds. Totally 34 species of migrants are recorded in the Sanctuary, of which 25 species are recorded from October to late March (this includes the aquatic migrants also) and 9 species visit the area from April to late September.

105 bird species were recorded on thirteen transects. Thirteen winter migrants and 8 summer migrants were recorded on the transects. The Malabar Pied Hornbill were frequently seen in the moist deciduous forest, although in winter these birds were seen in the dry deciduous forests also. During the study period, all five observations of Bluethroated Bee- eater and of Brown Rock Pipit was in the dry deciduous forests. Firecapped Tit and Common Rose Finch were seen in the moist deciduous forests. Complete list of birds along with their latin names is included in Appendix 1.

2.21 Results for Coppice with Reserve forests

Vegetation

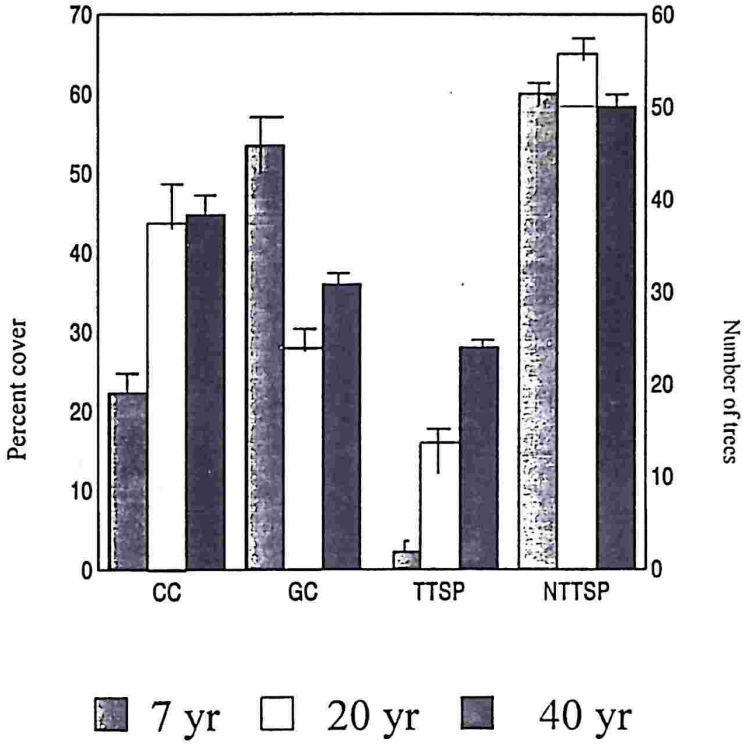
Table 2.2 Vegetation variables for CWR sites:

Variables	7 yr	20 yr	40 yr
Tree density / ha	239 (±.11) [a]	224(±.10) [a]	398 (±.21) [b]
Small tree density / ha	391(±.22) [a]	173(± .9)[b]	345(± .31)[c]
Sapling density / ha	56 (±.19)[a]	33(±.10) [b]	27(±.2) [c]
Mean shrub cover/ ha	16.7 [a] (±.16)	13 [a] (±.18)	31 [b] (±.23)
Mean GBH (cm)	89[a] (±.26)	77 [a] (±.61)	138[b] (±.84)
Heterogeneity (H')	1.28	1.6	0.83

Density values are numbers per ha. GBH and shrub covers are mean values. ± Standard error is shown in parentheses. Significant differences using ONE WAY ANOVA are indicated by alphabets. Same alphabet indicates no difference.

Large trees (> than 30 cm) were higher in 40 yr than 7 yr and 20 yr sites (ANOVA, F ratio = 6.03, p = .003, F= 5.71, p= .02). Small trees were higher in 7 yr site (F= 4.49, p =. 035, F= 5.6, p= .01) than other two sites. The 7 yr site had greater number of saplings than 20 yr site (F= 4.12, p= .031). Shrub cover was higher in the 40 y site than the 7 yr (F= 4.5, p= .03) and 20 yr site (F= 8.2, p=.001). The mean GBH was higher in the 40 yr site than both the other sites (F= 5.56, p=. 012).

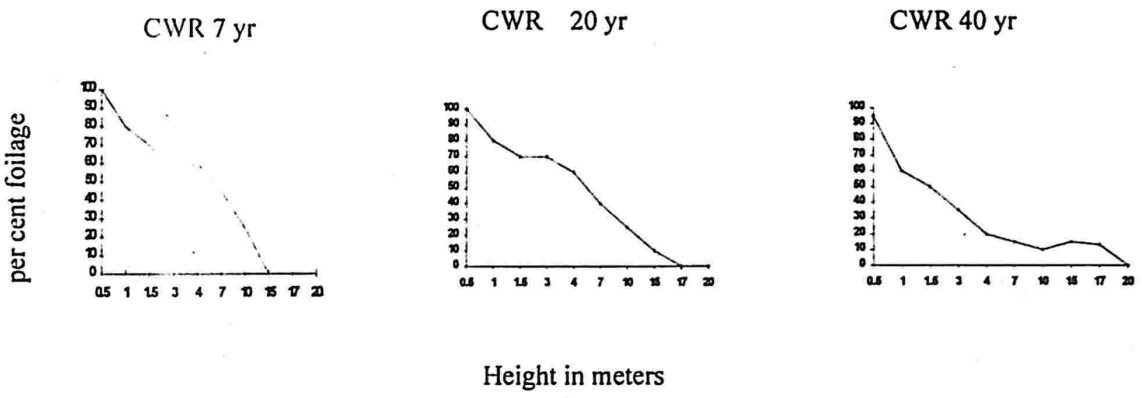
Figure 2.4 Vegetation Structural variables for CWR.



CC- canopy cover, GC - grass cover, TTSP- Timber Tree spp., NTTSP- Non-Timber Tree spp.

The figure shows some more structural variables for CWR. Canopy cover was significantly lower in the 7 yr site (mean = 22.3 ± 21) than the 20 yr site (mean = 43.8 ± 12, F= 5.8, p= .02) and 40 yr site (mean= 45.9 ± 14, F= 6.98 , p < .01). Grass cover was higher in the 7 yr site (mean = 53.4 ± 13) than 20 yr (mean = 27.9 ± 24, F= 11.1, p =. 002) and 40 yr (mean=34.3 ± 12, F= 6.5, p < .05). Number of timber trees in the 40 yr site was higher than 7 yr site (F= 5.09, p= .01) and 20 yr site (F= 4.10, p = .04). Number of non-timber trees did not show significant difference between the logged sites.

Figure 2.5 foliage profile for CWR sites.



The figure shows per cent foliage present in various height classes. Although the profiles are different, all three sites have foliage in almost all strata. The 7 yr site does not have foliage in trees above 10 m. height.

Bird abundance for CWR

Table 2.3 Species richness and diversity

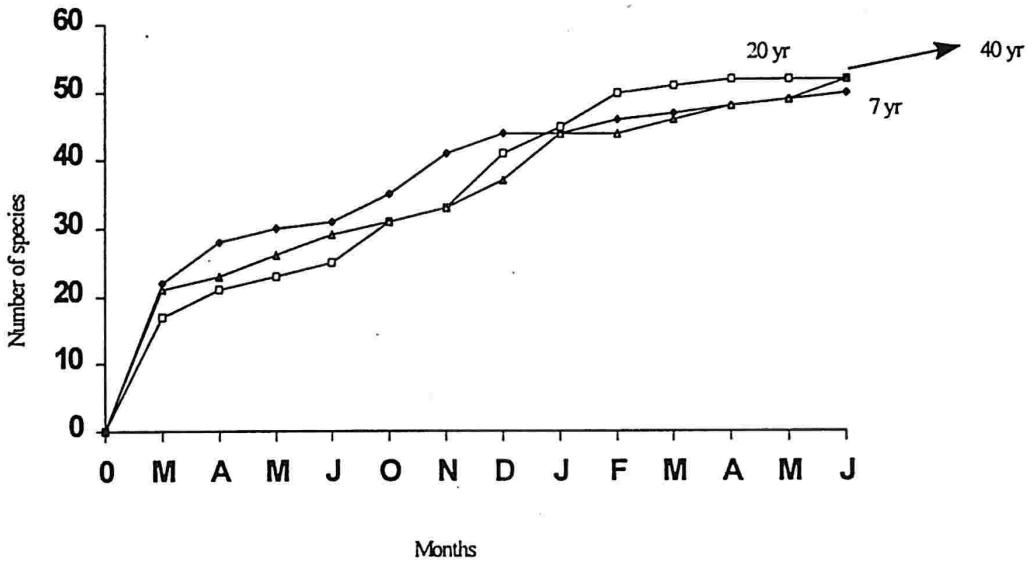
CWR	Richness	Diversity (H')
7 yr	23.0 (±.06)[a]	2.3 (±.15)[a]
20 yr	24.5 (±.08)[a]	2.4 (±.08)[a]
40 yr	25.3 (±.08)[a]	2.5 (±.08)[a]

Richness and diversity is expressed as mean ± standard errors. Paired t test was used to detect significant differences between two logged classes for richness and diversity. Same alphabet indicates no significant difference.

In CWR logged sites, bird species richness and diversity was not significantly different.

Cumulative Species Richness for CWR

Figure 2.6 Cumulative species richness curve for CWR sites.



The cumulative species richness curve shows that 7 yr and 20 yr sites had reached the asymptote indicating that most species in the site were recorded while the 40 yr site curve was beginning stabilize.

Similarity index for CWR

Table 2.4 Morista-Horn similarity Index for CWR sites.

CWR	20 yr	40 yr
7 yr	0.75	0.77
20 yr		0.74

The similarity is above 70 per cent between all logged sites.

Guild composition in the logged sites

To detect which groups of birds are common between two sites; guilds are compared within a working circle between the logged classes.

Table 2.5 Guild composition in CWR

Guilds	7 yr	20 y	40 yr
Obligate frugivore	1(10)[a]	1(6)[a]	1(6)[a]
Frugivore insectivore	2(11)[a]	1(7)[a]	1(9)[a]
Fruit-seed-Nectar-insectivore	5(22)[a]	7(93)[b]	7(138)[c]
Nectarivore insectivore	3(33)[a]	3(25)[a]	2(32)[a]
Understorey insectivore	7(46)[a]	4(64)[a]	4(91)[c]
Canopy insectivore	6(66)[a]	5(49)[a]	5(59)[a]
Trunk/ bark feeder	7(37)[a]	6(37)[a]	7(32)[a]
Sallying insectivore	8(27)[a]	8(53)[b]	8(55)[b]
Raptors	2(3)[a]	3(3)[a]	3(6)[a]
Granivore	7(126)[a]	5(86)[b]	5(67)[c]
Omnivore	6(43)[a]	5(45)[a]	4(17)[b]
Total species	54	49	47

N.B: Tabled values are number of species. A value in parentheses represents number of individuals in each guild. Significant differences detected by Mann-Whitney U test are denoted by different alphabets. Similar alphabet indicates no significant difference.

The fruit- seed- nectar- insectivore guild was higher in abundance in 40 yr site than the 20 yr site (Mann-Whitney U =12, p=. 05) and 7 yr site (U=83,p=. 01). Understorey insectivores were higher in 40 yr site than 7 yr (U=12, p=.05) and 20 yr site (U=18.5 ,p =. 005). Sallying insectivores were lower in the 7 yr site than 20 y site (U=11, p=.04). Number of granivores were higher in the 7 yr site than 20 yr (U =21, p=. 03) and 40 yr site (U= 16.5, p=. 001). Omnivores were higher in the 7 yr site than the 40 yr site (U=8.5, p=.01).

2.22 Results for Selection cum Improvement system (SCI)

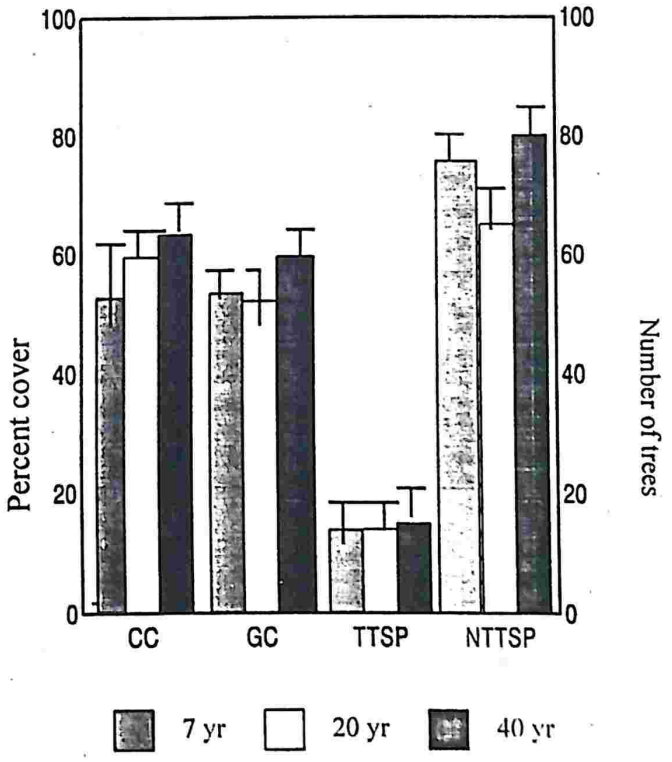
Vegetation

Table 2. 6 Vegetation variables in SCI.

Variables	7 yr	20 yr	40 yr
Tree density/ha	223 [a] (±.07)	217[a](± .12)	209 [a](± .11)
Small tree density/ha	226[a](± .21)	227[a](± .10)	217 [a](±.06)
Sapling density/ha	22[a](± .20)	47[b](± .23)	23[a](± .11)
Mean shrub cover	34.5 [a] (±.13)	18.8 [b] (±.21)	45.8 [c] (±.15)
Mean Gbh (cm)	96 [a] (± 2.5)	82 [a](±3.4)	86 [a](±2)
Heterogeneity (H')	1.21	1.44	1.27

In SCI, sapling density was higher in 20 yr site than 7 yr and 40 yr sites (F= 4.5, 5.01, $p < .05$). Shrubs were more in number in the 40 yr site than the 20 yr site (F=10.8, p=. 002), and 7 yr site (F= 5.6, p= .002).

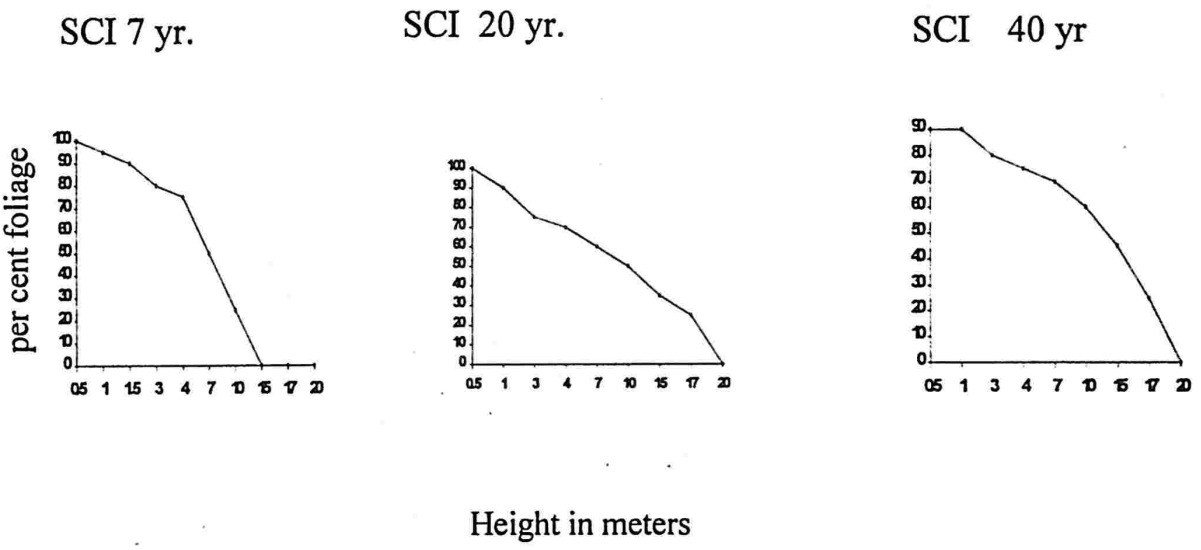
Figure 2. 7 Vegetation structural variables for SCI.



CC- canopy cover, GC - grass cover, TTSP- Timber Tree spp., NTTSP- Non-Timber Tree spp.

In SCI, logging did not result in changing the structure of the site significantly as can be seen from the figure. The non-timber trees in the 20 yr site was lower than 7 yr (F= 5.08, p= .02) and 40 y site (F = 4.12, p= .04).

Figure 2.8 Foliage profile for SCI sites



The profiles for all the sites are very similar, except in 7 yr site no foliage was seen above 12 m, whereas other two sites had foliage up to 17 m height.

Bird abundance

Table 2.7 Species richness and diversity:

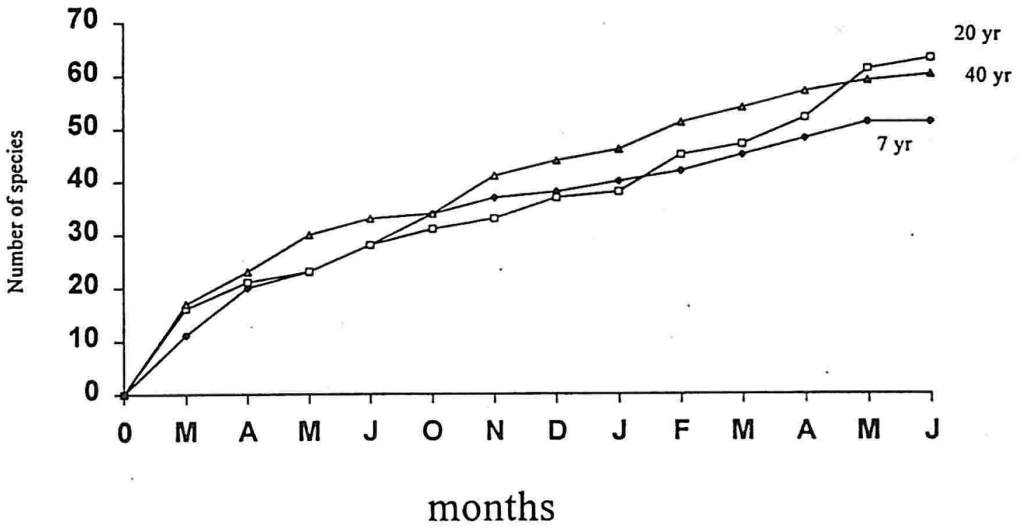
SCI	Richness	Diversity
7 yr	20.8 (±.16)[a]	2.2 (±.10)[a]
20 yr	25.4 (±.13)[b]	2.3 (±.09)[a]
40 yr	26.7 (±.11)[b]	2.5 (±.07)[b]

Richness and diversity is expressed as mean ± standard errors. Paired t Test was used to detect significant differences between two logged classes for richness and t test was used for diversity differences. Same alphabet indicates no significant difference.

In SCI, 7 yr site had lower richness than 20 yr (t = -3.19. p=.05) and 40 yr (t= -3.7, p= .04) site. The diversity was higher in 40 yr site than 7 yr (t= -3.2, p= .05) and 20 yr site (t = -3.9, p=.03).

Cumulative Species Richness for SCI.

Figure 2.9 cumulative species richness for SCI sites:



The 7 yr and 20 yr site curves had reached an asymptote while in the 40 yr site the curve had not stabilized.

Similarity Index

Table 2.8 Morisita- Horn index for SCI sites.

SCI	20 yr	40 yr
7 yr	0.77	0.75
20 yr		0.64

The 40 yr site had higher similarity with the 7 yr site than the 20 yr site

Table 2.9 Guild composition in SCI.

Guilds	7y	20y	40y
Obligate Frugivores	1(13)[a]	1(13)[a]	1(12)[a]
Frugivore insectivore	1(3)[a]	2(7)[a]	1(6)[a]
Fruit-seed-Nectar-insectivore	6(80)[a]	3(16)[b]	3(19)[b]
Nectarivore – insectivore	2(28)[a]	3(40)[a]	3(7)[a]
Understorey insectivore	6(24)[a]	6(58)[b]	4(12)[c]
Canopy insectivore	6(51)[a]	3(47)[a]	6(16)[b]
Trunk/ bark feeder	3(8)[a]	7(26)[b]	5(9)[a]
Sallying insectivore	7(29)[a]	3(36)[a]	7(15)[c]
Raptors	3(3)[a]	4(7)[a]	0
Granivore	5(129)[a]	5(89)[b]	3(7)
Omnivore	6(46)[a]	6(32)[a]	3(10)[c]
Total species	44	43	37

N.B: Tabled values are number of species. A value in parentheses represents number of individuals in each guild. Significant differences detected by Mann-Whitney U test are denoted by different alphabets. Similar alphabet indicates no significant difference.

The fruit-seed- nectar- insectivore guild was higher in abundance in 7 yr site than the 20 yr site (U=187, p=.01) and 40 yr site (U=193, p=.01). Understorey insectivores were higher in 20 yr site than 7 yr (U =48.5, p =. 04) and 40 yr site (U =67, p =. 02). 7 yr site had higher number of canopy insectivores than 40 yr site (U=54, p=.05). Number of sallying insectivores were lower in the 40 yr site than 20 y site (U= 71, p=.02) and 7 yr site(U=20,p=.04). Number of granivores were maximum in the 7 yr site when compared to 20 yr (U=191 ,p=.05) and 40 yr site (U=102, p=.04). Omnivores were higher in the 7 yr site than 20 yr (U=12, p=.03) and the 40 yr site (U=18,p=.01). Trunk -bark feeders were higher in abundance in the 20 yr site than 7 yr (U= 24, p= .03) and 40 yr site (U= 34, p= .04).

2.23 Results for General Teak Felling System (GTFS) sites

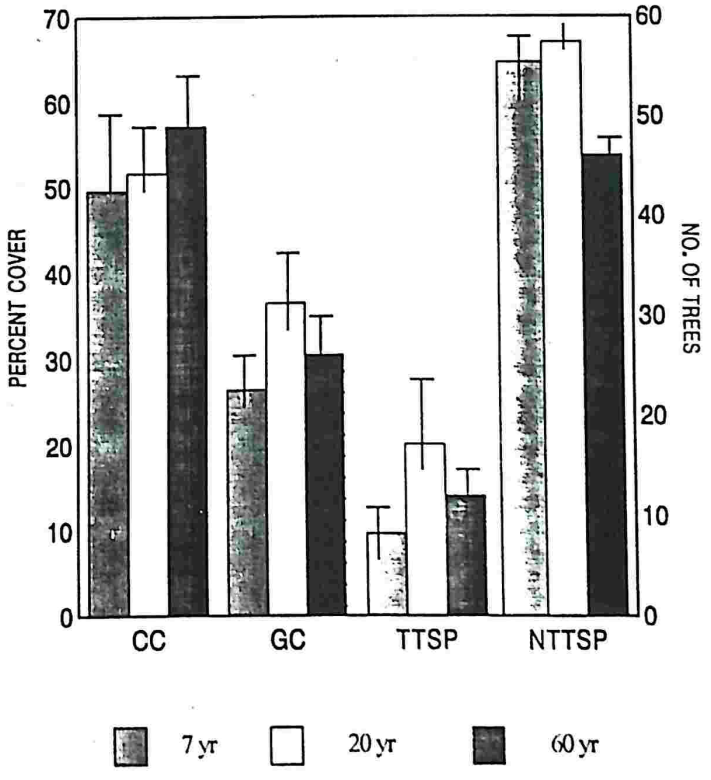
Vegetation

Table 2.10 vegetation variables in GTFS .

Variables	7 yr	20 yr	60 yr
Tree density/ha	196[a](± .31)	305[b](± .22)	153 [a](± .06)
Small tree density/ha	91 [a](± .16)	80 [a](± .7)	88 [a](± .21)
Sapling density/ha	66 [a](± .04)	39 [b](± .11)	34 [b](± .15)
Mean shrub cover	26 [a] (±.14)	31.5 [a] (±.14)	33.8 [a] (±.20)
Mean GBH (cm)	90 [a] (±2.2)	194[b](±1.4)	149 [c](±3.2)
Heterogeneity (H')	1.68	1.82	1.89

The 20 yr site had higher tree density than the 7 yr (F= 3 .43, p=.05), and 40 yr site (F= 5.12, p =. 01). Mean GBH was significantly higher in the 20 yr site than in the 7 yr (F= 6.5, p= .01) and 60 yr site (F = 6.9, p= .02).

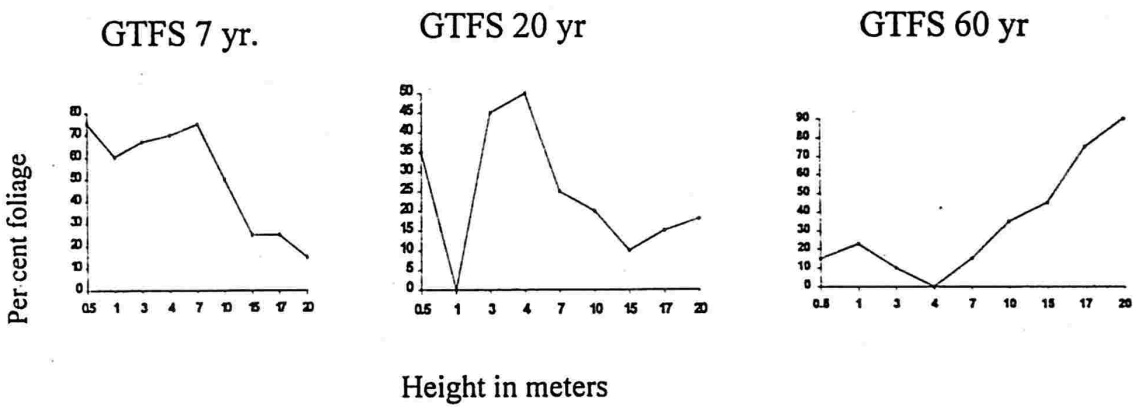
Figure 2.10 Vegetation structural variables in GTFS.



CC- canopy cover, GC - grass cover, TTSP- Timber Tree spp., NTTSP- Non-Timber Tree spp.

Canopy cover and grass cover did not differ significantly between the logged sites in GTFS. Number of timber trees were higher in the 20 yr site than in the 7 yr (F= 5.09, p= .01) and 60 yr site (F= 8.3, p= .007). Non-timber trees were higher in 20 yr site than the other two site (F= 6.09, p = .04, F= 5.71, p= .02).

Figure 2.11 Foliage profile for GTFS sites.



The logged sites differ in per cent foliage present between the sites. The 7 yr site and 20 yr site (except 2 m) has foliage in most height classes, while the 60 yr site had higher representation of foliage in taller trees (> 10 m).

Bird Abundance

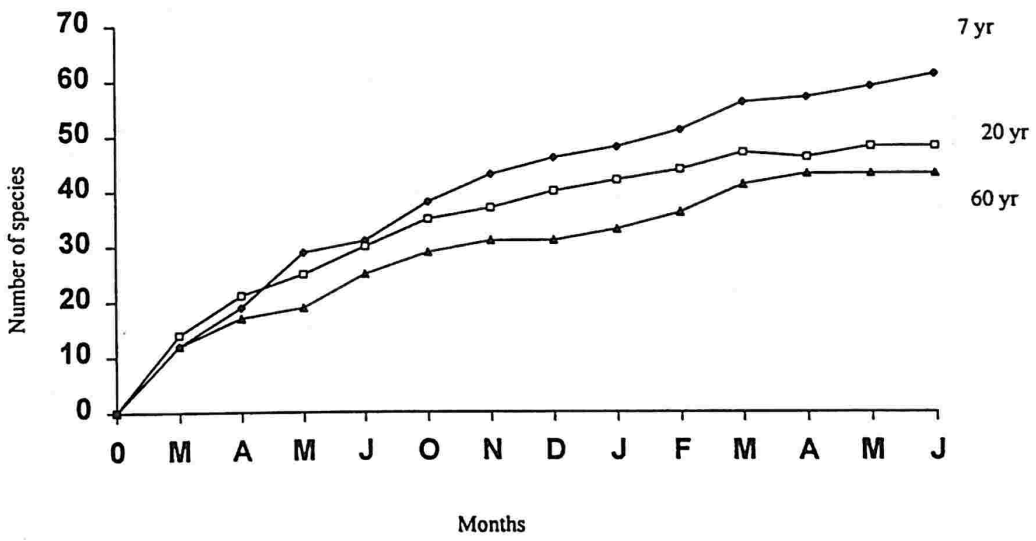
Table 2.11 Species Richness and diversity:

GTFS	Richness	Diversity
7 yr	27.5 (±.11)[a]	2.5(±.07)[a]
20 yr	25 (±.11)[a]	2.5(±.07)[a]
60 yr	22.9(±.12)[b]	2.3(±.08)[b]

In GTFS, the 7 yr site had higher richness than 20 yr (t= -4.3,p= .004) and 40 yr site (t= -3.17, p=.05). Bird species diversity was higher in the 7 yr site than 40 yr site (t=-4.2.p=.01).

Cumulative Species Richness

Figure: 2.12 cumulative species richness for GTFS sites.



The curves for all three sites had reached an asymptote, and the 7 yr site had higher number of species than the 60 yr site.

Table 2.12 Similarity Index for GTFS sites:

GTFS	20 yr	60 yr
7 yr	0.826	0.707
20 yr	-	0.543

The 20 yr site had higher simialrity in bird species composition wit the 7 yr site than with the 60 yr site. The 60 yr site had 70 per cent similar bird community with the 7 yr site.

Table 2. 13 Guild composition in GTFS.

Guilds	7 y	20 y	60 y
Obligate frugivores	1(7)[a]	1(5)[a]	1(7)[a]
Frugivore –insectivore	3(24)[a]	2(11)[a]	4(14)[a]
Fruit-seed-Nectar-insectivore	6(152)[a]	6(116)[b]	8(137)[a]
Nectarivore –insectivore	3(29)[a]	3(22)[a]	2(14)[a]
Understorey insectivore	8(52)[a]	6(91)[b]	6(52)[a]
Canopy insectivore	5(43)[a]	6(46)[a]	6(32)[a]
Trunk /bark feeders	9(98)[a]	6(111)[a]	6(103)[a]
Sallying insectivore	7(45)[a]	6(22)[b]	5(35)[a]
Raptors	3(7)[a]	3(4)[a]	2(3)[c]
Granivores	5(165)[a]	5(44)[b]	5(61)[b]
Omnivores	7(60)[a]	5(66)[a]	4(94)[b]
Total species	59	49	50

N.B: Tabled values are number of species. A value in parentheses represents number of individuals in each guild. Significant differences detected by Mann-Whitney U test are denoted by different alphabets. Similar alphabet indicates no significant difference.

The fruit-seed- nectar- insectivore guild was higher in abundance in 7 yr site than the 20 yr site (U=264, p=.006) and 60 yr site (U=128,p=.013). Understorey insectivores were higher in 20 yr site than 7 yr (U =30, p =. 001) and 60 yr site (U=24,p =.02). Sallying insectivores were lower in the 20 yr site than 60 y site (U=55,p=.001) and 7 yr site (U=8,p=.02). Number of granivores were higher in the 7 yr site than 20 yr (U = 55 ,p=.001) and 60 yr site (U=24, p=.002). Omnivores were higher in the 60 yr site than 20 yr (U=30,p=.001) and the 7 yr site (U=55 ,p= .01).

2.24 Results for Special Teak Felling System (STFS)

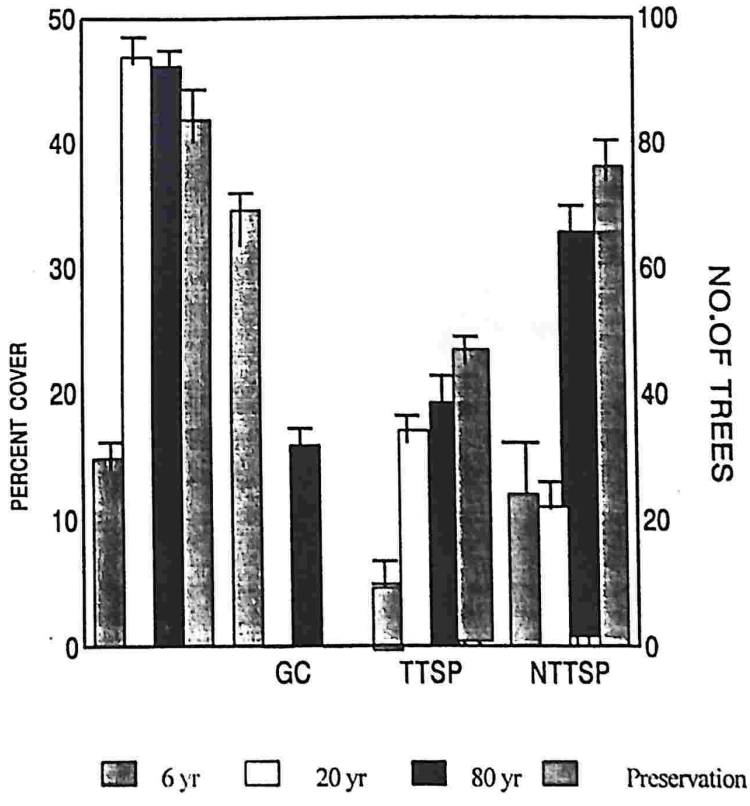
Vegetation

Table 2.14 Structural variables in STFS .

Variables	6 yr	20 yr	80 yr	Preservation plot
Tree density/ha	63[a](± .19)	139 [b](± .13)	189[c](±.18)	197[d](±.07)
Small tree density/ha	412[a](±.07)	242[b](±.21)	198[c](±.09)	0
Sapling density/ha	19(±.54)	20(±.31)	15(±.22)	0
Mean shrub cover	76[a] (±.26)	32[b] (± .20)	45[c] (±.11)	58[d] (±.25)
Mean GBH (cm)	83[a] (± .11)	152 [b](±3.6)	286[c] (±.13)	364[d] (±9.3)
Heterogeneity (H')	1.75	1.28	1.89	0.83

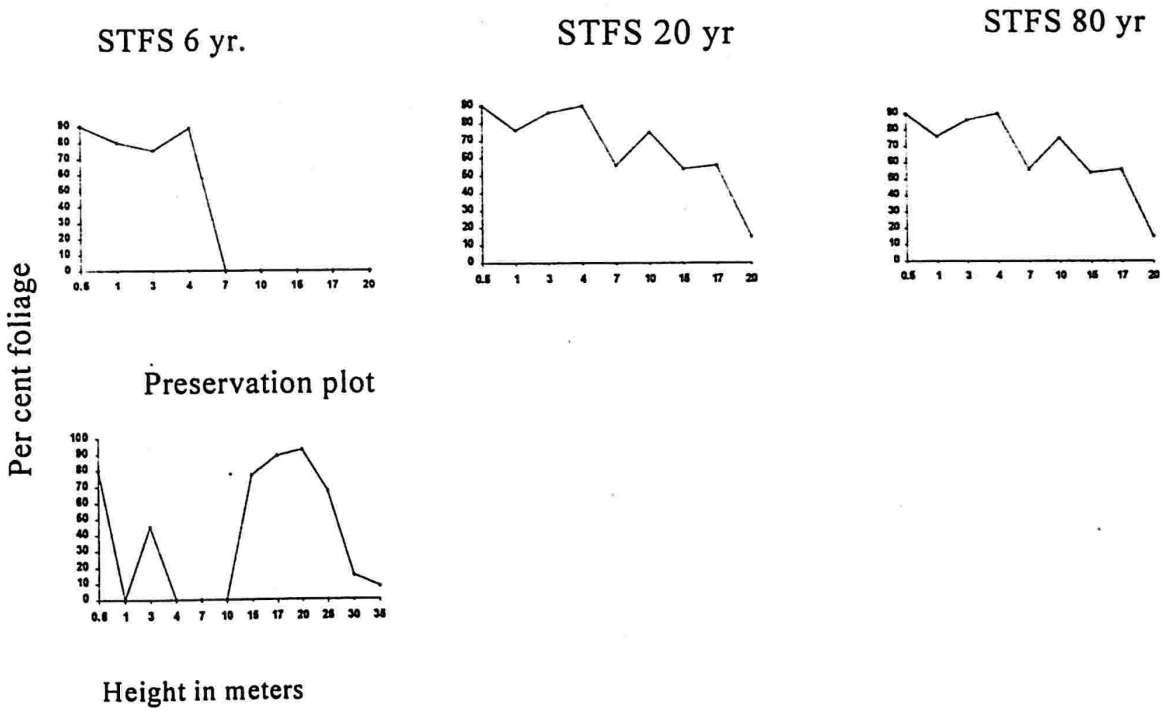
The Preservation plot had higher tree density and higher mean GBH than 6 yr (F= 4.3, 11.3 p < .05), 20 yr (F= 5.06, 8.79 , p < .05) and 80 yr site (F= 6.09, 6.7 p< .05). Small trees were higher in the 6 yr site than 20 yr (F = 6.9, p <. 05), 80 yr (F= 4.3, p< .05) and the preservation plot (F= 11.0, p<. 001). No saplings were recorded in the preservation plot.

Figure 2.13 Vegetation variables for STFS sites



Canopy cover was lower in the 6 yr site (mean = 14.8, ± 26) than the 20 yr (mean =46.8 ± 22 F = 8.34, p =. 002), 80 yr (mean = 45.3 ± 12.4, F = 11.54, p= 0.00) and preservation plot (mean = 41.9 ± 16, F= 6.01, p= .01). The 6 yr site had higher grass cover (mean=34.6 ± 10.6) than the 80 yr site (mean = 13 ± 12, F= 7.5, p= .003) whereas no grass cover was recorded in the 20 yr site and preservation plot. Number of timber and non-timber trees were lower in number in the 6 yr site than all the three sites.

Figure 2.14 Foliage profile for STFS sites



The 6 yr site is distinctly different in vertical representation of foliage as compared to other STFS sites. The 20 yr and 80 yr sites have almost similar foliage profiles. No foliage was present between 2 m and 15 m height in the preservation plot.

Bird Abundance

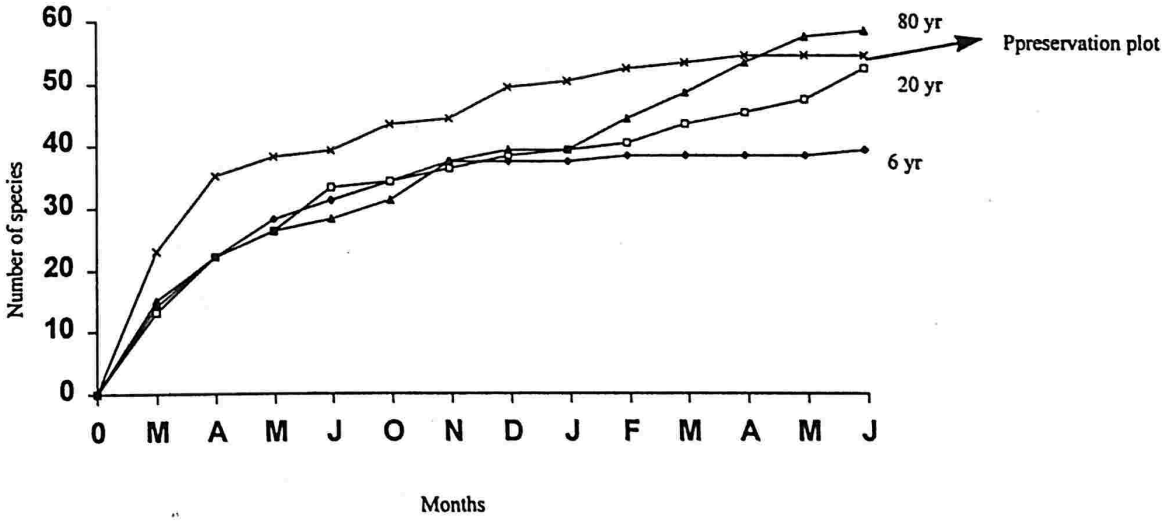
Table 2.15 Species Richness and diversity:

STFS	Richness	Diversity
6 yr	17.9(±.16)[a]	2.2(±.10)[a]
20 yr	25.5(±.05)[b]	2.4(±.05)[b]
80 yr	28.0(±.15)[c]	2.6(±.06)[c]
Preservation plot	26.3(±.13)[c]	2.5(±.59)[c]

In STFS system, the preservation plot and the 80 yr site had higher species richness than the 20 yr (t = -6.5, p=. 001) and 6 yr site (t=- 3.5, p=.001) . The bird diversity was also higher in preservation plot and 80 yr site than 20 yr (t= -3.6, p=.02) and 6 yr site(t= -3.8, p=.05).

Cumulative species Richness for STFS

Figure 2.15 Cumulative species richness for STFS sites



The preservation plot and 80 yr site curves were beginning to stabilize. The 6 yr site had lowest number of species and had stabilized earlier.

Similarity index for STFS sites

Table 2.16 Morisita -Horn index for STFS.

STFS	20 yr	80 yr	P.Plot
6 yr	0.349	0.297	0.192
20 yr	-	0.581	0.615
80 yr	-	-	0.795

The 6 yr site had lowest similarity with the preservation plot, 80 yr site and 20 yr site. The preservation plot shared about 80 per cent similar bird community with the 80 yr site.

Table 2.17 Guild composition in STFS.

Guilds	6y	20y	80y	Preservation plot
Frugivores	1 (9)^{a}	1(12)^{a}	1(13)^{a}	1(10)^{a}
Frugivore-insectivore	4 (20)^{a}	3(10)^{b}	5 (64)^{c}	5(16)^{d}
Fruit-seed-Nectar-insectivore	3 (97)^{a}	6(65)^{a}	7 (174)^{b}	7(137)^{c}
Nectarivore-insectivore	2 (13)^{a}	2(14)^{a}	3 (20)^{a}	2(24)^{a}
Understorey insectivore	8 (23)^{a}	7(50)^{b}	5 (17)^{c}	0
Canopy insectivore	3 (31)^{a}	5(28)^{a}	6 (29)^{a}	5(39)^{a}
Trunk /bark feeders	2 (10)^{a}	5(15)^{a}	5 (59)^{b}	6(69)^{b}
Sallying insectivore	4 (28)^{a}	6(16)^{b}	10 (75)^{c}	8(51)^{d}
Raptors	1 (2)^{a}	1(1)^{a}	3 (6)^{a}	3(3)^{a}
Granivores	5 (15)^{a}	4(5)^{a}	3 (13)^{a}	0
Omnivores	6 (75)^{a}	4(28)^{b}	3 (12)^{c}	3(42)^{d}
Total species	38	44	51	41

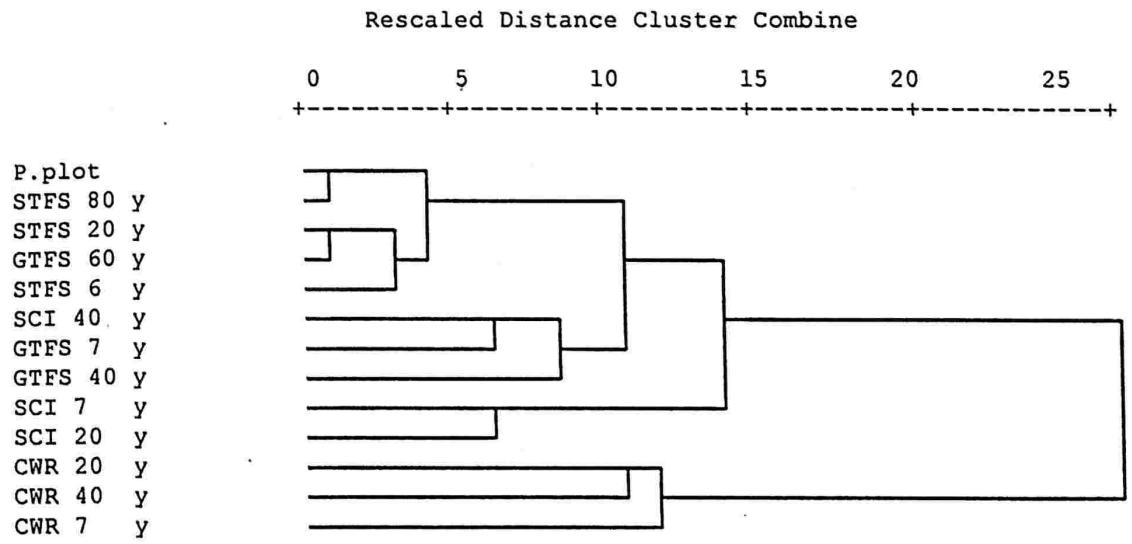
N.B: Tabled values are number of species. A value in parentheses represents number of individuals in each guild. Significant differences detected by Mann-Whitney U test are denoted by different alphabets. Similar alphabet indicates no significant difference.

The fruit-insectivore guild was represented in higher number in the 80 yr than 6 yr, (U=221, p=.002), 20 yr (U=354, p=.000) and preservation plot (U=21,p=.01). The fruit-seed- nectar-insectivores were also higher in 80 yr site than the 20 yr site (U=56, p=.04), 6 yr site (U= 66 ,p=.034) and the plot (U=312, p=.01). Nectar-insectivores were higher in the 80 yr site than 6 yr (U=56, p=.002), 20 yr (U= 41, p=.03) and the preservation plot (U=165, p=.04). Understorey iinsectivores were higher in 20 yr site than 6 yr (U=21, p=.01) and 80 yr site(U= 16, p= .002). Sallying insectivores were higher in the 80 yr site than 20 y site (U= 34, p=.002), 6 yr site (U=45 ,p=.05) and preservation plot (U=12, p=.05). Omnivores were higher in the 6 yr site than 20 yr (U=66 ,p=.001) and the 80 yr site (U= 89, p=.000).

2.25 Similarity in bird species composition across all logged sites in Bori Wildlife Sanctuary

I used cluster analysis technique to depict the sites with greater similarity in bird species composition. Clusters were formed on similarity values obtained by Morisita - Horn index given in the Appendix 2.

Figure 2. 16 Cluster of logged sites with similar bird species composition



The pattern obtained is as follows:

1. All sites show maximum similarity within the same forest type and same silvicultural system.

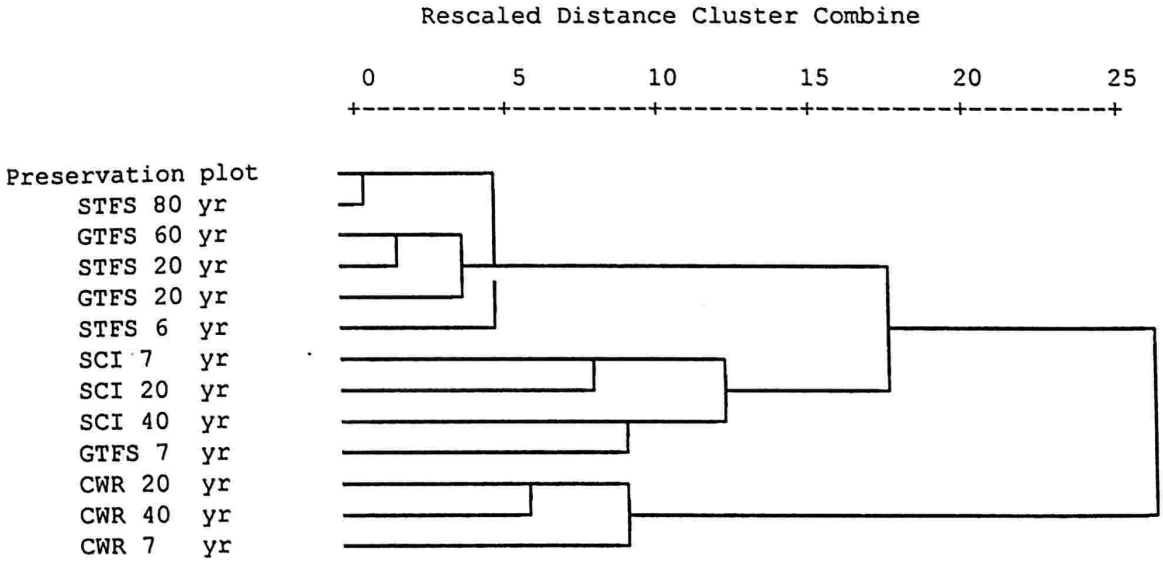
2. If one goes from west to east, (i.e. from CWR to STFS sites) similarity in bird species composition declines. However, the GTFS sites showed similarity with the SCI sites.

3. Bird species composition was not influenced by the age of the site as in many cases the 7 yr sites showed high similarity with the older logged sites.

The results indicate that there was a large overlap in bird community between the sites. To check if the logged sites had similar tree species composition, I performed similar analysis with tree species composition in each logged site. The similarity matrix between the sites is given in the Appendix 3.

2.26 Similarity in tree species composition across all logged sites in Bori Wildlife Sanctuary

Figure 2.17 Clusters of sites having similar tree species composition



From the figure, following patterns were seen:

1. The drier forests of CWR and SCI had maximum tree species similarity between them. The 7 yr site of GTFS was clustered with 40 yr site of SCI.

2. All the moist deciduous forest sites were in one cluster.

3. The clustered sites were independent of logging age.

Results from both the cluster analyses indicate one common trend. In spite of being in different forest types, the logged sites exhibit large homogeneity in tree species composition and bird communities.

2.27 Ordination of logged sites on Principal Component Axis

To check for the effect of all the vegetation variables on bird communities, I used PCA ordination technique for all transects. I checked for inter- correlation between variables. Tree density was positively correlated with tree diversity (r =. 64, p= .001), mean GBH (r= .68, p= .001), and timber tree richness (r = .76, p= .002). Positive correlation was found between Grass cover and soil (r= .58, p= .01) and negative correlation was found between grass cover and canopy cover (r= - 65, p= .001) and grass cover and shrub density(r= -58, p= .02). After eliminating the inter-correlated variables, following 7 variables were used for PC analysis : Small tree density, shrub cover, number of non-timber trees, number of timber trees, canopy cover, foliage height diversity and landscape heterogeneity. The PC 1 explained 70 per cent variation and PC 2 explained 19.6 per cent of the variation. The first axis explained decreasing gradient of heterogeneity in the transect, higher timber tree species richness, foliage height diversity and canopy cover. Higher number of timer trees, higher canopy cover and lower heterogeneity is characteristic feature of old logged sites in this area (pers. observ). The second axis was correlated to non-timber tree richness, small tree richness and decreasing shrub density, indicating the features of non-teak, miscellaneous forests.

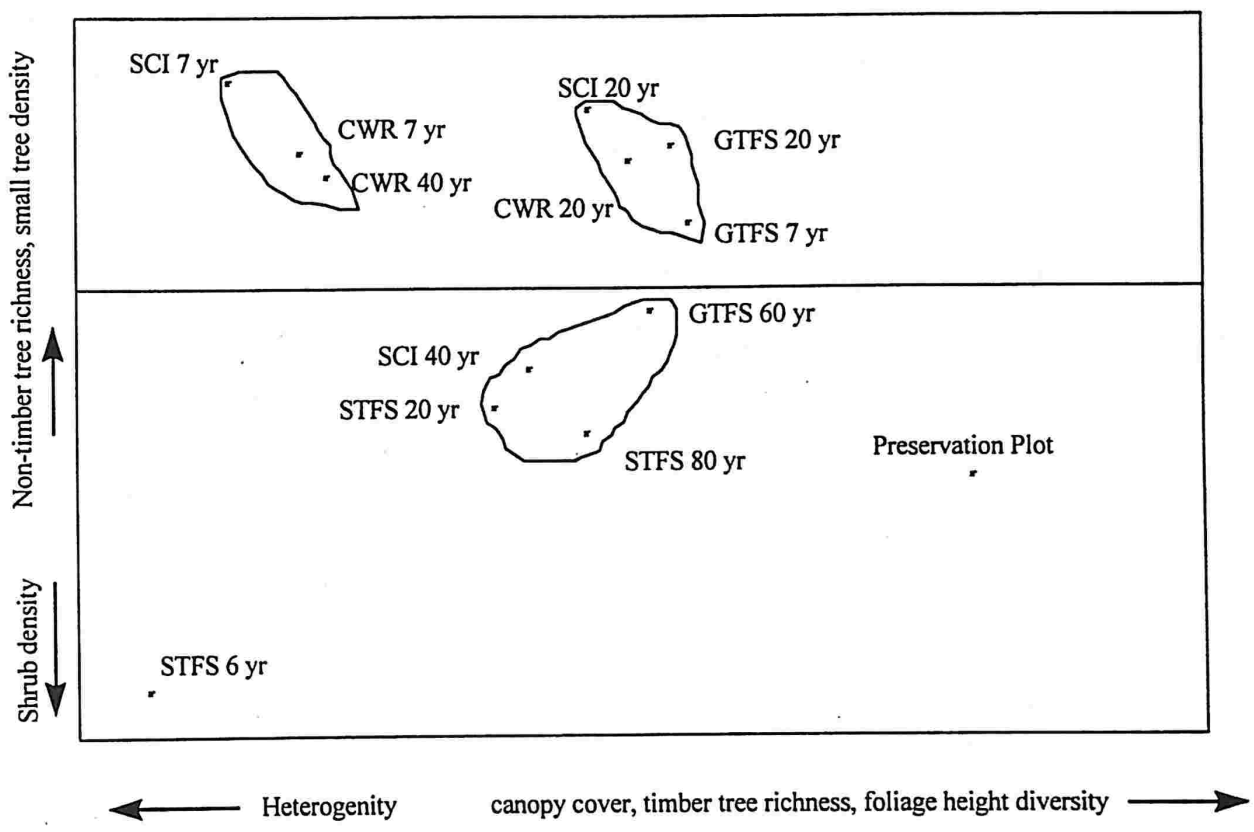
Table 2.18 Vegetation variables for Principal Component Analysis (PCA) Final statistics

variables	Multiple R^2	Factor	Eigenvalue	Per cent variation
Small tree density	0.8904	1	5.1745	68.6
Shrub cover	0.8825	2	2.784	19.6
Number of non -timber trees	0.8547			
Number of timber trees	0.7805			
Canopy cover	0.9142			
Foliage height diversity	0.7517			
Heterogeneity	0.9195			

Varimax rotated factor matrix:

Variables	Factor 1	Factor 2
Small tree density	.2979	.8951
Shrub cover	.0680	- .9328
Number of non timber trees	.2013	.9021
Number of timber trees	.8324	- .0132
Canopy cover	.9359	- .0244
Foliage height diversity	.8918	.0624
Heterogeneity	-.8773	.0991

Figure 2.18 Ordination of logged sites on PC axis.



The 6 yr site of STFS and preservation plot represents two extremes in relation to vegetation variables. The preservation plot had higher positive score for PC 1 axis, whereas the 6 yr site had negative score for the same axis. The preservation plot represented older logged forest with high vertical stratification (in the form of higher canopy cover and foliage height diversity) and lower landscapes heterogeneity. The STFS 6 yr site, on the other hand, had an undulating terrain with a riverbed running through that contributed to its higher landscape heterogeneity. This site had young teak plantation that was about 4 m tall with GBH less than 30 cm so it had negative score for canopy cover and foliage height diversity.

The sites from different forest types and logging age are united in three groups: The 7 yr site of CWR and SCI were united with 40 yr site of CWR. The 7 yr site of GTFS was clustered with 20 yr site of CWR, SCI and GTFS. The third cluster included old logged sites of SCI, STFS, GTFS and 20 yr site of STFS. The non-teak forests (CWR) are characterized by relatively open

forests compared to the moist deciduous forests and have higher number of non-timber trees. An interesting trend seen here was that the old logged site of SCI, though in drier locality, was placed closer to GTFS and STFS sites. The same pattern was reflected in clusters for tree composition and bird composition also (see figures 2.16 and 2.17). There could be two probable explanations for this: either the older logged forests of SCI were becoming similar to GTFS and STFS sites or after logging the moist forests of GTFS were getting converted to drier forests. This change in vegetation type could have resulted in having similar bird communities between the sites from different forest type. The homogeneity of the forests types were largely responsible for resulting in homogeneous bird community across sites.

2.28 Environmental variables related to Bird Species Richness and Diversity

To detect which principal component factors govern the community assemblage, I used PC axis score to correlate bird species richness and diversity.

Table 2.19 shows Spearman's Rank Correlation between the PC axes and bird richness and diversity.

Variables	PC Axis 1	PC Axis 2
Bird species richness	.57*	.42
Bird species diversity	.47	.68*

* indicates 2 tailed significance at p=. 01.

The bird species richness was correlated to mature forests, whereas bird species diversity was correlated to open, miscellaneous forests.

2.29 Guilds and their correlation to the PC scores

To determine the effect of the structural variables on bird communities, I correlated the number of species in a guild with factor scores of PC1 and PC2. I used Spearman's rank correlation to detect the relation between the guilds and the vegetation variables.

Table 2. 20 Spearman's rank correlation between guilds and PC axes.

Guilds	PC1	PC2
Obligate Frugivores	.26	.64*
Frugivore insectivores	.10	.50
Fruit-seed nectar-insectivores	.38	.59
Nectarivore insectivores	.26	.04
Understorey insectivores	.-30	.64*
Canopy insectivores	.53	.76**
Trunk/bark feeders	.51	.49
Sallying insectivores	.67*	.47
Raptors	.04	.13
Granivore	-23	.71*
Omnivores	-41	-35

* indicates 2 tailed significance at $p < .01$; and ** indicates $p < .001$

The following correlation was found:

The only obligate frugivore species, Yellow logged Green Pigeon was correlated to the open, miscellaneous forest axis on PC2. Understorey insectivores were correlated to axis 2 and sallying insectivores was correlated to axis 1. Canopy insectivores and trunk/bark feeders were not correlated to any axis. Granivores were correlated to open forests (PC 2). Raptors did not show any preference for any axis. Omnivores were negatively correlated to both the axes.

2.30 Discussion

The bird abundance measures vary at several scales. MacArthur emphasized on foliage volume to affect the bird diversity (1961,1965; MacArthur and Wilson 1967; MacArthur and Horn 1969). Many studies found other attributes of vegetation structure to play a role in predicting bird species diversity. Some of them were percent vegetation cover (Karr and Roth 1971; Wilson 1974; Verner and Larson 1989), canopy cover (Wiens and Rotenberry 1981; James and Wamer 1982; Moskat and Walliczky 1992), plant diversity (Rotenberry 1985; Willson and Belcher 1989; Daniels et al. 1990) and tree species richness (James and Wamer 1982). Several studies have documented changes in bird populations with changes in forest structure (MaCArthur 1966; Helle and Jarvien 1986; Mannan and Meslow 1984; DeGraff and Chadwick 1987, see section 1.7 in Chapter 1). Apart from habitat structure, other factors such as isolation effect (MaCArthur and Wilson 1962, Diamond 1975, Brash 1987), size of the area (Ambuel and Temple 1983) and habitat heterogeneity (Freemark and Merriam 1986; Thiollay 1990) are also found to cause changes in bird population. Studies (May 1992, Hanski et al. 1995) report an increase in abundance of generalists and a decline in specialist following habitat modification. Forest specialists prefer forested areas and are specific about their selection and mode of food and generalists are those species that are wide spread and survive on wider array of food. In my study area, Specialists include species like hornbills, barbets, orioles, woodpeckers, nuthatches, some flycatchers, owls, and some understorey and canopy insectivores. The generalists include tree pies, mynas, bulbuls, parakeets, bee-eaters, shrikes, and some commonly found insectivores.

In Bori Wildlife Sanctuary, variations were seen in bird abundance in all silvicultural systems. Did the silvicultural system affect the structure of the site and consequently the composition of bird species?

2.31 Silvicultural Practices and Bird community composition

Coppice with Reserve (CWR)

Structurally, the 7 yr site had lower canopy cover, low foliage diversity, less number of timber trees, but had higher number of smaller trees and fruiting trees than the 20 yr and 40 yr site. The site represented open, grassy, non-teak forests. The forests in this area were largely of this type, so the vegetation in 7 yr site may not necessarily be an effect of logging. In spite of being logged, these forests were not devoid of large trees, as in the case of clear felling. Although there were differences in structure, the 7 yr and 40 yr sites were placed close to each other on PC ordinates (Figure 2.18) indicating that the old logged and recently logged sites were structurally similar. The tree species composition and bird species composition also showed large degree of similarity between all three sites (Figures 2.16 and 2.17). This shows that Coppice felling system did not result in creating major alteration in vegetation and structural aspect in the forests.

Some differences in bird composition were seen between all three sites. Out of the three species of parakeets, only Blossom Headed Parakeets were seen commonly in the 7 yr site but they were much less in number than in the 20 yr and 40 yr sites. Teak fruits are fed upon mainly by parakeets that feed on other fruits as well. The 7 yr site had no mature teak trees, but parakeets were seen feeding on *Buchnania lanzan, Diospyros melanoxylon, Embelica officinalis, Aegel marmelos* and *Bridelia retusa* fruits. Interestingly, the Roseringed and Alexandrine parakeets were not observed in the 7 yr site regularly. Why it was so, is difficult to explain but I had observed both these species feeding in wheat crop fields that were located close to the site. The birds were seen in crop fields in winters and at times in summers also. In the 20 yr and 40 yr sites, all three species of parakeets were seen feeding on teak seeds and other fruiting trees. Both these sites did not have crop fields nearby, as they were located far away from the village. Possibly, the crop fields were attracting the birds in the season

when the resources were lean in the site. Amongst the other fruit feeder species, Common Grey Hornbills were higher in number in the 7 yr site. Grey Hornbills possibly may have been a regular visitor to the 7 yr site prior to logging and continued to be so after logging as none of the fruit trees were felled. Wilson and Johns (1982), and Johns (1986) reported that most hornbill species is not affected by selective logging. Johns (1986) inferred that since most frugivores, including Hornbills were highly 'mobile' species they could travel large distances tracking food resources and feed from different tree types. Species such as the Small Minivet, Iora, Common Wood Shrike was found in the 7 yr site. Lesser Goldenbacked Woodpecker and Browncapped Woodpecker were also present in almost the same number in the 7 yr site as the other two sites.

Selection cum Improvement (SCI)

Except the lower shrub cover in the 7 yr site, other structural parameters were not significantly different in the 40 yr site. However, the 7 yr site showed greater bird species similarity with the 20 yr site than the 40 yr site (Figure 2.16, and 2.18). In the 7 yr site, canopy feeders were more in number than the 40 yr site. Grey Hornbill was seen only in the 20 yr logged site. Forest specialist species such as Spotted Grey creeper and Blacknaped Flycatcher was seen in the 40 yr site only, and the species such as Whitebrowed Fantail Flycatcher was more in number in the 7 yr site and present in equal abundance in the 20 yr and 40 yr site. Granivores such as Yellow Throated Sparrow and Jungle Bushquail were present only in the 7 yr site. Apart from this abundance of other species did not show any difference between the sites. All SCI sites had lower number of timber trees (Figure 2.7). On PC ordinates, the 7 yr site was placed closer to the CWR 7 yr site as both of these sites had no mature teak trees and represented open forests. It is possible, that after logging, gradually the SCI sites are getting converted to non-teak forests.

General Teak Felling Series (GTFS)

The 7 yr site had more number of large trees than the 60 yr site, although the canopy cover and grass cover was not significantly different. The 60 yr site had more number of smaller trees and in effect resembled a recently logged site rather than an old logged site. One reason could be that this site, after it was main felled, had undergone thinning (this is done to facilitate the growth of smaller trees by felling large trees that are obstructing the growth of others) after every ten years which would have resulted in sparse distribution of bigger trees in the area.

GTFS was operational in teak dominant moist deciduous forest. The bird community in this area was different from the dry deciduous forests. Forest specialists such as orioles, barbets, tits, nuthatches, owls and all five species of woodpeckers (apart from two mentioned above, there were three more; Small Yellownaped Woodpecker, Yellowfronted Woodpecker and Blackbacked Woodpecker) were frequently encountered in this forest. The 7 yr and 60 yr site had more species of birds in common than the 20 yr had with the 60 yr site. In the 60 yr site, fruit-seed -insect feeders such as mynas, parakeets and Tickell's Blue flycatcher, Blacknaped Flycatcher, White Browed Fantail Flycatcher were more than in the 7 yr site. Trunk-bark feeders (tits, nuthatches, and woodpeckers) were higher in abundance in the 20 yr site while in the 7 yr and 60 yr sites their abundance was almost equal. In the 7 yr site, sallying insectivores and granivores were represented by more species and their abundance was also higher than the other two sites.

Special Teak Felling Series (STFS)

After logging, the 6 yr site had been planted with teak. The transect passed through almost the entire plantation which was about 5 m tall. The canopy and grass cover was significantly lower in the 6 yr site than in the other sites. Overall, the 20 yr, 80 yr, and preservation plot showed large degree of similarity in

structural and floristic aspect between them. However, the 6 yr site represented the other extreme of structurally complex preservation plot and this was apparent from its foliage profile and PC ordination (Figures 2.14, 2.18). The preservation plot and 80 year old site had similar tree and bird species composition (Figure2.15 and 2.16) but on PCA ordinates, the preservation plot was not placed close to the 80 yr site (figure 2.18).

The bird community composition was different in the 6 yr site from other STFS sites. This site was dominated by generalist species such as Red Vented Bulbul, Franklin's Wren Warbler, Magpie Robin, Rufousbellied Babbler, and TailorBird. The 20 yr and 80 yr sites showed over 75 percent similarity in species composition with each other. Preservation plot, being in the same forest type, had maximum similarity with the 80 yr site. The 80 yr site represented mature forest with fairly good representation of understorey insectivores such as babblers, and Orange Headed Ground Thrush. The preservation plot and 80 yr site did show similarity in bird species composition, but there were differences between them. Granivores and understorey insectivores guilds were completely absent from the preservation plot. Although there were intra-site differences, all STFS sites clustered together for tree and bird species composition. STFS logging altered the structure of the sites to a large extent as seen in the 6 yr site.

Summarizing the composition of bird communities between sites, it is apparent none of the guilds showed discernible differences with age of the site. For e.g. in SCI, the abundance of sallying insectivores and fruit-seed-nectarivores was lowest in the 40 y site as compared to its 7 y site, while in CWR the 40 y site had higher abundance of both the guild than its 7 y site. Omnivores were higher in abundance in all the 7 y site except GTFS, where higher abundance was seen in the 60 y site. Some changes are inherent to bird populations, irrespective of changes in habitat structure.

2.32 Area dependent changes in the bird community

The bird community composition is known to be influenced by its immediate surroundings. This was established in studies carried out on

plantations located in natural forests. Daniels et al. (1990,1995) noted that plantations acquire bird community composition similar to the surrounding forest types, in spite of having distinctly different structure and floristic composition. Coulsen and Coulsen 1995 (in Taylor and Haseler 1995) noted that once the primary forest surrounding the logged forest was also felled, the species richness of the logged forests declined immediately. A study in west Mengo forests in Uganda found that unlogged forests had 93 per cent similarity with the logged forests. This was because the unlogged forests were surrounded by agricultural fields that contributed to an increase in generalist species that were common in the logged sites also (Dranzona and Johns 1992: in Johns 1997). Composition of the bird community can change in area which are isolated and do not have nearby resource population. This was the basis of the Island biogeography theory. A fragmented patch of habitat puts a physical barrier on the ability of birds to move across habitats (Fahrig and Merriam 1994., Desrochers and Hannon 1997). The inference to be drawn from results of these studies is that the regional pool of species available largely influences the species richness of an area, which is likely to have mostly historical origin.

In Bori Sanctuary, the older logged sites surrounded all the recently logged sites. The surrounding older logged areas serve as source pool for colonizing species. Within a silvicultural system, all logged sites show high degree of similarity between them (Tables 2.4, 2.8, 2.12 and 2.16). This proves that in spite of the difference in age of the sites, the species composition remained largely similar because they shared the same regional pool. Refugia size is another important factor that affects the community composition. Smaller sized areas can not support large number of species and have impoverished bird community (Amble and Temple 1983, Blake and Karr 1986, Askins et al., 1987). The area of the preservation plot was very small (38 ha) compared to the other sites that were about 200 ha. In size. Structurally, the plot was less heterogeneous (stratified) than other sites as there were only two strata; tall trees and shade-tolerant shrubs of *Colebrookia oppositifolia*. Primary, undisturbed forests are reported to support lower number of total species, than moderately disturbed forests that has a mosaic of all vegetation types (Beehler 1987;

Thiollay 1990). Thiollay (1990) found that moderately logged forests had higher bird species richness and diversity than old logged sites. Though the plot had 70 % similarity in bird community with the 80 yr site, the guild composition was different. Granivore guild that includes doves, quails, munias and Yellowthroated Sparrows were not recorded here. Also the understorey feeders such as robins, babblers, junglefowls and peafowls were not seen in the plot (Table 2.9). Beehler et al. (1987) had found similar results in Eastern Ghats in India, where the ravine forests had impoverished bird community because of isolation from other forest plots and its small size. In smaller areas, the microclimate required for some species may be missing or the area may be too small for large territorial birds. Also smaller areas would be less heterogeneous and thus support less number of species (Askins et al 1987).

2. 33 Patterns of bird diversity in Bori Wildlife Sanctuary

In Bori, the bird species richness was correlated with mature forests and diversity was correlated with presence of fruiting trees (Table 2.19). Presence or absence of a species in an area is largely governed by the availability of the resource (Karr 1976., Karr and Freemark 1985., Bette and Blake 1992). Yellow Legged Green Pigeon is an obligate frugivore (Ali and Ripley 1983) and feeds primarily on *Ficus* fruits and frequently on *Bridelia retusa, Lannea grandis*, and *Garuga pinnata* fruits (pers.observ). The presence of this species was correlated with number of fruiting trees and small tree density. Green Pigeons were found in sites wherever the resource was available including different habitat types and across all age classes. Hornbills, orioles, barbers also did not show preferences for age of the site. These birds feed on insects and fruits and are found where the resource is available. Same is true for the Malabar Pied Hornbill frequently seen in the riparian area in the moist deciduous forests, and in the 20 yr site in STFS. Though in the study area, the Malabar Pied Hornbill was confined to moister forests, a flock of 36 birds was seen in the dry deciduous forests feeding on petals of Bomabx ceiba flowers in February 1993. This indicates that such species are opportunistic feeders and that they track food resources.

Seed feeders like parakeets and other frugivores like mynas were abundant in number and are known to exploit wider range of food sources, apart from feeding on teak seeds (Ali and Ripley, 1983). Insectivores also displayed trend similar to frugivores, as most canopy insectivores, trunk/bark and understorey insectivores were found in recently logged and old logged sites, although their numbers did vary.

In Bori, almost all forest species are diet specialists and are therefore found across different forest types and age classes. Such findings indicate that specialists did not completely disappear from the logged sites. Does this mean that logging did not have a major impact on the forest structure and therefore on the specialists species? Specialists can be further divided in two broad categories as diet specialist and habitat specialist. The diet specialists are selective about the food resource that may or may not be widely distributed. For example, the birds feeding on figs are considered as diet specialists. *Ficus* trees are present in dry and moist forests. Fig dependent species can track the fruiting *Ficus* tree, irrespective of the forest type where trees are present. In contrast to this, habitat specialists are those birds that are confined to a particular habitat type and are also specific about their diet. For instance, species residing in wet lands, evergreen forests, or grassland. Rolstad et al (1988) found that the Black Woodpecker that was considered to be an inhabitant of old logged, mature forest preferred young, spruce dominated plantations for feeding and mature forests for roosting and displaying. This was the reason why the bird was found in mature as well as young forests. Benkman (1993) makes a case for the crossbill species, as they are highly specialized taxa feeding on the seeds of pinecone. Due to Pine harvesting, these birds are facing major threat for their survival in North America as Crossbils are both dieting and habitat specialists. Such species will be relatively more sensitive to habitat alteration as opposed to diet specialist that can survive in a altered habitat provided their food resource is not depleted.

The continued presence of specialists in logged sites in the study area could be attributed to several factors; firstly, the actual data in gain or loss of a species could be arrived at only if we have data on spatial (i.e before and after

logging for the same area) and temporal (a control or an unlogged area) control. Since pre -logging data was unavailable, the next best option was to compare the abundance of birds with the old logged sites. No two different sites would have identical structural and florisitic composition. Therefore, it is likely that differences in bird communities may not primarily be due to logging. Secondly, the site was being monitored after 7 yr of logging activity, so immediate changes in avifaunal composition that could have occurred were not available. Given a time period of 7 years, the existing pattern of avifauna could be a result of recolonization. It is tempting to infer from results that within 7 years, the forests of Bori Sanctuary are capable of recovering its avifauna. However, only longer duration and more detailed studies can help validate this inference in future.

Of equal importance in finding a situation of no difference in this case is, that except the 6 yr site in STFS, none of the other sites faced clearfelling. Felling was selective as only trees of specific diameter were felled and fruiting trees were retained as part of the felling guidelines. Therefore, overall structure of the forest did not change greatly as it does in clearfelling.

None of the bird species in Bori forests were highly specialized and most species could survive in logged forests provided the disturbance is moderate magnitude and alternate resources are present. For instance, loss of large trees could result in severe habitat loss for woodpeckers, but if there are species of other large trees present than it is possible that there would not be significant changes in woodpecker abundance. This rule applies for all specialists species.

CHAPTER THREE

Response of bird communities to Selective logging in the Reserved Forests of Melghat Tiger Reserve, Maharashtra.

3.1 Introduction

Prior to 1855, Melghat forests belonged to Korku Kings, who were the original inhabitants of the hills. The Korkus used to earn their living by "dahiya' (slash and burn) cultivation and export of timber and bamboo from the forest to the plains of Berar. In 1855, the Nizam of Hyderabad gave away the rights of these forests to the British. In return, the Korku *were* given land elsewhere in the plains. The British administration was wise enough to realize the importance of the teak forests of the area and declared a ban on tree removal till the area was restocked with sufficient number of teak trees. In 1865, Colonel Pearson gave directives for regular forest administration in Melghat. Gugamal, presently the National Park, was declared as the state Reserved Forest in 1866. In 1913, Gugamal was declared as 'A' class reserved forest maintained exclusively for timber and fuel reserves. In 1927, certain parts of the reserve, where game animals were abundant were declared as shooting blocks. The shooting block system was abolished only as late as in 1968, until then the Tiger Reserve was a popular hunting range. In 1969, Melghat Tiger Reserve was created by combining three shooting blocks and was called as Dhakna-Kolkaz Game Sanctuary. Three years later in 1972, Melghat Tiger Reserve was included in country's nine premier Project Tiger habitats and the very first one in the state of Maharashtra. In 1987, Gugamal forests were declared as National Park with an area of 361 km^2 (Gogate 1988).

This study was carried out in the Reserved forests, which were contiguous with the forests of Melghat Tiger Reserve. The western and eastern forest divisions of Melghat forests where logging was going on, were always maintained as reserved forests and has had over 100 years old history of silvicultural tending (Gogate 1988, Gupta 1990). Three sites in the reserved forests were selected; namely, Chunkhedi, Jarida and Dharni range.

As these forests were contiguous with Melghat Tiger Reserve, the general description is common for all the three sites. The intensive study site is described in detail, followed by a brief description on methods. Most Methods were same as described in Chapter 2, with a few modifications, which are mentioned

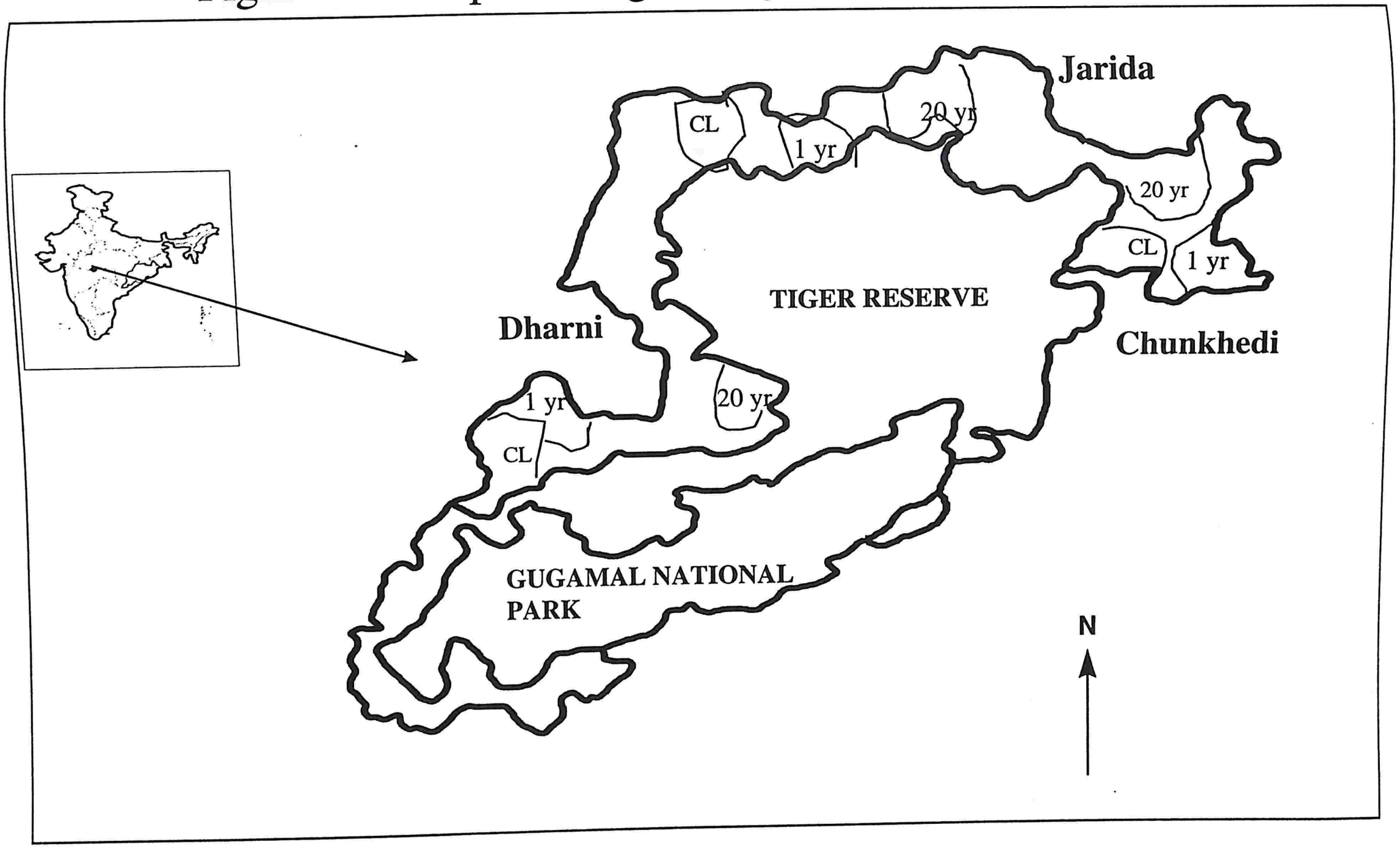
3.2 Location of Melghat Tiger Reserve

The Melghat forests located on Gavilgarh hills of southern Satpura range extends over 3,000 km^2 in Amravati district in Maharashtra State. ' Melghat ' as the name implies means "meeting of hills". The whole area is hilly, traversed by numerous valleys and cliffs. This has resulted in undulating terrain in Melghat. The Tiger Reserve extends for about 65 km. between 21° 46 ' and 20 ° 11 ' and 95 km. between 77° 34 ' and 76° 38'. The altitude of the area varies from 380 m.a.s.l in the east to 950 m.a.s.l in the west. The highest plateau in Melghat is Chikhaldara and the highest peak is at the western extreme at a height of 1,178 m.a.s.l where Vairateshwar temple is situated. The total area of the Tiger Reserve is 1,100 km^2. The Gugamal National Park with an area of 361 km^2, is located in the southern boundary of the reserve where the terrain is rugged and steep (Gogate 1988).

3. 3 Geology, rock and soil

The entire Tiger Reserve consists of Deccan traps, which is formed due to horizontal lawa flows of basaltic composition. Trap formations are commonly seen on flat-topped hills as step like terraced structure. In the southern ridge of Melghat, vertical trap formations are seen (Gogate 1988, Sawarkar 1990). Most commonly seen rock formation is basalt, which is seen as dykes and out crop in several sites. (Gogate 1988). Melghat terrain is mostly composed of bouldery soil. Good quality miscellaneous forests are grown in this type of soil in valleys and slopes. Superior quality teak forests are found on trap derived soil. Lateritic soil generally forms the top of the trap. This soil is very shallow and dry and supports stunted tree growth (Gogate 1988).

Figure 3.1. Map of Melghat Tiger Reserve



3. 4 Climate

The area has three distinct seasons. Winter (October to February), summer (March to mid -June) and monsoon (mid-June to September).

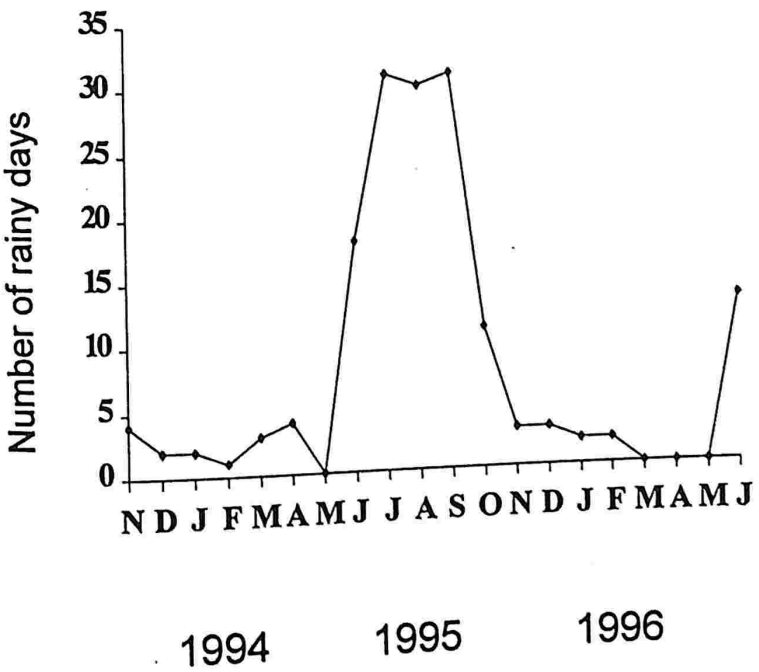
I had recorded daily temperature in the three field sites. Average value for maximum and minimum temperature is shown for the season in the table.

Table 3.1 Average temperature (° c) in Melghat during 1994-1996.

Season	Minimum ° c	Maximum ° c
Winter 1994	9.5	22.5
Summer 1995	26.7	35.5
Winter 1995	11.0	21.6
Summer 1996	21.9	37.5

Rainfall: Monsoon begins from late - June and lasts up till September. The area receives winter rains mainly from December to February. Occasional rains during early March and April is not uncommon in Melghat. I collected data on number of rainy days in the Tiger reserve during 1994 – 1996.

Figure 3.2 Number of rainy days per month between October 1994 to June 1996.



3. 5 Drainage

Tapti is the major river running along the northern boundary of the Reserve. There are five tributaries running from east to west and draining off to Tapti in the North West. They are Khandu, Khapra, Sipna, Garga and Dolar. The direction of the drainage is towards the north and north-west of the Reserve (Gogate 1988).

3.6 Vegetation

Melghat forests are the typical dry deciduous forests of Central India. Revised classification of Champion and Seth (1968) describes the Melghat forests into following types:

Group 5: Tropical dry deciduous forests.

Sub Group 5 Southern tropical dry deciduous forests.

According to Rodgers and Panwar's Biogeographic classification (1988), the forests of Melghat are included under Deccan biogeographic (6) zone and Central High land (6E) biotic province. Detailed work on Melghat floristics is described by Witt in 1916 and Patel in 1968. After twenty years, Dhore made a detailed descriptive inventory of the plants found in the Reserve. Out of the 720 recorded species, 648 were natural species belonging to 97 families and 72 were cultivated species. Altogether, 88 tree species, 316 herbs, 56 climbers, 66 shrubs, and 99 grass species were documented from Melghat (Gogate 1988).

3.7 General description of the forests

In flatter areas, the forests consist of bigger trees while the slope of hills show stunted growth of tree (Patel 1968). Higher slopes show mixed forests with more of *Ougeinia oogenesis* and little of teak. The western part of the Reserve is dominated by *Boswellia serrata*. The upper canopy (trees up to 15-20 m height) of the forests is dominated by all deciduous trees such as *Tectona grandis, Adina cordifolia, Mitragyna parviflora, Lannea coromandelica,*

Buchanania lanzan, Madhuca latifolia, Terminalia tomentosa, Anogeissus latifolia, and *Lagerstromeia parviflora.* These trees shed leaves by the end of winter season. The lower canopy (trees up to 8 -14 m tall) is also deciduous in nature with trees such as *Flacourtia indica, Wrightia tinctoria, Randia uliginosa, Embelica officinalis.* The undergrowth in the forests is predominantly of *Lantana camara, Helicteres isora, Colebrookia oppositifolia, Carvia callosa, Securinega virosa,* and *Azenza lampas.* Grass cover is not very dense in the forests and commonly seen species are *Alpaca mutica, Heteropogon ritchiei, H. contortus, Chloris dolichostachya, and Pennisetum pedcellatum.* Bamboo (*Dendrocalmus strictus)* is occasionally present but not in dense clumps (Patel 1968, pers.observ).

3.8 Fauna

29 species of mammals have been recorded from the area. Among the herbivores, gaur *Bos gaurus* are often seen in herds of 20-25 animals. Sambar (*Cervus unicolor*) and barking deer (*Muntiacus muntjak*) are distributed throughout the forests. Chitals (*Axis axis*) were very sparsely distributed in the area , localized to two- three places in the Reserve. During the study, a herd of 25-30 individuals was seen at Patulda in the north-western part of the Reserve for the first time. Among other mammals, striped hyena (*Hyena hyena*), small Indian civet (*Viverricula indica)*, are seen in the forests. As per the recent tiger census, there are 70 tigers (*Panthera tigris*) and 56 leopards (*Panthera pardus*) in the area (Wankhade, pers. comm).

Bird life in Melghat Tiger Reserve: The earliest compilation on birds of this region comes from Wright's (1942) publication. The list is mainly for the plains of Berar but includes some parts of Melghat and includes 54 species for this region. During 1973-79, a systematic and detailed compilation of birds of Melghat Tiger Reserve was carried out by Sawarkar (1988). The survey documents 243 species from 146 genera and 48 families. This study recorded 215 bird species during the period of two years. The species that were not recorded during this study are listed in the table below. A complete list of birds seen in Melghat is given in Appendix 1.

Table 3.2 shows species not recorded earlier in (1988) and those not recorded during this study (1994-96).

Species not recorded during 1988 survey	Species not recorded during this study
Indian Shag, Night heron, Black Partridge, Greenish Leaf Warbler, Yellowbrowed Leaf warbler, Olivaceous Leaf Warbler, Blyth's Reed Warbler, Brown Leaf Warbler, Indian Tree Pipit, Wryneck, Black capped Kingfisher, Blue headed Rock Thrush, Brown Flycatcher, Small Yellow naped Woodpecker, Goldfronted Chloropsis, Spangled Drongo, Crested Bunting, Lesser Whitethroat	Lesser Whistling Teal, Common Teal, Gadwall, Shoveller, Black Eagle, Crested Goshawk, King Vulture, Pale harrier Saheen Falcon, Demoiselle Crane, Painted Sandgrouse, Brown Wood Owl, Shorteared Owl, Little Scalybellied Woodpecker, Black Woodpecker, Heart spotted Woodpecker, Small Greenbilled Malkoha, Orphean Warbler, Striated Marsh Warbler, Rufous Fronted Wren Warbler, Tickell's Leaf Warbler, Drongo - Cuckoo.

3.9 People

The Melghat forests are surrounded by villages. There are about 65 villages in East Melghat division, and 57 villages in the Western Melghat division. Melghat belt is populated by Korkus, Gonds and Nihal tribal communities. Professionally skilled in forestry operations, Korkus are facing a major employment problem now. Nihals were the first habitants of the area but due to subjugation by the Korkus, they are ranked lower in the social systems. Gonds have traditionally occupied the hills but later was forced to migrate to different parts of Central India. Gonds are skilled hunters and an aggressive tribe. Gaolis, the descendent of 'Krishna ' are the only non-tribals in the area. The Gawilgarh fort on Gawilgarh hill is believed to be owned by Gaoli kings (Gogate 1988).

3.10 History of forest management

Presently, the logging operations are carried out in the Reserved forests adjacent to the study area and not inside the Tiger Reserve. The study sites were, therefore chosen outside the Tiger Reserve. The past forestry practices

in the reserve is briefly recapitulated in the next section followed by the description of present working in the area.

Past forestry practices in the area

By 1913, the British brought about reservation against indiscriminate felling in this area. Up until 1935, these forests were worked under improvement felling. From 1955 to 1970, Selection-cum improvement felling was carried out in better quality forest, and Coppice with Reserve felling in poor quality forest. During 1975-85, wildlife management prescriptions were introduced for the first time in forestry working. This plan excluded areas of 100 m. radius near perennial streams and water holes from felling and advocated retention of fruiting trees. These prescriptions were improvised upon and incorporated in subsequent plans.

The present working plan

The present working follows Sinha and Thengdi 's plan for East Melghat division, Bahadur, and Thengdi's plan for West Melghat division. The duration of the plan was from 1993 -2003.

The demarcated forests were managed under Selection -cum- improvement felling. Sinha's and Thengdi's plan of East Melghat division includes wildlife protection measures also. Both the plans had similar objectives and prescription, which are described below:

The following were the objectives of the forestry-working plan.

1.To obtain large sized timber,

2.To increase the stocking of teak and other species,

3. To promote the growth of teak and other valuable species by improving the condition of growing stock and

4. To improve the site quality against soil erosion.

Before felling begins, a systematic marking of the boundary line is carried out. A compartment is the working unit in the system. Within each compartment,

different areas are demarcated prior to logging on a treatment map in the following manner:

A area: These are areas having greater than 45 ° slope. Such sites would be exempted from felling. Felling is also exempted from 20 m. on either side of the perennial nallah or riverine patch.

B area: This area represents blank or understocked sites within a compartment. Again, no felling was suggested in such areas.

C area: These are sites with young pole crop of valuable species such as teak, *Pterocarpus marsupium, Dalbergia sissoo, Anogeissus latifolia, Boswellia serrata* There will be no felling in such area.

D area: This is the workable area. Where there are adequate seedlings (625/ha) for regeneration, the area is expected to regenerate naturally. Areas where the regeneration is not sufficient, artificial plantations would be carried out after felling.

The felling rules for the D area are outlined below:

The trees are classified in two girth classes; harvestable girth class is 120 cm. and above and approach class is between 105 -120 cm. From the harvestable girth class, 50 % of the available trees are felled, provided that the trees in approach class are more in number than in the harvestable girth class. If the trees in approach class are less than those in the harvestable class, then number of trees equal to this difference of trees in these two classes will be retained. In addition, 30% of these remaining trees will be marked for felling. All dead trees and climbers will be removed. All the edible fruiting trees will be retained (Sinha and Thengdi 1993; Bahadur and Thengdi 1993).

In the study site, I had chosen three different sites where logging was going on. In east Melghat division, I selected Chunkhedi and Jarida and in West Melghat division, I chose Dharni as the intensive study site.

3.12 Intensive study sites

Chunkhedi range: This range is located along the south eastern boundary of the reserve. The area has generally well stocked deciduous forests that are considered better in quality than seen in Jarida and Dharni. The forests were along a *nalla* so associate species seen were Ougeinia *oogensis, Schleichera oleosa, Mangifera indica, Ficus glomerata, Terminalia arjuna, Stereospermum* species. *Ficus* trees were present in good number in these forests. *Lantana camara* formed the thick, and dense undergrowth here. Due to this, there was hardly any grass cover. The average tree height was about 18-20 m. Three compartments were chosen in Chunkhedi range for the study.

1. **Compartment no. 200 (20 yr. site)**: This compartment was logged under selective felling in 1976-78. Therefore, this site represented the control site logged 20 years ago. The area of the compartment was 270 ha. The site was located along the *nalla* and the terrain was hilly and undulating. The vegetation was of mixed type. Along with large teak trees , there were large sized trees of *Adina cordifolia, Mitragyna parviflora, Ficus glomerata, Ficus benghalensis, Schrebera swieteniodes, Lannea coromandelica, Bauhinia racemosa, and Syzygium cumini, Butea superba* and *Bauhinia vahlii* were frequently seen climbers in this site. There was thick undergrowth of *Colebrookia oppositifolia* in the compartment.

2. **Compartment no. 205 (1 yr. site)**: This site was logged in 1993 -1994. The area of the compartment was 220 ha. The terrain was not as hilly as the 20 yr. site. The vegetation composition was almost similar to that of the 20 yr. site with large *Ficus* trees in the compartment. The undergrowth had been uprooted during logging leaving the ground exposed without much grass cover. The absence of grass cover could be due to the bouldary soil. On the transect, I counted 15 stumps of previous year's logging.

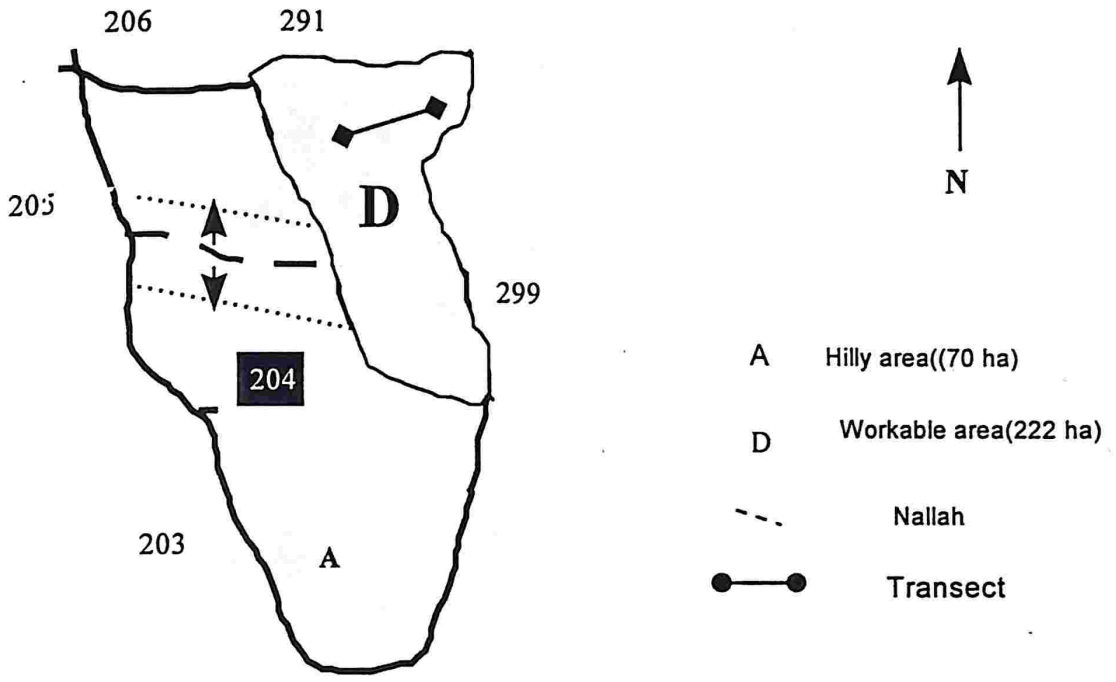
3. **Compartment no. 204(CL site)**: This compartment was logged during the study in 1995-96. I could monitor this site before, during and after logging and this site represented the currently logged (CL) site. This compartment was located adjacent to the 1 yr. site. The terrain and vegetation composition was

similar to the 1 yr. site. The undergrowth was represented by *Lantana camara* and *Woodfordia floribunda* . The total area was 322 ha. Total trees enumerated were 2,350 of which 1,347 trees were between 105-120 cm, and 997 trees were above 120 cm. Total 518 timber trees and 67 non-timber trees were felled. The extraction rate was 3 trees /ha.

Table 3.3 Extraction record for Compartment no. 204.

Girth class of trees felled	Number of Timber trees	Other species
15-30 cm	162	-
30-90 cm	53	3
90-120 cm	33	2
120-150 cm.	198	50
Over 150 cm.	17	14

Figure 3.2 Treatment map for Compartment 204.



The treatment map shows the demarcated areas in compartment no. 204. On the left side are compartments, which are already logged, in previous years. To the right are unlogged compartments. Area marked as A is hilly and is not felled. On 20 m. of either side of the Nallah, no felling was carried out.

Jarida range: This range was located in the northern part of the Reserve The forests were teak dominant dry deciduous types. The associated species were *Anogeissus latifolia, Lannea coromandelica, Terminalia tomentosa, Adina cordifolia, and Buchanania lanzan.* The area was relatively more open and sparse than Chunkhedi range. The undergrowth was a mix of open grassy patches with *Lanatana camara, Helicteres isora and Holarrhena antidysenterica.* The three sites chosen are described.

1. Compartment no. 375 (20 yr. site): This compartment was logged in 1973-74. The compartment was located on a hill and the terrain was uneven and rocky. The forest was teak dominated. Other species such *as Madhuca latifolia, Mitragyna parviflora, Terminalia* species were present. The area of the compartment was 300 ha. *Lantana camara* was sparse as the terrain was rocky and hilly.

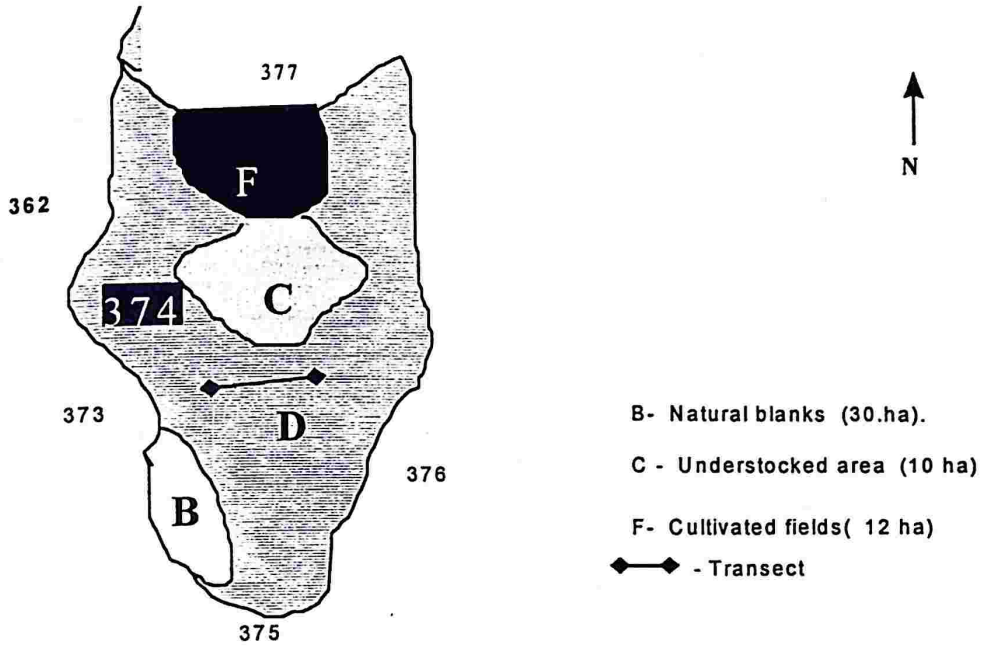
2. Compartment no. 361 (1 yr. site): This compartment was situated far away from the 20 yr. site and was logged in 1993-94. The area was 231 ha. The terrain was moderately hilly. The forest department had undertaken plantation after felling in a 20 ha plot in the compartment. This was teak dominant forest with almost no undergrowth and grass cover. 9 stumps of previous year logging were counted on the transect.

3. Compartment no. 374 (CL site): This compartment was on the opposite side to that of the 20 yr. site, situated on top of a hill. The terrain was very hilly and rocky. The total area was 276 ha. Logging began in October 1995. The area was again very dry and supported very dry deciduous teak and its associate species such as *Anogessius latifolia, Adina cordifolia, Butea monosperma.* The undergrowth was of *Lantana camara.* There were agricultural fields near the site. Total numbers of trees enumerated were 3,450. The were 2,020 trees over 105-120 cm and 1,470 trees were above 120 cm. 1226 timber trees and 56 non-timber trees were felled.

Table 3.4 Extraction record for compartment no. 374.

Girth class Of trees felled	Number of Timber trees	Other species
15-30 cm	246	3
30-90 cm	177	3
90-120 cm	64	2
120-150 cm.	280	28
Over 150 cm.	27	24

Figure 3.3 Treatment map for compartment 374.



The map shows demarcated areas in the compartment. Area marked as F was under cultivation. The old logged compartments are on eastern side and the 1 yr. logged site is shown on the western side of the compartment. The extraction rate was 4.3 trees per ha.

Dharni range: This range was in the Western Melghat division. The site was in plains and the terrain was flat. The forest type was mixed deciduous with predominance of teak. Teak and associated species such as *Terminalia* species, *Butea monosperma, Bridelia retusa, Madhuca latifolia* were seen commonly here. The common undergrowth was that of Hyptes *suavlance, Lantana camara*, and *Helicteres isora*. The following compartments were selected for the study.

1. Compartment no. 703 (20. yr. site): This site was logged in 1973-74. The compartment was located in the interiors of the forest. The terrain was mildly hilly. Area of the compartment was 250 ha. This was a mixed forest with teak and species such as *Diospyros melanoxylon, Embelica officinalis, Cassia fistula, Bombax Ceiba* and undergrowth of Hyptes *suavlance, Heteropogon ritchiei*, and *Lantana camara*. There was a massive fire in the compartment in April 1995, which burnt the undergrowth completely.

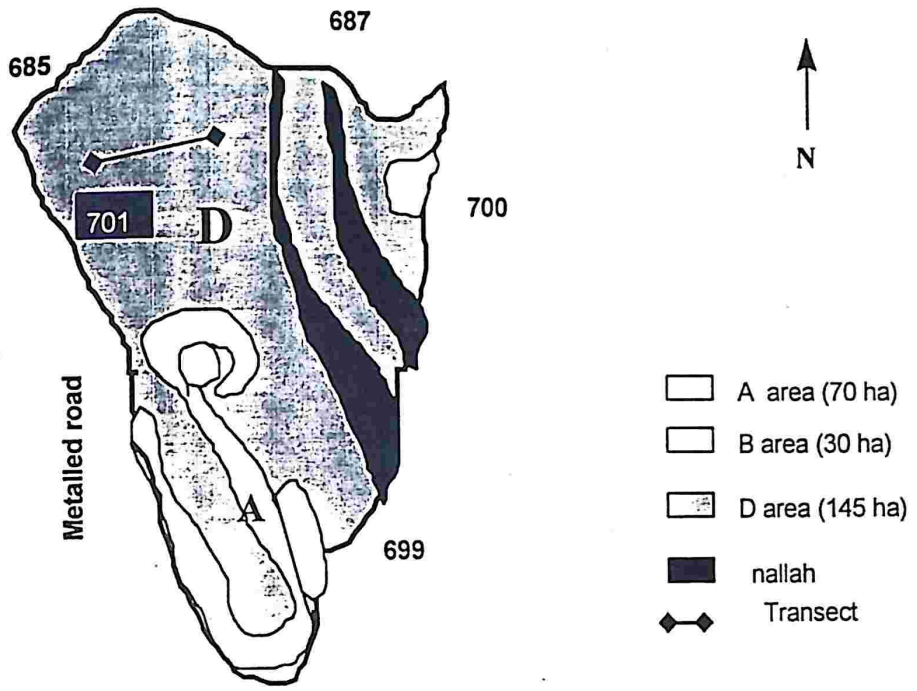
2.compartment no. 719 (1 yr. site): This compartment was close to agricultural fields. The logging was done in year 1993-1994. Area of the site was 210 ha. The terrain was moderately hilly. A perennial nalla bisected the compartment. The vegetation was mixed type with teak and associated species such as Buchanania *lanzan, Madhuca latifolia, Schrebera swietenioides, Diospyros melanoxylan and Butea monosperma, Syzygium cumini, Terminalia arjuna.* There were 17 stumps from previous year's logging on the transect.

3. Compartment no. 701(CL site): This site was logged during the study period. The total area was 245 ha. This was located closer to the 20 yr. site. The terrain was flat and vegetation composition was similar to the other two sites. Total numbers of trees enumerated were 8,450. The trees over 105-120 cm GBH were 879 and those above 120 cm were 369. Total timber trees felled were 3,031 and non-timber trees felled were 60. The extraction rate was 6.7 trees per ha.

Table 3.5 Extraction record for compartment no. 701.

Girth class Of trees felled	Number of Timber trees	Other species
15-30 cm	1295	3
30-90 cm	2,108	3
90-120 cm	64	2
120-150 cm.	164	28
Over 150 cm.	-	14

Figure 3.5 Treatment map for compartment 701.



The compartment map shows demarcated area. The compartment was surrounded by old logged compartments on the northern and eastern side. A metalled road passes through the western side of the compartment.

3.13 Methods

Methods used for measuring bird abundance were the same as described in section chapter 2 for Bori Wildlife Sanctuary. However, in Melghat there were a few modifications in the stratification and vegetation sampling.

In Melghat, the study was started in October 1994 but due to logistic problems, data collection could begin only by the end of December 1994. The study was completed in June 1996. The transects were marked in the following strata:

1. Chunkhedi range : 20 yr. site, 1 yr. site and CL site.
2. Jarida range: 20 yr. site, 1 yr. site and CL site.
3. Dharni range: 20 yr. site, 1 yr. site and CL site.

In Bori Wildlife Sanctuary, the canopy cover, ground cover and the foliage height diversity were measured at every 50 m on the transect. In Melghat, these measurements were measured at every 10 m. Monitoring the changes at closer intervals i.e. at every 10 m can reflect the changes in structural variables. The structural measurements are reported as mean along with the standard errors. The number of trees felled in the 50 m width of the transect was counted and extraction rate per ha was calculated for each CL site. The damage incurred to the trees was subjectively assessed. Damage was considered severe, if a tree was found to be totally uprooted or had a completely broken canopy, branches and had no chances for survival. A tree that had only the side branches broken but otherwise undamaged and in condition to survive was rated as moderately damaged and a tree that showed signs of less damage than the mentioned categories was rated as nominally damaged.

3.14 Analysis

Changes in vegetation structure

Tree density, canopy cover, ground cover, and shrub cover and mean GBH was compared before and after logging. One-way ANOVA was used to test for the significant differences in structural variables in the CL site.

Phenology in the logged sites

I compared the number of fruiting, flowering timber trees and non-timber trees before and after logging using Mann-Whitney U test. Number of trees with young leaves before and after logging was compared in the CL site. For each month, per cent trees fruiting and flowering were plotted for the CL and 20 yr site.

Bird data analysis

Species richness, diversity, and density

In Melghat, the information regarding monthly changes in bird abundance was considered most crucial in the currently logged site. Therefore, instead of averaging the number of birds as done for Bori, I have reported monthly species density, diversity, richness for MTR. Species richness was calculated using total number of species seen per month. Species diversity was calculated

using Shannon-Weiner's index. The number of observations in 35 m width was included for all bird abundance calculations.

Cumulative species richness

The rate of encounter of new species in an area may either increase or decrease after logging in the CL site. The difference in rate of encounter of new species may differ with season also. I plotted number of species seen per walk for each area in the CL site and the control sites.

Similarity Index

Morisita-Horn similarity index was used to compare the bird species composition in the CL site before and after logging and in the control sites for summer 1995 and summer 1996.

Guilds in the logged sites

To check for differences in bird species composition, I compared the number of individuals in guilds before and after logging in the CL site. In the 20 yr, and 1 yr site, comparisons were made between the seasons. Mann-Whitney U test was used to detect the differences in number of individuals per guild.

Vertical distribution of birds in the logged sites

Bell (1982) found a change in foraging height of bird species with respect to seasons, availability of resources and disturbance in the French Guainan Rainforests. In this study, I attempted to find how birds respond to theses changes in the dry deciduous forests. Do they move out of the area or they shift their foraging height in response to seasonal changes or logging? I compared the foraging heights of number of birds seen in different strata before and after logging in the CL sites using Kruskal Wallis One Way ANOVA. In the 20 yr. site, the comparison was made between the years in same seasons.

Sensitive and resilient species: which species is compatible with logging?

While comparing bird species composition between the sites, it appeared that some species are more sensitive to disturbance than others. Individual species density was calculated for each season. For each species, observations within 35 m width on either side of the transect was considered for density calculations. For the CL site, density of each species was considered before and after logging. To depict the trend of change in species abundance, density of individual species before and after logging was plotted in the scatter graph.

For the 1 yr. and 20 yr. site, I plotted the density of birds in summer 1995 against density in summer 1996.

3.15 Results

Effect of logging on vegetation

The tree density was compared before and after logging for the CL site. Canopy cover was compared for winter season before logging and during logging as deciduous forests do not have canopy cover in summers.

Table 3.6 Vegetation structural variables for the CL site before and after logging at Chunkhedi.

Variable	Pre-logging	Post-logging
Tree density/ha	269(±.12)	251(±.18)
Small tree density/ha	167[a](±.09)	135[b](±.15)
Mean Gbh (cm)	78.8 (±. 34)	66.8 (±.19)
Mean Canopy cover	32.9 (±1.55)	28.9 (±.89)
Mean Shrub cover	17.9(±6.8)[a]	9.7(±4.5)[b]

N.B.: Trees and shrub density are expressed as numbers per ha. Standard error is presented in parentheses. Significant changes (using One Way ANOVA) are denoted by different alphabet. No alphabet indicates no significant change.

In Chunkhedi, after logging the tree density and mean GBH did not change, but the small tree density had lowered (One Way ANOVA F ratio = 9.8, p= .001). Shrub cover also declined after logging (F = 7.7, p= .02). In this site, 11 small trees were severely damaged, 6 large trees were moderately damaged and 4 large tree had suffered nominal damage.

Table 3.7 Vegetation structural variables for the CL site before and after logging at Jarida.

Variable	Pre-logging	Post-logging
Tree density/ha	291(±0.07)	280(±.4)
Small tree density/ha	154[a](±.14)	132[b](±.22)
Mean Gbh	63.6(±.32)	50.9(±.39)
Canopy cover	63.7(±.3)	59.8 (±.7)
Shrub Cover	18.6 [a](±.7)	7.8 [b](±. 4)

After logging, small tree density (F=5.8, p=. 04), and shrub cover (F= 11, p=. 0001) had lowered in Jarida. In this site, 6 small trees suffered severe damage and 15 large trees were damaged moderately due to felling.

Table 3.8 Vegetation structural variables for CL site before and after logging at Dharni.

Variable	Pre-logging	Post-logging
Tree density/ha	238(±.10)[a]	198(±.19)[b]
Small tree density/ha	82.7(±.32)[a]	53.6(±.19)[b]
Mean Gbh	68.7 (±.29) [a]	50.6 (±.7) [b]
Canopy cover	41.7(±.5)[a]	23.4 (±.18)[b]
Shrub cover	13.7 (±.9)[a]	6.7 (±.37)[b]

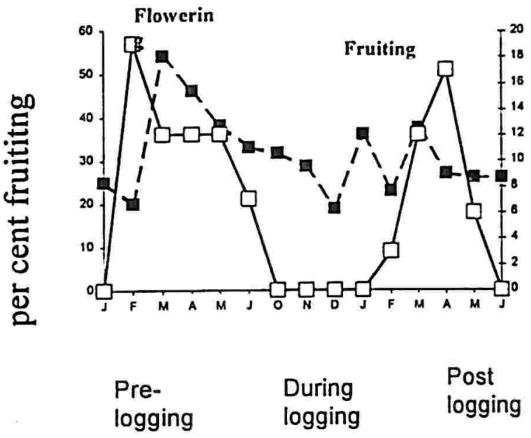
Large trees (F= 7.8, p= .002) and small tree density declined (F= 9.4, p= .0001) after logging. Canopy cover and shrub cover was higher before logging in the CL site (F=8.9 p =. 02 and F= 4.3. p=. 04). Mean GBH was lower after logging (F= 5.7, p= .05). In Dharni, 19 small trees had been damaged severely and 11 large trees were damaged nominally.

Phenology of trees in the CL site

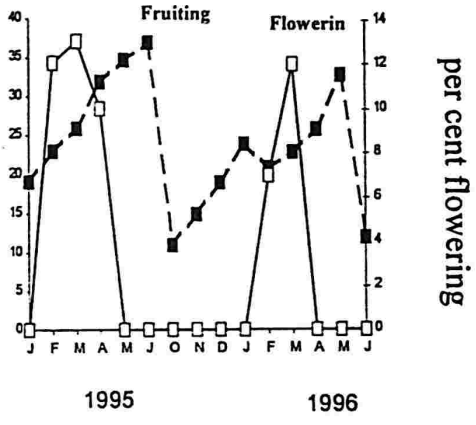
Results for total trees flowering and fruiting every month for the CL sites and the 20 yr sites is presented in the figures below.

Figures 3.6 shows monthly variation in phenology of trees in Chunkhedi in the CL and control sites.

The CL site



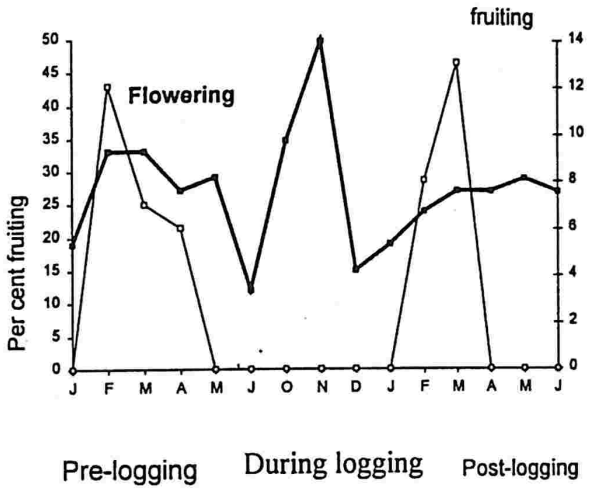
The 20 yr site



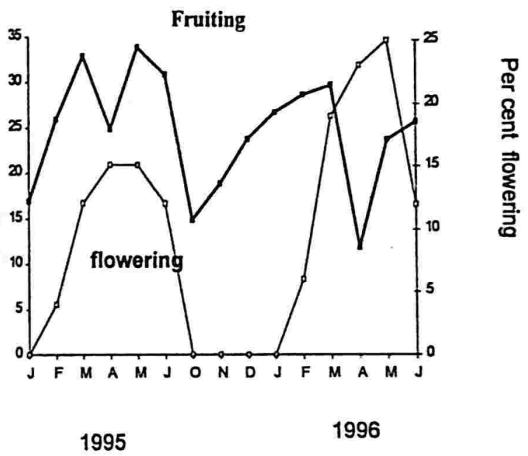
Both the sites show availability of fruits almost through out the year. This is mainly due to presence of teak fruits that remain on the tree for a long time. Flowering peak is between February and May.

Figure 3.7 shows monthly variation in phenology of trees in the CL and control site in Jarida.

The CL site



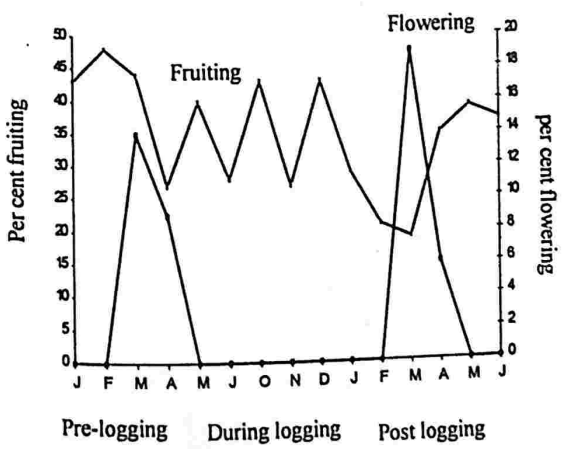
The 20 yr site



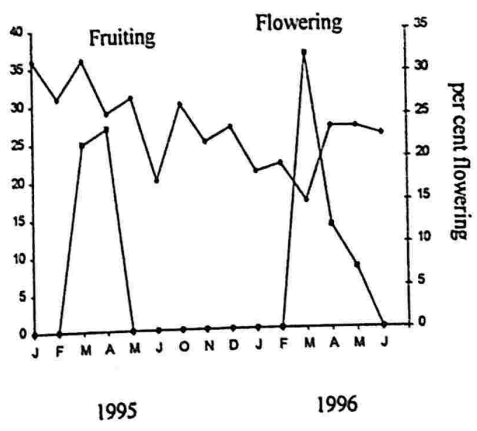
In Jarida, fruits were available all year round, and flowering peak was observed between February – May.

Figure 3.8 Monthly variations in phenology of trees in the CL and control site in Dharni.

The CL site



The 20 yr site



In Dharni, the pattern in fruiting and flowering was similar to Chunkhedi and Jarida sites. All the three sites were dominated by teak trees. The fruits of teak remain on tree for many months, and as a result, it appears that fruits are available through out the year. Although the fruits are available, teak fruits are

eaten only by parakeets and occasionally by mynas. Therefore, I compared the per cent fruiting, flowering and young leaves in timer and non-timber trees in the CL site. I compared the phenological patterns before logging (summer 1995) and after logging (summer 1996). The changes in phenology were detected using Mann-Whitney U test.

Table 3.9. Phenology of trees in the CL site at Chunkhedi before logging (summer 1995) and after logging (summer 1996).

	Pre-logging			Post-logging			
	Fruit	Flower	Young leaf		Fruit	Flower	Young leaf
Timber trees	18.5	-	12.5[a]	Timber trees	14.7	-	6.9[b]
Fleshy fruit trees	11.5	10	2.9	Fleshy fruit trees	7.3	9.0	2.3
Non-fleshy fruit trees	14.7	6.3	8.7	Non-fleshy fruit trees	13.8	3.2	-

N.B.: The values in table are percentages. The significant differences are (Mann-Whitney U test, p =0.05) shown by different alphabet as a superscript. No superscript indicates no difference.

In the CL site at Chunkhedi, per cent young leaf was higher before logging than after logging (U = 12, p= .04). This was due to the fact that in summer 1995 (i.e. before logging), the area received summer rains which resulted in early leafing in the month of May and June.

Table 3.10. Phenology of trees in the CL site at Jarida before logging (summer 1995) and after logging (summer 1996).

	Pre-logging			Post-logging			
	Fruit	Flower	Young leaf		Fruit	Flower	Young leaf
Timber trees	29.6[a]	-	11.5	Timber trees	11.5[b]	-	-
Fleshy fruit trees	7.5	10	7.9	Fleshy fruit trees	5.7	8.0	-
Non-fleshy fruit trees	6.2	4.3	4.7	Non-fleshy fruit trees	4.1	5.7	-

The number of fruiting timber trees had declined after logging (U= 33, p= .001) in Jarida.

Table 3.11. Phenology of trees in CL site at Dharni before logging (summer 1995) and after logging (summer 1995).

	Pre –logging				Post-logging		
	Fruit	Flower	Young leaf		Fruit	Flower	Young leaf
Timber trees	19[a]	-	7.4	Timber trees	13.7[b]	-	-
Fleshy fruit trees	3.5[a]	7.0	3.9	Fleshy fruit trees	8.3[b]	3.4	4.4
Non-fleshy fruit trees	2.4	2.9	4.7	Non-fleshy fruit trees	2.8	-	-

In Dharni, the fruiting timber trees declined (U= 22, p= .003) and the fleshy fruiting trees declined (U= 6.8, p= .01) after logging.

3. 16 Bird abundance in Melghat

Of the 217 species seen, 146 species were resident and 69 were migrants. Of the 69 migrants, 16 were aquatic and 53 species were terrestrial migrants that included 15 summer migrants and 38 winter visitors. On the transect, I encountered 139 species including the migrants. Lagger Falcon was seen once in the month of January near the western part of the Tiger Reserve. Blackcapped Kingfisher was sighted for the first time in this area in January 1995. Green Munia was seen frequently feeding on *Lantana camara* bushes. The Black and Yellow Flycatcher was seen during Winter months in Chikhaldara.

3.17 Bird Community in Chunkhedi.

Bird species richness

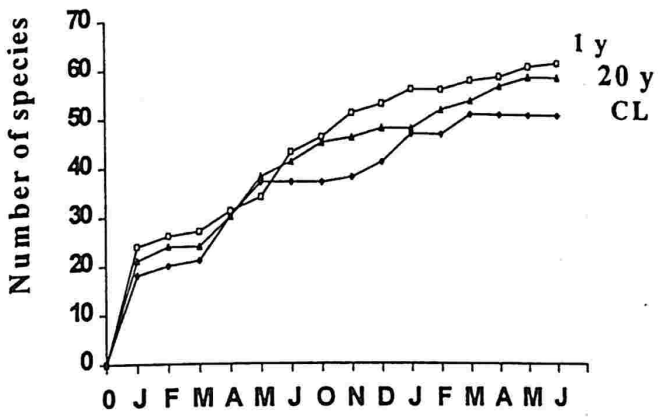
Table 3.12 number of bird species and individuals in the logged sites at Chunkhedi.

	Species	Individuals	Species	Individuals	Species	Individuals
	CL		1 yr.		20 yr	
	Pre-logging		Summer 1995		Summer 1995	
Mar.	21	47	27	70	27	69
April	28	95	16	64	24	78
May	23	45	14	44	19	36
June	21	38	23	69	17	24
	During logging		Winter 1995		Winter 1995	
Oct.	11	21	22	82	21	54
Nov.	7	23	21	64	25	66
Dec.	20	74	17	56	20	30
Jan.	23	49	29	97	21	34
Feb.	23	78	31	89	26	33
	Post – logging		Summer 1996		Summer 1996	
Mar	10	26	22	76	27	36
Apr.	25	99	13	38	31	54
May	23	58	23	32	21	42
June	26	65	26	49	19	38

The CL sites showed least number of species and individuals during logging period. The 1 yr. site and 20 yr sites also showed fluctuations in number of species and individuals recorded during different seasons.

Cumulative Species Richness:

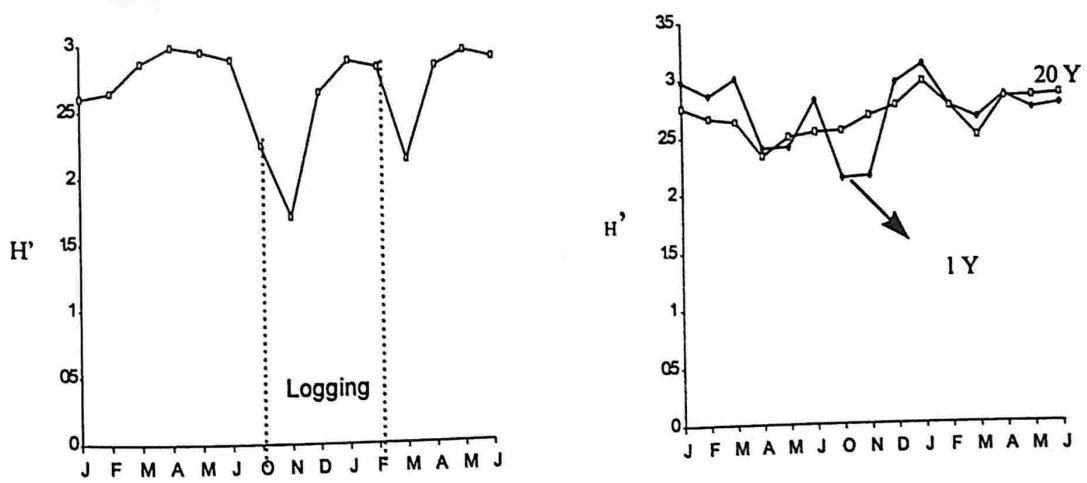
Figure 3.9 Cumulative species richness curve for all logged sites at Chunkhedi.



The figure shows that in the CL site, during logging no new species were recorded. After logging, species richness increased and began to stabilize. The 1 yr and 20 yr sites show increasing cumulative species richness.

Bird diversity in Chunkhedi

Figure 3.10 shows changes in diversity (H') per month in the CL and the control sites:

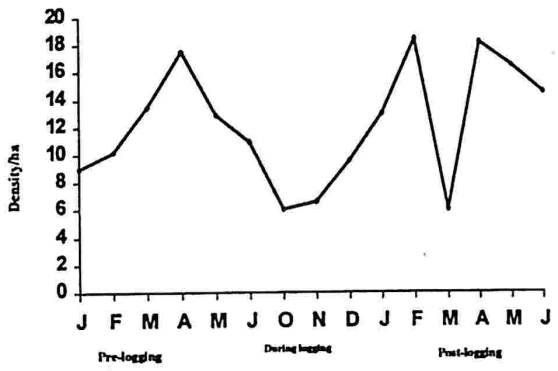


The diversity in the CL site had declined during logging period and after logging it attained the pre logging level. The 1 yr and 20 yr sites also showed monthly variations in diversity value.

Bird density in Chunkhedi

Figure 3.11 shows monthly variation in total bird density in the CL site, 1 yr site and 20 yr site.

The CL site



1 yr site

20 yr site

The density was compared between the months of the same season. In the CL site, before logging, density did not differ between the months. In October, during logging period, the density was low and began increasing gradually. Density in January was higher than December (Kruskal- Wallis 1 way ANOVA, x^2= .11, p=.01), February density was higher than January (X^2= 3.5, p= .05). After logging, the density was higher in April ,May and June (x^2= .51, p= .02). The 1 yr site had lower bird density in April (x^2 = .3.7, p= .4) and the 20 yr site did not show significant change in bird density.

Summarizing the results for changes in bird species richness, diversity and density for the CL and control sites in Chunkhedi, following patterns were observed.

The CL site

Before logging: During summer 1995, an increase in all the three measures was seen in the CL site. Between March and May, flocking species such as mynas, parakeets, Yellowthroated Sparrows, babblers, bulbuls, increased in numbers.

During logging: Diversity declined during October-November with a parallel decline in richness and density. During this period, Grey Tit, Franklin's Wren Warbler, and Redvented Bulbul were dominant in the site. From December-February onwards, richness, diversity and density increased. Small Minivet, Yellowfronted Pied Woodpecker, Jungle Babbler, White Eye, Franklin's Wren Warbler were seen during this period. Grey Hornbill, Lesser Goldenbacked Woodpecker and Large Green Barbet were not observed during this period.

After logging: In March 1996, although the density and diversity had declined species richness had increased (figure 3.9). After logging, Indian roller, Indian Tree Pie and Yellowthroated Sparrow were recorded for the first time in this site. This resulted in higher (cumulative) species richness in spite of low species diversity. By end of June, richness, diversity and density had almost reached the pre-logging values.

The Control sites: In the 1 yr. and 20 yr. sites, also changes were seen. Both the sites showed rise in diversity and richness during March 1995 and 1996. Species such as mynas, bulbuls, parakeets and babblers had increased in abundance at this time. In April 1995, the 1 yr. site showed lower density in number of birds as parakeets, babblers, and mynas were not observed. However, during April 1996, maximum number of mynas, parakeets, Franklin's wren warblers, and babblers were seen in the same site. The 20 yr. site at Chunkhedi showed more 'stable' (unvarying) community compared to the CL site and the 1 yr. site (figure 3.15).

Similarity Index:

Bird community composition was compared before and after logging for the CL site and between different seasons for the control sites. Similarity was compared between the same season for all the sites.

Table 3.13. Morisita - Horn similarity index for all the logged sites at Chunkhedi.

	CL site (summer 1996)		CL site (winter 1996)
CL site (summer 1995)	0.69	CL site (winter 1995)	0.59
	1 yr. (summer 1996)		1 yr. (winter 1996)
1 yr. (summer 1995)	0.80	1 yr. (winter 1995)	0.75
	20 yr. (summer 1996)		20 yr (winter 1996)
20 yr. (summer 1995)	0.83	20 yr. (Winter 1995)	0.78

For the CL site, after logging the community was 70 per cent similar to pre logging community, whereas in the control sites it was above 80 per cent similar. During logging, 60 per cent species were similar to the pre - logging winter community in the CL site, while in the control sites similarity was above 75 per cent during winters. There were changes occurring in community composition in all three sites, irrespective of its logging status. However, the CL sites did show higher dissimilarity after and during logging period. For the CL site, I compared the bird community in the same season between the months to detect the months showing higher and lower similarity in species composition.

Table 3.14. Monthly similarity index for the currently logged site at Chunkhedi.

MONTHS	Pre-logging
March – April	0.47
April-May	0.66
May-June	0.33
March-June	0.65
	During -logging
October-November	0.22
November-December	0.34
December- January	0.64
January- February	0.20
October - February	0.04
	Post-logging
March – April	0.53
April-May	0.64
May-June	0.42
March-June	0.67

Before logging, the April and May and March and June showed above 60 per cent similarity. As logging began, there was constant change in the community composition. December and January community became more similar after which again the composition became very dissimilar. After logging, the months of April- May and March- June showed high similarity.

Guild composition in the logged sites at Chunkhedi

The next step was to identify the guilds, which were common between the sites. For this purpose, species were categorized in 11 major guilds. I checked for differences in number of individuals for each guild for the currently logged site before and after logging. Since I did not have complete data on pre-logging winter, I compared the pre-logging, January and February data to during logging January - February data. For the 1 yr. and 20 yr. sites guild composition was compared between the same seasons.

Table 3.15. Comparison of guild composition before, during and after logging in the CL site at Chunkhedi.

	Summer		Winter	
Guilds	Pre-logging	Post-logging	Pre-logging	During - logging
Frugivores	1(12)	0	1(10)	0
Fruit-insectivore	5(11)	3(6)	4(17)	0
Fruit-seed-Nectar-insectivore	6(44)	6(35)	6(43)[a]	5(10)[b]
Nectar-insectivore	2(16)[a]	2(4)[b]	2(14)[a]	1(6)[b]
Understorey Insectivore	5(25)[a]	3(15)[b]	3(11)	3(9)
Canopy insectivore	5(21)[a]	3(11)[b]	5(18)[a]	3(9)[b]
Trunk/bark feeder	7(36)	5(29)	6(22)[a]	2(8)[b]
Sallying insectivore	5(15)	5(11)	4(13)	2(10)
Raptors	2(2)	2(8)	0	0
Grainivore	3(20)	3(19)	4(27)	2(22)
Omnivores	3(11)[a]	4(32)[b]	2(12)	3(19)
Total species	44	36	37	21

N.B.: Tabled values are number of species and numbers of individuals are shown in parentheses. Significant differences (Mann-Whitney U test, at $p < 0.05$) are indicated by different alphabets as superscript. No alphabet in superscript indicates no statistical difference.

The nectarivore - insectivore guild declined after logging ($U=7.6$, $p= .02$) and during logging ($U= 11.5$, $p= .01$). Understorey insectivores had declined after logging ($U=22$, $p= .002$), and during logging ($U= 17$, $p= .01$). Trunk/bark insectivores declined during logging ($U= 13$, $p= .01$) and after logging ($U = 23$, $p= .03$). Omnivores increased after logging ($U = 6.5$, $p=. 03$).

Table 3.16 Comparison of guild composition in the 1 yr. site between seasons at Chunkhedi.

Guilds	Summer 1995	Summer 1996	Winter 1995	Winter 1996
Frugivores	1(16)	1(16)	1(14)	1(12)
fruit-insectivore	3(6)	3(6)	3(6)	3(4)
fruit-seed-nectar-insectivore	5(57)	7(65)	4(32)[a]	5(65)[b]
Nectar-insectivore	1(1)	1(1)	1(2)	1(4)
Ground insectivore	4(22)	3(18)	4(10)	4(17)
Canopy insectivore	3(20)	3(15)	4(16)	2(19)
Trunk/foliage /bark feeder	4(10)[a]	6(38)[b]	5(16)	6(11)
Sallying insectivore	2(16)	2(12)	3(10)	3(12)
Raptors	2(4)	1(2)	0	0
Grainivore	3(12)	2(12)	2(17)	2(11)
Omnivores	3(21)[a]	4(37)[b]	3(15)	3(19)
Total species	31	33	30	30

The 1 yr. site showed an increase in the number of fruit-insect feeders in the winter of 1995 (U= 11, p= .01) and in trunk/bark insectivores in summer 1996 (U= 8, p= .001).

Table 3.17 Comparison of guild composition between seasons in the 20 yr. site at Chunkhedi.

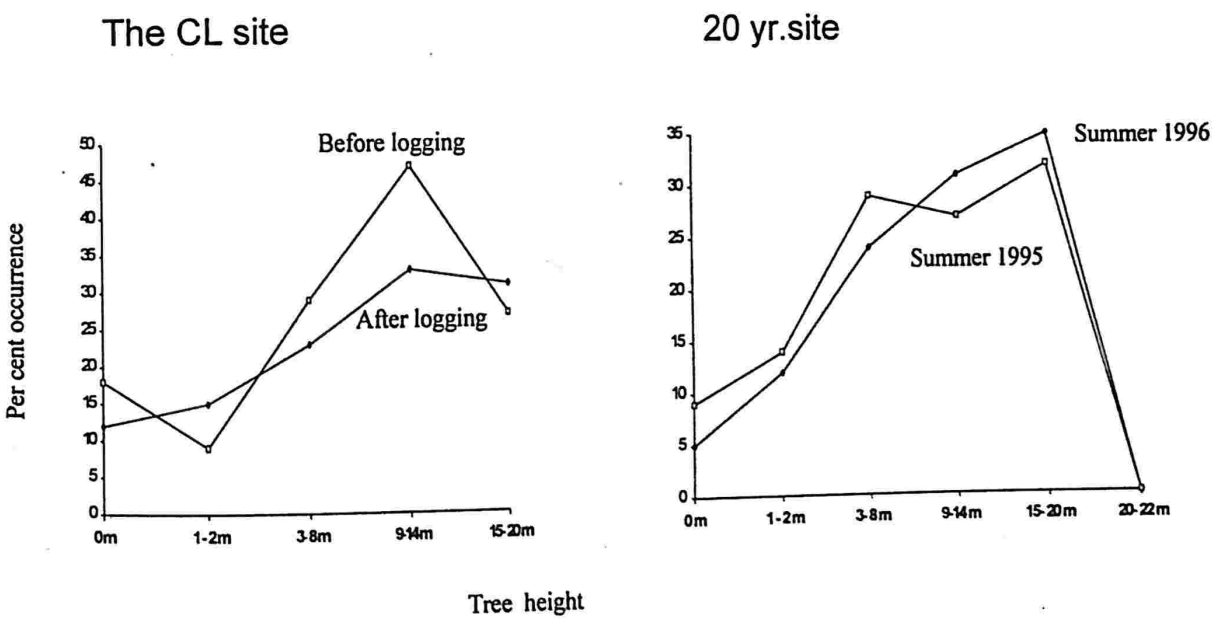
Guilds	Summer 1995	Summer 1996	Winter 1995	Winter 1996
Frugivores	1(9)	1(5)	1(12)	1(10)
Fruit-insectivore	3(8)	2(6)	3(5)	2(9)
Fruit-seed-nectar-insectivore	5(21)	4(30)	5(22)	5(21)
Nectar-insectivore	2(8)	2(3)	2(5)	2(4)
Ground insectivore	5(11)	1(13)	4(11)	3(10)
Canopy insectivore	2(6)	3(13)	4(9)	3(10)
Trunk/ bark feeder	5(9)[a]	6(23)[b]	4(12)	3(9)
Sallying insectivore	3(9)	3(9)	3(10)	3(10)
Raptors	0	2(2)	0	0
Grainivore	1(4)	2(12)	1(11)	1(15)
Omnivores	3(29)	3(31)	2(25)	3(18)
Total species	30	29	29	26

The 20 yr site had higher number of trunk /bark feeders in summer 1996 (U= 23, p=.004) than summer 1995.

Foraging height and logging

Selective logging targets trees of only a certain girth class and species. I compared the number of birds in different height strata in the CL site and the 20 yr site.

Figure 3.12 Total number of birds observed in different height strata in the CL and the control site at Chunkhedi.



The CL site showed significant decline in number of birds observed at the ground level (0 m) (K-W one way ANOVA, x^2= 5.7, p=. 001), 3-8 m (x^2 = 12.5, p= .02), and 9-14 m (x^2 = 7.2, p=. 04) after logging. The control site did not show significant changes in number of birds observed at different height classes between years.

Sensitive, resilient and opportunist species

Abundance of species varied before and after logging in the CL sites and between the seasons in the 1 yr. site and 20 yr. sites. The following figures (3.13 to 3.15) show variation in bird density in different sites.

For all the three CL sites, the pre-logging density is plotted on the x-axis and post-logging density is plotted on the Y axis. For the 1 yr. and 20 yr. sites, density of summer 1995 is plotted on the X-axis and density of summer 1996 is plotted on the Y axis. The figures depict changes in density of each species. Those species below the line have declined and those above the line have increased in density. Species along the line have not changed in abundance. To avoid clustering, all species are not shown in the figure but are mentioned in the table below the figure.

The species which are lost in the second year would be placed on the x axis (as they had zero density in the second year) and those which arrived in the area in the second year would be placed on the Y axis (having zero density on x axis).

Figure 3.13 Changes in bird density in the CL site in Chunkhedi.

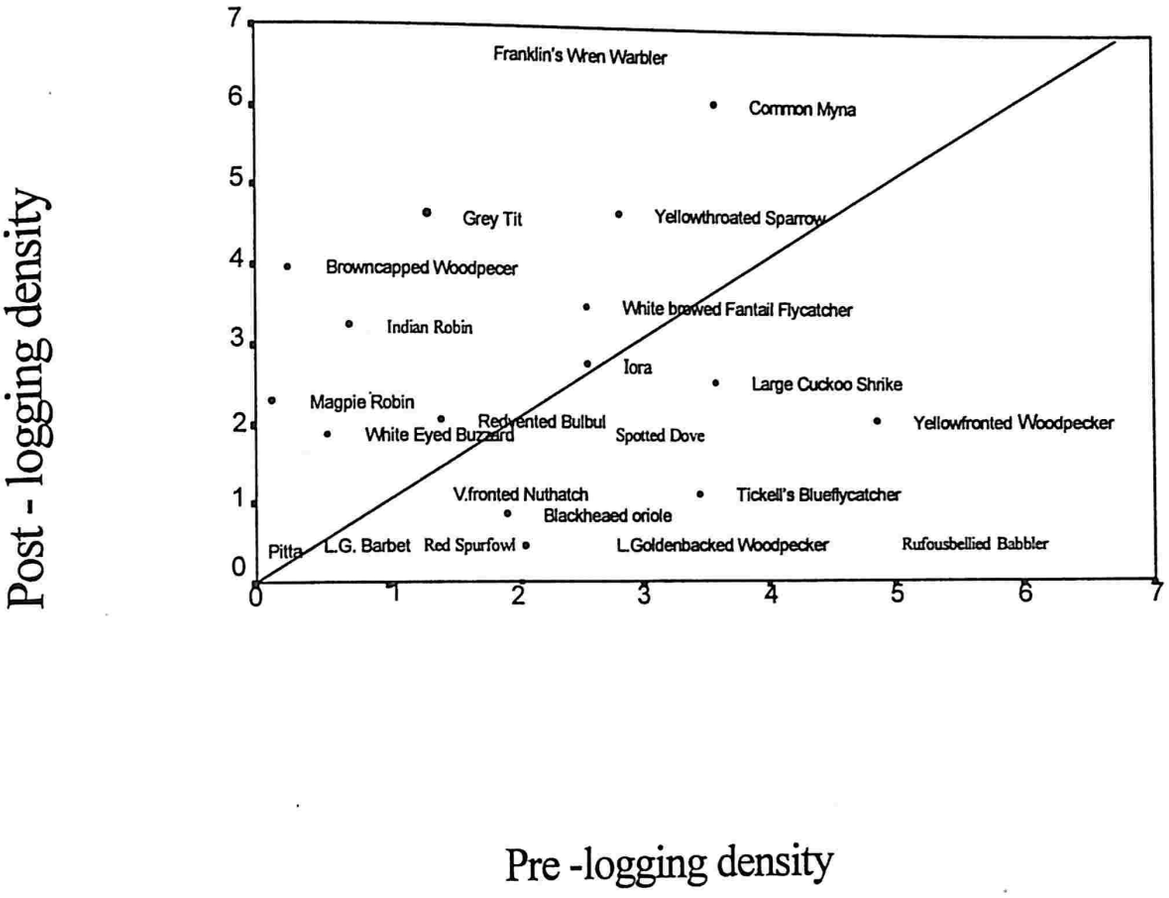


Table 3.18 lists species that exhibited changes in density in the CL site at Chunkhedi.

Species lost	Large Green Barbet, Rufousbellied Babbler,Quaker Babbler; Large Cuckoo Shrike ,Pied Flycatcher Shrike,Red Spurfowl
Species declined	Blossom headed Parakeet, Spotted Dove, Common Myna, Green Pigeon, Tickell's Blueflycatcher, Blackheaded Oriole, Velvetfronted Nuthatch, Lesser Goldenbacked Woodpecker
Resilient Species	White browed Fantail Flycatcher, Iora
Species increased	Common Wood Shrike, Redvented Bulbul, Jungle Babbler, Purple Sunbird, Grey Tit, Yellow Throated Sparrow, Yellow Fronted Pied Woodpecker, Black Drongo, White-eyed Buzzard Eagle
Species gained	Magpie Robin

Figure 3.14 Changes in bird density in the 1 yr site in Chunkhedi.

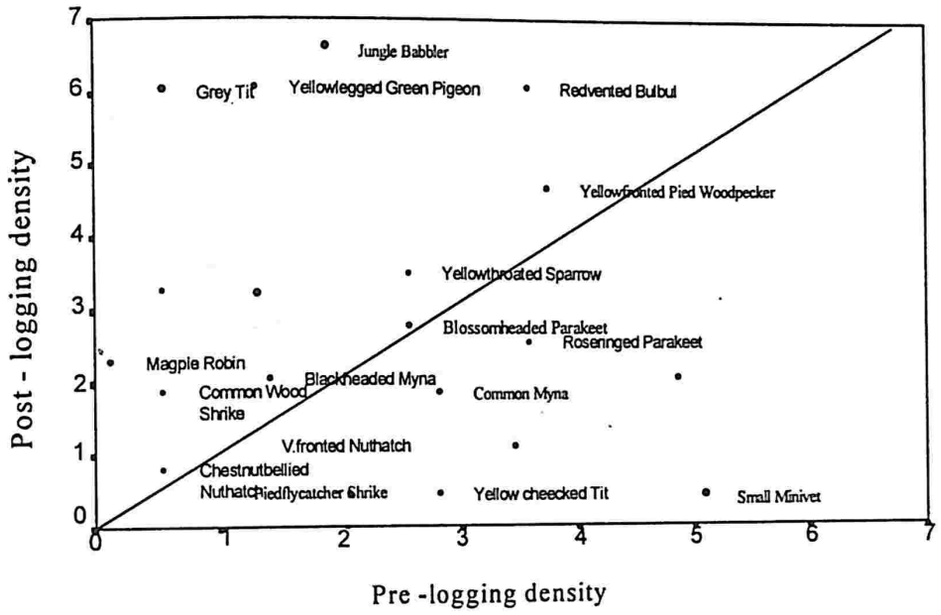


Table 3.19 lists species that exhibited change in density in the 1 yr. site at Chunkhedi

Species lost (not seen in summer 1996)	Tailor Bird, Small Minivet, Yellowcheeked Tit, Pied flycatcher shrike
Species declined	Blossomheaded Parakeet, Roseringed Parakeet, Redvented Bulbul
Resilient Species	Blackheaded Myna, Indian Robin, Yellowthroated sparrow, Yellowfronted Pied Woodpecker Chestnutbellied Nuthatch, Common Myna
Species increased	Jungle Babbler, Yellowlegged Green Pigeon Grey Tit, Black Drongo, Lesser Goldenbacked Woodpecker
Species seen during summer 1996 only	Tree Pie, Rufousbellied Babbler, Common Wood Shrike

Figure 3.15 Changes in bird Density in the 20 yr site in Chunkhedi.

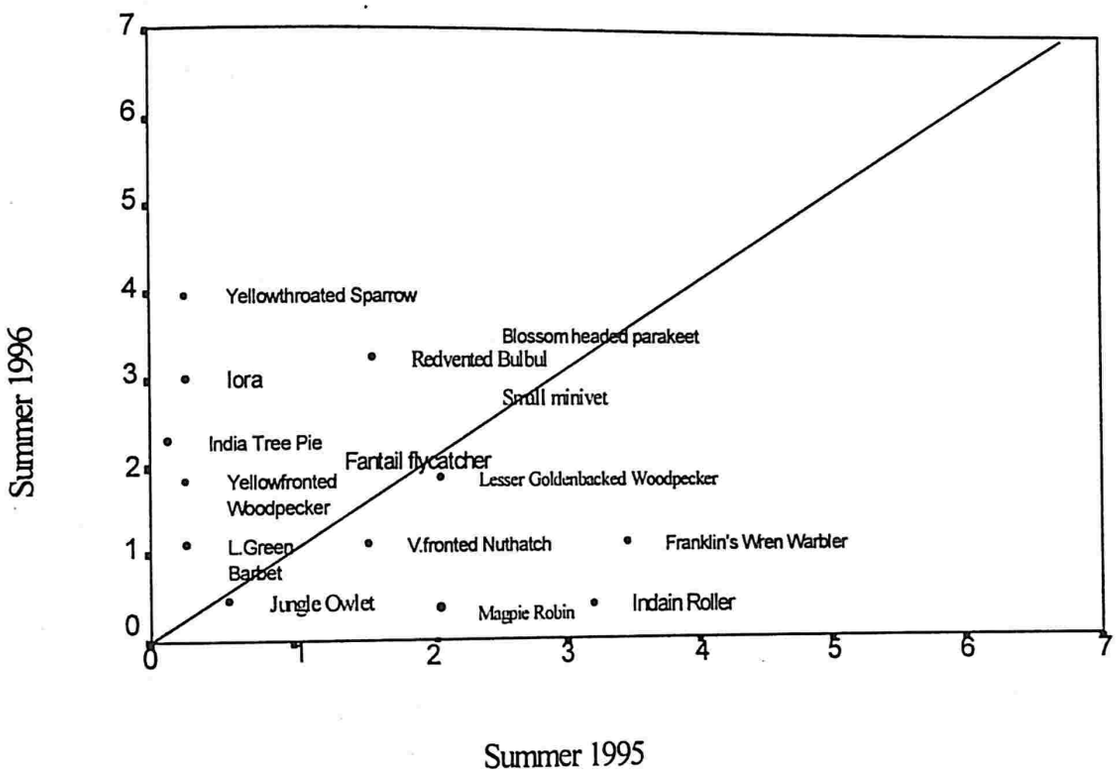


Table 3.20 lists species that exhibited change in density in the 20 yr. site at Chunkhedi

Species lost (not seen in summer 1996)	-
Species declined	Indian Roller, Indian Robin, Magpie Robin
Resilient Species	Yellow Fronted pied Woodpecker ,Small Minivet Grey Tit, Redvented Bulbul, Iora, White browed Fantail Flycathcer, White spotted Fantail Flycatcher
Species increased	-
Species seen during summer 1996 only	Indian Tree Pie, Blackheaded Myna, Yellow throated Sparrow

The results for Jarida and Dharni, are presented in the same patterns as Chunkhedi in the following sections.

3.19 Bird community in Jarida

Bird species richness:

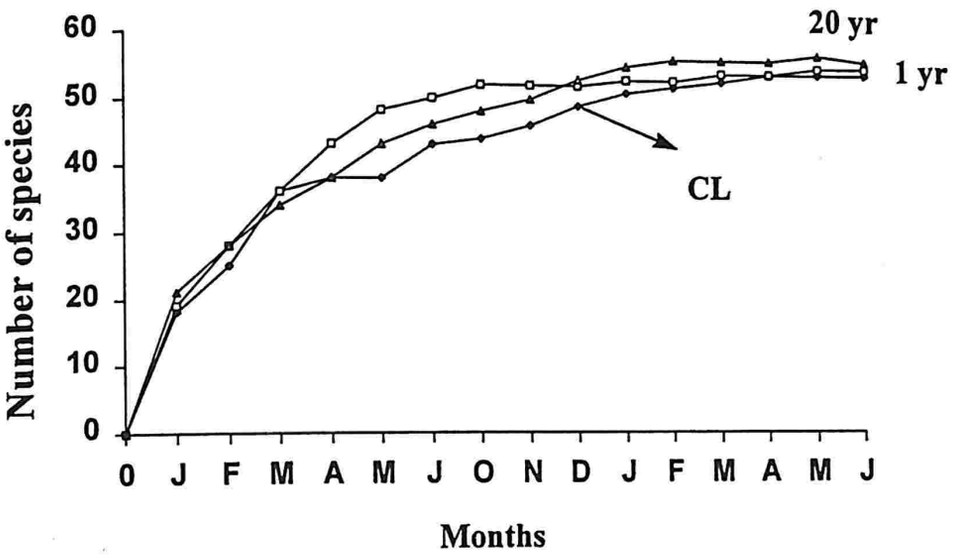
Table 3.21 number of bird species and individuals in logged sites at Jarida

	Species	Individuals	Species	Individuals	Species	Individuals
	CL		1 yr.		20 yr.	
	Pre- logging		Summer 1995		Summer 1995	
March	23	66	10	26	22	65
April	15	52	18	49	24	76
May	14	42	16	36	27	31
June	19	40	23	49	31	45
	During logging		Winter 1995		Winter 1995	
Oct.	14	21	18	43	19	44
Nov.	19	25	17	47	20	39
Dec.	15	21	11	31	16	30
Jan.	13	16	19	45	21	34
Feb.	19	30	23	79	26	33
	Post-logging		Summer 1996		Summer 1996	
Mar	15	41	19	43	27	36
Apr.	13	28	21	35	31	54
May	19	47	22	36	21	42
June	23	60	20	40	19	38

During the logging months, number of individuals recorded were less. The 1 yr and 20 yr sites also showed differences in number of individuals and species recorded.

Cumulative Species Richness:

Figure 3.16 shows cumulative species richness curve for the logged sites at Jarida.

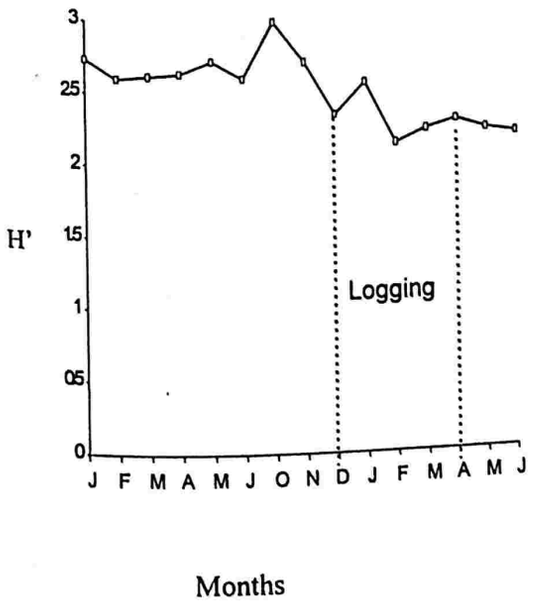


In the CL site, no new species were recorded while logging was going on. After logging, number of new species recorded increased and then the curve stabilized. In the 1 yr site, there was an increase in the number of new species in winter 1995, after which the curve began to stabilize. The 20 yr site showed a stable curve from April 1996.

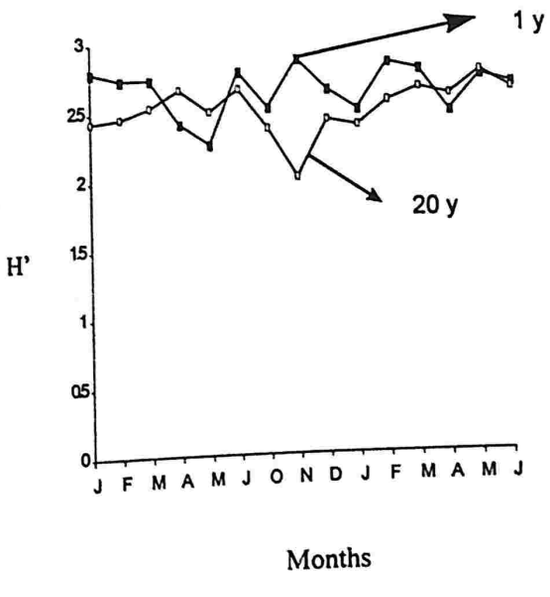
Bird Species diversity in Jarida:

Figure 3.17 Variations in bird species diversity (H') in Jarida in the CL and conrtol sites.

The CL site



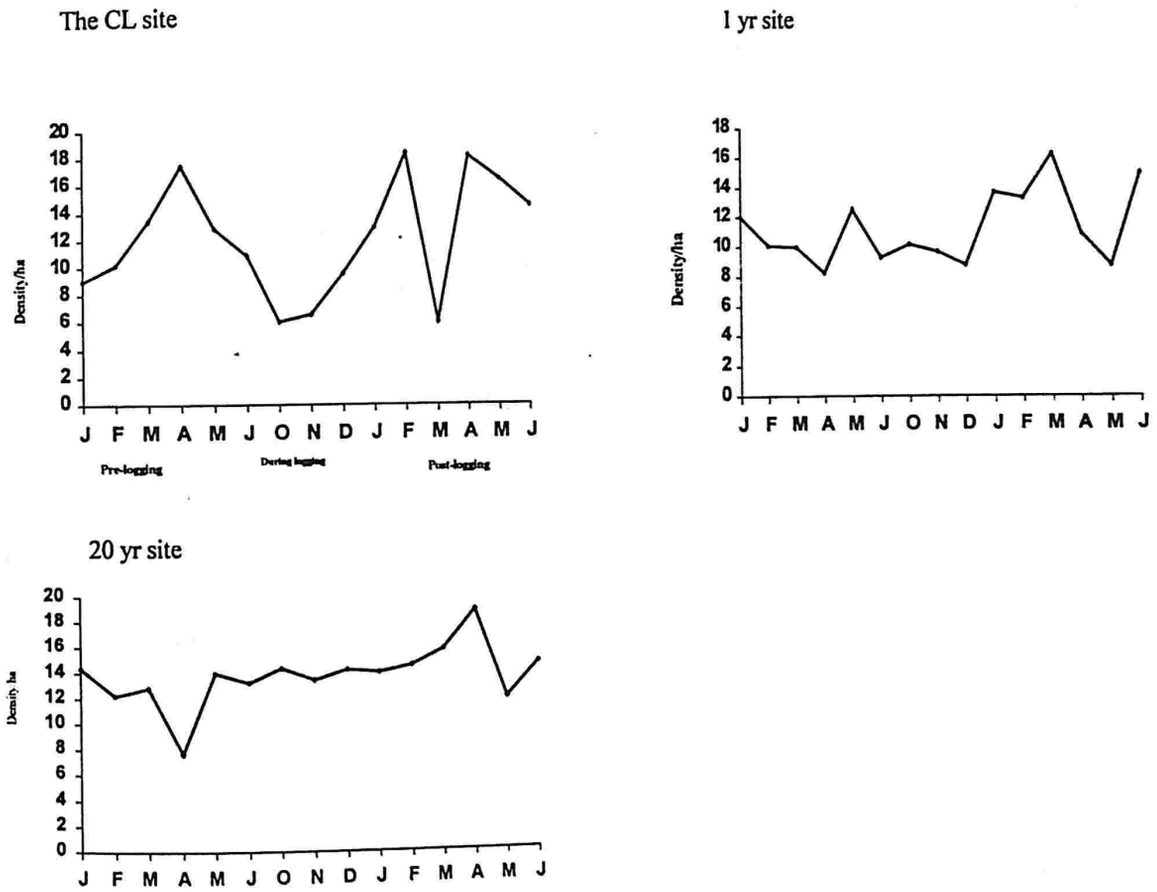
The control sites



During logging, the diversity increased in the CL site and then began declining. After logging, the diversity was lower than the pre logging level. The control sites showed monthly variations in both sites.

Bird density in Jarida:

Figure 3.18 shows monthly variations in bird density in the CL and the control sites at Jarida.



The density in the CL site did not show significant differences between the months. The 1 yr site had higher density in the month of March 1996 than May 1996 (K - W 1 way ANOVA, x^2= 7.9, p= .01). The 20 yr site had lower density in the month of October and November than January and February (x^2 = 8.4, p= .02; x^2= .56, p= .002).

Summarizing the results for changes in bird species richness, diversity and density, following patterns were observed for the CL and control sites in Jarida.

The CL site

Before logging: The CL site before logging had relatively stable diversity (figure 3.17) and richness (Table3.21). During March, April and May, total density was greater due to higher number of parakeets, mynas, Spotted Dove and Redvented Bulbuls.

During logging: Species such as Magpie Robin, Iora, Small Minivet and Black Drongo were recorded for the first time in this site while logging was going on.

After logging: Bird density declined in April 1996 (Fig.3.18). After logging, species like Jungle Babbler, Rufousbellied Babbler, Jungle Bushquails had declined in abundance. Parakeets and Franklin's Wren Warblers had increased in numbers. New species recorded were Indian Robin, Yellowthroated Sparrow, Plain Wren Warbler, Rufousbacked Shrike and Whitebellied Drongo.

The Control sites: The 1 yr. and 20 yr. sites

Diversity and species richness showed more fluctuations in the 20 yr. site than the 1 yr. site (figure 3.18). Maximum fluctuations were seen in the month of March, April and May.

Similarity Index

Table 3.22 Morisita – Horn similarity index between seasons for all the logged sites at Jarida.

	CL (Summer 1996)		CL (Winter 1996)
CL (Summer 1995)	0.58	CL (Winter 1995)	0.37
	1 yr. (Summer 1996)		1 yr. (Winter 1996)
I yr. (Summer 1995)	0.77	1 yr. (Winter 1995)	0.79
	20 yr. (Summer 1996)		20 yr. (Winter 1996)
20 yr. (Summer 1995)	0.78	20 yr. (Winter 1995)	0.73

After logging, 58 per cent community was similar to the before logging bird community, and during logging 37 per cent community composition remained similar to before logging community. In the control sites, over 70 per cent community showed similarity between years.

Table 3.23 Monthly similarity index for the currently logged site at Jarida

MONTHS	Pre-logging
March – April	0.59
April-May	0.66
May-June	0.76
March-June	0.79
	During -logging
October-November	0.56
November-December	0.11
December- January	0.21
January- February	0.24
October-February	0.05
	Post-logging
March – April	0.51
April-May	0.72
May-June	0.66
March- June	0.34

The results show that during logging, the bird community becomes most dissimilar between months and after logging gradually it becomes more similar between months.

Guild composition in the logged sites at Jarida:

Table 3.24. Comparison of guild composition in the CL site before, during and after logging at Jarida.

	Summer		Winter	
Guilds	Pre-logging	Post-logging	Pre-logging	During logging
Frugivores	0	0	0	0
Fruit-insectivore	2(5)	0	2(7)	0
fruit-seed-nectar-insectivore	6(50) [a]	6(37) [b]	4(21) [a]	6(44) [b]
Nectar-insectivore	2(4)	1(1)	0	0
Understorey insectivore	3(22) [a]	2(9) [b]	2(11) [a]	1(3) [b]
Canopy insectivore	5(11)	4(15)	4(8)	2(5)
Trunk/foliage bark feeder	4(19)	6(23)	4(12)	2(7)
Sallying insectivore	4(23) [a]	3(10) [b]	4(19)	4(11)
Raptors	0	0	0	0
Grainivore	3(28)	2(25)	3(25)	3(21)
Omnivores	4(35)	4(38)	4(31) [a]	4(16) [b]
Total species	33	28	27	22

After logging, the CL site showed lower number of fruit-seed- insectivores (U= 23, p= .04), understorey insectivores, sallying insectivores (U= 9.3, p=. 01). During logging, there was an increase in the fruit-seed -nectarivores (U = 7.8, p=. 03) and a decrease in the understorey insectivores (U= 56, p= .001), and omnivores (U= 23, p= .004).

Table 3.25. Comparison of guild composition in the 1 yr. site between seasons at Jarida

Guilds	Summer 1995	Summer 1996	Winter 1995	Winter 1996
Frugivores	1(3)	1(6)	1(7)	0
fruit-insectivore	1(3)	1(4)	1(4)	1(3)
fruit-seed-nectar-insectivore	4(31)[a]	4(17)[b]	4(12)	4(10)
Nectar-insectivore	1(7)	0	1(5)	1(4)
Ground insectivore	3(11)	3(9)	3(6)	3(9)
Canopy insectivore	3(15)	3(12)	1(5)	1(6)
Trunk/foliage/ bark feeder	5(13)	5(14)	5(9)	5(9)
Sallying insectivore	3(11)	2(10)	3(10)	3(7)
Raptors	0	0	0	0
Grainivore	3(17)	3(12)	3(43) [a]	3(29)[b]
Omnivores	4(10)	4(10)	4(10)	2(6)
Total species	28	26	26	23

N.B.: Tabled values are number of species and numbers of individuals are shown in parentheses. Significant differences (Mann-Whitney U test, at $p < 0.05$) are indicated by different alphabets as superscript. No alphabet in superscript indicates no statistical difference.

The 1 yr site had higher number of fruit- seed -insectivores in the summer 1995 than summer 1996 (U= 8.7, p=. 012) and higher number of granivores in winter 1995 than winter 1996 (U= 44, p= .01).

Table 3.26. Comparison of guild composition in the 20 yr. site between season at Jarida.

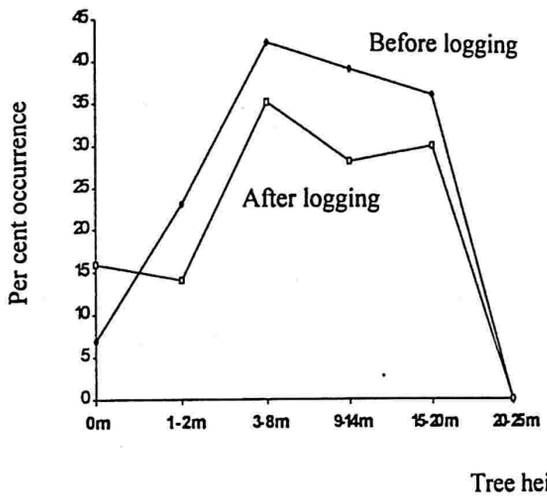
Guilds	Summer 1995	Summer 1996	Winter 1995	Winter 1996
frugivores	0	0	0	0
fruit-insectivore	1(6)	1(6)	1(2)	0
fruit-seed-nectar-insectivore	6(112)[a]	7(69)[b]	4(30)	3(34)
Nectar-insectivore	2(14)	2(16)	2(8)	2(7)
Understorey insectivore	3(7)	1(8)	4(13)	3(7)
Canopy insectivore	3(39)	3(41)	3(10)	4(13)
Trunk/foliage/ bark feeder	6(14)	6(14)	4(16)	5(19)
Sallying insectivore	3(13)	4(16)	2(4)	6(22)
Raptors	3(4)	0	0	1(1)
Grainivore	2(24)	3(39)	2(11)	2(17)
Omnivores	4(32)	4(31)	3(8)[a]	4(27) [b]
Total Species	33	31	25	30

In the 20 yr site, fruit-seed -insectivores were much higher in summer 1995 than summer 1996 (U= 22, p=. 02). The number of Omnivores had increased in winter 1996 than in winter 1995 (U= 12, p= .002).

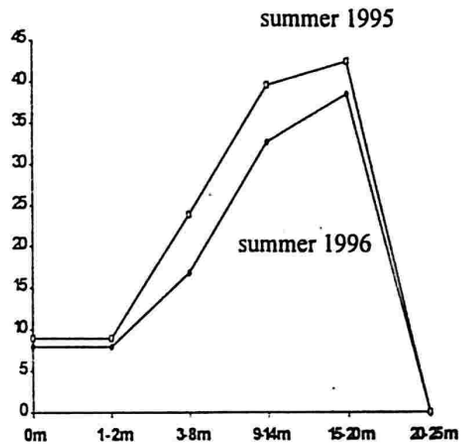
Foraging height and Logging:

Figure 3.19 shows number of birds observed in different height strata in the CL and control site.

The CL site



The Control site



In the CL site, number of individuals using the 0 m height increased after logging (x^2 =9.4, p= .04). After logging, number of birds in 1-2 m (x^2 = 5.2, p= .002), 3-8 m (x^2 = 6.8, p=. 001) and 9-14 m (x^2 = 5.2, p= .002). The number of birds in the control sites did not show significant difference in different height class.

Species density in the logged sites at Jarida:

Figure 3.20 Changes in bird density in the CL site at Jarida

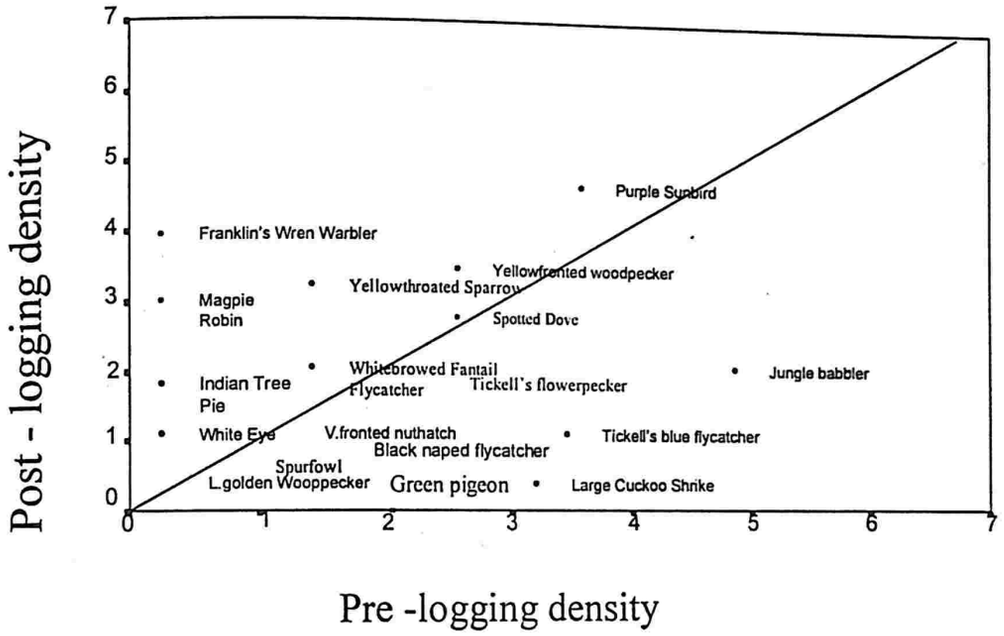


Table 3. 27 lists species that exhibited changes in density in the CL site at Jarida.

Species lost	Large cuckoo shrike,Grey Hornbill, Golden Oriole, Jungle bush Quail, Pied Flycatcher Shrike, Yellowlegged Green Pigeon Red Spurfowl
Species declined	Jungle Babbler, Blackheaded Myna, Lesser Goldenbacked Woodpecker, Tickell's Blue Flycatcher
Resilient Species	White browed Fantail Flycatcher,Yellowfronted Pied Woodpecker
Species increased	Grey Tit, White spotted Fantail Flycatcher, Blossomheaded Parakeet, Franklin's Wren Warbler, Roseringed Parakeet Purple Sunbird
Species gained	Magpie Robin, Iora, Small Minivet, Black Drongo Magpie Robin

Figure 3.21 Changes in bird density in the 1 yr site at jarida.

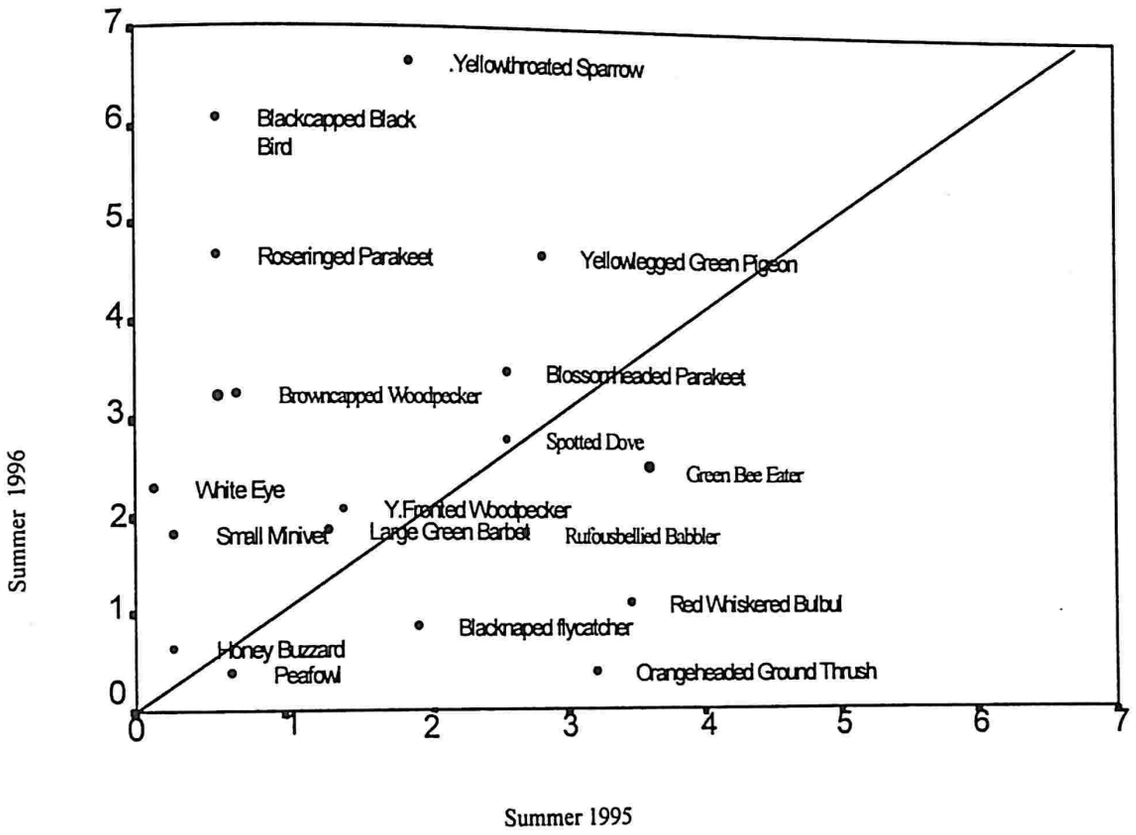


Table 3.28 lists species that exhibited change in density in the 1 yr. site at Jarida

Species declined	Orangeheaded Ground Thrush, Redwhiskered Bulbul, Blacknaped flycatcher
Resilient Species	Jungle Babbler, Rufousbellied Babbler, Lesser Goldenbacked Woodpecker, Blossom headed Parkeet, Honey Buzzard, Peafowl, Large Green Barbet, Yellow Fronted pied Woodpecker ,Small Minivet, Grey Tit, Redvented Bulbul, Iora, White browed Fantail Flycathcer, White spotted Fantail Flycatcher
Species increased	Yellowthroated Sparrow, White-Eye, Small Minivet Browncapped Woodpecker, Blackcapped Blackbird
Species seen during summer 1996 only	Roseringed Parakeet, Yellowlegged Green Pigeon Crimson Breasted Barbet, Indian Roller, Common Myna

Figure 3.22 Changes in bird Density in the 20 yr site at Jarida.

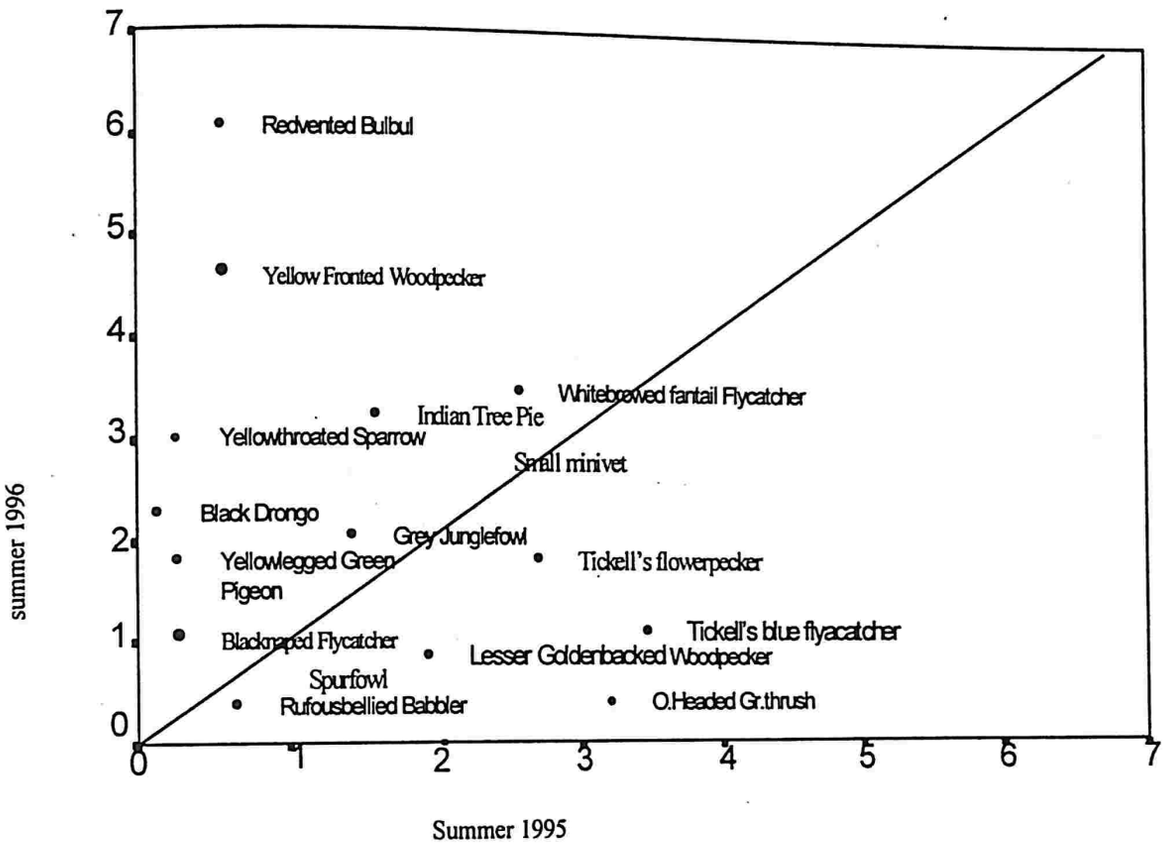


Table 3.29 lists species that exhibited changes in bird density in the 20 yr. site at Jarida

Species lost (not seen in summer 1996)	-
Species declined	Rufousbellied Babbler, Greyheaded Myna Spotted Dove, Orangeheaded Ground Thrush
Resilient Species	Grey Junglefowl, Common Wood shrike Tickell's Blue flycatcher, Jungle Owlet White –Eye, Pied Flycatcher Shrike
Species increased	Yellowthorated Sparrow, Redvented Bulbul Yellowfronted Woodpecker, Browncapped Woodpecker, Blackcapped Blackbird
Species seen during summer 1996 only	-

3.20 Bird community in Dharni:

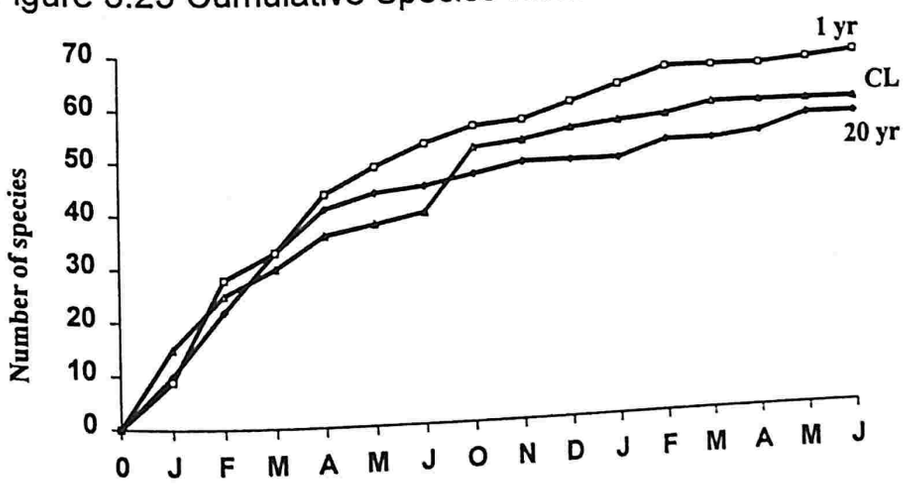
Bird Species richness:

Table 3.30 number of species and individuals in logged sites at Dharni.

	Species	Individuals	Species	Individuals	Species	Individuals
	CL		1 yr.		20 yr.	
	Pre-logging		Summer 1995		Summer 1995	
March	21	75	23	66	26	95
April	21	85	22	90	24	68
May	19	49	19	51	11	17
June	30	62	22	49	13	37
	During logging		Winter 1995		Winter 1995	
Oct.	12	29	19	53	15	49
Nov.	15	57	20	39	17	91
Dec.	8	27	15	31	16	63
Jan.	14	31	17	38	11	32
Feb.	33	104	19	79	24	87
	Post- logging		Summer 1996		Summer 1996	
Mar	24	46	21	66	14	35
Apr.	22	47	19	56	16	39
May	21	38	20	76	18	37
June	24	59	18	40	19	38

From the above tables it appears that least number of species were recorded between October to February the currently logged sites at Dharni. The 1 yr and 20 yr. sites also show fluctuations in the number of species and individuals recorded.

Figure 3.23 Cumulative Species Richness curve for all logged sites in Dharni.

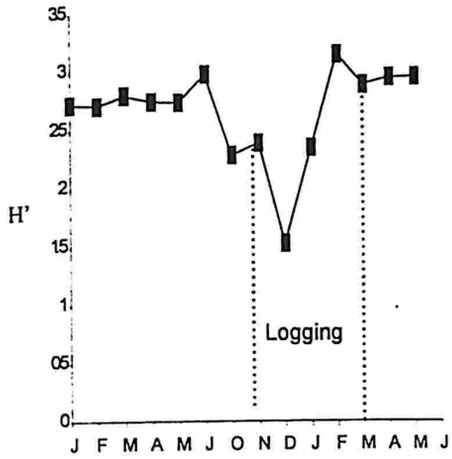


New species are encountered after logging in the CL site. The curve began to stabilize after logging. In the control sites, new species are being encountered.

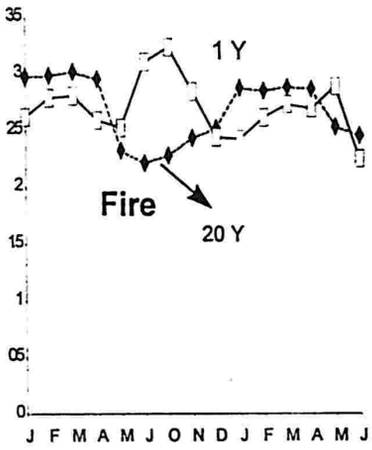
Bird species diversity in Dharni:

Figure 3.24 Variations in monthly diversity (H') in Dharni in the CL and control site.

The CL site



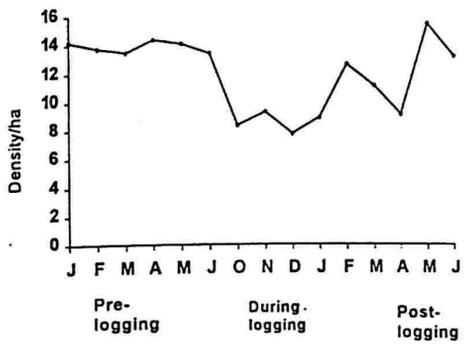
The control sites.

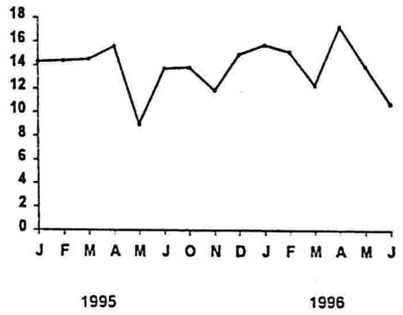


In the CL site, the diversity had declined during the logging period and increased after logging. The 1 yr site showed variations in diversity in all the months. The 20 yr site showed an immediate decline in the diversity in the month of April 1995, following the fire incident.

b. Bird density in Dharni:

Figure 3.25 shows variations in monthly bird density in the CL and control sites.





After logging, the CL site showed higher density in the month of March than in April (x^2= 4.8, p= .01), in May than in April (x2= 7.4, p= .02) and in June than in March (x^2= 4.9, p= .025). The 1 yr site showed higher density in April than May (x^2= 6.1, p= .04) and in May than in June (x^2= 5.2; p=.02). In winter the density varied between the month of November and December 1995 (x^2= 3.5, p= .05). In Summer 1996, March-April density varied significantly (x^2= 4.8, p= .02). The 20 yr site showed variations during the month of April -May (x^2= 5.3, p= .03) and December - January (x^2= 5.8, p= .01).

Summarizing the results for changes in bird species richness, diversity and density for the CL and control sites in Dharni, following patterns were observed :

The CL site

Before logging: In this site, diversity remained stable until May (Figure 3.24). In the Month of June, there was a marginal increase in diversity due to increase in abundance of mynas, babblers and parakeets.

During logging: From October to December, diversity and richness lowered (Figure 3.24 and Table 3.30). Most abundant species present at that time were Green Beeeater, Whitebrowed Fantail Flycatcher and Roseringed Parakeet. In January, other species began to reappear. Amongst the first to arrive were species such as Yellowthroated Sparrow, Small Minivet, Indian Robin, Grey Tit, Yellowfronted Woodpecker, Iora and Indian Tree Pie.

After logging: The diversity was lower in the month of March, but gradually increased with progressing summer. Species such as Browncapped Woodpecker, Small Minvet, Common Wood Shrike, Yellowthroated Sparrow, Large Cuckoo Shrike had increased in numbers.

The control sites: The 20 yr. site had low richness, diversity and density in May 1995 (Table 3.30, figure 3.24 & 3.25). In the month of April 1995, there was a major ground fire in the compartment that resulted in burning the site. The fire continued for three days. After a week of the fire incident, I recorded lowest number of birds on this transect. Species dominant then were Grey Tit, Common Myna, Peafowl, Black Drongo, Green Beeeater and Magpie Robin. Apart from this incident, species abundance remained stable all through other months in this site. The 1 yr. site showed usual seasonal fluctuations as observed in all other sites.

Similarity Index:

Table 3.31 Morisita-Horn similarity index between seasons for all logged sites at Dharni.

	CL (summer 1996)		CL (winter 1996)
CL (summer 1995)	0.76	CL (winter 1995)	0.68
	1 yr. (summer 1996)		1 yr. (winter 1996)
I yr. (summer 1995)	0.75	1 yr. (winter 1995)	0.80
	20 yr. (Summer1996)		20 yr. (winter 1996)
20 yr. (summer 1995)	0.58	20 yr. (winter 1995)	0.71

After logging, over 75 per cent community remained similar in the CL site. The 20 yr site showed low similarity between the two summer seasons, possibly due to the fire incident.

Table 3.32 Monthly similarity index between months for the currently logged site at Dharni.

MONTHS	Pre-logging
March - April	0.74
April-May	0.54
May-June	0.31
March-June	0.45
	During -logging
October-November	0.14
November-December	0.26
December- January	0.42
January- February	0.47
October-February	0.03
	Post-logging
March - April	0.25
April-May	0.39
May-June	0.58
March-June	0.67

The table shows that there was monthly variation between the bird community in the same season also. Before logging, the community was most similar in the month of March- April, and April-May. By the end of logging period, similarity increased and was maximum between January and February. Immediately, after logging there was 60% similarity in the site.

Guild composition in the Logged sites at Dharni:

Table 3.33 Comparisons of guild composition in the CL site before, during and after logging in Dharni.

	Summer		Winter	
Guilds	Pre-logging	Post-logging	Pre-logging	During - logging
Frugivores	1(5)	1(6)	1(8)	0
Fruit-insectivore	2(4)	0	1(2)	3(10)
Fruit-seed-nectar-insectivore	5(50)[a]	7(102)[b]	4(57)[a]	4(37)[b]
Nectar-insectivore	3(37)	2(24)	1(11)	3(20)
Understorey insectivore	5(13)	5(28)	2(11)	3(9)
Canopy insectivore	6(34)[a]	4(18)[b]	6(51)[a]	3(14)[b]
Trunk/bark/foliage feeder	6(46)[a]	3(28)[b]	5(30)	3(20)
Sallying insectivore	6(21)	4(16)	8(25)	4(15)
Raptors	1(1)	2(2)	2(2)	1(2)
Grainivore	3(28)	3(31)	4(36)	4(29)
Omnivores	6(38)[a]	8(60)[b]	2(16)	3(23)
Total species	44	39	36	31

N.B.: Tabled values are number of species and numbers of individuals are shown in parentheses. Significant differences (Mann-Whitney U test, at $p < 0.05$) are indicated by different alphabets as superscript. No alphabet in superscript indicates no statistical difference.

After logging, the number of fruit-seed- insectivores (U= 7.8, p= .01) and omnivores (U= 5.6, p= .002) were higher. The abundance of canopy insectivores, (U= 5.6, p=. 002) and trunk bark insectivores (U= 21, p= .05) had declined after logging. During logging, the abundance of fruit-seed insectivores (U= 22, p= .03) and canopy insectivores (U= 34, p= .01) had declined.

Table 3.34 Comparison of guild composition between seasons in the 1-yr. site at Dharni.

Guilds	Summer 1995	Summer 1996	Winter 1995	Winter 1996
Frugivores	0	0	0	0
Fruit-insectivore	1(6)	1(6)	2(7)	2(3)
Fruit-seed-nectar-insectivore	6(112)[a]	7(69)[b]	6(69)[a]	6(89)[b]
Nectar-insectivore	2(14)	2(16)	2(14)	2(14)
Understorey insectivore	3(7)	1(8)	3(11)	3(15)
Canopy insectivore	3(39)[a]	3(11)[b]	3(11)	3(13)
Trunk/bark/foliage feeder	6(14)	6(14)	5(9)	6(11)
Sallying insectivore	3(13)	4(16)	3(20)[a]	2(9)[b]
Raptors	3(4)	0	0	0
Granivore	2(24)[a]	3(39)[b]	2(21)	2(26)
Omnivores	4(32)	4(31)	4(18)	4(21)
Total species	33	31	30	30

The fruit -seed -insectivores (U= 21, p= .002), canopy insectivores (U= 12, p= .003) were higher in summer 1995. The granivores were higher in abundance in summer 1996 (U= 12, p= .01). In winter 1995, the fruit-seed-insectivores were higher in winter 1996 (U= 24, p= .002), and sallying insectivores were lower (U= 9.8, p= .002).

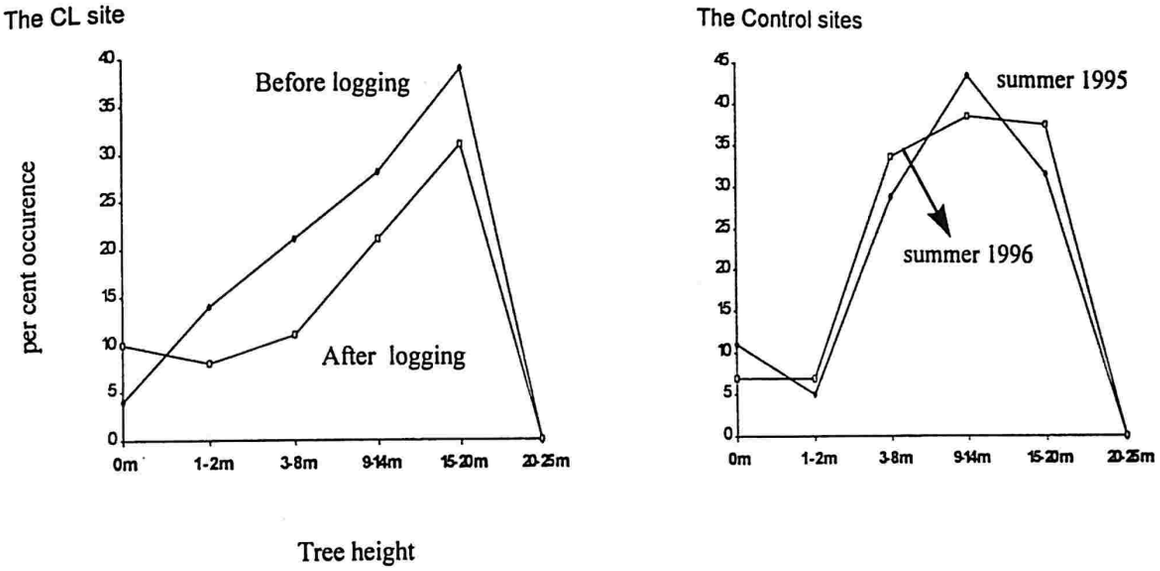
Table 3.35 Comparison of guild composition between seasons in the 20 yr. site in Dharni.

Guilds	Summer 1995	Summer 1996	Winter 1995	Winter 1996
frugivores	0	0	1(8)	1(12)
fruit-insectivore	1(2)	0	2(3)	3(10)
fruit-seed-nectar-insectivore	6(54)[a]	4(39)[b]	3(34)	4(39)
Nectar-insectivore	2(5)	1(2)	2(4)	2(6)
Ground insectivore	6(32)	5(24)	6(25)	6(26)
Canopy insectivore	3(10)	3(4)	3(11)	3(13)
Trunk/foliage/ bark feeder	4(23)	6(20)	3(6)	2(8)
Sallying insectivore	4(17)[a]	4(27)[b]	3(17)	3(13)
Raptors	4(4)	0	3(3)	1(2)
Grainivore	2(22)	2(28)	2(25)	2(20)
Omnivores	4(29)	3(17)	3(5)	3(12)
Total species	36	28	31	30

In the 20 yr site, the fruit-seed -insectivores were higher in abundance in summer 1995 (U= 23, p= .002), and sallying insectivores were higher in number in summer 1996 (U= 12, p= .01).

Foraging height and logging:

Figure 3.26 shows number of birds observed in different height strata in the CL and control site in Dharni.



The CL site had lower number of birds in 3- 8 m (x^2= 6.6, p= .003), 9 -14 m (x^2= 5.6, p= .02), and 15-20 m (x^2 = 7.8, p= .01) after logging. The ground level had higher number of birds after logging (x^2 = 11.2, p= .05). The control site showed lower number of birds (x^2 = 6.7, p= .001) at the ground level in summer 1996.

Species density in Dharni:

Figure 3.27 Changes in bird species density in the CL site at Dharni.

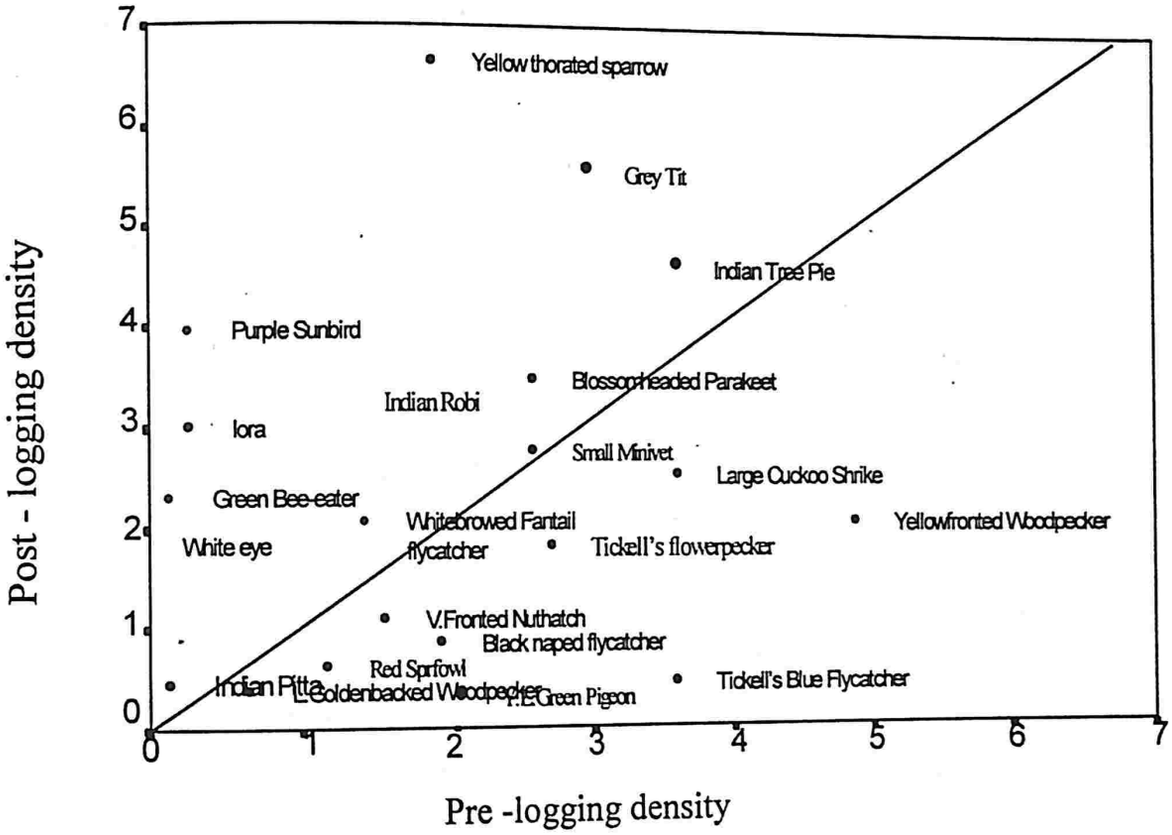


Table 3.36. Lists species that exhibited changes in bird density in the CL site at Dharni.

Species lost	Lesser Goldenbacked Woodpecker, Red Spurfowl, Indian Pitta Yellowlegged Green Pigeon
Species declined	Tickell's Blue Flycatcher, Blacknaped Flycatcher, Velvet fronted Nuthatch, Tickell's Flowerpecker, Large Cuckoo Shrike, Jungle Babbler
Resilient Species	Spotted Dove, Small Minivet, Whitebrowed Fantail Flycatcher Rufousbacked Shrike, Yellowfronted Pied Woodpecker, White browed Fantail Flycatcher
Species increased	Yellowthorated Sparrow, Indian Robin, Iora, White-Eye Blossomheaded Parakeet
Species gained	Green bee eater, Little brown Dove

Figure 3.28 Changes in bird density in the 1 yr site in Dharni.

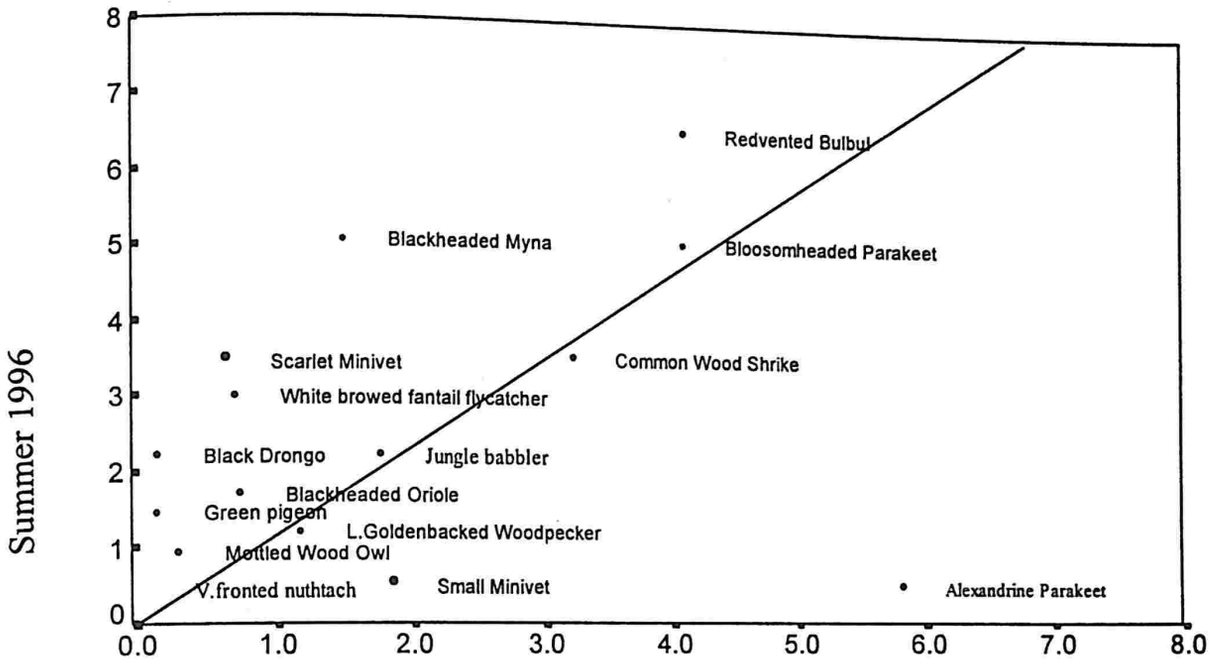


Table 3.37 lists species that exhibited changes in density in the 1 yr.site at Dharni.

Species lost (not seen in summer 1996)	-
Species declined	Jungle Babbler, Greyheaded myna Small Minivet, Alexandrine Parakeet
Resilient Species	Lesser Goldenbacked Woodpecker, Velvetfronted Nuthatch, Black Drongo, Crimsonbreasted Barbet Blackbacked woodpecker, Grey tit, Yellowlegged Green Pigeon, Racket- tailed Drongo, Large Green Barbet, Blackheaded Oriole
Species increased	Roseringed Parakeet, Yellowthroated Sparrow, Redvented Bulbul, Alexandrine Parakeet Franklin's Wren Warbler, Blackheaded Myna Spotted Dove
Species seen during summer 1996 only	Greenbee Eater, Rufousbacked Shrike Crested Tree Swift

Figure 3.29 Changes in bird density in the 20 yr site Dharni.

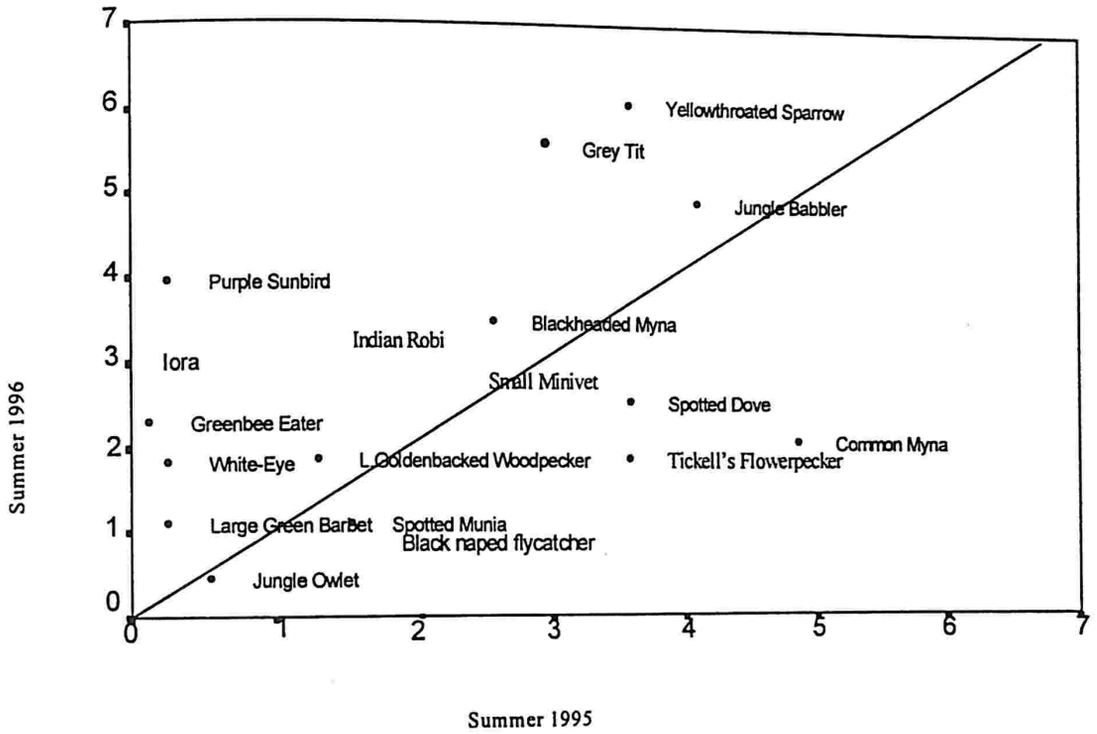


Table 3.38 lists species that exhibited changes in density in the 20 yr. site at Dharni.

Species lost (not seen in summer 1996)	-
Species declined	Indian Roller, Common Myna, Blacknaped Flycatcher, Spotted Munia .
Resilient Species	Lesser Goldenbacked Woodpecker, Yellowlegged Green Pigeon, Jungle owlet, Blackheaded Myna Grey Tit
Species increased	Large Green Barbet, Purple Sunbird Yellowthroated Sparrow, Roseringed Parakeet,
Species seen during summer 1996 only	-

3. 21 Discussion

The results of this chapter will be interpreted keeping in view the effect of logging as well as that of the season. The climatic pattern has considerable influence on the fruiting, flowering and production of young leaves (Fogden 1972). This in turn can influence the composition of the bird community. If any pattern is found exclusive only to all CL sites, then more likely it is caused due to logging. On the other hand, if a similar pattern is found in the control sites as well, then seasonal or annual variations could be the cause of change. I shall first discuss about the changes in vegetation structure followed by discussion on changes in the bird communities.

3. 22 Structural changes in the Currently Logged (CL) sites

Tree density and mean GBH

Number of large trees and mean GBH did not show a significant change after logging in the CL sites at Chunkhedi and Jarida (Table 3.6, 3.7). In selectively logged forests, not all trees are felled, and the felling is dispersed all over the workable area. Johns (1986) found that owing to the random nature of timber extraction in Malaysian rain forests, density of trees after logging did not show a significant change. Also presence of other non-timber trees in the area that were not felled resulted in not reducing the total tree density and mean GBH in the CL site after logging. However in the CL site in Dharni, total trees felled were over 3,000 in number and extraction rate was high (6.7 trees per ha). In Dharni, total trees felled were over 3,000 (Table 3.5). As a result, density of large and small trees as well as mean GBH was found to be lower after logging (Table) in this site.). Density of small trees (< 30 cm) declined significantly after logging in all three CL sites. This is because the smaller trees were felled more in proportion to the larger trees. This was true for all the CL sites. It is possible that after so many years of felling cycles, mature trees in the forests are becoming less abundant and therefore smaller trees are felled (pers. observ). Damage due to logging also leads to lowering of tree density as reported by other studies (Crome et al., 1992; Johns 1997) . Although in Melghat the extent of damage was not as high (section 3. 17) as reported by other studies, it did lead to reduction in number of small trees. Crome et al.,

(1992) reported lower tree density from smallest and largest girth classes after logging in Queensland, Australia. He explained that apart from extraction, smaller trees (< 30cm Gbh) were being damaged due to the 'knock-on' effect resulting in overall decline in their numbers. Several studies (Crome et al., 1992, White 1994; Verissimo et al., 1995, Johns 1992, 1997) have found that damage due to felling and construction of the extraction path for logging resulted in loss of more trees than actual tree removal. During Mahogany logging in Brazil, tree density decreased due to construction of skid trails and logging damage than due to actual removal (Whitman et al., 1997, Webb 1997). In the tropical rain forests, the extraction paths and skid roads are as wide as 30 m. All the trees on the path are felled and eventually these areas remain perpetually barren because of dragging and skidding activity (Lamb 1990). In Indonesia, 30 - 40% of the forests are lost to the extraction paths (Kirtawana 1978: in Johns 1992). Although such large-scale habitat alteration was not observed in the logged areas in Melghat, small tree density did decline due to logging.

Canopy cover

After logging, the canopy cover did not show a significant decline from that of the pre - logging level in Jarida and Chunkhedi. However, in the CL site at Dharni, canopy cover declined after logging. The timber extraction rate for Dharni was higher than in Chunkhedi and Jarida and therefore most structural variables showed changes after logging in Dharni site. However, the canopy opening was not of greater extent as reported in the rain forests as felling was not localized and was distributed all over the place. Moreover, the felling of trees in the dry deciduous forests does not have the same effect as that in the tropical rain forests. The spread of timber trees (teak and saj) crown is not as widespread as reported for the dipterocarps forests, which have crown cover up to 20 m (Verissimo 1995). Therefore, removal of a single tree in the rain forests could result in major gap formation. In the teak dominant deciduous forests, such gap formations are rarely seen. Crome et al., (1992) have reported gap formation up to 70 % due to selective logging in Australian rainforests. For detecting the change in canopy opening, they used advanced methods such as aerial photography and fish-eye photography techniques to

survey the entire site, which gives an overview of the area affected. In my study, I used the ocular tube to estimate canopy cover which could detect changes on the transect and not all over the compartment. Perhaps this could be the reason why changes in total canopy openings were not detected.

Shrub cover

In all three CL sites, shrub cover had declined significantly after logging. The undergrowth of *Woodfordia floribunda, Lantana camara, Holarrhena antidysentrica* and *Helicteres isora* was uprooted prior to logging. This was done to facilitate the sawing of trees, moving of bullock carts and bulls to drag fallen trees. Damage due to fallen trees also contributed to a decline in the shrub cover (Plates 5 and 7).

3. 23 Changes in Phenology of trees in the CL and control sites

Fruits and flowers are erratic food resources (Fogden 1972). They are affected by climatic changes. Changes in fruiting and flowering occur between months, seasons and years (Leighton and Leighton 1983). This pattern is common in animal dispersed fleshy fruits as well as wind dispersed non-fleshy fruits.

Figures 3.6 to 3.8 shows monthly patterns in phenology of trees. There are two peaks in fruiting trees, a major one in February and a minor peak in May. There was an overall decline in fruiting after logging, but per cent flowering did not show significant changes. In Dharni CL site, although less number of trees fruited in the second year (i. e after logging), the difference was not statistically significant. When I compared the differences in fruiting between the timber and non-timber trees, it appeared that the both the timber and non-timber trees fruited less in number in the second year. This indicated that the decline in total trees fruiting after logging could be a dual effect of logging and inter-annual variations.

How does season affect the phenology of trees? The forests in Melghat are teak dominant. The dry deciduous teak forests exhibit maximum seasonal changes (Tiwari 1992). Teak being a deciduous species sheds leaves from November to January and remains leafless through out the summer season. Young leaves appear from June onwards, and in areas where the ground is

moist or there are summer showers, it begins leafing as early as April - May. Flowers appear from June to October. The fruits ripen from November to January and fall gradually. Sometimes fruits remain on the tree through the summer season (Tiwari 1992).

Other associated species of teak show similar phenophase; species such as *Terminalia tomentosa*, *Anogeissius latifolia, Madhuca latifolia, Buchanania lanzan, Mitragyna parviflora , Lannea coromandelica* shed leaves from March onwards and remain leafless till June. They bear fruits by April, which ripens in May-June. In winter, most trees are green and with the exception of teak, none of them bears flowers. In the dry deciduous forests, flowering peak is between February-May. During this period, trees such as *Butea monosperma, Madhuca latifolia, Cassia fistula, Lagerstroemia parviflora,* and climbers such as *Bauhinia vahlii*, and *Butea superba* begin to flower (Patel 1968, pers.observ)

I found that after logging, fruiting and flowering had declined in all CL sites. This cannot be due to felling alone as the extraction rate for Chunkhedi and Jarida was quite low (see extraction rate for each site). As per the felling rules, selected timber trees are felled, keeping aside the other timber and non-timber tree species. Moreover, this pattern was observed in the control sites also. Thus, it appears that a change in phenology of trees is influenced largely by seasons than by logging. Johns (1988) and other studies (in Johns 1997) reported higher per cent of young leaf after logging. Johns (1988) attributed higher leaf production with opening up of canopy after logging. In the rainforests, most trees and shrubs are photophilic and their fruiting and flowering patterns responds positively with increasing radiation. In the CL site at Chunkhedi, I found significantly higher per cent of young leaf after logging (Table 3.9). Since in my study site, the canopy opening was not of significant level, greater leaf productivity appears more to be a function of the summer rains in May 1995 and does not seem to be related to logging. In any case, leafing in dry deciduous forests is triggered by rains and is not stress or light induced as in the rain forests.

The patterns discussed so far indicate that the changes occurred in vegetation structure, fruiting and flowering is possibly an effect of season as well as logging. Next section deals with the characteristics of bird communities in the logged sites.

3.24 Changes in bird abundance in the CL sites.

All the CL sites and controls sites exhibited fluctuations in species richness, diversity and density. Studies report a parallel change in species richness and diversity (See review in Verner and Larson 1989) and use either of the indices. In my study, I did not find increasing diversity to be always correlated to increasing species richness. In Chunkhedi CL site, prior to logging species richness, diversity and density showed a parallel increase, but after logging species diversity and density declined while species richness increased. After logging, new species were encountered in the CL site after logging that were not recorded earlier. All CL sites had higher number of new species in the area after logging, in spite of low species diversity. During logging, a definite decline in richness, diversity and density was observed in all CL sites but not in the control sites. After logging, gradually the number of species began to increase in the logged site. Although the species richness, diversity and density had almost attained the pre-logging level in all CL sites, the composition of the community had most certainly changed. This was most evident when similarity in species composition was compared before and after logging. Change in species composition was more pronounced in the CL sites than in the control sites.

An increase in species richness, diversity and density during March – May was observed in all the CL and control sites. This was in response to availability of fruits and flowers in the forests during these months. The species that increased during this period were flocking frugivore such as mynas, parakeets, and bulbuls. Other flocking species such as Yellowthroated sparrows, babblers, minivets, doves and resident wren warbles also showed an increase during this period.

3.25 Similarity in bird communities in CL sites

In studies, where the degree of change has to be quantified in the same site, an index of overlap is more useful in terms of identifying how much the original community has been retained due to disturbance. Table (3.14, 3.23, and 3.32) compares the pre and post logging community in the same season for the CL, 1 yr. and 20 yr. sites. In all three CL sites, after logging almost 60% bird community was same as that before logging, whereas during logging, the similarity in community declined. However, a change in community composition was seen in the control sites also. This indicates that there are inter - year and intra - year differences in bird community composition. In the CL sites along with annual variation, logging would also have an effect on the community composition. The 1 yr. and the 20 yr. sites showed over 75% common species between the years. There were variations in these sites also but overall similarity was higher than the CL sites. During the fire incident, the similarity between years in the 20 yr site at Dharni had lowered to 60 per cent. The fact that control sites also showed variations in bird community composition proves that changes can be brought about due to seasons as well as disturbance (logging or fire). Next section discusses how seasons can bring about changes in bird communities.

3.26 Effect of seasons on bird communities in Melghat Forests

The monthly similarity between bird community showed that during March-April and April- May, bird composition is more similar than during other months. In all the CL sites, higher similarity during these months was seen after logging (Table 3.14, 3.23 and 3.32)

Even without facing any environmental changes, bird communities undergoes monthly alteration cycle due to seasonal shifts in resources and climatic changes. In the study area, summer season is considered to begin in March. Winter migrants are beginning to depart by end of the month. Summer visitors become active around this time. Species most abundant then are Blackheaded Mynas, Greyheaded Mynas, Rosy Pastors and Magpie Robins. By April, there is a peak in the movement of most breeding birds as nesting

By April, there is a peak in the movement of most breeding birds as nesting activity is just beginning. Cuckoos have settled in their territories and are heard all over the forests. Pitta, another transient migrant arrives between late April to early May. Community composition becomes similar largely between March-April-May; more between the last two months. This was observed in all sites. In the month of June, occasionally a little change in composition was seen. Grain/seed/fruit feeders such as parakeets, mynas, doves may move to nearby crop fields or villages for feeding and sometimes nesting (pers. observ.) Therefore, these birds may not be seen in the forests during this month. Also, nesting birds sitting on the nests are more sedentary and less active (Price 1979), in which case they may be encountered less often in the forest. In June the sky remains overcast and clouded, this affects the activity of birds (Robbins 1981). All these factors act on different bird species to change the community structure during the month of June. Since there was no data from July to September, the community composition for winter months is discussed below.

In temperate forests, there is a marked decline in bird activity (Price 1979) but in the tropical forests the activity increases with the progressing winter (Bell 1982b). In October, fewer winter migrants are encountered on the transect. By mid-November, most migrants would have arrived and have established their territories. From January onwards, bird abundance and activity was observed to be more. In the month of February, I noted maximum sighting of birds on all transects. Thus, it is clear that the observed variations or similarities in bird communities between months could be a function of changing seasons that affected birds in all the sites, irrespective of its logging status. In the CL site, along with seasonal variations, logging activity was also responsible for inducing changes. Even if tree removal is not taking place at that particular location, the presence of about 2,000 people in the site is enough to drive the birds away from the site. All the mentioned factors collectively cause changes in the bird community.

3. 27 From communities to guilds: Guild structure in the logged sites

Species response to seasons and disturbance varies. Some groups of birds increase in a particular season and in disturbed sites while others may decrease. In the following section, I have discussed the patterns of changes in the guilds in all sites and evaluated the role of effect of season and of logging.

Fruit and flower dependent guilds: Obligate frugivores, such as Yellowlegged Green Pigeons feed on the pulp of fig fruits. Green pigeons have large home ranges, but are known to occur almost with certainty on fig trees (Leighton and Leighton 1983). Such specialized frugivore population densities vary substantially as they move elsewhere during lean fruiting season (Fogden . 1972, Leighton & Leighton 1983, Crome 1991). The presence of this species is dependent on the availability of fruits, which is a seasonal resource. In case of other frugivore species such as barbets, orioles, bulbuls, hornbills, mynas the pattern is a little different as they supplement their fruit diet with substantial amount of insects. These birds are more active in the summer season as fruits, flowers (Figures 3.6, 3.7, and 3.8) and insects (Price 1979) are available. Necatrivores like sunbirds, White-Eyes and flowerpeckers feed on the mixed diet of insects and nectar. Nectar is also a seasonal and erratic food resource as fruits and flowers are. The abundance of these birds is related to availability of flowers and insects in the area.

In all sites, the number of birds in these three guilds showed variations between years. Seasonal variations in fruit/flower and nectar resources are discussed in the earlier section. Variations in availability of resources could cause changes in the abundance of these birds, irrespective of the logging status of the site. It has been observed in other studies (Terborgh and Weske 1969; Johns 1983; Crome 1991; Thiollay 1991; Taylor and Haseler 1995) that frugivores being mobile species are versatile in exploiting a variety of fruits. In logged areas, most frugivores have been observed in larger flocks than in the unlogged areas, if the fruiting resources are available (Johns 1983; Crome 1991). But what happens in case of the removal of the same resource that is used by birds? Crome (1991) noted that in Australia if the harvested trees serve as a resource for birds, then the abundance of dependent species might

get affected. I observed that the abundance of parakeets and mynas had declined in the CL site at Chunkhedi. However, a similar decline was seen in some of the control sites as well where there was no removal of teak trees but fruiting of teak as well as other trees was lower (Fig.3.2). This finding is in agreement with other studies that suggests that fruiting tree availability plays a major role in governing the composition of fruit dependent species.

Nectarivore birds are not specialized to feed on a particular food plant and they obtain additional proteins from insects. Although logging did not remove non-timber flowering trees, the abundance of Tickell's Flowerpecker, Purple Sunbird and White-Eye showed variable response after logging. Johns (1997) reported an increase in some nectarivores and a decrease in some other. He found that nectar producing shrubs and trees had increased in abundance in logged areas, as these shrubs were photophilic. Canopy opening facilitated the growth of these plants that attracted the nectar feeders. The species that were highly specialized to feed on certain type of flowers may get affected due to logging if those trees are felled, and those species that are adaptive and can feed on non -specific resources will persist in the logged forests. The three necatrivore species mentioned above do not show any specialization for feeding on nectar. In fact, Davidar (1983) notes that White-Eyes and Flowerpeckers take about 77% insects, 13% fruits and only 10% nectar. Sunbirds are more dependent on flower nectar than other species are (Pandit 1997) as the shape of the bill allows it to exploit the nectar from the corolla tube which other birds may not be able to do so (Ali and Ripley 1983). Bell (1982b) observed in New Guinean raniforests that amongst other guilds, nectarivores displayed maximum seasonal and daily fluctuations. Daily fluctuations in nectarivore bird activity was due to decrease in quantity of nectar with the progressing day. In the study area, the cause for variations in abundance of these birds could be due to season as well as disturbance caused due to logging.

Insectivore guilds: Insect abundance varied in the season. In the dry deciduous forests, fluctuations in leaf cover are considerable from January onwards. Janzen (1973) found 90% decrease in insect abundance in the

beginning of dry season in Costa Rican Forests. Price (1979) documented increase in insect abundance with progressing summer season, new leaf growth and flowering in Eastern Ghats in India. Like frugivores, insectivore population also varies with the availability of resources.

Insectivores are more specialized than frugivores are. Due to logging, perch sites as well as food availability get affected. Insect abundance is more likely to get affected due to microclimatic changes. How do various insectivores cope with these changes?

Understorey feeders: Newmark (1991) reported that the susceptibility of understorey insectivores was higher than other terrestrial bird species. Understorey insectivores are more specialized as they are adapted to exploit low light conditions and are less tolerant to heat (Stouffer and Bierregaard 1995). Thiollay (1992) reported 70% decline in understorey birds following logging in French Guianan Rain forests. Johns (1989) found 50 % decline in understorey insectivores in Malaysian rainforests. The logged forests in west Malaysia had impoverished species and individual abundance of understorey birds after logging (Wong 1985).

In all the CL sites, the understorey insectivore abundance showed variations. As the understorey had been removed from the site, a change in their numbers was expected. Within a guild, it is possible to find some species more tolerant than the other and these species show variable response. For example, species such as the Grey Junglefowl, Red Spurfowl, Bush Quails, and most species of babblers are sensitive to microclimatic changes and had moved from the site after logging. Other species such as robins, and Crow Pheasants had moved in the area after logging, as these species prefer open area for foraging. After the removal of understorey, the habitat was more conducive for such open area species and they could colonize the area.

Canopy insectivores: These birds utilize mainly the upper canopy of the trees. In summers, the abundance of insects keeps the population of canopy feeders highly variable in tropical forests (Price 1979). In the CL site, canopy feeders showed fluctuations in numbers in summer and winter. In the control sites also

abundance of canopy insectivores varied between the seasons. Although no significant change in the canopy cover or tree density was observed after felling, abundance of canopy feeders did show variations. Therefore, the observed pattern could not be attributed to logging alone. Studies report differing response of canopy insectivores to logging. Johns (1983) and Taylor and Haseler (1995) reported an increase in selectively logged forests whereas Thiollay (1992) reported a marginal decline in their abundance after logging. According to Johns (1983), the increase in the numbers of canopy feeders in the logged sites could be due to increased visibility, increased foraging volume after fragmentation and feeding on regenerating undergrowth. This study could not attribute reasons for changes in abundance of canopy feeders in the CL site to any such factors as canopy was not a constrain in sighting birds in deciduous forests. The possibility of seasonal effect and chance event are likely to have caused changes in species composition.

Trunk/bark/foliage feeders: Woodpeckers, tits and nuthatches feed from certain part of the tree and are largely territorial (Conner 1979). In most sites, this guild exhibited variation in their abundance. For woodpeckers and nuthatches, large sized trees are a prerequisite for feeding and nesting (Crawford et al., 1981). In the CL site, not all large trees were felled, in spite of which the abundance of these species had declined. It is possible that in the CL sites, the damage incurred to standing trees and their bark could have caused the birds to move away from the area. In all CL sites, Lesser Goldenbacked Woodpecker was not recorded after logging, but Yellowfronted Woodpecker as well as Browncapped Woodpecker were seen in the site. The Velvetfronted Nuthatch and the Chestnutbellied Nuthatch were not seen after logging. Grey Tit was present all through the logging operation while the Yellowcheeked Tit abundance had declined. Johns (1997) noted that in most guilds species substitutions occurs where some species are replaced by others species of the same guild. Which species remain and which are eliminated is determined largely by microclimate specialization. In all guilds, this pattern was seen. Since insect abundance was not quantified, no conclusive remarks could be made about availability of insects in the site. Johns (1989) did not find a significant decline in the number of woodpecker species in the logged forests

as he found that some species (*Picus* Spp., *Hemicircus* spp) switched to foliage -gleaning in logged forests. In the CL sites, such alteration in foraging substrate was not observed. The species that moved away from the site during the logging phase were sensitive to disturbance. Their presence in adjacent 1 yr logged sites indicates that they may recolonize the site after a period of time.

Sallying Insectivores: Flycatchers, drongos and shrikes respond differently to logging activity in the CL sites. Tickell's Blue Flycatcher and Whitebrowed Fantail Flycatcher were relatively more resilient to logging disturbance than Blacknaped Blue Flycatcher, Paradise Flycatcher and Verditer Flycatcher. Resident flycatchers are prone to reduction in numbers in disturbed sites, as they are territorial and not powerful fliers (Johns 1997). But as in other guilds, response of each species varied individually. The Whitebrowed Fantail Flycatcher adopts to sallying mode of feeding using various tree heights. Tickell's Blue Flycatcher, on the other hand is a sedentary bird observed to be feeding from the ground. It is possible that both the species could survive in the logged forests, as logging did not result in altering their mode of feeding resource. The Blacknaped and Verditer Flycatcher are forest inhabiting species. Reduction in mature forest flycatchers is documented by Johns (1986 and 1991) study. The mature forests species are replaced by species characteristic of edge forests. Among other sallying insectivores, Whitebellied Drongo was observed to be using mature forest areas substantially more than the Black Drongo. Prior to logging, at the CL site at Dharni, a pair of Whitebellied Drongo was observed nesting at over 15 m height on a Saj tree. Next year, the birds did not return to the same nesting tree and were not observed in the CL site elsewhere. Another sallying insectivore, the Rufousbacked Shrike was seen nesting in the CL site at Jarida prior to logging. After logging, the bird was seen but no nesting activity was observed.

Carnivore Guild: Raptors have larger home ranges than smaller bird species and the size of the area they use changes seasonally (Fuller 1996). Except in Chunkhedi CL site, raptors did not show significant variation in the abundance pattern in other sites. After logging in the CL site at Chunkhedi, a nest of White-Eyed Buzzard Eagle with two chicks was seen in the month of May

1996. Increased abundance of raptors has been noted in the logged forests by Johns (1989). Johns (1989) attributes higher occurrence of birds of prey in the logged forests to opening up of canopy and greater visibility. Thiollay (1991) reported a decline in raptor abundance after logging. In this study, logging did not necessarily create favorable habitat for raptors by opening up the canopy or increasing the visibility, so an increase in their abundance could be a chance event.

Granivores: The grain feeders such as doves, munias and Yellowthroated Sparrows showed different response to logging. The doves and munias either declined or increased in the CL sites, but the Yellowthroated Sparrow had increased after logging in all the CL sites. In the CL site at Dharni, a nest of Yellowthroated Sparrow was observed nesting and feeding the young after logging. This species is a hole nester and their presence in the logged forests suggests that they could find suitable resource to nest in the logged forests. The doves, munias and sparrows are found to prefer open, sparse forests (Ali and Ripley 1983), but none of the CL sites bore the appearance of such open forests. It is likely that these species are among the primary colonizers and prefer to occupy disturbed areas small openings are available and possibly, where number of other species is lower. John's (1989) and Thiollay's (1991) work did not report any changes in the abundance of this guild following logging.

Omnivores: There was an increase in abundance of members of this guild in all the CL sites after logging. Birds classified under this guild are non-specific about their habitat and food and are found almost everywhere. Omnivores are widely distributed and become the first colonizers in any disturbed site (Probst et al., 1992, May 1992). Indian Tree Pie, Indian Roller and Jungle Crow are opportunistic feeders found in forest edges. Their increased abundance in logged sites could be attributed to availability of open areas for perching and foraging.

Bird communities display constant variations in population. It is difficult to tease out effects of logging and season as both have major influence on the community. Some groups of birds fluctuate with season, whereas some

respond to logging, while others respond to both. Species that are more sensitive are replaced by those that are more tolerant to environmental variations. Composition of the communities changes with respect to resource availability. Some species can not cope up with changes while some can by foraging from a broader range of food types (Wagner 1981). Species within a guild are most often separated by foraging site and perch height (Bell 1980a; Landres and MacMahon 1980, Wagner 1981). The next section discusses the changes in the composition of the community at different height strata before and after logging.

3. 28 Vertical distribution of birds in the logged sites

Ground level (0 m): There was a significant increase in number of birds using this height in Chunkhedi and Jarida CL sites, though in Dharni CL site, less number of birds were observed at this level after logging. In all the three sites, there were differences in species composition at this level. Before logging species such as mynas, Blackcapped Blackbird, babblers, thrushes, robins, quails, Tickell's Blue Flycatcher, Junglefowls, Spur fowls, and Peafowls, partridges and doves were seen feeding at this level. After logging, the larger species were replaced by bulbuls, Grey Tits, drongos, White Eyes, Crow Pheasants, and munias. The larger species such as the Junglefowls, partridges, Blackbird, and flycatchers are sensitive to disturbance and would be expected to move away from the site. These species were not encountered in the site after logging. The species that replaced them were widely abundant in the area and could easily colonize the disturbed sites.

Shrub layer (1-2m): Shrubs such as *Lantana camara, Helicteres isora, woodfordia floribunda,* were present at this height. Before logging, bulbuls, White Eye, Sunbird, flycatchers, parakeet, Tailor Bird, Grey Tit, Franklin's and Ashy Wren Warblers, babblers, robins and chats were observed in this height class. These birds were observed feeding on the fruits and flowers at this height. During logging, the shrubs were uprooted. In response to this, the species feeding at this height moved to different height strata. These species were replaced by Grey Tit, Franklin's Wren Warbler, and Redvented Bulbuls after logging. Again, the species that were noted here after logging were widely

abundant in the area and were among the primary colonizers. The removal of shrubs during logging had resulted in changing the species composition at this height. The control sites did not show changes at this height. However, most of the species that were seen feeding at this height prior to logging were encountered after logging also, although not at the same height. This indicates that although the species had changed their foraging preferences, they were still using the logged sites.

Low canopy (3 - 8 m): All bird except raptors were observed at this height in the CL sites before logging. After logging, the use of this height class had declined in Chunkhedi and Dharni CL sites. Species such as Jungle Babbler, woodpecker, Golden Oriole, White-Eye, Lesser Goldenbacked Woodpecker, Whitebrowed Fantail Flycatcher and nuthatches were seen at this height. These species were replaced by Spotted Dove, Magpie Robin and Indian Tree Pie, Tailor Bird. At Dharni, the Crested Serpent Eagle, Roseringed parakeet, Blossomheaded parakeet and Blackheaded Mynas were observed using this height class after logging. Although there were trees present at this height in the CL site, the reasons for the species to move away could be the sensitivity of the mentioned species to disturbance. This was validated as no change in community composition was seen at this height in the control sites.

Mid-canopy (9-14 m) : Prior to logging, species such as barbets, Grey Hornbill, Small Minivet, Large Cuckoo Shrike, woodpecker, nuthatches, Whitebellied Drongo were observed in the CL site at Chunkhedi. After logging, none of these species was encountered in the CL site. Species seen at this height after logging were parakeets, mynas, Indian Tree Pie, Magpie Robin, and Jungle babblers. A nest of White- Eyed Buzzard Eagle was seen on *Adina cordifolia* at 14 m height in the CL site after logging at Chunkhedi. The control sites also showed changes in number of birds at this height, although the composition of the community did not show changes in the control site

Top canopy (15-20 m): All sites showed changes in community composition at this height after logging. Before logging, the species observed at this height were the Yellowlegged Green Pigeon, barbets, Grey Hornbill, lora, Tickell's Flowerpecker, parakeets, woodpecker, nuthatch, and orioles. After logging,

species such as parakeets, mynas, Indian Roller, Indian Tree Pie, and doves were observed at this height.

The patterns discussed so far suggest that in the CL sites at most height strata community composition had changed. The change in composition was between and within a guild. Bell (1982a) states three factors, which are known to alter the foraging behavior of birds. These are climatic changes, availability of insects and availability of fruits and nectar. In his study in New Guinean rain forests, he found certain guilds showing more seasonal fluctuations than the others. These included frugivores, sallying insectivores, and carnivores. Within a guild, two or more species feeding in the same habitat are separated from each other by feeding at different heights, feeding from different parts or by taking different foods. Holmes et al., (1979) found in their study in Northern Hardwood in New Hampshire, that among insectivores foraging height was the determining factor for co- occurrence of two species. Height is associated with presence of foliage and branching pattern of a plant and insectivores are specific about these characteristics. Some species are able to exploit the resource that other members of the same guild may not be able to. Gibb (1960) noted that in spring season, Grey Tit spent maximum time feeding among the leaf litter whereas Tree creepers and Goldcrest retained their arboreal feeding habit. Species replacements as seen in the CL sites are indicative of such spatio -temporal separations within and between the guilds. A common pattern seen here was that all those species that were sensitive to disturbance had moved away from the site whereas the more tolerant species occupied the height strata that were vacated by the specialist species after logging. The change in species composition between months was clearly reflected in the similarity values as it showed when the community became more similar or dissimilar. Up till now, I have discussed the variations in guilds in species in various months and seasons. The next section discusses what are the likely causes that make some species more sensitive to disturbance than other species.

3.29 Ecological characteristics of Species affected by logging

Diamond (1984) characterizes species that are likely to show decline due to disturbance in their population as those which are (1) small in size, (2) having naturally variable population and (3) which are short-lived. Species resilient to disturbances are species that are (1) large bodied and long lived (2) and having relatively stable population. Diamond et al (1987) further elaborated on this aspect when they found that small populations in Western Java, that did not have a nearby source population eventually resulted in species loss from the affected area. Species rarity is an equally important aspect, which affects its ability to persist in a disturbed area (Johns 1989). A species, which is rare in abundance, will be more sensitive to the effect of disturbance than a species that is more abundant.

Tables 3.18 to 3.20, 3.27 to 3.29, and 3.36 to 3.38 describes which species increased and which decreased after logging. Some species came in as primary colonizers and others had completely moved out of the site after logging. Which species are more sensitive to logging and what makes other species persist after logging?

At any location, variability of a population depends on how variable are the environmental factors (Pimm 1991). Following logging the structure of the site would change and therefore the composition of bird community is expected to change as well. However, there was a clear lack of trend when differences are examined at guild level in the study area. A guild is an assemblage of different species and each species varied in its response to logging. Johns (1997) compiled results from three study sites in the logged forests and found that guild membership did not exhibit significant changes between logged and unlogged forests. Response of guilds in the area depends upon the availability of a food resource, and my findings report an increase in certain species and a decline in other species of the same guild. Within a guild, species adopt different foraging strategies. Apart from feeding resources, some birds are highly parochial and show greater degree of territoriality in non-breeding season. Almost all species show specific preference for perching and nesting resource. Some studies (Morris 1990; Pimm 1991; Ricklefs and Schluter 1993)

note that apart from food other factors such as the natural history of a species can explain the variability of a population). Keeping the natural history of species in view, I will discuss the changes in abundance of species with respect to body size, territoriality and nesting requirements.

Body size : Pimm (1991) found that larger birds have greater resistance to environmental variations as in harsher winters larger birds could fare better than the smaller birds. He reasoned that larger birds had more body fat stored than smaller ones, so they could survive food shortages. Also larger birds live longer than smaller ones, so their population would appear less variable than the smaller birds (Ricklefs and Schluter 1993; Pimm 1991). I correlated the body weight with density of species before and after logging (Figure). The body weights of species were obtained from literature (Ali and Ripley 1983). The legend is as given below. All the species are not listed , only the representative species of the given body weight class are given in the table.

The pre- logging density is plotted on the X axis and post – logging density is plotted on the Y axis. Species nearer to x-axis had declined after logging, and those nearer to y-axis increased after logging. Species closer to the line did not show changes in density after logging.

Figure 3.30 Shows changes in density of species in the CL site. The legend refers to body weight class

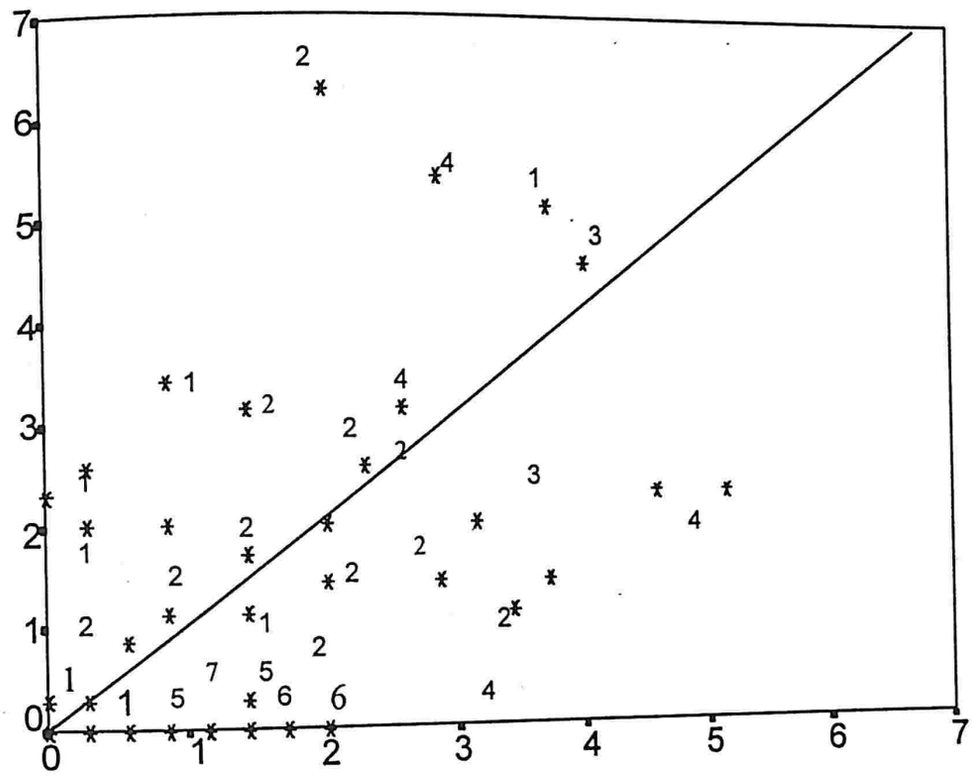


Table 3.39 bird species classified as per their body weight (from Ali and Ripley 1983).

Code	Body weight	Representative species
1	1-10 g.	Tailor Bird, Pied Flycatcher Shrike, White Eye,Purple Sunbird, Wren warblers, Green Leaf warbler, Yellow browed Leaf Warbler, Redbreasted Flycatcher
2	11-25 g.	Tits, lora, flycatchers, Browncapped Woodpecker, munias, Small Minivet, Indian Robin, Little Green Bee eater, Yellowthroated Sparrow, nuthatch
3	26-50 g.	Crimson Breasted Barbet, Greyheaded Myna, Large Cuckoo Shrike, Scarlet Minivet, bulbuls, Magpie Robin, drongo, Chloropsis. Redvented Bulbul
4	51-70 g.	Golden Oriole, Blossomheaded Parakeet, Jungle Babbler, Small Yellownaped Woodpecker, Jungle Bushquail.
5	71-100 g.	Blackheaded Oriole, Large Green Barbet, Lesser Golden Woodpecker, Blackbacked Woodpecker, Haircrested Drongo.
6	101-400 g.	Yellowlegged Green Pigeon, Grey Hornbill, Alexandrine Parakeet, Roseringed parakeet, Spotted Dove, owls, Red Spurfowl, Indian Roller
7	0ver 400 g.	Peafowl, Grey Jungle Fowl, Crested Serpent Eagle.

Among all the body weight classes, the smallest (1 to 25 g) and the large (70 g to 400 g) bodied species showed decline in abundance. However, even within the same body class, species showed different responses. Some species remained or increased in the logged sites, while the others declined or moved out. For instance, Franklin's Wren Warbler, Grey Tit, Whitebrowed Fantail Flycatcher, Green Beeeater, Indian Robin, Yellowthroated Sparrow and White Eye showed an increase after logging whereas in the same body size class, Purple Sunbird, Chestnutbellied and Velvetfronted nuthatch, Small Minivet, Iora, Verditer Flycatcher, Rufousbellied Babbler either declined in abundance or were not seen in the site after logging. Similarly, in large bodied birds the Green Pigeons, Lesser Goldenbacked Woodpecker, Grey Hornbill, Red Spurfowl, Golden and Blackheaded Oriole, Large Green Barbet always showed a declined in abundance and other larger birds such as parakeet, Yellowfronted Pied Woodpecker, Indian Roller, Indian Tree Pie, Redvented Bulbul showed an increase in abundance after logging. In French Guainan logged forests, 50 - 80 % large birds (> 170 g body weight) declined compared to a 23-30 % decline in smaller bodied birds (<170 g weight) after logging (Thiollay 1992).

In the present study, no clear relationship between body size and sensitivity to logging could be derived. It appears that the body size coupled with some other characters could be responsible for sensitivity of a species. A species that is more abundant is likely to be more noticed than rarer specie. Smaller birds (1 to 25 g) were more abundant than larger birds, and therefore changes in their abundance would be more conspicuous. Another factor coupled with body weight could be dietary specialization. Between frugivores and insectivores, the latter were among the most affected group of birds. However, in frugivores and insectivores, specialists were more sensitive than generalists. Dietary specialization was seen across all body weight classes. A nuthatch was a specialist, whereas in the same body weight class, the Yellowthroated Sparrow was a generalist. Same is true for frugivores: the Redvented Bulbul is a generalist compared to the Large Green Barbet ,although both belong to same body weight class. Overall, large body weight and smaller species were affected by logging. Apart from body weight, other

factors such as territoriality can also influences the survival ability of a species in logged forests.

Territoriality: Smaller birds have smaller territories, as their food requirements are less than larger birds. All the bird species are territorial in their breeding season, but some species are territorial even outside their breeding season. Nuthatches, most flycatchers, Junglefowls, barbets, woodpeckers, and owls are territorial species. Such species are likely to show variation in population following habitat disturbance. Johns (1997) reports that most territorial species do not abandon their former territory unless there is a severe alteration in their food source following logging. Not much is known about the size of territory of individual bird species, but generally, flycatchers are known to have smaller territory than manifest, which have smaller territory than green pigeons, hornbills and raptors. In case of birds with very small territory such as the Tickell's Blue Flycatcher, logging could have opposing effects. If the logging activity has affected that very small territory that the bird inhabits, than the species is likely to abandon the territory. On the other hand, if the logging activity has not affected that small area, species may not move out of the territory and continue to be present there. This was observed in case of the CL site at Dharni where Tickell's Blue Flycatcher was observed after logging. In Jarida, this species was not seen after logging. Medium sized territory birds such as woodpecker, barbet and oriole had moved out from all CL sites during logging. However, very large territory birds like raptors and hornbills are less likely to get affected due to logging disturbance, as they are more vagile species and can travel large distances on a daily basis. It appears that if resource depletion is not severe and if the structure of the site has not altered the territory of the bird, birds may survive the logging disturbance. However, birds having larger territory and bigger body size also showed sensitivity to logging disturbance. Species such as Grey Junglefowls and Red Spurfowls have physical constraints as they are weak fliers and once if they fly away they may not return to the same site. On the other hand, species like hornbills can persist or will come back to the area if the resource is available as these birds are highly mobile and can track resources (Johns 1989). Territory size is

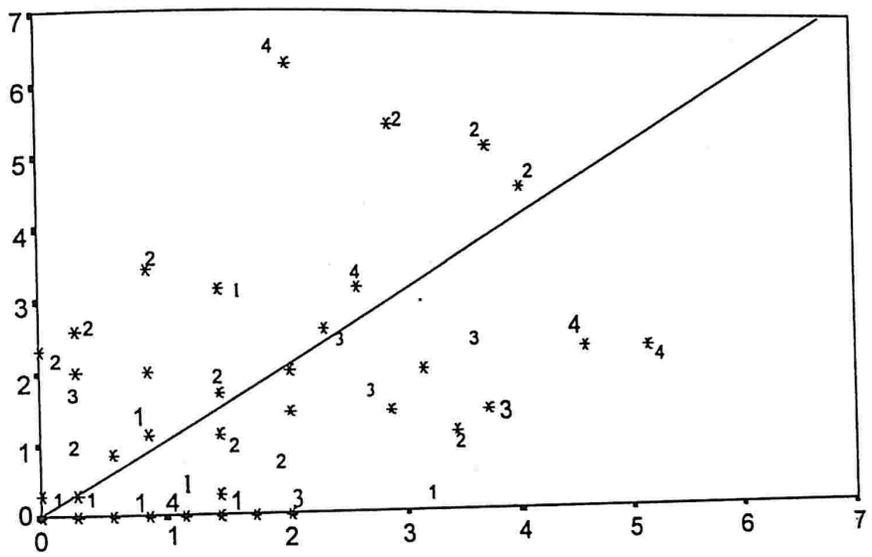
one of the factor that can determine the response of a species to logging along with other characters mentioned above.

Most species are specific about the food as well as the nesting resource. Depletion of food resource and population variation has been discussed in earlier section already. Nesting requirements is another equally important factor that birds are selective about.

Nesting requirements: Prior to logging, I had opportunistic observations on the substrate and height of nests seen during the study. The density of birds is compared before and after logging, and data is interpreted considering the nesting height used by these species. I had nesting data for 19 species and for the remaining species, the information was obtained from Ali and Ripley(1983).

The pre- logging density is plotted on x-axis and post- logging density is on the Y-axis.

Figure 3.31 shows a trend in change in bird density in the CL site and the legend in the figure refers to their nesting height preference.



The legend is as given:

1. ground nesting birds;

2. nesting between 1m to 8m;

3. nesting between 9 m to above 15 m.

4. cavity and secondary hole nesting

The species nesting at ground level were most affected. These include bigger, territorial birds such as Grey Junglefowl, Red Spurfowl, Peafowl, Orange headed Ground Thrush, and Pitta. Ground nesters also include smaller birds like robins, chats, and Wren Warblers. Species nesting between 1 m – 8 m height showed variable response. Species included in this class are Redvented Bulbul, Jungle Babbler, Spotted Dove, Purple Sunbird, White-Eye, shrikes and most flycatchers. Amongst these birds, species that nested at

lower heights (up to 5m) such as babblers, doves, bee-eaters declined in abundance, although abundance of Redvented Bulbul (nest was observed up to 5 m height) did not decline. Birds using tall trees for nesting (between 9m - 17m) did not show a clear trend in change in abundance. For instance, Whitebellied Drongo, Golden and Blackheaded Oriole, White eyed Buzzard Eagle, Scarlet Minivet using tree height above 10 m. varied in their response to logging disturbance. Some increased in abundance while the others declined. Their response in the CL site has been discussed in the earlier section. Hole nesting species such as barbets, Yellowthroated Sparrow, parakeet, myna, hornbill, owl, woodpecker, Grey Tit showed variable response to logging. Although 5 snags per ha were retained nest trees were not felled as per the felling rules, the abundance of woodpecker, barbet, and hornbill had declined while that of myna, Grey Tit, Yellowthroated Sparrow and parakeets did not decline. Woodpeckers are primary hole nesters and all other species are secondary hole nesters. Decline in woodpecker abundance in logged forests could be due to loss of foraging resource, but very unlikely due to loss of nesting resource as all trees are not felled. Same could be true for barbets, and hornbills. Hornbill density was not correlated to hole nester in any selectively logged forests (Johns 1997). Woodpecker density also did not change in Sabahan rainforest. Cavities are not a limiting factor in logged forests as they can be formed due to damage to other trees during felling operation (Johns 1997). Presence of Mottled Wood Owl in CL and 1 yr site in Chunkhedi suggest that their roosting or nesting resource had not been disturbed.

Presence of a species in an area does not necessarily indicate that it will be breeding in the same site. Resident population is likely to use the area for feeding, but they may be using the neighboring areas for nesting if suitable substrate is available (Welsh and Capen 1992). More mobile species can use different areas for feeding and nesting purpose. This clearly puts less mobile species at a disadvantage since they can not fly long distances. Such species may not be able to return to the original site for some time unless there is a source population nearby to recolonize the area. Thus, it appears that mobility is an important feature of the species that decide its fate largely.

3.30 Retaining Bird diversity in logged sites

Body size, mobility, territoriality, feeding and nesting requirements are the characters that determine a species response to logging. Apart from this, some species are sensitive to any form of disturbance and will disappear during that phase of disturbance. Once the site regains its original status in terms of resource availability or undisturbed status, some species may return to the site. Species such as Lesser Goldenbacked Woodpecker, Large Green Barbet, Small Minivet, nuthatch had moved out of the CL site after logging. However, they were present in the neighboring 1 yr. site. It is possible that after a period of a year, these species would have come back to the same site. Though this is predictive inference, it is worth mentioning as all the 1 yr sites showed this pattern. The recolonization of species is largely dependent upon how close will the population be to the affected site. If the species were mobile, it would probably fly off to the nearest or a distant available habitat and can return to the original site within a short time period. For those species, that are not as mobile, moving out of the area and return to the original site may not be possible.

Evidently, the factor that is crucial for mobile and not so mobile species is the availability of refuge areas near by. For this to happen, provision of undisturbed forests surrounding the logged sites to act, as buffer is very vital. Crome (1991) found that after logging bird diversity did not decline as the nearby undisturbed riparian area served as dispersal corridor for birds to move between the two areas. Most studies (Wong 1985; Johns 1986; Thiollay 1991; Crome 1991) have identified the role of refuge areas to assist in species recovery. In Malaysian forests, reserving parts of Virgin Jungle Reserves (VJRs) within logged areas is mandatory (Jonhs 1997). The refuge areas should be large enough to accommodate all species and territories of large birds, should be linked to logged areas and have similar vegetation as that of the logged sites (Johns 1997) so that species abundance in logged sites does not decline after logging.

Natural variations occurring in a population could explain sudden increase or decrease in abundance. Most frugivores show more seasonal fluctuations than

insectivores do. Birds feeding both on plants and animal matters show little changes in abundance through the year. Among insectivores, sedentary species have relatively stable populations than those which are mobile (Landaus and MacMohan 1988). As logging activity commenced, most birds moved out, irrespective of their mobility. As soon as logging was over, some species began to reappear, some did not. How long do these species take to come back and do they come back at all would require monitoring of the same site for a longer period. From this study, it appears that in the 1 yr. site, all species were present that were present in the CL site before logging. It can be assumed that these species could have returned over a period of 1 year after logging to the site.

Within a forest, a patchwork of logged and unlogged sites can form a matrix of heterogeneous habitats. Within a logged site, provision of fruiting trees, riparian areas, snags and cavities could counteract the negative impacts of logging.

CHAPTER 4

Timber harvesting and bird communities in Satpura Conservation Area.

Up till now, discussions focused on results from each study area. In this Chapter, common patterns seen on both the areas will be elucidated. In Chapter 1, I had proposed the expected outcome of this study as hypotheses. In the following section, each hypothesis will be discussed in detail.

4.1 Hypotheses

Hypothesis 1

Long rotation cycles give sufficient time for recovery of the vegetation and therefore of the bird communities .

This was true for this study.

In the Satpura Conservation Area, I had data for four old logged sites. They were of 20 year (selection system, Melghat), 40 years (CWR and SCI in Bori), 60 years (GTFS in Bori) and 80 years (STFS in Bori). These sites belonged to different rotation cycles. Rotation cycles are fixed according to the condition of the forests. In moderate quality teak forests, the cycle is fixed for 20 to 40 years. In better quality forests where teak can grow to large dimensions, rotation cycle is for 60 or 80 years. The main principle behind giving the 'regrowth ' period after felling is to restock the area with harvestable crop between the cycles (Matthews 1989).

I expected the old logged sites of each silvicultural system to have higher species richness than their respective recently logged sites. This was true only for two sites. In SCI and STFS, the old logged sites had higher species richness than their recently logged sites. The 7 yr sites of CWR and GTFS had equal or higher species richness than their old logged sites. In spite of long rotation cycle, the 60 yr. site in GTFS had lower bird species richness, and in CWR, within 7 years, the site had attained species richness equal to its

old logged site. Does this indicate that in the 7 yr site at CWR and GTFS, the species were not affected by logging or that they returned to the site within 7 years?

The rate of recovery of birds in a logged site depends on two factors, firstly, on the intensity of felling and secondly, on the specialization of the bird community. In Bori, i did not have pre-logging data so the intensity of felling could not be quantified. Nonetheless, from the objective of management, one can hypothesize about the extent of felling in the logged sites in Bori. The objective of felling in CWR and SCI sites was to improve the forest quality and restock the area (section 2.12). In such a situation, it is likely that felling would be less intensive than GTFS and STFS sites, where the objective was to yield large sized timber. This is an assumption that could not be validated in present time. However, about the bird community it could be stated that the CWR area comprised more of generalist species that were widely abundant in the area. Commonly seen species in CWR sites were parakeets, mynas, bulbuls, Grey Tit, Jungle Babblers and shrikes. These species were seen in the CL site in Melghat while and after logging, so it is possible that such species showed greater degree of resilience to logging and may have returned to the area within a short time after logging species.

In the moist deciduous forests of GTFS and STFS, forest specialists were represented in higher numbers than in the drier forests. These species could not establish themselves in sites where the structure had been modified due to logging. For example, the altered vegetation structure in the 6 yr site in STFS and 60 yr site in GTFS was responsible for lower bird species richness and diversity (see section 2.34). In the 60 yr site, forest specialist species such as hornbill, barbets, woodpeckers and flycatchers were represented less in number than its 7 yr site. Frequent thinning in the 60 yr site at GTFS can be considered to simulate the effect of felling in a shorter rotation cycle. The net effect of thinning at 10 years intervals resulted in a decline in tree species density and richness in the 60 yr site at GTFS. Shorter rotation cycles reduces the proportion of time a given forest has for regenerating and does not allow several mature forest characters such as large trees, snags and ground cover

to recover (Helle and Jarvien 1986, Warkentein 1995; Johns 1997; Christian et al., 1997).

Various studies report different recovery rates after disturbance. Logging by clear felling is an extreme situation. But still, in clear felled areas about 80% of the species, including some specialists had returned within 5 years (Lamb 1991). Presence of some specialists in clear felled areas is attributed to increased habitat heterogeneity in the site (Thompson and Capen 1988; Probst et al 1992; Willson et al., 1994). Recolonization by specialists is possible in logged areas if the specific resource requirements are met with. However, some species may take longer time than others to recolonize or some may not return. Shankar Raman (1995) reported that 25 years after *jhuming* the bird community was almost similar to that in the primary forest, but some specialists were confined to older logged sites only. The rotation cycles for the above mentioned studies were between 20 to 40 years. Thompson (1993) simulated the effects of different rotation cycle on bird populations. The model predicted lower bird species richness with shorter rotation cycles. He found that compartments managed under longer rotation had higher number of mature forests species than those maintained on short rotation period. A decline in abundance of Crossbills in pine forests was noted by Benkman (1993) and was attributed to the fact that Crossbills require mature pine cones for feeding which were not available in plantations with short rotation cycle.

Thiollay's study (1992) reported recovery of only 58 % of mature forest species after 10 years of logging whereas John's study (1989) reported almost 80 % recovery within 12 years after selective logging. Thiollay (1997) recommended rotation cycle above 50 years in French Guianan forests for recovery of the specialized rain forest avifauna. Recher et al., (1987) studied the effect of eucalypt forests managed under 40-50 years rotation cycle at Eden, New South Wales. Their study recommends longer rotation for areas having high floral and faunal diversity. Their study recommends logged sites to be located close to an old logged site, so that source population can colonize the logged sites.. It appears that primarily, it is the richness of bird community that decides its rate of recovery after logging. The more specialized community

requires longer time to return to the logged site, while wide spread species can recolonize the sites in shorter time. Other factors that are equally important in affecting bird community composition in an area are the proximity of old logged sites and the intensity of felling. In the study site, the present rotation cycles seem to be suitable for the given forest type and allows recovery of the bird community by the end of the rotation cycle. However, repeated thinning in GTFS areas causes periodic disturbance and prevents full recovery of the bird species and reduces bird species richness in the area. Repeated thinning should therefore be avoided.

Hypothesis 2

Bird species diversity is higher in areas having higher vertical and horizontal diversity.

This proved to be true for this study.

Vertical diversity means that there is presence of foliage at different heights, it is more commonly referred to as the foliage height diversity (FHD). Horizontal diversity refers to the availability of different sub-habitats (such as woodland, grassland, edge, valley, slope, and nallah) within a habitat. A lot of work has been done which examines the role of vertical (MaCArthur and MaCArthur 1961; Wilson 1974; James and Wamer 1982; Morrison et al 1995) and horizontal (Karr and Roth 1971; Cody 1975; Scheieck et al., 1995) diversity in affecting bird composition. A common term, which describes both these factors (variability or patchiness of a system), is habitat heterogeneity (Li and Reynolds 1995). Alternatively, the hypothesis can be stated, as a more heterogeneous area would support a more diverse bird community.

When a habitat is more variable, the capacity to accommodate more species is greatly enhanced. (Thiollay 1990). Treefall gaps, changes in topography, vegetation, watercourse, forest types, all contribute to heterogeneity in an area. Such changes can either be natural (Brokaw 1985) or induced, especially due to long term silvicultural practices (Thiollay 1990). However, an intensively managed forest as well as an intensively protected forest can exhibit low habitat heterogeneity, as both the sites may not have full

complement of structural diversity (Thiollay 1990). My findings in the preservation plot and the 6 yr site in STFS exemplify this. Interestingly, on the PC axis both the sites had opposite scores (Figure 2.18). Preservation plot had higher vertical heterogeneity but low horizontal patchiness, whereas converse was true for the 6 yr site. Species richness in an area increases when the full mosaic of habitat necessary for each species is made available (August 1983; Karr and Freemark 1983; 1985; Brown 1984; Brokaw 1985; Feinsinger et al 1988). In Melghat, after logging an increase in numbers of Indian Robin, Magpie Robin, Yellowthroated Sparrow, mynas, and Grey Tit was observed immediately after logging but gradually some forest species also started to reappear. Provision of unlogged patches of forest, or riverine areas within the logged sites provide refuge for forest species that are disturbed due to logging (Johns 1986; Naomi and Hanowski 1984; Crome 1990; Thiollay 1990; Baker & Lacki 1997) and after the disturbance subsides, these species may reappear. In Bori and Melghat, the forestry practices could create such hospitable habitats by leaving some areas unlogged within the logged site that increased the habitat heterogeneity.

Studies have reported increase in bird diversity after clear felling (Dickson and Selequist 1979, Thomson and Fritzell 1990; Triquet et al 1990) and selective logging (Thomson and capen 1988; Taylor and Haseler 1995). More often, the reported increase is of species that were not present earlier in these sites. Species that are first to colonize the disturbed sites are generalists and forest edge species. Christian et al., (1997) found that pine plantations that were structurally more heterogeneous had higher bird diversity than those plantations that were structurally not as diverse. Annand and Thompson (1997) studied bird diversity in Central Hardwood Forests in New York and inferred that managed areas with an interspersion of logged and unlogged areas had high richness and diversity of bird species than an area that was protected from any management.

Hypothesis 3

Selective logging results in decline in tree density, basal area, bird species richness, and diversity.

This was partially true for this study.

Tropical silvicultural systems fall into two broad categories, monocyclic and polycyclic. Monocyclic systems involve clear felling the area in a single felling operation. This system has been discontinued in the country since 1977. Selective logging falls under polycyclic systems, where harvesting is done in smaller areas and at repeated intervals (Prakash & Khanna 1988).

One would expect that changes in structural parameters would be more drastic in case of severe habitat modification such as due to clear felling. Clear felling results in large canopy openings that are followed by invasion of grass and weed species changing the composition of the vegetation (Matthews 1989. Johns 1997). These changes would be followed by changes in the bird community composition. Clear felling for plantations will result in loss of natural tree diversity in the area and will only support those species that are more adaptive to these modifications .

In Bori, the cause of changes in the structural attributes such as tree density, mean GBH, and canopy cover could not be attributed to logging alone as pre-logging data was not available. In Melghat, the density of large and small trees had declined following logging in the CL site in Dharni, whereas in Chunkhedi and Jarida, only small tree density had declined after felling (Table 3.6 and 3.7). Mean GBH was reduced proportionately to tree loss rates. However, in areas where other big sized trees were present, overall GBH was not reduced (Table 3.6, 3.7, 3.8). Apart from preserving large trees, random nature of felling also contributed in a situation of no difference.

Spatial arrangement of logged sites also plays crucial role for reducing the impact of logging. In Bori and Melghat, the compartments allotted for felling in successive years were located close to each other. This is logistically simpler and facilitates extraction process. For every new felling operation, the same

PLATE 5. Timber felling being carried out by hand - saws in the Currently Logged (CL) site. Shrubs and saplings are removed prior to logging.

PLATE 6. Fallen tree of Saj (*Terminalia tomentosa*).

PLATE 7. Fallen tree of teak (*Tectona grandis*). Damage to undergrowth and a sapling is visible.

PLATE 8. Carting of logs with the help of bullocks along the established extraction path.

logging road and extraction paths are used. This prevents further damage and disturbance to the site. In section 3.22, the consequences of damage in the logged sites in tropical rain forests has been discussed. In Melghat, over all impact of logging was reduced because the intensity of felling was lower and as a result the damage incurred was not as high as in the rain forests.

Other important aspects in reducing the damage caused by logging are the implementation of the felling rules and the skill of the felling agency (Johns 1992). In Bori, the forestry-working plan had incorporated recommendations for wildlife management in the logged areas as discussed in Chapter 2. The prescriptions for selective logging in Melghat are discussed in Chapter 3. In Bori and Melghat, felling was carried out by the territorial wing of the forest department and not by private contractors. The department gets the enumeration done for each compartment and accordingly the compartments are allotted for felling. A year prior to logging, enumeration and marking of trees is done under the supervision of a Range Officer. A treatment map demarcating different areas is prepared, and in the next year, before the logging season begins the Range Officer conducts a workshop for training the forest guards and laborers. The range officer and the guards are instructed about the number and species of trees to be felled so there can be a control on excessive removal. The laborers are mostly Korkus and Gonds who have been in this profession long enough to know in which direction the trees should be felled to minimize damage (Plates 5, 6, 7 and 8). In Chapter 1, I have reviewed other studies that report negligence in felling and post-felling care due to which the regeneration was poor in the logged sites. I have observed the logging process, and would give credit to the forest department for following the felling rules and taking care to avoid damage to the vegetation. Johns (1997) has pointed out how lack of training of the forest staff in tropical countries can result in higher damage and subsequent loss of biodiversity during logging. Most studies have reported the current logging practice to be unsustainable and have suggested measures for improvements, but rarely are these put to practice (Thiollay 1992).

significantly lower in a planned logging operation as compared to an unplanned operation in Eastern Amazonian rainforests. In the dry deciduous forests in Madagascar, there was no significant decline in tree density following light semi-mechanized logging, as other trees were present in the logged site. (Ganzhorn et al. 1990).

The bird species richness and diversity had declined during the logging operation in all the CL sites in Melghat. However, the control sites also exhibited a concurrent decline in species composition, so the cause for changes in the CL site can not be attributed solely to logging. Even though the number of species had declined due to logging in the CL site, it is likely that they may recolonize the area after some time. Though this is predictive, it is not unlikely as this pattern was seen in all the 1 yr sites in Melghat and the recently logged sites in Bori.

Specialization and the adaptive nature of bird communities determine the extent of change in composition in a disturbed site (Karr 1990 in Johns 1997). This aspect has been discussed in Chapter 3 in section 3.33. Certain features of mature forests in a logged site can lessen the degree of changes in bird communities following logging. Provision of unlogged sites close to the logged sites has proved to be highly beneficial (Johns 1983, Crome et al., 1990, Taylor and Hassler 1997, this study). Retaining large trees, fruit trees and snags have resulted in increased abundance of forest species in the logged sites (Mannan and Meslow 1994). In the CL sites, the hilly areas, riparian, and understocked areas were left untouched. This created a matrix of undisturbed areas within the logged site. Availability of unlogged and old logged compartments close to the CL sites served the purpose of refuge areas for the logged areas.

Taylor and Hassler (1995) found that partial logging systems that selectively remove the trees could reduce the impact of logging. They reported that Shelterwood system that is in principal, similar to the selective logging system caused relatively lower changes in bird abundance than other types of felling system. Baker and Lacki (1997) compared different silvicultural practices and their results showed that bird composition did not change

significantly under those systems where tree removal was minimal. In the final analysis, it appears that apart from the actual loss caused due to logging, the subsidiary damage due to tree removal and road making activity incurs more harms to the site. If care is taken to prevent this, negative impact of logging can be lessened to a considerable extent.

Hypothesis 4

Immediately after logging, the abundance of the generalist increases and that of the specialists declines.

This is supported by my data.

In the recently logged sites in Bori, the most abundant species generally were Franklin's Wren Warbler, Yellowthroated Sparrow, parakeets, mynas, doves and robins. The forest specialists such as woodpeckers, nuthatches, orioles, hornbills, owls although encountered in the 7 yr. sites, were more frequently seen in the mature forest sites. However, results from Bori need to be interpreted with a little more caution. Firstly, 7 years had lapsed after logging and these were inter - site comparisons that had no control for the intrinsic variations between the sites. In the CL site at Melghat, generalists increased and specialists declined immediately after logging. Studies in India have reported mynas, drongos, bulbuls, white eyes, Yellowthroated Sparrows, and parakeets as the most commonly occurring generalists in disturbed sites (Beehler 1987,. Joshua and Johnsingh 1986; Price 1979, Daniels 1989, 1995). My study also found these species to be of common occurrence than the specialists in the recently logged sites. Other studies have also noted the preponderance of generalists in the logged or early successional sites while specialists were more common in the mature or old logged sites (Neimi and Hanowski 1984, Blake 1991, May 1992, Knick and Rotenberry 1994, Warkentin 1994, Taylor and Hasler 1995, Baker and Lacki 1997).

The general pattern that emerges from studies of bird communities in various disturbance regimes is that after some habitat alteration, generalists become widely abundant whereas the specialists decline in abundance. Brown (1984) explains the relationship between the abundance of bird species and

their distribution. He states that widely occurring species that can tolerate different conditions and acquire sufficient resources so as to attain high densities in some places can also occur in many other sites. Similarly, species that are otherwise similar but have narrower requirements and can not attain high abundance anywhere and will be restricted in their distribution. These are 'area sensitive' species. He further suggests that an environmental variation influence the community composition. Changes in more than any two or three such factor are likely to cause change in the number of specialists, while it is likely that generalists can adapt to these conditions fairly well. Specialists are relatively more sensitive to changes whereas generalists are more adaptive. Body weight, territoriality and dispersal ability is some of the factors that influence the sensitivity of a species in addition to its ecological specialization (Hanski et al 1993, see Chapter 3 for further discussion). Having moved away, the species may or may not recolonize the area. The response to any form of disturbance therefore depends on the versatility of the species. Generalists are more suited to occupy disturbed areas than are the specialists.

4.2 Major implication of logging in Satpura Conservation Area (SCA)

For evaluating the impact of logging on bird communities, I studied the inter-site differences in Bori and intra-site differences in Melghat. The main problem in comparing inter-site differences is the high degree of spatial heterogeneity between sites that is not controlled for. Natural variations due to spatial heterogeneity can be greater than variations due to disturbance. The results obtained from inter- site studies are thus, largely predictive. The results from CL site in Melghat demonstrated the actual effect of logging as intra-site comparison control for natural variations within a site. The results from 1 yr and 20 yr sites in Melghat give predictive results about the recovery of bird communities after logging. Except for the CL sites, none of the result obtained from other sites could be ascribed exclusively to logging. Even within a site, variations in species composition may be due to patchy distribution or local variations in their relative abundance. Results from inter-site and intra-site differences therefore need to be interpreted carefully keeping the natural and local variations in view.

However, there were certain results that were common to Bori and Melghat regarding the variations in bird community composition. None of the sites unless modified extensively (for example, the 6 yr site in STFS, and CL site in Dharni) showed differences in structural parameters after logging. The granivores and omnivores were higher in number in all recently logged sites in Bori and CL sites in Melghat. Trunk/bark feeders, understorey insectivores and canopy insectivores did not show response to age of the site, although they were represented in lower numbers in sites that had varied structure (preservation plot, 6 yr site in STFS, CL site Dharni). Members of the same guild showed similar response in both the sites: Lesser Goldenbacked Woodpecker declined in most CL and recently logged sites, whereas other species of woodpeckers did not show any definite pattern. Blacknaped Blue Flycatcher showed a decline in numbers in all CL and recently logged site, whereas Whitebrowed Fantail and Tickell's Blue Flycatcher were present in these sites. However, changes in guild representations were seen in control sites, as well, therefore these results could not be entirely an effect of logging.

There are other factors, which obscures the effect of logging on bird communities. For example, teak and *saj* were the main species that were felled and these species do not offer important resources for the most birds. Also, as per the felling guidelines, all important fruit trees were retained at the time of logging. Thirdly, the felling was 'conservative' in the sense that the number of trees felled did not exceed the number of mature trees in the logged site. As a result, the logged sites appeared more like the surrounding natural forests.

Also important is the history of management in the area. The entire Satpura Conservation Area was managed under various forestry practices for over a century, as mentioned in section 1.5, Chapter 1. This long history of management must have led to innumerable changes in floral and faunal composition of the area, which are gradual but not immediately perceptible. Regional evolutionary process can influence the response of a community to disturbances. For instance, in the island forests of Melanesia and Philippines, the bird communities recover quickly as they are naturally adapted to high levels of damage due to annual cyclones occurring there (Karr 1990: in Johns

1997). Wilcove (1980) noted high resiliency to habitat alteration in temperate forest bird community as the temperate bird community have faced habitat modification for a longer time and had become "pre adapted " to changes.

The bird community in the managed forests of Bori and Melghat comprises of common taxa found in the dry deciduous forests. Dry deciduous bird communities do not exhibit great degree of dietary specialization as rain forests bird communities (Wilcove 1980). The specialists in the dry deciduous forests, showed fluctuations due to logging as well as season. Species that ceased to occupy the area immediately after felling were forest specialists such as woodpeckers, nuthatches, some flycatchers, Grey Junglefowl, Red Spurfowl, barbets, and the Yellow Legged Green Pigeon. After a period, some of these species did come back to the logged sites and while others took a longer time to recolonize. The main reason for the recovering these species in the same site was that the vegetation structure had not changed significantly due to felling. Some generalists were recognized as primary colonizers species that responded positively to logging. This pattern was common to almost all the logged sites.

4.3 Selective logging and conservation of bird diversity

Of all the polycyclic systems, selective logging can be considered less harmful because the felling guidelines recommends felling selected timber trees, and protecting the future crop for next felling. So at any given point of time, trees are always present in the site. The felling results in random removal of trees and this diffuses the structural changes due to felling. Besides this, the food resource availability is not radically changed in selectively logged areas. Amongst the guilds, frugivores are relatively more generalized feeders than insectivores (Johns 1985). If fruiting trees are retained in the logged sites, then frugivores are less likely to get affected. The insectivores, on the other hand, are sensitive to microclimatic changes following logging. The changes in insect abundance and availability of suitable perch sites can reduce the abundance of insectivore. These species may disappear immediately after logging, and may or may not recolonize the area depending upon the extent of change in the site. Most studies on selective logging have reported a greater decline in

insectivores than in other guilds. Absence of suitable nesting sites in logged sites causes a decline in bird populations. However, some hole - nesters such as hornbills did not decline in logged sites, as holes were easily formed in the damaged trees (Johns 1997). Density of raptors also increased in the logged sites due to increased visibility and availability of prey in the area (Johns 1983, 1985). In the CL site at Chunkhedi, I observed a nest of White- Eyed Buzzard after logging, suggesting that the prey accessibility may have been enhanced in the logged site as suggested by Johns (1985).

Selective logging system has its merit in being "conservative". However, it is to be noted that despite selective and conservative felling, bird communities did show differences in the recently logged and CL sites. An increase in total species richness or diversity after felling does not indicate a prosperous system because an increase in the number of generalist species at the cost of specialists does not make ecological sense.

To reduce the negative impact of logging there are balancing strategies that could be introduced in the system by way of protective measures that can lessen the ecological loss. There are corrective factors that can reduce the detrimental effects of selective logging by creating suitable habitats for all species.

4.4 Management recommendations for the Satpura Conservation Area

The suggestions given here are an outcome the study carried out in the area. These are specific to the site and applicable to areas mentioned in the study. Objectives of effective wildlife management should be to maintain viable populations all native species. Management efforts should clearly focus on those species that will be negatively impacted by logging. One strategy for maintaining these species is to incorporate component of old -growth forests such as snags, large sized trees and unlogged sites within logged sites. Although, these recommendations are already included in the working plan, they should be always reviewed with latest findings from surveys and reports.

Recommendations prior to logging

1. Presently, total enumeration of principal timber tree species is carried out prior to logging, while the rest of the species are grouped as miscellaneous trees. It is suggested that along with timber trees, all other trees, shrubs and climbers should be enumerated so that a complete vegetation profile of the site could be obtained. This information could be used to procure details about the most dominant species in the site, the regeneration pattern and density of endemic or rare trees, and shrub species. This way, the potential of logged areas can be assessed in terms of vegetation diversity and its ability to regenerate after logging.

2. Before a compartment is marked for logging, a complete survey of the site can be carried out to assess the diversity of flora and fauna in the site. Survey work could be given as research projects for professional workers from private agencies, like NGOs, local nature clubs or WWF. Provision for the budget can be made from the territorial funds of the Forest department. The findings of this survey could be used for comparing results before and after logging. The project can have several components to assess the effect of logging in an area. At preliminary level, a complete inventory of all life forms should be carried out. Species of trees, shrubs and climbers utilized by birds and other animals for feeding and other purpose should be recorded. Sites for nesting, denning and roosting should be on located and marked. Later, these findings could be brought about prior to logging in setting aide areas of biological importance. For instance, nesting, roosting and denning sites should be marked on the treatment map and felling should not be permitted close to these sites. The marking and felling of trees should be done after ascertaining that major food trees in the site will not be affected due to felling. As per the existing felling rules, snags, caves and hollows should be marked against felling.

3. Apart from already delineated areas, felling should be avoided near roadside, and boundaries of the compartment. Very often there are large trees present on the boundaries and roadsides and these are felled. Felling these trees would result in exposing the sites near roads and isolating the area from the surrounding natural forests.

4. The compartments to be felled are usually located close to each other. This certainly has its benefits as mentioned earlier. But on the longer run, the forest may have all recently logged sites located close to each other and there would be no older logged forests close by. To preserve the mosaic of habitat heterogeneity, we suggest that alternate compartments should be marked for felling. Once the logged compartment has matured sufficiently to support resource requirements by mature forest fauna, the neighboring compartment could be felled. This matrix of logged and unlogged sites would add to the biological diversity of an area.

5. There are detailed instruction regarding the direction in which each marked tree should be felled, but often this is not followed. This is a very important aspect, and it should be implemented. The range officer can mark the direction in which each tree has to be felled with paint on a nearby tree before logging. This should be done after assessing the direction of least damage to vegetation. Climbers cutting as suggested by the felling rules should be done prior to felling.

6. Apart from species that are reserved from felling, trees of *Bridelia retusa, Adina cordifolia, Mitragyna parviflora, Schrebera swietenioides* should be retained in greater proportion in main fellings. Species such as Yellowlegged Green Pigeon, parakeets, mynas, Blackcapped Blackbird, birds were observed to be feeding on the fruits and flowers of these species. Many insectivores also use the flowers as feeding resource.

During logging

7. The fallen trees are cut into smaller logs and are carted by bullock carts. The trails used by bullock carts should be marked out and made use of regularly to prevent further damage to surrounding vegetation. This would prevent development of a large number of haphazardly developed track systems in the site.

8. If larger trees are not available, felling of smaller trees should be avoided. Logging smaller trees not only reduces the overall diversity, and richness but also lowers the number of trees in the pre-harvest class. A review of marking

rules is necessary so that adequate numbers of trees in lower diameter classes are retained.

Post logging

9. The fallen logs of economical viability should be removed as soon as possible, so the area is not disturbed over unduly longer periods. However, uneconomical large hollow logs may be left on the forest floor for use by small mammals and birds. The peak season in forestry working is summer and that is also the breeding season. While this is a principle routine followed in silvicultural systems, a review is necessary keeping wildlife management in focus as well as timber logging.

10. The forest department in Madhya Pradesh and Maharashtra prescribes planting 50 % teak, 15 per cent fruit trees and 35 % other species. Many birds and arboreal animals eat *ficus* fruits. *Ficus* stakes could be planted in logged sites. These should be of mixed species so that minimum 5 established *Ficus* trees per hectare could develop.

11. Repeated thinning after logging should be minimized. The interval between two thinning should be minimum 20 years. The logged sites should be protected from fire and grazing to prevent further damage as is the standard practice.

12. Provision of Preservation plots should be mandatory in each area where logging is going on. Unlogged areas greater than 200 ha should be declared as preservation plots. At least 5 compartments of this size should be protected as preservation plot. Small sized plots are of limited use in the conservation of native flora and fauna. Apart from serving as refugia for faunal population, these plots can serve as ecological reference centers for each forest types. Preservation plots have a temporal function over the period of time. From these plots, one can estimate the changes in tree species composition, regeneration, and diversity following disturbance.

13. The logged sites should be monitored regularly for assessing the rate of recovery of species and vegetation regeneration. This information can be used to modify the felling cycle, felling rules and management recommendations.

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* Original paper not seen.

APPENDIX 1

Bird list of Bori Wildlife Sanctuary and Melghat Tiger Reserve (November 1992 - June 1996).

			BORI	MELGHAT	STATUS
	FAMILY : PODICIPEDIDAE				
1.	Little Grebe	*Podicep ruficollis*	*	*	WU
	FAMILY : PHALACOCORACIDAE				
2.	Indian Shag	*Phalacrocorax fusicollis*	*		WC
3.	Little Cormorant	*P.niger*	*	*	WC
4.	Darter	*Anhinga rufa*	*		WC
	FAMILY : ARDEIDAE				
5.	Grey Heron	*Ardea cinerea*	*		U
6.	Pond Heron	*A. grayii*	*	*	RC
7.	Purple Heron	*A. pupurea*	*		RC
8.	Night Heron	*Nycticorax nycticorax*	*		RU
9.	Little Green Heron	*A.rdea striatus*	*		RC
10.	Cattle Egret	*Bubulcus ibis*	*	*	RC
11.	Large Egret	*Ardea alba*	*	*	MU
12	Median Egret	*Egretta intermedia*	*		MU
13	Little Egret	*E. garzetta*	*	*	RC
	FAMILY : CICONIIDAE				
14.	Whitenecked Stork	*Ciconia episcopus*	*	*	R0
15.	Openbilled Stork	*Anastomus oscitanus*	*		R0
16.	Black Stork	*Ciconiia nigra*	*	*	WU
	FAMILY : THRESKIORNITHIDAE				MU
17.	White Ibis	*Threskiornis aethiopica*	*	*	MU
18.	Black Ibis	*Psuedibis papillosa*	*	*	BU
19.	Spoonbill	*Platalea leucordia*	*		MU
20.	Glossy Ibis	*Plegadis falcinellus*	*		BU
	FAMILY : ANATIDAE				
21.	Ruddy Shelduck	*Tedorna ferruginea*	*	*	WU
22.	Pintail	*Anas acuta*	*		WU
23.	Lesser Whistling Teal	*Dendrocygna bicolor*	*	*	WU
24.	Spotbilled Duck	*Anas poecilorhyncha*	*	*	MU
	FAMILY : ACCIPTRIDAE				
25.	Blackwingwd Kite	*Elanus caeruleus*	*	*	RC
26.	Honey Buzzard	*Pernis ptilorhyncus*	*	*	RC

27.	Pariah Kite	*Milvus migrans govinda*	*	*	RC
28.	Brahminy Kite	*Haliastur indus*	*	*	RC
29.	Shikra	*Accipiter badius*	*	*	RC
30.	White-eyed Buzzard	*Butastur teesa*	*	*	RC
31.	Crested Hawk Eagle	*Spizhaetus cirrhatus*	*	*	RC
32.	Bonelli's Eagle	*Hieraaetus fasciatus*	*	*	RU
33.	Tawny Eagle	*Aquila rapax vindhiana*	*	*	RU
34.	Sparrow Hawk	*Accipiter nisus nisosimilis*	*	*	RC
35.	Cinereous Vulture	*Aegypius monachus*	*		WU
36.	Indian Longbilled Vulture	*Gyps indicus*	*	*	RU
37.	Indian Whitebacked Vulture	*G. bengalensis*	*	*	RU
38.	Indian Scavanger Vulture	*Nephron percnopterus*	*	*	RC
39.	Short-toed Eagle	*Circaetus gallicus*	*	*	RU
40.	Crested Serpent Eagle	*Spilornis cheela*	*	*	RC
41.	Osprey	*Pandion haliaetus*	*	*	WU
	FAMILY : FALCONIDAE				
42.	Lagger Falcon	*Falco biamicus jugger*		*	WU
43.	Kestrel	*F. Tinnunculus*	*	*	WO
44.	Peregrine Falcon	*F. peregrinus japonensis*	*	*	WU
	FAMILY : PHASIANIDAE				
45.	Black Partridge	*Francolinus francolinus*	*	*	RC
46.	Grey Partridge	*F.pondicerianus*	*	*	RC
47.	Jungle Bushquail	*Perdicula asiatica*	*	*	RC
48.	Rock Bushquail	*P.argoondah*	*	*	RC
49.	Red Spurfowl	*Galloperdix spadicea*	*	*	RC
50.	Grey Junglefowl	*Gallus sonneratii*	*	*	RC
51.	Common Peafowl	*Pavo cristatus*	*	*	RC
	FAMILY: TURNICIDAE				
52.	Little Bustardquail	*Turnix sylvatica*			RC
53.	Common Bustardquail	*Turnix suscitator*	*	*	RC
	FAMILY : RALLIDAE				
54.	Whitebreasted Waterhen	*Amanornis phoenicurus*	*	*	RU
55.	Redwattled Lapwing	*Vanellus indicus*	*	*	RC
56.	Spurwinged Lapwing	*V. spinosus*	*	*	RU
57.	Little Ringed Plover	*Charadrius dubius*	*	*	WU
58.	Greenshank	*Tringa nebularia*	*	*	WU
59.	Green Sandpiper	*T. ochropus*	*	*	WC
60.	Common Sandpiper	*T. hypoleucos*	*	*	WC
61.	Coot	*Fulica atra*	*	*	WU
62.	Purple Moorhen	*Porphyrio porphyrio*	*	*	WU
	FAMILY: JACANIDAE				
63.	Bronzewinged Jacana	*Hydrophasainus chirurgus*	*		WU
64.	Phesant-tailed Jacana	*Metopidus indicus*	*		WU

	FAMILY : RECURVIROSTRIDAE				
65.	Blackwinged Stilt	*Himantopus himantopus*	*	*	RC
	FAMILY : GLAREOLIDAE				
66.	Indian Courser	*Cursorius coromandelicus*		*	RC
67.	Small Indian Pratincole	*Glareola lactea*	*	*	RC
	FAMILY : LARIDAE				
68.	Indian River Tern	*Sterna aurantia*	*		WU
69.	Brownheaded Gull	*Larus brunnicephalus*	*		WU
	FAMILY : PTEROCLIDIDAE				
70.	Indian Sandgrouse	*Pterocles exustus*		*	MU
71.	Painted Sandgrouse	*P. indicus indicus*		*	MU
	FAMILY : COLUMBIDAE				
72.	Yellowlegged Green Pigeon	*Treron phoenicoptera*	*	*	RC
73.	Rufous Turtle Dove	*Streptopelia orientalis*	*	*	WC
74.	Indian Ring Dove	*S.decaocto*	*	*	RC
75.	Red Turtle Dove	*S.tranquebarica*	*	*	RC
76.	Spotted Dove	*S.chinensis*	*	*	RC
77.	Little Brown Dove	*S.senegalensis*	*	*	RC
78.	Emerald dove	*Chalcophaps indica*	*		RU
	FAMILY : PISITTACIDAE				
79.	Alexandrine Parakeet	*Psittacula eupatria*	*	*	RC
80.	Roseringed Parakeet	*P. krameri*	*	*	RC
81.	Blossomheaded Parakeet	*P. cyanocephalus*	*	*	RC
	FAMILY : CUCULIDAE				
82.	Pied crested Cuckoo	*Clamator jacobinus*	*	*	BC
83.	Common Hawk Cuckoo	*Cuculus varius*	*	*	BC
84.	Indian Cuckoo	*C. micropterus*	*	*	BC
85.	Small Cuckoo	*C. poliocephlaus*	*	*	BC
86.	Indian Plaintive Cuckoo	*Cacomantis passemius*	*	*	BC
87.	Indian Baybanded Cuckoo	*C. sonneratii*	*	*	RC
88.	Koel	*Eudynamus scolopacea*	*	*	RU
89.	Sirkeer Cuckoo	*Taccocua leschenaultii*	*	*	RC
90.	Crow -Pheasant	*Centropus sinensis*	*	*	RC
	FAMILY : STRIGIDAE				
91.	Collared Scops Owl	*Ottus bakkamoena*	*	*	RU
92.	Barn Owl	*Tyto alba*	*	*	RC
93.	Great Horned Owl	*Bubo bubo*	*	*	RC

94.	Forest Eagle Owl	*B.nipalensis*	*		RU
95.	Brown Fish Owl	*B.zeylonensis*	*	*	RC
96.	Jungle Owlet	*Glaucidium radiatum*	*	*	RC
97.	Brown Hawk Owl	*Ninox scutulata*	*		RU
98.	Spotted Owlet	*Athene brama*	*	*	RC
99.	Mottled Wood Owl	*Strix ocellata*		*	RC
	FAMILY : CAPRIMULGIDAE				
100.	Indian Jungle Nightjar	*Caprimulgus indicus*	*	*	RC
101.	Common Indian Nightjar	*C. asaiticus*	*	*	RC
102.	Franklin's Nightjar	*C.affinis*	*	*	RC
	FAMILY : APODAIDAE				
103.	Alpine Swift	*Apus melba*	*	*	RU
104.	House Swift	*Apus affinis*	*	*	RC
105.	Crested Tree Swift	*Hemiprocne longipennis*	*	*	RU
106.	Whiterumped Spinetail Swift (?)	*Chaetura sylvatica*			RU
	FAMILY : ALCEDINIDAE				
107.	Common Kingfisher	*Alcedo atthis*	*	*	RC
108.	Whitebreasted Kingfisher	*Halcyon smyrnensis*	*	*	RC
109.	Pied Kingfisher	*Ceryle rudis*	*	*	RC
110.	Storkbilled Kingfisher	*Pelargopsis capensis*	*	*	RU
111.	Blackcapped Kingfisher	*Halcyon pileata*		*	MU
	FAMILY : MEROPIDAE				
112.	Green Bee eater	*Merops orientalis*	*	*	RC
113.	Bluebearded Bee-Eater	*Nyctyornis athertoni*	*		WU
	FAMILY : COARCIIDAE				
114.	Indian Roller	*Coracias benghalensis*	*	*	RC
	FAMILY : UPUPIDAE				
115.	Hoopoe	*Upupa epops*	*	*	RC
	FAMILY : BUCERITODAE				
116.	Common Grey Hornbill	*Tockus birostris*	*	*	RC
117.	Malabar Pied Hornbill	*Anthracoceros coronatus*	*		RU
	FAMILY : CAPITONIDAE				
118.	Large Green Barbet	*Megalaima zeylanica*	*	*	RC
119.	Crimsonbreasted Barbet	*M.rubricapilla rubricapilla*	*	*	RC
	FAMILY : PICIDAE				
120.	Wryneck	*Jynx torquilla*	*	*	WU
121.	RufousWoodpecker	*Micrpternus brachyurus*	*		RU

122. Small Yellownaped Woodpecker	*Picus chlorolophus chlorigaster*	*	*	RC
123. Lesser Goldenbacked Woodpecker	*Dinopium benghalensis*	*	*	RC
124. Yellowfronted Pied Woodpecker	*Picoided maharattensis*	*	*	RC
125. Browncapped Pigmy Woodpecker	*Picoides nanus*	*	*	RC
126. Blackbacked Woodpecker	*Chrysocolaptes festivus*	*	*	RU
FAMILY : PITTIDAE				
127. Indian Pitta	*Pitta brachyura*	*	*	BU
FAMILY : ALUDIDAE				
128. Ashycrwoned Finch Lark	*Eremopterix grisea*	*	*	MC
129. Rufoustailed Finch Lark	*Ammomanes phoenicurus*	*	*	MC
130. Small or Eastern Skylark	*Alauda gulgula*	*	*	RC
FAMILY : HIRUNDINIDAE				
131. Dusky Crag Martin	*Hirundo concolor*	*	*	WC
132. Redrumped Swallow	*H.daurica*	*	*	WC
133. Wiretailed Swallow	*H.smithii*	*	*	RC
134. Cliff Swallow	*H. fluvicola*		*	RC
FAMILY : LANIIDAE				
135. Grey Shrike	*Lanius excubitor*	*	*	RC
136. Baybacked Shrike	*L. vittatus*	*	*	RC
137. Rufousbacked Shrike	*L. schach*	*	*	WU
138. Brown Shrike	*L.cristatus*	*	*	WU
FAMILY : ORIOLIDAE				
139. Golden Oriole	*Oriolus oriolus*	*	*	RC
140. Black headed Oriole	*O. xanthornus*	*	*	RC
FAMILY : DICRURIDAE				
141. Black Drongo	*Dicrurus adsimillis*	*	*	RC
142. Whitebellied Drongo	*D.caerulscens*	*	*	RC
143. Haircrested Drongo	*D.hottentottus*	*	*	WU
144. Large Racquettailed Drongo	*D. paradiseus*	*	*	RC
FAMILY : ARTAMIDAE				
145. Ashy Swallow-Shrike	*Artamus fuscus*	*	*	MU
FAMILY : STURNIDAE				
146. Greyheaded Myna	*Sturnus malabaricus*	*	*	MC
147. Black headed Myna	*S. pagodarum*	*	*	BC
148. Rosy Pastor	*S.roseus*	*	*	MU
149. Pied Myna	*S. contra*	*	*	RC
150. Commom Myna	*Acridotheres tristis*	*	*	RC
151. Bank Myna	*A. gingianus*	*	*	RU

152. Jungle Myna	*A. fuscus*	*	*	RU
FAMILY : CORVIDAE				
153. Indian Tree Pie	*Dendrocitta vagabunda*	*	*	RC
154. House Crow	*Corvus splendens*	*	*	RC
155. Jungle Crow	*Corvus macrorhynchos*	*	*	RC
FAMILY : CAMPEPHAGIDAE				
156. Pied Flycatcher Shrike	*Hemipus picatus*	*	*	RC
157. Common Wood Shrike	*Tephrodornis pondicerianus*	*	*	RC
158. Large Cuckoo-Shrike	*Coracina novaehollandiae*	*	*	MC
159. Black headed Cuckoo-Shrike	*C. melanoptera*	*	*	RC
160. Scarlet Minivet	*Pericrocotus flammeus*	*	*	RC
161. Small Minivet	*P. cinnamomeus*	*	*	RC
162. Whitebellied Minivet	*P. erythropygius*	*	*	RU
FAMILY : IRENIDAE				
163. Iora	*Aegithina tiphia*	*	*	RC
164. Goldmantled Chloropsis	*Chloropsis cochinchinensis*	*	*	RC
165. Goldenfronted Chloropsis	*C. aurifrons*	*	*	RU
FAMILY : PYCNONOTIDAE				
166. Redwhiskered Bulbul	*Pycnonotus jocosus*	*	*	RC
167. Redvented Bulbul	*P.cafer*	*	*	RC
FAMILY : MUSCICAPIDAE				
subfamily : Timalinae				
168. Spotted Babbler	*Pellorneum ruficeps*	*	*	RC
169. Deccan Slatyheaded Scimitar Babbler	*Pomatorhinus horsfieldii schisticeps*	*	*	RC
170. Rufousbellied Babbler	*Dumentia hyperythra*	*	*	RU
171. Yelloweyed Babbler	*Chrysomma sinense*	*	*	RC
172. Common Babbler	*Turdoides caudatus*	*	*	RC
173. Large Grey Babbler	*T.malcolmi*	*	*	RC
174. Jungle Babbler	*T. straitus*	*	*	RC
175. Quaker Babbler	*Alcippe poioicephala*	*	*	RC
subfamily : Muscicapinae				
176. Redbreasted Flycatcher	*Muscicapa parva*	*	*	WC
177. Whitebrowed Blue Flycatcher	*M.superciliaris*	*	*	WU
178. Tickell's Blue Flycatcher	*M.tickelliae*	*	*	RC
179. Verditer Flycatcher	*M.thalassina*	*	*	RC
180. Greyheaded Flycatcher	*Culicicapa ceylonensis*	*	*	WC
181. Whitebrowed Fantail Flycatcher	*Rhipidura aureola*	*	*	RC
182. Whitespotted Fantail Flycatcher	*R. albicollis*	*	*	RC
183. Paradise Flycatcher	*Terpsiphone paradisi*	*	*	RC
184. Brown Flycatcher	*Muscicapa latirostris*	*	*	RU
185. Blacknaped Blue Flycatcher	*Hypothymis azurea*	*	*	RC
186. Black and Yellow Flycatcher	*Muscicacpa ficedula*			WU

subfamily : Sylviinae

187. Franklin's Wren- Warbler	*Prinia hodgsonii*			RC
188. Plain Wren-Warbler	*P.subflava*	*	*	RC
189. Ashy Wren- Warbler	*P. socialis*	*	*	RC
190. Jungle Wren-Warbler	*P.sylvatica*	*	*	RC
191. Tailor Bird	*Orthotomus sutorius*	*	*	RC
192. Blyth's Reed Warbler	*Acrocephalus dumetorum*	*	*	WC
193. Brown Leaf Warbler	*Phllyscopus collybita*	*	*	WC
194. Olivaceous Leaf Warbler	*P. griseolus*	*	*	WC
195. Yellowbrowed Leaf Warbler	*P.inornatus*	*	*	WC
196. Dull Green Leaf Warbler	*P.trochiloides*	*	*	WC
197. Blyth's Leaf Warbler	*P.reguloides*	*	*	WC
198. Lesser Whitethroat	*Sylvia curruca*		*	WU

subfamily : Turnidae

199. Magpie-Robin	*Copsychus saularis*	*	*	RC
200. Black Redstart	*Phoenicurus ochruros rufiventris*	*	*	WC
201. Collared Bush Chat	*Saxicola torquata*	*	*	WC
202. Pied Bush Chat	*S.caprata*	*	*	RC
203. Indian Robin	*Saxicoloides fulicata*	*		RC
204. Blue Rock Thrush	*Monticola solitarus*	*		WU
205. Blue headed Rock Thrush	*M. cincloryhnchus*			WU
206. Malabar Whistling Thrush	*Myiophonus horsfieldii*	*	*	RC
207. Orangeheaded Ground Thrush	*Zoothera citrina cyanotus*	*	*	RC
208. Blackcapped Blackbird	*Turdus merula nigropileus*			BC

FAMILY: PARIDAE

209. Grey Tit	*Parus major*	*	*	RC
210. Yellow-cheeked Tit	*P. xanthogenys*	*	*	RC
211. Firecapped Tit	*Cephalopyrus flammiceps*	*		WU

FAMILY : SITTIDAE

212. Chestnutbellied Nuthatch	*Sitta castanea*	*	*	RC
213. Velvetfronted Nuthatch	*Sitta frontalis*	*	*	RC
214. Spotted Grey Creeper	*Salpornis spilonotos*	*	*	RU

FAMILY : MOTACILLIDAE

215. Indian Tree Pipit	*Anthus hodgsoni*	*	*	WC
216. Tree Pipit	*Anthus trivialis*	*	*	WC
217. Brown Rock Pipit	*Anthus similis*	*		WU
218. Paddyfield Pipit	*A.novaeseelandiae*	*	*	WU
219. Yellowheaded Wagtail	*Motacilla citreola*	*	*	WC
220. Grey Wagtail	*M. cinerea*	*	*	WC
221. White Wagtail	*M.alba dukhunensis*	*	*	WC
222. Large Pied Wagtail	*M. maderaspatensis*	*	*	RC

FAMILY : DICAEIDAE				
223. Thickbilled Flowerpecker	*Dicaeum agile*	*	*	RU
224. Tickell's Flowerpecker	*D.erythrorhynchos*	*	*	RU
FAMILY : NECTARINIDAE				
225. Purplerumped Sunbird	*Nectarinia zeylonica*	*	*	RC
226. Purple Sunbird	*N.asiatica*	*	*	RC
FAMILY : ZOSTEROPIDAE				
227. White-Eye	*Zosterops palpebrosa*	*	*	RC
FAMILY : PLOCEIDAE				
228. House Sparrow	*Passer domesticus*	*	*	RC
229. Yellowthroated Sparrow	*Petronia xanthocolliis*	*	*	RC
230. Baya	*Ploceus philippinus*	*	*	RU
231. Streaked Weaver Bird	*P.manyar*	*	*	RU
232. Red Munia	*Estilda amandava*	*	*	RU
233. Green Munia	*E. formosa*		*	RU
234. Whitebacked Munia	*Lonchura striata*	*		RU
235. Whitethroated Munia	*L.malabarica*	*	*	RU
236. Spotted Munia	*L.punctulata*	*	*	RU
FAMILY : FRINGILLIDAE				
237. Common Rosefinch	*Carpodacus erythrinus*	*	*	WC
FAMILY : EMBERIZIDAE				
238. Blackheaded Bunting	*Emberiza melanocephala*	*	*	WC
239. Greynecked Bunting	*E.buchanani*	*	*	WC
240. Crested Bunting	*Melophus lathami*			WC

The common and scientific names of species and classification follows Ali and Ripley (1983). The last column refers to movement status and abundance scale of each species.

R - Resident
W - Winter migrant
M - Migrant (Species whose movement records were uncertain)
B - Breeding migrant
C - Common
U - Uncommon
O - Occasional

APPENDIX 2

Morisita- Horn Similarity Index for bird species composition across all logged sites in Bori Wildlife Sanctuary.

		CWR												
		7yr	20 yr	40yr	7 yr	20yr	40yr	7yr	20yr	60yr	6yr	20yr	80yr	*PP
	7 yr	*	0.75	0.88	0.87	0.69	0.11	0.43	0.49	0.56	0.33	0.17	0.19	0.16	0.18
CWR	20 yr	*	*	0.74	0.8	0.89	0.17	0.44	0.47	0.62	0.29	0.21	0.32	0.22	0.27
	40 yr	*	*	*	0.85	0.89	0.22	0.47	0.45	0.61	0.26	0.24	0.34	0.17	0.22
	7 yr	*	*	*	*	0.77	0.76	0.66	0.69	0.71	0.21	0.26	0.41	0.37	0.23
SCI	20 yr	*	*	*	*	*	0.65	0.65	0.68	0.61	0.29	0.32	0.71	0.42	0.31
	40 yr	*	*	*	*	*	*	0.55	0.59	0.41	0.69	0.81	0.67	0.66	0.26
	7 yr	*	*	*	*	*	*	*	0.82	0.71	0.31	0.34	0.59	0.61	0.32
GTFS	20 yr	*	*	*	*	*	*	*	*	0.54	0.34	0.29	0.44	0.41	0.48
	60 yr	*	*	*	*	*	*	*	*	*	0.21	0.49	0.61	0.77	0.54
	6 yr	*	*	*	*	*	*	*	*	*	*	0.29	0.31	0.19	0.61
STFS	20 yr	*	*	*	*	*	*	*	*	*	*	*	0.58	0.69	0.21
	80 yr	*	*	*	*	*	*	*	*	*	*	*	*	0.81	0.53
	*PP	*	*	*	*	*	*	*	*	*	*	*	*	*	0.69

*PP – Preservation plot.

APPENDIX 3

Morisita- Horn Similarity Index for tree species composition across all logged sites in Bori Wildlife Sanctuary.

		CWR			SCI			GTFS			STFS			
		7 yr	20 yr	40 yr	7 yr	20 yr	40 yr	7 yr	20 yr	60 yr	6 yr	20 yr	80 yr	*PP
	7 yr	*	0.70	0.72	0.60	0.69	0.80	0.43	0.49	0.40	0.33	0.17	0.30	0.27
CWR	20 yr	*	*	0.82	0.80	0.77	0.60	0.70	0.47	0.70	0.29	0.40	0.40	0.22
	40 yr	*	*	*	0.85	0.82	0.50	0.34	0.45	0.60	0.19	0.45	0.34	0.23
	7 yr	*	*	*	*	0.67	0.78	0.33	0.34	0.34	0.18	0.38	0.36	0.31
SCI	20 yr	*	*	*	*	*	0.81	0.54	0.50	0.30	0.22	0.32	0.31	0.26
	40 yr	*	*	*	*	*	*	0.45	0.49	0.46	0.21	0.34	0.21	0.32
	7 yr	*	*	*	*	*	*	*	0.84	0.80	0.31	0.34	0.42	0.48
GTFS	20 yr	*	*	*	*	*	*	*	*	0.78	0.28	0.33	0.65	0.54
	60 yr	*	*	*	*	*	*	*	*	*	0.25	0.54	0.67	0.61
	6 yr	*	*	*	*	*	*	*	*	*	*	0.34	0.13	0.21
STFS	20 yr	*	*	*	*	*	*	*	*	*	*	*	0.45	0.53
	80 yr	*	*	*	*	*	*	*	*	*	*	*	*	0.69
	*PP	*	*	*	*	*	*	*	*	*	*	*	*	*

*PP – Preservation plot.