SHIFTING CULTIVATION AND CONSERVATION OF TROPICAL FOREST BIRD COMMUNITIES IN MIZORAM, NORTH-EAST INDIA.

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BY
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UNDER THE SUPERVISION OF
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Dedicated to the wonderful village people

of Mizoram

> *" .... a faithful description of real cases converts ... science into natural history, in which unique details are as important as the principles by which they are explained."*
>
> - E. O. Wilson, *The diversity of life.*

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that T. R. Shankar Raman of the Wildlife Institute of India has carried out a piece of original research work entitled "Shifting cultivation and the conservation of tropical forest bird communities in Mizoram, North-east India" in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot. These investigations were carried out under my supervision at the Wildlife Institute of India from November 1994 to July 1995. I also certify that this work has not been submitted for any other degree of any other university.

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SUMMARY

The impact of the traditional practice of shifting cultivation or *jhum* on evergreen and semi-evergreen forest bird communities was studied in Dampa Tiger Reserve in western Mizoram, north-east India. Bird community changes through vegetation succession was studied by comparing sites that were *jhumed* 1, 5, 10, 25, and 100 years ago with primary forest that has never been cleared. Systematic line-transect sampling showed that bird species richness, abundance, and diversity, increased from very low levels in the 1-year old fallow to maximum levels in undisturbed and 100-year old forest, with intermediate values in the 5-25 year fallows (bamboo forests). The trend of increase was not linear but hyperbolic, with a rapid increase up to 25 years approaching an asymptote at 100 years or so. Similarity in bird community composition between two sites was inversely related to the difference in the logarithm of their ages.

Trends in bird communities were closely related to changes during vegetation succession. Vegetation variables measured were summarised by Principal Components Analysis, which yielded two components (PC1 and PC2), accounting for 91.9% percent of the variance in the data-set. PC1 was correlated positively with tree density, woody plant species richness, vertical stratification, depth of leaf litter, and canopy cover, and negatively with horizontal heterogeneity in the vegetation. PC1 thus represents the changes occurring during woody plant succession. PC2 was correlated strongly with bamboo density, which shows an increase from 1 to at least 25 years after *jhuming* and declines in mature forest, and this axis was taken to represent bamboo succession.

Bird species richness and abundance were positively correlated with PC1 (woody plant succession). When the effects of PC1 were removed by partial correlation, both variables were negatively correlated with PC2. The number of species in guilds such as frugivores, nectarivore-insectivores, bark-feeder, canopy insectivores were positively related to PC1. Only the bamboo-substrate feeding guild was related to PC2. These results suggest that bird community structure is largely determined by woody plant succession. Mature forests were found to be the main habitat for forest specialists, rare birds, and altitudinal migrants. Thirteen specialised open-country birds and two species of latitudinal migrants occurred mainly in *jhumed* areas. These were generally common and widespread

species that will likely persist in highly disturbed areas. In terms of conservation of the forest birds of the region, mature forests are most important.

The major implication of the study relates to the observed hyperbolic changes in bird species richness, and vegetation variables such as woody plant species richness. This suggests species loss in *jhumed* areas will be a logarithmic and not linear function of the age, i.e. a decline in *jhum* cycle from 100 to 50 years (a 2-fold difference) will have less impact than a decline from 25 to 5 years (a 5-fold difference). This implies that under the 5-10 year *jhum* cycles that are prevalent in most parts of north-east India today, there will be substantial losses in bird species richness. This effect may be accentuated if primary forests are not part of the *jhum* habitat matrix.

1. INTRODUCTION

1.1 *General Introduction*

Changes brought about by human land-use practices on natural landscapes in the tropics are of increasing concern today for those interested in the conservation of biological diversity. Land-use practices that alter the relative proportions of primary and secondary habitats can lead to changes in the abundance and distribution of species and in the overall community structure (Pickett and White 1985, Askins and Philbrick 1987). It is plausible that such impacts may be particularly pronounced in complex, species-rich tropical habitats such as moist evergreen and semi-evergreen forests, which are globally acknowledged to be reservoirs of biological diversity.

In India, an important region containing extensive tropical evergreen and semi-evergreen forests is north-east India, in the Eastern Himalayas and north-east hill states (Champion and Seth 1968). This region is among the top 18 biodiversity 'hot-spots' identified in the world (Myers 1988, 1990). Currently, human land-use practices such as unregulated logging and conversion to agriculture are believed to be responsible for widespread environmental degradation and loss of nearly two-thirds of the estimated 340,000 km^2 of forest area that existed in the Eastern Himalayan region (Myers 1988, 1990). Numerous authors have implicated the traditional practice of shifting agriculture or *jhum* as a major factor in the loss of forests and biodiversity in the region (see Literature Review). *Jhum*, variously termed as rotational bush-fallow agriculture, swidden cultivation, or slash-and-burn cultivation, is the predominant form of land-use in the hills of north-east India today. At least 100 different indigenous tribes and over 620,000 families depend on *jhum* for their subsistence in the NE region (Ramakrishnan 1992). *Jhum* typically creates a patchy mosaic of secondary successional vegetation ranging from recently abandoned weedy-herbaceous fallows to dense bamboo forest, mixed tree-and-bamboo late successional forest, and remnants of primary forest (Ramakrishnan 1992). The questions that arise are: 'Does *jhum* really have substantial negative impact on the biodiversity of the tropical forest ecosystems in north-east India? What are the processes governing secondary succession in abandoned *jhum* fallows and the recovery of the tropical forest ecosystem.' Despite much that has been written, the answers to this question have at best been sketchy and restricted to illustrative reports and surveys in the past (see Literature Review).

Bird communities are particularly suitable for studying the process of ecosystem recovery concurrent to vegetation succession. By determining whether different bird species exhibit a diversity of responses through succession one can attempt to gain a deeper insight into the dynamics of these changes. The process of recovery of the forest ecosystem after *jhum* can basically be studied in two ways. One, is by monitoring particular *jhum* fields over a long time-period of, say, several decades, or, alternatively, by comparing sites which had been cleared at various time-periods in the past and which currently represent various stages of recovery. For practical reasons, the latter approach was followed in this study, and sites cleared 1, 5, 10, 25, and 100 years ago have been compared with moderately disturbed, and undisturbed primary forest. Also, the hill ranges of north-east India are known to be particularly diverse in terms of bird species - at least 534 species were recorded in the Eastern Himalayas by Ali (1978) but recent records indicate that there may be as many as 657 species in Arunachal Pradesh alone (Singh 1994). A scientific appraisal of the impact of *jhum* on the diverse bird communities of the region would thus be a valuable prerequisite in determining conservation policies. With this as the primary goal, I carried out this study in Dampa Tiger Reserve in the hills of Mizoram state in north-east India. I present a brief review of relevant literature below after which the main study questions are posed.

1.2 *Literature review*

1.2.1 *Avifauna and biogeography of north-east India*

A measure of the diversity of birds in north-east India can be obtained by looking at the avifauna of Arunachal Pradesh, a state which has been relatively well-surveyed ornithologically (see Ali 1978, Katti *et al.* 1992, Singh 1994). Singh's (1994) recent compilation of 657 species for

Arunachal Pradesh represents over 50% of the bird species known to occur in the Indian sub-continent (Ali and Ripley 1983). Of the 657 species, 578 species are land birds. In comparison, the avifauna in the Western Ghats in south-west India, comprises 507 species, of which only 363 are land birds (Daniels *et al.* 1992). The vast majority of the birds in north-east India are forest species, occurring typically in moist forests. The fact that the number of bird species in families that typify humid forests, such as Columbidae, Trogonidae, Bucerotidae, Capitonidae, Picidae, Pycnonotidae, Muscicapidae (particularly sub-family *Timaliinae*, the babblers), are much higher in Eastern Himalayas and North-east Hill States reinforces the point that the humid forests here are richer in bird species than in the Western Ghats (Daniels *et al.* 1992). This is presumably because the forests of north-east India are contiguous with forest tracts of Yunnan, Myanmar, and south-east Asia.

North-east India is considered to be a biogeographic highway linking the Indian Peninsula to the Malay and Indochinese sub-regions (Mani 1974). The avifauna of the Indian sub-continent is predominantly Oriental, with 62% of the 176 endemic species showing affinities with the Indo-chinese sub-region (Ripley 1959). A peculiar aspect of the north-east Indian avifauna is the discontinuous distribution of several species. Species such as imperial pigeon, blackcrested and Blyth's baza, threetoed kingfisher, fairy bluebird etc. occur only in the humid evergreen forest biotope in north-east India and the Western Ghats and nowhere in-between (Ali and Ripley 1983). Other species occur only in these two regions and in Orissa and/or the Eastern Ghats, e.g. yellowbreasted babbler, hill myna, and little spiderhunter. However, a large number of species occur only in north-east India within the sub-continent.

1.2.2 *Shifting cultivation or* jhum *in north-east India*

A detailed review of the literature on shifting agriculture is outside the scope of this thesis. I highlight aspects of interest to north-east India. *Jhum* was widely labelled as a destructive practice from colonial times, and discrimination against tribes practising *jhum* has led to the disappearance of this form of cultivation from many parts of Peninsular India (von Fürer-Haimendorf 1982, Gadgil and Guha 1992, Guha 1994). Even today the view persists that *jhum* devastates forests (Tewari 1991, Dwivedi 1993, Lal and Prajapathi 1990), destroys biodiversity (Rao and Hajra 1986, Dwivedi 1993), and causes widespread environmental problems such as soil erosion and desertification (refs. above). However, empirical evidence to substantiate these claims are largely lacking for most of the Himalayan region. Even satellite estimates of changes in area under 'dense' and 'open' forests (due to *jhum* and other causes) are conflicting (GOI 1987).

Serious scientific and anthropological studies, in contrast, generally come out in favour of shifting cultivation as a form of land-use (Conklin 1969, von Fürer-Haimedorf 1982, Horst 1989). Shifting cultivation is often regarded as a well-adapted and diversified system of cultivation, but this view is often merely assumed and not scientifically substantiated (see review in Eden 1987). In India, detailed studies by Ramakrishnan (1992) indicate that stabilisation of *jhum* at a 10-year cycle appears most suitable to achieve ecological and economic efficiency without unduly disrupting traditional lifestyles of tribals. However, in some areas that have high human pressures on land it might be necessary to stabilise *jhum* at 5-year cycles using modern technical inputs, while concurrently developing agroforestry, horticulture, and other village-based occupations (Ramakrishnan 1992).

1.2.3 *Shifting cultivation and birds*

The literature on bird communities and plant succession is substantial (Odum 1950, Johnston and Odum 1956, Karr 1971, Shugart and James 1971, Smith and MacMahon 1981, and numerous other refs., see May 1982 and Wiens 1989). However, studies focusing specifically on the effects of shifting cultivation are surprisingly few. Kricher and Davis (1990), Lynch (1989, 1990), and other papers in Hagan and Johnston (1990) address the impact of traditional shifting agriculture or 'milpas' on birds in the Neotropics. These papers have highlighted the fact that several latitudinal migrants are abundant in successional habitats, but the main habitat for most residents and other long-distance migrants is mature tropical forest. Altitudinal migrants, in contrast, may occur largely in mature forest (Loiselle and Blake 1992) perhaps as they are more closely tied to the forest types within a given geographical region. Blankespoor (1991) found that the avifauna of abandoned fallows aged one to seven years in Liberia comprised very few primary forest specialists, more generalists, and showed a trend of increase in bird species richness with age of successional vegetation. Bowman *et al.*'s (1990) study in Papua New Guinea compared a cross-section of habitats from gardens and open fields through primary forest. They also found significant increases in bird species richness, the number of primary forest specialists, with succession but guilds such as granivores were dominant in early successional vegetation. However, their point-count sampling was biased toward primary forest where counts were longer in duration. In a recent paper, Andrade and Rubio-Torgler (1995) found using mist-net sampling only small differences between abundance and richness of understorey birds in shifting cultivation fallows (aged 1-17 years) and the understorey of primary forest. They suggested that it may be possible to reconcile conservation goals with traditional human land-use practices. I have not found any studies that explicitly address the impact of shifting cultivation on birds in south Asia. The present study may well be the first of its kind in the region.

1.3 *Background and study questions:*

Various hypotheses have been advanced by biologists with regard to the impact of *jhum* on biodiversity. Some have suggested that *jhum* leads to irrevocable loss of biodiversity (Dwivedi 1993). In contrast, Gadgil and Guha (1992), hypothesized that clearance of small patches of forest alternating with long fallow periods under traditional systems of shifting cultivation will enhance biodiversity. Empirical investigations of bird communities tend to support the latter view that as long as intact primary forest is part of the habitat mosaic, the diversity of bird species is enhanced (Blankespoor 1991, Kricher and Davis 1989, Lynch 1989a,b, Bowman *et al.* 1991). However, it is necessary to critically examine whether the increase in diversity is significant from a conservation point of view. For instance, it can be reasonably argued that birds that are habitat specialists, rare, and have geographically restricted distributions, are most important for conservation (Usher 1986).

It may however be that early-regrowth habitats are colonised by forest species that are common, have large geographical ranges and broad diets (Leck 1979) or the increase in diversity reflects the entry of birds of more open surrounding habitats at the expense of highly-specialised forest birds. What is the true scenario with regard to *jhum* in north-east India? In this study, I address the following main questions:

1) Does the traditional practice of shifting cultivation of tribals in north-east India lead to the maintenance of higher bird species richness in disturbed areas compared to primary forests? What is the timescale of recovery of the mature forest bird community?

2) How is bird community succession related to vegetation structure and floristics? Does *jhum* have differential effects on different guilds of birds?

3) Are primary forests more important than successional habitats for the conservation of rare birds and habitat-specialists?

4) Do long-distance migrants prefer successional vegetation while altitudinal migrants and residents prefer undisturbed forest in north-east India?

2. STUDY AREA

Dampa Tiger Reserve in western Mizoram was chosen as the study site after a preliminary survey of three protected areas in Mizoram in December-January 1994 (Mishra *et al.* 1994, Fig. 1). The main considerations were that this area had a cross-section of habitats from open *jhum* fallow to undisturbed primary forest, and an altitude range of 250 - 1,100 m implying that several species of altitudinal migrants would occur through the winter.

2.1 *Location, Area, and Physical features*

Dampa Tiger Reserve (henceforth Dampa TR) is located in the hills of western Mizoram. Mizoram is the southernmost state in north-east India, flanked by Myanmar (Burma) and Bangladesh on the east and west, and by the neighbouring states of Assam and Tripura to the north and north-west (Fig. 1). The Mizo or Lushai hills of Mizoram, consist of a series of parallel hill ranges running in a North-South direction along the Burmese arc of the Himalayan mountain chain (Mani 1974). These ranges are distinct from the ranges of the Eastern Himalayas as in Arunachal Pradesh, which run in a more or less east-west direction. Within Mizoram, the stretch of hills range in altitude from 200-1200 metres above sea level (m a.s.l.) in the west adjoining the Chittagong hill tracts of Bangladesh and the hills of Tripura. In the east and south-east, the hills are considerably higher ranging between 1,500-1,800 m a.s.l. adjoining Myanmar. The highest peak, Blue Mountain or Phawngpui (2,157 m a.s.l.), is in south-east Mizoram (Fig. 1). The terrain is highly dissected with streams and rivers. The slopes are generally steep, commonly 30-50° over much of the protected areas I visited (Mishra *et al.* 1994). Another feature worth noting is that the western aspect of the hill ranges in Mizoram are generally steeper, and form long chains of cliffs (Pachuau 1994).

Dampa TR is located between 23°20' and 23°47' N, and between 92°15' and 92°30' E. The Tropic of Cancer (23°30'N) passes through the centre of the Reserve. It occupies an area of about 500 km², including peripheral buffer areas. It is bordered on the east and north by metalled roads,

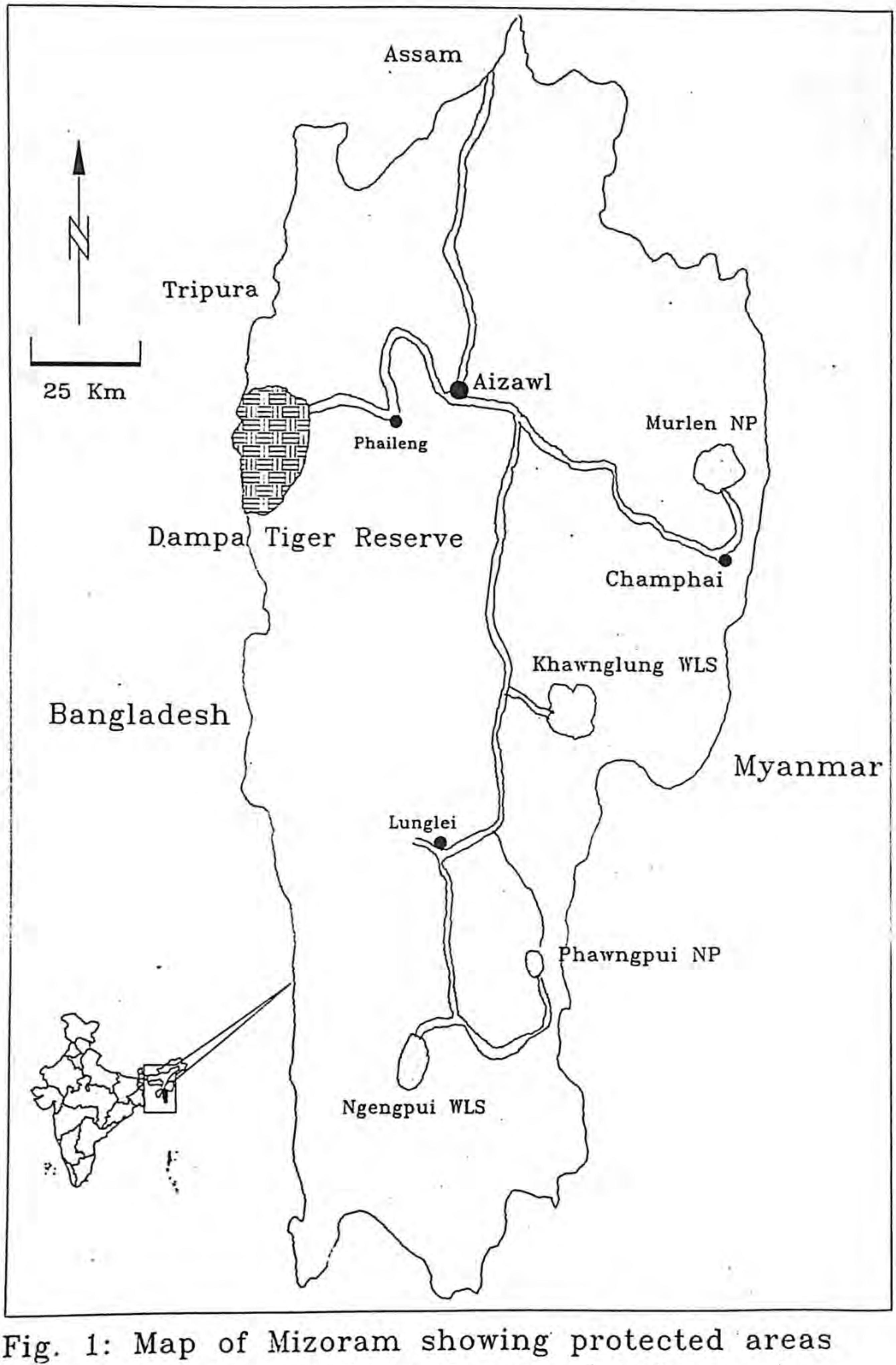


Fig. 1: Map of Mizoram showing protected areas and Dampa Tiger Reserve (study area).

and on the west by the Saza lui (*lui* = river) or Kothlantuipui lui, which forms the international border with Bangladesh (Fig. 2). The altitude ranges from about 250 m a.s.l. in the moist valleys (such as Tuichar valley) to 1,100 m atop Chawrpialtlang. There are two main ridges in the area - Chawrpialtlang (*tlang* = ridge in Mizo language) and Dampatlang (Fig. 2). The western aspects are steeper with long chains of cliffs. The hills are dissected by numerous rocky streams, which feed the main perennial rivers in the area - such as the Teirei lui, Tuichar lui, and Sazuk lui.

2.2 *Climate*

Mizoram possesses a tropical climate with distinct seasonality. At least three broad seasons can be recognised (Pachuau 1994):

(i) *Summer (March - April)*: this season is characterised by high maximum temperatures (commonly, 30-35°C in the study area) and occasional heavy thundershowers. The minimum temperatures seldom go below 20-25°C, except perhaps in the highest altitudes.

(ii) *Monsoon (May-October)*: this season is both hot and humid and receives heavy rains from the south-west monsoon (mean monthly rainfall in this season = 300 mm). About 84% of the 2,150 mm rain that Mizoram gets on average is received during this season (calculated from data in Pachuau 1994, on monthly rainfall in Aizawl, 1984-1993).

(iii) *Winter (November-February)*: this season is characterised by low mean monthly rainfall (26 mm), low minimum and maximum temperatures (generally 3.5° to 20°C in the study area, and lower in the higher altitudes in eastern Mizoram).

2.3 *Vegetation*

2.3.1 *Natural vegetation*

The vegetation in Mizoram ranges from tropical evergreen and semi-evergreen forest in the lower altitude hills in west and central Mizoram to sub-tropical hill forests in the high hills of the east Champion and Seth (1968). The vegetation in Dampa TR corresponds to the Tropical evergreen

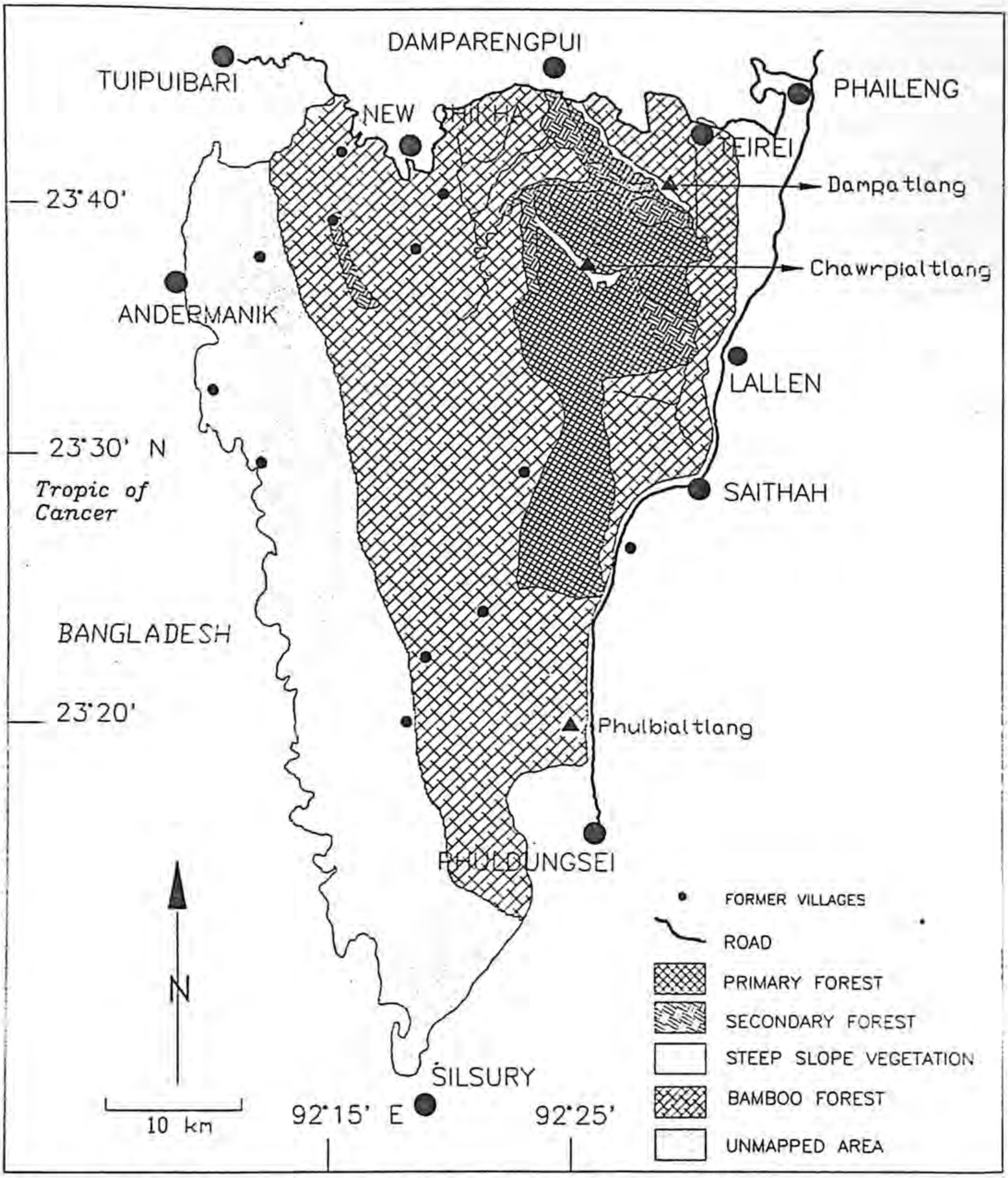


Fig. 2: Map of Dampa Tiger Reserve showing major vegetation zones and locations of former and existing villages

and Semi-evergreen forests (Type 1B and 2B) of Champion and Seth (1968). The low moist valleys have evergreen vegetation characterised by species like *Michelia champaca*, *Dipterocarpus turbinatus*, and *Terminalia chebula*. The higher slopes (700 m - 1,000 m) have semi-evergreen forest characterised by species such as *Castanopsis indica*, *Schima wallichi*, *Mesua ferrea*, and occasionally oaks (*Quercus sp.*).

On the steep western slopes below the long cliffs of Dampatlang and Chawrpialtlang, are somewhat open forests with many deciduous species (such as *Lannea coromandelica*, *Sterculia villosa*, and *Gmelina arborea*) and *Dendrocalamus longispathus* (Vern.: *Rawnal*) bamboo in the understorey. On the higher slopes of Chawrpialtlang are expanses of open grassland on rocky surfaces. In ravines and tree-fall gaps one finds dense successional vegetation which is preferred by many bird species. The natural vegetation in Dampa TR thus contains a cross-section of habitats ranging from grasslands, successional habitats, and open forests to dense, lofty, primary evergreen riverine forest.

2.3.2 *Vegetation in* jhumed *areas*

The seral vegetation that arises soon after the *jhum* field is abandoned consists of weeds, herbs, and surviving crop plants. *Eupatorium adenophorum* and *Mikania scandens* are common and woody plants are restricted to a few seedlings of *Macaranga sp.*, *Mitragyna diversifolia* etc. From two years onwards, the fallow is dominated by bamboo forest composed almost entirely of *Melocanna bambusoides* (Vern.: *Mautak*). The bamboo grows profusely particularly in moist valleys and forms a closed canopy in five years or so. Woody plants sprout in the shade of the bamboo and by about 60 years or so replace the bamboo vegetation (Ramakrishnan 1992). An approximate vegetation map made during the preliminary survey and checked during this study clearly shows that *jhumed* areas (bamboo forest 5-10 years old) dominate the land area of Dampa TR, occupying over half and perhaps as much as two-thirds of the area (Fig. 2, Mishra *et al.* 1994). Secondary forests (c. 20-30 years old) are limited in extent. A large patch of primary forest occurs between the Dampatlang and Chawrpialtlang and this was the intensive study area (Fig. 2). Jhuming occurred every year within Dampa TR until the 12 villages inside that Park were relocated in 1989-90. Currently, due to pressure from village people, *jhuming* is being allowed in the periphery of the sanctuary and the *jhumed* areas are converted to plantations following abandonment. Plantations of *Michelia champaca* and *Gmelina arborea* thus occur along the Reserve periphery, especially bordering villages.

2.4 Jhuming *and people around the protected area*

During the study, I observed tribals go about their annual *jhuming* operations, and gathered substantial historical information regarding changes in land-use, regulation of *jhum* activities at the village level, past conflicts with the Forest Department etc. While I realise that these have a strong bearing on the implications of this study, the detailed results are too elaborate to present here, hence only aspects of relevance to this thesis are mentioned. *Jhuming* activities in surrounding villages are currently regulated largely by individual households, the village councils having very little to do with it (T. R. S. Raman, *unpubl. data*). In brief, jhuming involves cutting bamboo forests (only in one case was primary forest cleared, in an area outside Dampa TR) in January-February, drying the slash for about 1 - 1½ months, then burning it in March-April. Crops are sown after the first rains in April. Generally intercropping of at least 15-20 varieties occurs in the *jhum* plots that are generally 1-4 ha. in area. Detailed information on the typical form of *jhum* in lower altitude areas of north-east India is given by Ramakrishnan (1992). There are nine major villages on the Reserve periphery (includes Riang villages - Damparengpui, Chikha, Chakma villages - Andermanik, Silsury, and Mizo villages - Lallen, Saithah).

3. METHODS

3.1 *Birds*

Proper identification of bird species is a *sine qua non* for studies of tropical forest bird communities. I took the following steps toward developing identification skills necessary for this study:

i) Detailed, but generally incidental observations on identification and calls of 101 bird species were made during the one-month long preliminary survey in Mizoram in 1993-94 (Mishra *et al.* 1994).

ii) Between August and October 1994 an exhaustive 'expected' species list of over 300 species was prepared based on distributional information in Ali and Ripley (1983). Careful notes made on visual identification of difficult groups such as warblers, babblers, and green pigeons during this period were later of immense help in the field. On detecting birds I could then either identify them immediately or look for the diagnostic characters.

iii) During the first three weeks of intensive bird observations and plant collections, I conclusively identified 125 species and recorded calls for a majority of these.

iv) The practice of learning bird calls, locating, and identifying birds was continued throughout the study. 'Casual' birdwatching observations were made in various habitats on an almost daily basis throughout the study. Calls heard on transects were sometimes confirmed later during such casual observations. Due to these efforts, I was able to detect one error in species identification - individuals of Beavan's wren warbler in worn winter plumage were wrongly identified as plain prinia, the two species, particularly in the north-east Indian races, being very similar in plumage and calls (Ali and Ripley 1983). The error is regretted.

v) Overall the policy of 'no record at all is better than an erroneous one' was adhered to while making observations on transects. However, unidentified birds and calls comprised less than 2-4% of the detections per transect.

The transect count method (Verner 1985) was chosen to sample birds as it has been proved useful in sampling forest bird communities in other parts of

India (e.g. Katti 1989, Daniels *et al.* 1992), and was suitable for the terrain and visibility conditions of the study area. For the purposes of this study, it was necessary to compare various successional habitats with primary forest. Therefore, two replicate transects, each 500 m in length, were marked with paint in each of the following successional and primary habitats:

(i) One-year fallow - cultivated and abandoned in 1994

(ii) Five-year fallow - abandoned in 1989

(iii) Ten-year fallow - abandoned in 1985

(iv) Twenty-five-year fallow - abandoned in 1969

(v) Disturbed primary and 100-year-old forest

(v) Primary forest (that has never been *jhumed*)

All transects were in the altitudinal range of 250-750 m a.s.l. Of each pair of transects, one transect in the 250-450 m altitude range was designated a 'valley' transect, and the other in the 450-750 m altitude range was designated a 'hill' transect. In general, the two transects in a given successional stage were separated by a linear distance of 1.5 - 6 km in the study area. The exception was the 25-year fallow transects, where both transects were in a moist valley and were just 150-200 m apart in the only such patch found in the study area. The 100-year old forest represents a site where two villages (Dampa and Pathlai Lunglen) were abandoned between 1895-1900 (Pu Dârbuaia, *pers. comm.*). The disturbed primary forest site is contiguous with the above area and is surrounded by 10-year old bamboo forest on three sides. The ages of the fallow and information on the history of the 100-year old site were determined by detailed interviews with several local tribals and village elders. All transects, excluding the 25-year fallow and primary forest transects, were laid in more or less contiguous habitats along the Dampatlang ridge and hills along Teirei river (Fig. 2). The latter transects were in contiguous areas in Chawrpialtlang-Tuichar valley area separated from the above transects by a linear distance of 3-6 km. I would like to note here that the 10- and 25-year fallow transects were all located less than 150-200 m away from tall, mature forests.

Transects were marked from random starting points along existing animal trails or by clearing a small path. Bird observations along transects were restricted to the first three hours after daybreak when birds were active feeding and calling (Daniels and Hegde 1990, Terborgh *et al.* 1990, *pers. obs.*). I recorded birds by walking at a slow, uniform pace so as to complete each transect in 50 minutes. This allowed the identification and recording of all birds detected. Based on the visually-estimated perpendicular distance from the transect line, each detection was placed in one of the following ranges: 0-5 m, 5-10 m, 10-15 m, 15-20 m, 20-30 m, 30-50 m, and 50-100 m, the ranges being wider further away from the line to minimise errors in distance estimation. Detections over 100 m from the transect were excluded as these were nearly always in adjacent fallows or habitats. All birds seen or heard along the transect were recorded. Birds flying under the canopy or less than 5 m over it were also included. Overall the emphasis was on establishing a uniform sampling procedure so that meaningful comparisons can be made.

In studies of successional trends, simple species richness lists may suffice to document species turnover with advancing succession (Verner 1985). Since it was highly unlikely that all species using a given habitat would be recorded in a single transect, it was necessary to repeat (pseudo-replicate) the transects several times. As the logistics involved in moving between camps at Teirei village, Dampatlang watchtower, and Tuichar Pukpui, a large cave by Tuichar river, were considerable, it was possible to do each transect only twice a month. Thus, between December 1994 and April 1995 each transect was walked ten times and each successional stage covered by twenty pseudo-replicates.

3.2 *Vegetation*

Vegetation sampling was undertaken to study vegetation changes *per se* as well as to relate bird community changes to vegetation attributes. I employed the methods of Daniels *et al.* (1992)

with some modifications to suit the needs of this study. The following vegetation attributes were quantified: tree density, woody plant species richness, bamboo density, canopy density, vertical stratification, and depth of leaf litter. Woody plant species richness and tree (>20 cm girth at breast height, GBH) density were determined for each of ten 100 m² circular plots per transect. The centres of the plots were alternatingly located ten metres to the right and left of points spaced at 50 m intervals on the transect line. Bamboo culms were counted in 25 m² circular plots nested within the above plots. The extent of canopy density was scored as 0 when there was none overhead, 1 when canopies of adjacent trees or bamboo culms > 5m in height barely met, 2 when adjacent canopies overlapped with the sky still showing through, and 3 when the sky was no longer visible through the overhead leaves (Daniels *et al.* 1992). A total of 100 points were scored thus at 5 m intervals along the transect lines (the points were located 1 m away from the transect line alternating on each side). To see whether the canopy density values were affected by taking readings close to the transect line, the procedure was repeated in the 1, 5, 10-year fallows, and disturbed primary forest by taking a total of 120 readings at points 5, 10, 15 metres on either side of 25 equally spaced points on the transect line. Only in one of the 5-year fallows, where villagers tended to cut bamboos and trees close to the trail, was there a significant difference (t-test, $p<0.01$) and the higher reading (1.38 *vs.* 0.87) was used as being more accurate. The depth of leaf litter was measured to the nearest 0.5 cm using a calibrated wooden stick at 100 points as in the canopy density measurements. Vertical stratification was also assayed at these 100 points by noting the presence or absence of foliage in the height intervals 0-1 m, 1-2 m, 2-4 m, 4-8 m, 8-16 m, 16-24 m, 24-32 m, and >32 m directly above and within a 0.5 m radius of these points (visual estimation). A bamboo pole calibrated to 8 m height was used initially for developing the ability to estimate heights. Arithmetic means of the canopy density scores, and number of strata with foliage present were calculated to represent canopy density and vertical stratification, respectively. As the vertical stratification readings were taken at 100 points along the transect, its coefficient of variation was used as an index of horizontal heterogeneity of the vegetation.

3.3 *Data analysis*

The mean bird species richness per transect and the cumulative species richness within a successional stage were the primary variables of interest. The number of individual birds tallied within 50 m on either side of the transect was used to calculate density, the assumption being that detectability does not differ across habitats. Both, $e^{H'}$ (where H' is the Shannon-Weiner information index = $- \sum p_i \ln p_i$) and the reciprocal Simpson's index ($D = 1/\sum p_i^2$) were used as measures of bird species diversity, where p_i is the proportion of individuals of the i^{th} species on the transect (Magurran 1988). Species turnover and similarities between sites were studied using the Morisita index (Wolda 1981):

$$C_\lambda = \frac{2\sum (n_{1i} \times n_{2i})}{(\lambda_1 + \lambda_2) N_1 \div N_2} \qquad where: \quad \lambda_j = \frac{n_{ji} \times (n_{ji-1})}{N_j \times (N_j - 1)}$$

n_{ji} = number of individuals of species i in sample j

N_j = number of individuals in sample j

For comparisons of bird community attributes across the six successional sites the data from the two transects (i.e 20 pseudo-replicates) in each site were pooled. As adjoining habitats were often in the 50-100 m range from the transect line and birds in such areas could be detected as 'noise' on transects, all detections greater than 50 m away from the transect line have been omitted in all subsequent analyses.

Differences in vegetation variables through succession were tested using one-way Analysis of Variance (ANOVA) of each variable, followed by Duncan's multiple range test for multiple comparisons of means (Zar 1984). A probability level of 0.05 was considered significant. Only two variables (canopy cover and vertical stratification) were not normally distributed as required for ANOVA. However, as sample sizes were large (N = 200) and equal across treatments the parametric procedure was adhered to as it is robust to non-normality and heteroscedasticity of data under such conditions (Zar 1984). Vegetation variables were summarised using principal components analysis (PCA) with the Pearson's product-moment correlation matrix of the variables as the input (Pielou

1984). The procedure was performed on SPSS/PC+ software, and the obtained factor matrix was rotated by the Varimax method to assist in interpretability and display of results (Norušis 1990). Pearson product-moment correlation coefficients between bird community attributes and scores of the extracted principal components were used to detect patterns in relation to vegetation succession. Birds were assigned to specific guilds after Terborgh and Robinson (1986) based on natural history information in Ali and Ripley (1983) and personal observations. To study patterns of abundance and rarity, bird species were placed in five abundance classes following Lynch (1989, 1990) with some modification:

(i) Unique and Characteristic species: species detected a minimum of three times solely in the given successional stage or detected at least thrice as many times as in other successional stages.

(ii) Abundant species: Birds detected > 30 times on the transect but not belonging to (i)

(iii) Frequent species: Birds detected 11-30 times but not belonging to (i)

(iv) Infrequent species: Birds detected 3-10 times but not belonging to (i)

(v) Strays, Vagrants and Rare species: Birds detected < 3 times in a given successional stage.

Due to the close juxtaposition of habitats, several species were detected very irregularly or on a few chance occasions - such as when a bird flew in to perch briefly on a tree and then fly on never to be detected on that transect again. In order to address this, I found it useful to place all species seen less than three times in category (v) above, and exclude them from the cumulative list and guild analyses as a conservative measure. However, these species have been considered in detail separately (see Results). Simple species-abundance curves were also used to graphically illustrate the changes in bird community structure with succession.

4. RESULTS

4.1 *Trends in bird species richness and abundance*

4.1.1 *Comparisons across sites - from 1-year* jhum *fallow to primary forest*

A total of 215 bird species were identified in the study area (Appendix 1) of which 139 species were detected on transects. Of this, 99 species were detected at least five times (as individuals or groups) overall, and 73 species were detected at least 10 times overall. The mean number of bird species detected per transect showed a highly significant increase from 10.95 in the one-year *jhum* fallow to 24.90 in the primary forest (ANOVA, $F = 17.93$, $p < 0.001$). While the values of mean bird species richness in the 5-, 10-, and 25- year fallows were intermediate (i.e. 15.80, 15.20, and 19.05, respectively) the disturbed primary and 100-year old forest had a value nearly identical to the undisturbed primary forest site (Table 1). Comparisons of the 5- and 10-year fallows showed that they also were not significantly different from each other (Table 1). These results clearly indicate that there is a significant increase in bird species richness from 1 to 5 years after *jhuming*, after which there is no significant change up to 10 years. As the age of the fallow increases to 25 and 100 years the bird species richness recovers to levels found in primary forest (Fig. 3). Henceforth, when referring to the disturbed primary, 100-year forest, and primary forest sites put together, I will call them 'mature forest' sites, to distinguish them from the 1 to 25-year fallows (open *jhum* fields and bamboo forests).

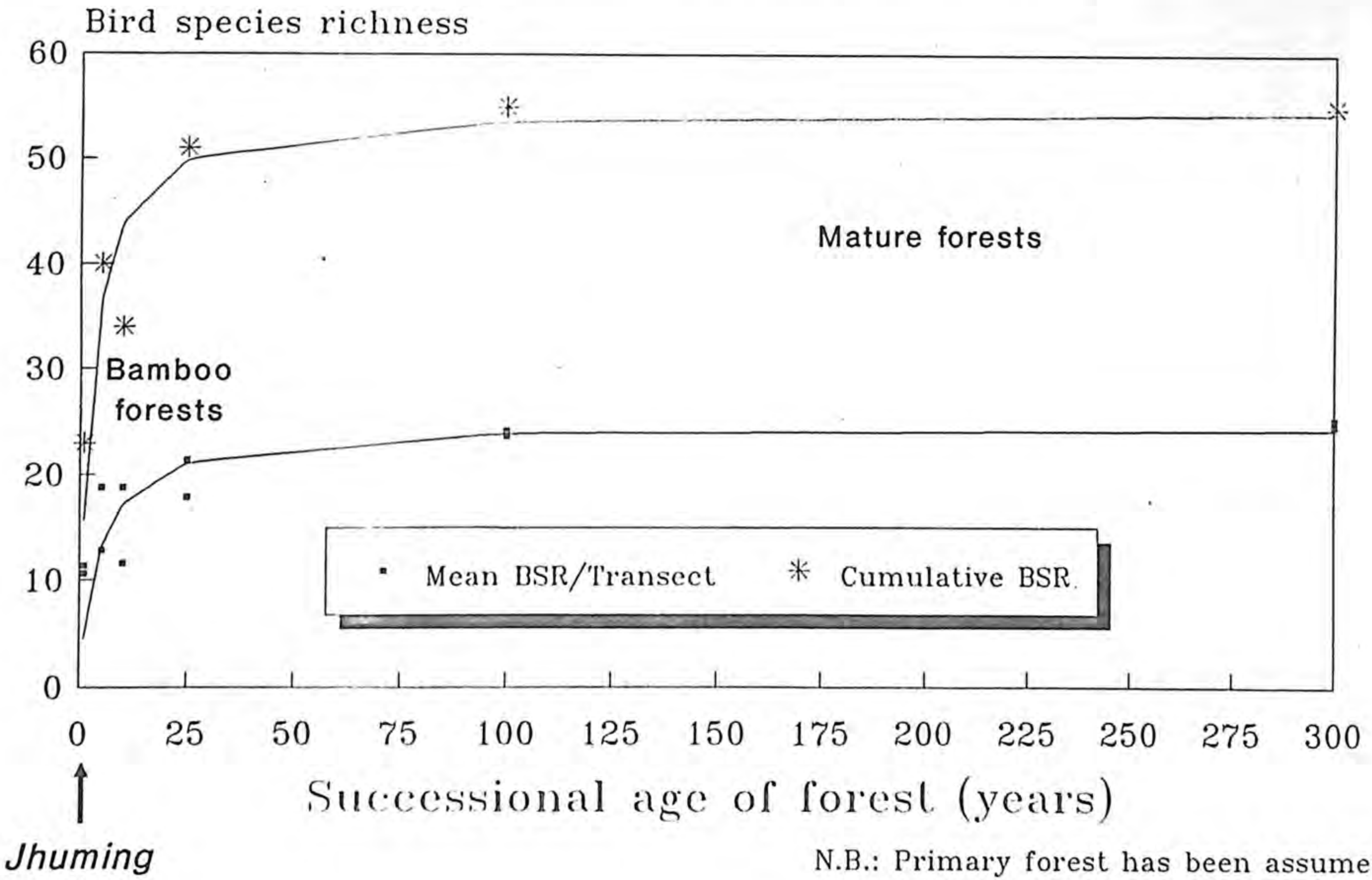
The trend in the cumulative bird species richness of the successional sites reinforces the above conclusion. The cumulative values of bird species richness (considering only species detected a minimum of three times) in the 1-, 5-, 10-, and 25-year fallows, disturbed primary and 100-year forest, and primary forest were: 23, 40, 34, 51, 55, 55, respectively (Fig. 3). This again depicts an increase in bird species richness from 1 to 5 years after *jhuming*, followed by increases after 10 years and up to 100 years, by which time the bird species richness parallels that of primary forest.

Table 1: Changes in bird species richness and abundance through succession from open, 1-year *jhum* fallow to primary forest

Variable	Bird Species Richness	Bird Abundance	Exponential Shannon-Weaver Diversity	Reciprocal Simpson's Diversity Index
Category	Mean/ 500X100m transect	Number/ 500X 60 m transect	$e^{H'}$	D
1-Year Fallow	10.95^{a} (0.53)	36.75^{a} (4.17)	9.01^{a} (0.70)	4.75^{a} (0.44)
5-Year Fallow	$15.80^{b,c}$ (1.32)	34.25^{a} (3.51)	$17.19^{b,d}$ 0	5.73^{a} (0.75)
10-year Fallow	15.20^{b} (1.22)	39.35^{a} (3.33)	15.18^{b} (2.10)	6.15^{a} (0.80)
25-year Fallow	19.05^{c} (1.14)	45.60^{a} (3.47)	17.98^{b} (1.37)	9.71^{b} (0.63)
Dist. Pri. & 100-yr	23.85^{d} (1.43)	66.45^{b} (4.64)	23.44^{c} (2.33)	9.85^{b} (0.53)
Primary	24.90^{d} (1.69)	68.15^{b} (4.30)	22.90^{d} (0.87)	8.82^{b} (0.67)
N*	20	20	20	20
F ratio	17.93 (HS)	14.76 (HS)	7.49 (HS)	11.72 (HS)

N. B.	:	Values in the table represent means (± S.E.).
N*	:	Number of sample points in each successional category.
F	:	F-ratio of one-way parametric ANOVA.
HS	:	Highly significant result ($p < 0.001$).
a - f	:	Variable means sharing the same alphabet are do not significantly differ in multiple comparisons between successional categories (Duncan's Multiple Range Test, $p < 0.05$).

Fig. 3: Changes in mean and cumulative bird species richness (BSR) with successional age of *jhum* fallow



N.B.: Primary forest has been assumed to be at least 300 years old after Riswan *et al.* (1985).

It is worth noting that the 25-year fallow had a value of bird species richness (51) close to that found in the surrounding mature forests (55).

The trends in bird species richness are clearly not linearly related to the age of the regenerating *jhum* fallow (Fig. 3). Instead, a hyperbolic functional response curve implying initial rapid increase with decreasing rates of change over time, gives a good fit (fit was produced by iteration of values) to the data, i.e.:

Mean BSR = (25 X age)/(4.5+age), ($R^2 = 0.75$, df= 10)

Cumulative BSR = (55 X age)/(2.5+age), ($R^2 = 0.85$, df = 4).

The curve is of the form BSR = (*V* X age)/(*k*+age), where *V* and *k* are constants reflecting the biological properties of the recovery process (see Discussion).

Trends in abundance of birds show somewhat different patterns through succession. The abundance of birds does not change appreciably from the 1-year fallow through the 25-year fallow but increases significantly in the mature forest sites (Table 2). The above comparison was made considering only birds seen or heard within 30 m of the transect line to minimise biases due to differences in visual and aural detectability. The open one-year fallow which had the best detectability conditions nevertheless had a very low mean bird abundance of 36.8 individuals per transect (Table 2). The mature forest sites which had the least favourable conditions for detectability nevertheless had the highest mean bird abundance (66.5 and 68.2 birds per transect, respectively, see Table 2).

The exponential Shannon-Weiner index ($e^{H'}$) and the reciprocal Simpson's index (D) were chosen as composite indices of bird species diversity reflecting both changes in species richness and abundance. The results presented in Table 2 reflect similar patterns as found using the simpler species richness and abundance measures and the conclusions regarding changes and differences through succession are almost identical. The significant changes in the exponential Shannon measure parallel the significant changes in bird species richness, while the changes in Simpson's diversity

Table 2: Changes in vegetation variables through succession from open, 1-year *jhum* fallow to primary forest

Variable Category	Tree Density Trees/ 100^2	Bamboo Density Culms/ $25m^2$	Woody Plant Spp. Richness	Canopy Cover	Depth of Leaf Litter (cm)	Vert. Stratification	Horiz-ontal Heterogeneity
1-Year Fallow	0.10^{a} (0.07)	10.40^{a} (1.32)	5.95^{a} (0.63)	0.01^{a} (0.00)	0.50^{a} (0.01)	1.53^{a} (0.05)	49.9
5-Year Fallow	2.80^{b} (0.59)	25.55^{b} (4.63)	5.25^{a} (0.50)	1.02^{b} (0.06)	2.88^{b} (0.18)	2.27^{b} (0.09)	53.4
10-year Fallow	2.45^{b} (0.51)	40.11^{c} (5.64) (N=19)	8.20^{a} (0.81)	1.90^{c} (0.05)	4.73^{c} (0.14)	2.85^{c} (0.07)	36.4
25-year Fallow	3.50^{b} (0.78)	45.95^{c} (5.75)	27.30^{b} (1.92)	2.22^{d} (0.05) (N=199)	4.45^{cd} (0.16)	3.64^{d} (0.08) (N=199)	32.8
Dist. Pri. & 100-yr	8.25^{c} (0.53)	3.85^{a} (2.47)	33.55^{c} (1.49)	2.35^{d} (0.05)	5.11^{d} (0.15)	4.38^{e} (0.09)	29.3
Primary	11.50^{d} (1.01)	0.00^{a}	37.80^{c} (3.61) (N=15)	2.34^{d} (0.05)	7.31^{e} (0.15)	4.70^{f} (0.08)	25.0
N*	20	20	20	200	200	200	200
F ratio	42.89 (HS)	24.02 (HS)	81.41 (HS)	421.36 (HS)	254.98 (HS)	240.44 (HS)	-

N. B.: Values in the table represent means (± S.E.).

N* : Number of sample points in each successional category (except where stated otherwise in parentheses).

F : F-ratio of one-way parametric ANOVA.

HS : Highly significant result ($p< 0.001$).

a - f: Variable means sharing the same alphabet are do not significantly differ in multiple comparisons between successional categories (Duncan's Multiple Range Test, $p< 0.05$).

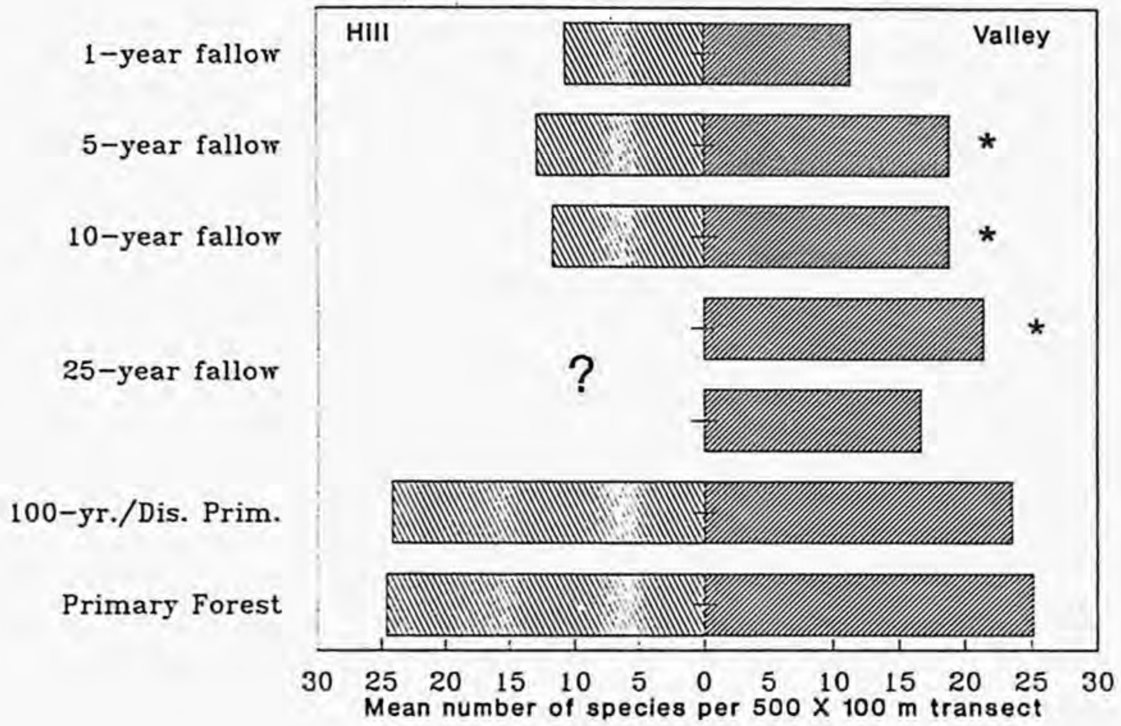
measure parallel closely the changes in abundance (Table 2). The fact that these measures of diversity reflect changes in a way similar to richness and abundance is only to be expected as both $e^{H'}$ and D are strongly correlated with both mean bird species richness per transect (Pearson's $r = 0.95$ in both cases, $p < 0.001$) and bird abundance ($r = 0.76$ and 0.75, respectively, $p < 0.001$). The overall trends in bird species richness, abundance, and diversity (Table 2), imply that the mature forest sites have the highest values of these variables and are substantially different from the open one-year *jhum* fallows and bamboo forests that are 5-25 years old. The regenerating bamboo forests occupy intermediate positions between open fallows and mature forest in terms of bird species richness and diversity.

4.1.2 *Comparing 'Hill' and 'Valley' transects*

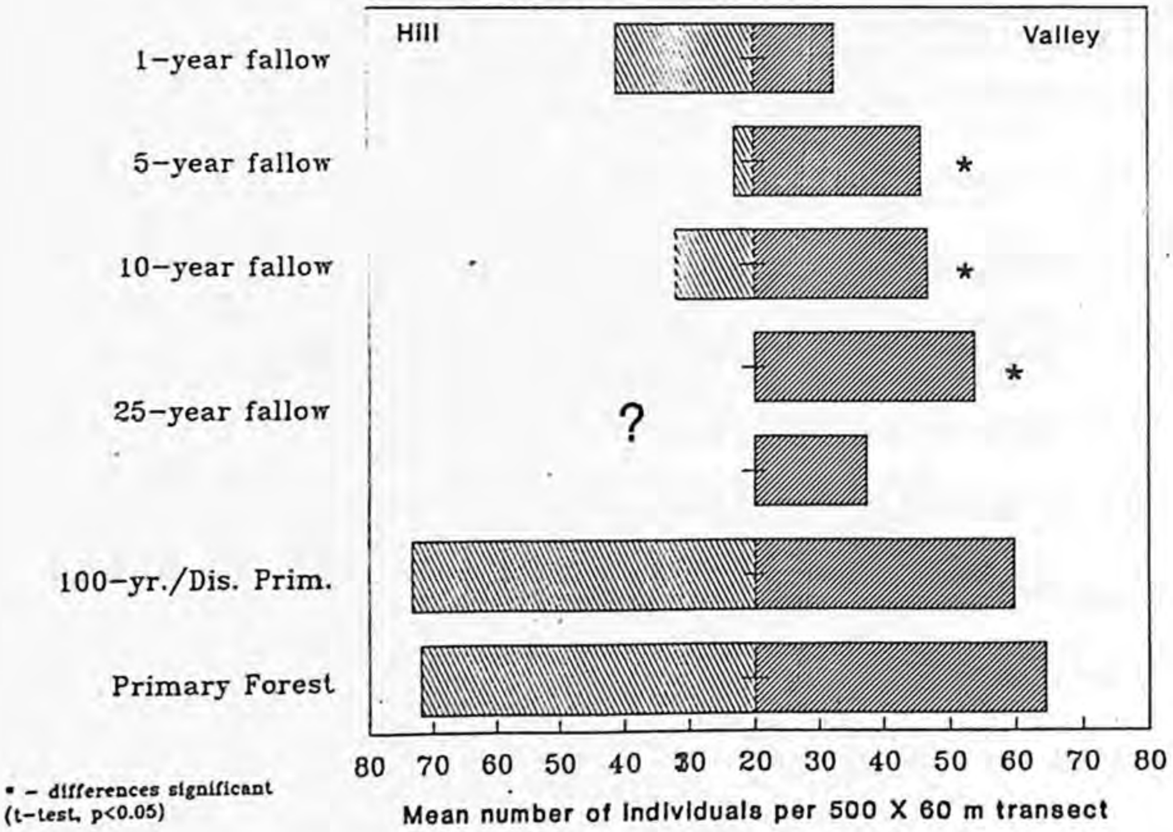
Except for the 25-year fallow, one transect of each pair in a given successional stage was in the 250-450 m altitudinal range and the other was in the 450-750 m altitudinal range. I compared bird species richness and abundance between the former 'valley' transects with the latter 'hill' transects using t-tests. Significant differences were found in the 5-, and 10-year fallows (bamboo forests) in both bird species richness and abundance, with the sites in the valley having higher mean bird species richness and abundance (t-tests, 2-tailed $p < 0.05$). In the 5- and 10- year old bamboo forests, mean bird species richness was 65-70% greater and mean abundance 50-69% greater in the valley sites. Within the 1-year fallow and mature forest categories there were no significant differences in bird species richness and abundance with respect to the two altitude zones ($p > 0.05$, Fig. 4). Surprisingly, the two 25-year fallow transects, which were both in the lower altitude zone and separated by just 150-200 m, also showed significant differences in mean bird species richness and abundance ($t=2.27$ and 2.74, $p < 0.05$, Fig. 4). One transect of the pair that was closer to primary forest and had a small patch of primary vegetation interspersed with it, had 22% lower mean bird species richness and 30% lower mean bird abundance than the other transect (Fig. 4).

Fig. 4: Comparisons between hill and valley transects - bird species richness and abundance

(a) Bird species richness



(b) Bird abundance



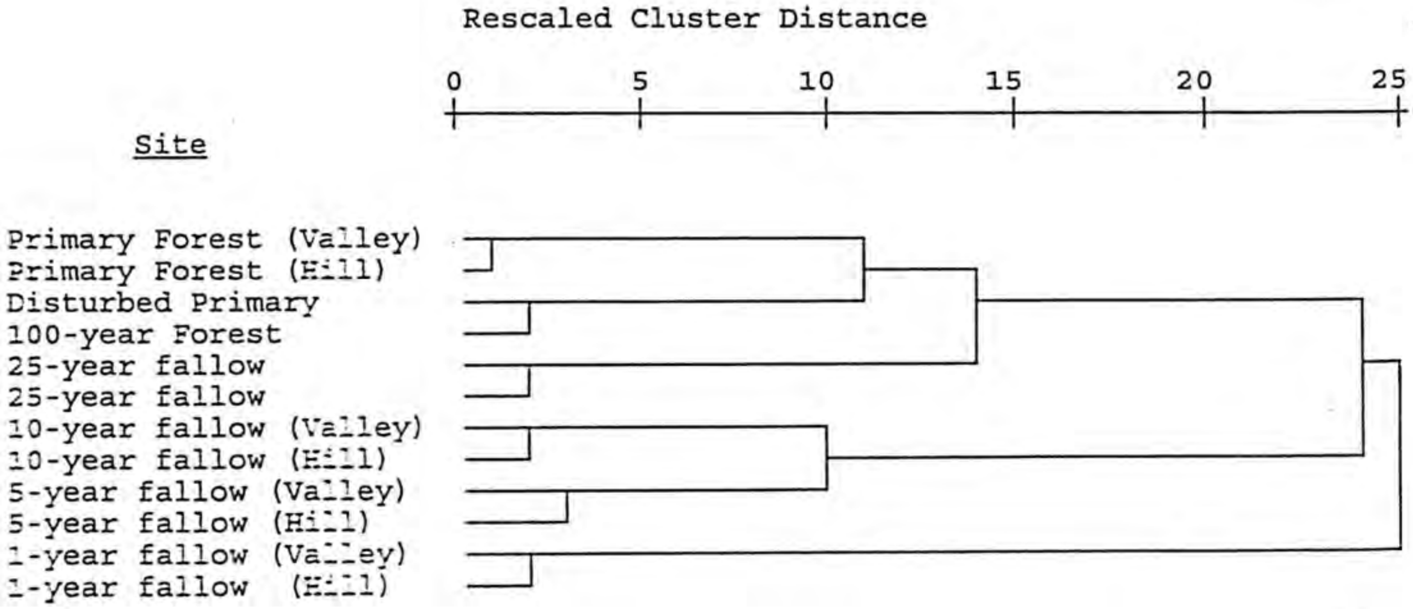
4.1.3 *Similarities in bird species composition between and among sites*

To determine how similar or dissimilar the different successional sites and mature forests were in terms of the abundance of different bird species, i.e. the *composition* of the bird community, I used the technique of cluster analysis, which helps to place similar sites closer together as clusters while separating sites that are very different. Morisita similarity indices were used to generate a dendrogram using hierarchical cluster analysis (centroid method) to depict the degree of similarity across sites in terms of the bird community composition. The result is illustrated in Figure 5. Three aspects are clear from this figure:

1. Each pair of transects within a particular successional stage are most similar to each other (Morisita similarity indices ranging from 0.83 to 0.95).
2. The 5-and 10-year fallows are very similar to each other as are the mature forest sites to each other. This parallels the findings reported in Section 4.1.1 that these two pairs of sites did not show significant differences in bird species richness, abundance, and diversity. In effect, each pair of sites represents a near-identical habitat in terms of bird community composition (see section 4.3.1).
3. Sites are arranged in exactly the same sequence as one would predict based on successional age. The more divergent the two sites are in age, the more different they are in bird community composition. For instance, while the similarities between the mature forest sites and the 1-year fallow are very low (< 0.01), the similarity of mature forest sites with the late-successional 25-year fallow is high (0.76-0.80). In fact, there is a significant negative correlation between the difference in the logarithm of the ages between two sites and their degree of similarity in bird community composition ($r = -0.75$, $df = 64$, $p < 0.001$).

Overall, these results suggest that as the fallow regenerates during succession from open fallow to mature forest, the bird community shows substantial *sequential* changes in community composition.

Figure 5: Dendrogram of similarity in bird community composition among the successional sites studied



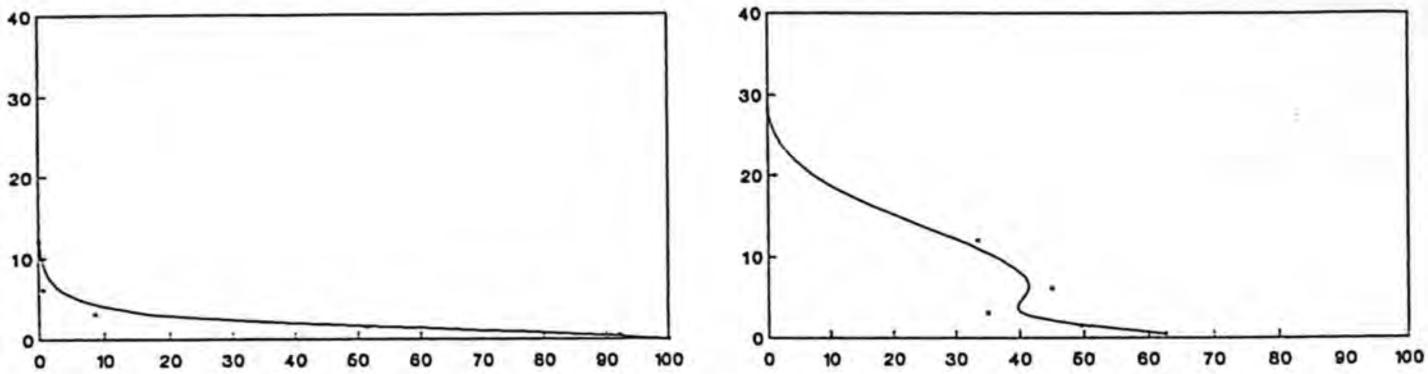
4.2 *Vegetation succession - relating avian succession to vegetation attributes*

Until now, I have been discussing changes in bird community structure with increasing succession. A proper understanding of these trends requires a close look at the underlying changes in vegetation structure and plant communities. This is a necessary prelude to the analysis of guilds and habitat specialisation in birds which are discussed later.

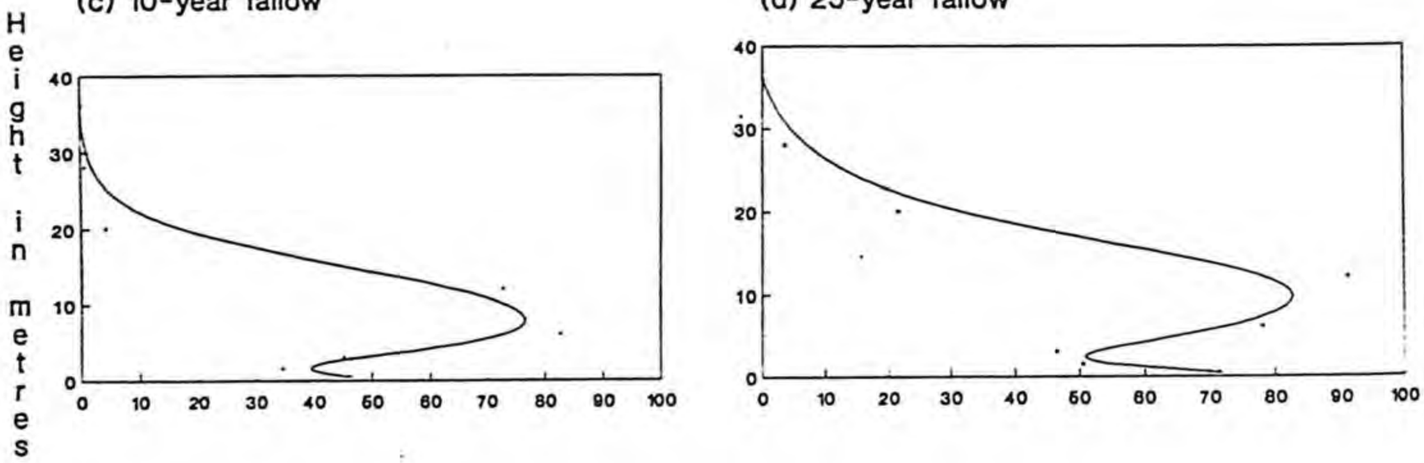
4.2.1 *Qualitative changes in vegetation*

As one would expect in a comparison of successional stages ranging from open one-year old *jhum* fallow to primary forest, there are clear and distinct trends in the vegetation. The most obvious changes are those in foliage profile, physiognomy, and stature of the forest (Fig. 6). As bamboos and trees succeed on the abandoned *jhum* fallow, the foliage profile changes markedly, resulting ultimately in a tall, multi-canopied, mature forest vegetation (Fig. 6). The open 1-year fallows were composed chiefly of grasses, weeds such as *Eupatorium adenophorum* and *Mikania scandens*, surviving crop plants such as tomato, chilly, and brinjal, climbers, and gourds. Bananas and tobacco generally occurred in the periphery of the plot. There were two or three standing dead trees on the plot but otherwise it was open-canopied. The 5-year fallows had vigorously-growing bamboos (almost entirely *Melocanna bambusoides*), bananas, young trees such as *Callicarpa arborea* and *Macaranga sp.*, and a few tall remnant trees that had survived the *jhuming* operations. The 10-year fallows were similar except for greater stature attained by trees and bamboos. By 25 years, the regeneration of the fallow is visually impressive - bamboos commonly reach a height of 15-25 m and a continuous tree and bamboo canopy is established. The trees were noticeably of higher girth than in the 10-year fallow and often reached well above the bamboo in height unlike most trees in the 5- and 10-year fallows. The mature forest sites were remarkably similar in physiognomy (Fig. 6) - the 100-year old forest site had already attained a dense multi-storey appearance and was dominated by trees such as *Schima wallichi* and *Mesua ferrea*. Tree-fall gaps

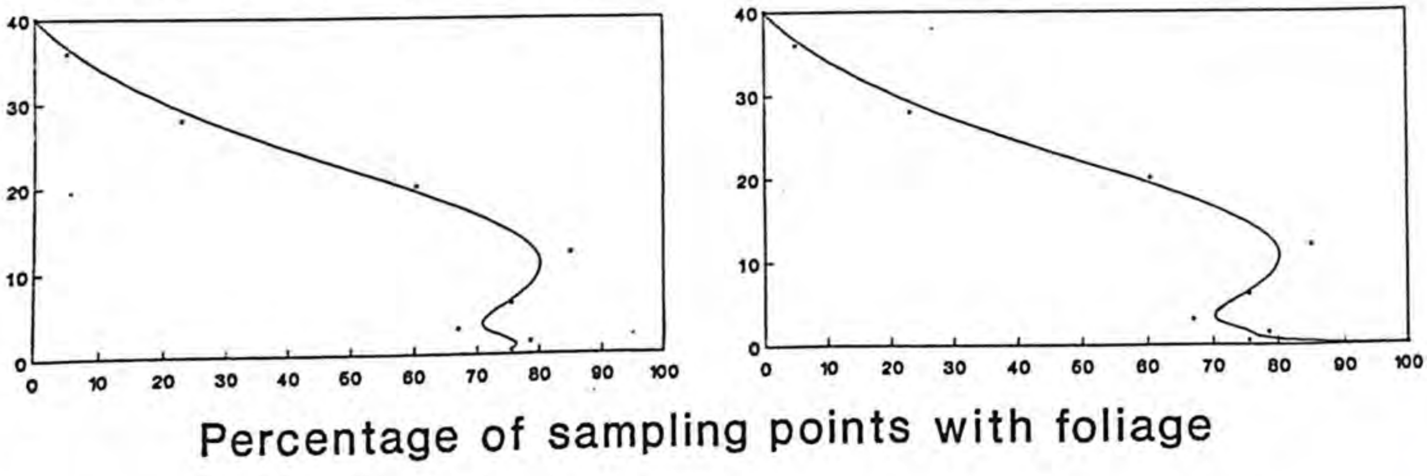
Fig. 6: Foliage profile through succession from open 1-year *jhum* fallow to primary forest


(a) 1-year fallow

(b) 5-year fallow


(c) 10-year fallow

(d) 25-year fallow


(e)100-year and disturbed primary forest

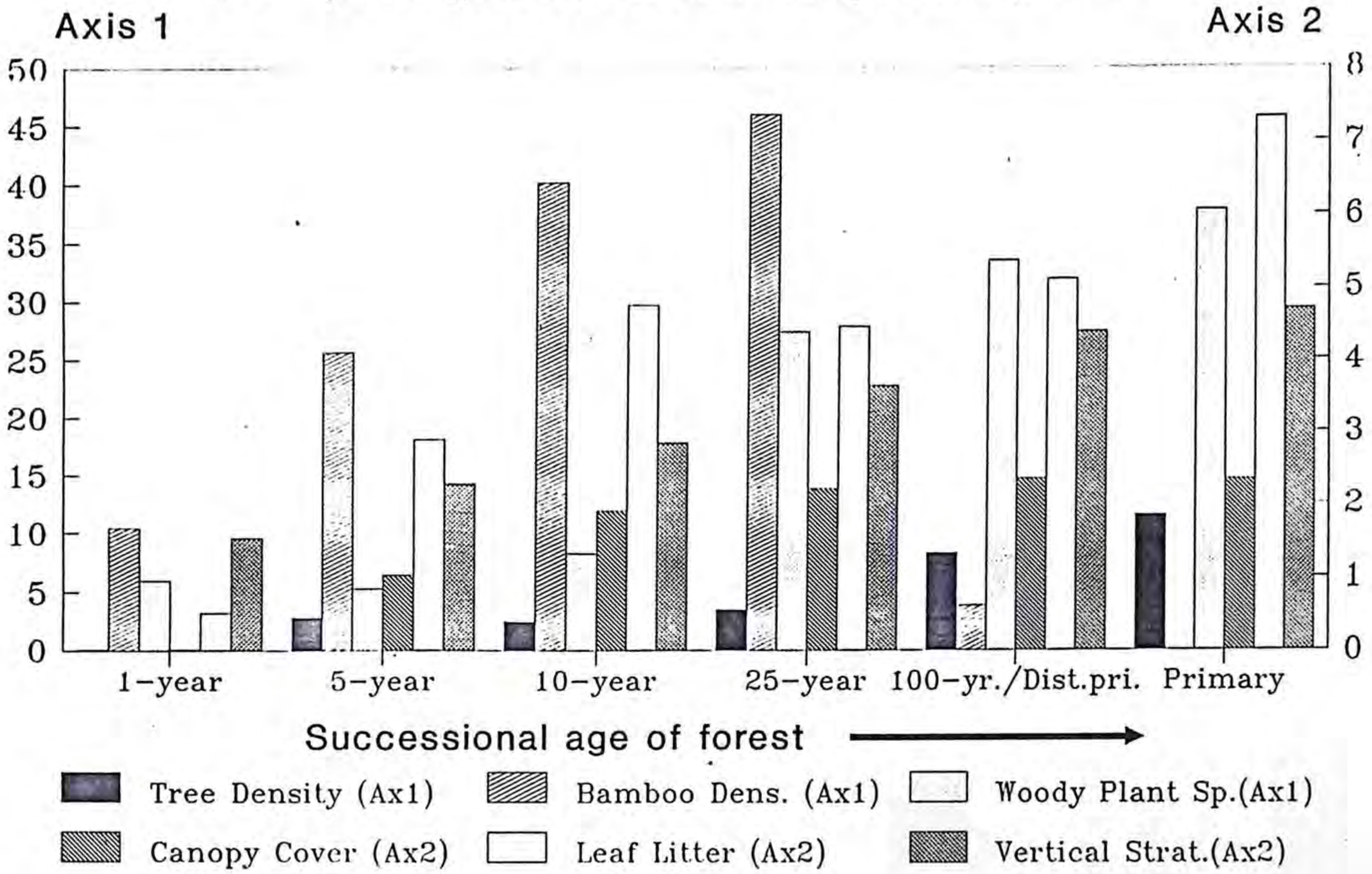
(f) Primary Forest

were noticed but large emergents appeared to be rare. The primary forest sites, particularly, the site in the Tuichar valley was similarly characterised by a predominance of woody plants, huge lianas, canes, and tall emergents such as *Michelia champaca* and *Terminalia myriocarpa*. The vegetation thus, at first glance, presents several striking differences across the successional spectrum.

4.2.2 *Quantitative changes in vegetation*

Among the measured vegetation variables, several clearly increased through succession: tree density, woody plant species richness, canopy cover, depth of leaf litter, and vertical stratification (Fig. 7 and Table 2). The 1-year fallow has practically no tree and canopy cover and the lowest values of all the above variables due to the dramatic changes in vegetation after the slash-and-burn operations of *jhum*. At the other extreme, the primary forest attains high values of all these variables, tree density increases to 11.5 trees / 100 m^2, woody plant species richness increases to a mean of 37.8 species / 100 m^2 plot , and so on (Table 2). A diametrically opposite trend is seen in horizontal heterogeneity, with the early successional fallows having higher values (49-56 %) compared to the mature forest sites (18-38%). A final pattern is apparent in the case of bamboo culm density. Bamboo (*Melocanna bambusoides*) density increases substantially from 1 to 25 years, from 10.40 to 45.95 culms per 25 m^2, but thereafter plunges to zero in the primary forest sites (Table 2). Only in the disturbed primary forest site that was surrounded on three sides by 10-year *jhum* fallows was *Melocanna bambusoides* found in some density (7.7 culms / 25 m^2) in the understorey. Other bamboos, particularly *Melocalamus sp.*, occurred at very low densities (*Melocalamus sp.*: 2.7 - 5.7 culms per 25 m^2) in primary forest, in tree-fall gaps and ravines. Comparisons were made to see if the 100-year forest significantly differed from the primary (hill) transect in any way. Significant differences were found in mean tree densities (mean of 8.6 *vs.* 12.7 trees per 100 m^2, $t = 2.96$, 2-tailed $p<0.01$), depth of leaf litter (5.26 *vs.* 7.22 cm, $t = 6.69$, $p<0.001$), and woody plant species richness (36.2 *vs.* 45.0 species/100 m^2, $t = 2.54$, $p < 0.05$). However, the

Fig. 7: Changes in vegetation from open one-year *jhum* fallow to primary forest



For units of measurement please refer text and Table 2.

difference between the 100-year forest and primary forest in these variables is small compared to the magnitude of their differences from early successional stages (Table 2).

Highly significant differences have been shown to exist in the measured vegetation variables through succession (ANOVA, $p < 0.001$, Table 2). Generally, with minor variations, the 5 and 10-year fallows are very similar to each other in the measured variables (except bamboo density which increases from 25.55 to 40.11 culms/25 m^2), as are the mature forest sites to each other. The 25-year fallow takes on intermediate values that are significantly different from both earlier and later successional stages (Duncan's multiple range tests, $p < 0.05$, Table 2). While the overall trends of increase hold in all other variables, bamboo density is exceptional in that it reaches its highest values in the 10-25 year fallows (40.11 to 45.95 culms / 25 m^2), with the one-year fallows and mature forest sites having significantly lower bamboo density.

4.2.3 *Principal Components Analysis (PCA) of vegetation variables*

As mentioned earlier, one of the aims of vegetation analysis was to be able to later correlate bird community attributes to vegetation variables. However, the results in the above section suggest that several vegetation variables show very similar trends through succession and may thus be highly inter-correlated. This was apparent when a correlation matrix of all variables was generated and showed strong and significant ($p < 0.01$) correlations between each variable and at least one other variable. I therefore decided to use the multivariate technique of Principal Components Analysis (PCA) to collapse the variables in the data-set into fewer uncorrelated components that account for as much of the inherent variation as possible.

PCA extracted two components (PC1 and PC2) that accounted for 91.9% of the variance in the data set, and succeeding components with eigenvalues less than 1 were discarded as not being useful. The first component (PC1) accounted for as much as 74.8% of the variance in the data-set, while PC2 accounted for 17.1% of the variance. The factor coefficients were sufficient to accurately predict the value of each of the original variables in the data-set (Multiple $R^2 = 0.83$ to 0.97). These results are presented in Table 3.

PC1 and PC2 can be taken to represent two uncorrelated variables that describe the vegetation in the twelve sites. PC1 is highly positively correlated with successional age of the fallow, woody plant species richness, tree density, canopy cover, and vertical stratification, and negatively correlated with horizontal heterogeneity (Table 3). These opposite trends through succession (i.e. increasing tree density, canopy cover etc., and decreasing horizontal heterogeneity) were already remarked upon in the previous section, and PC1 simply reflects this. PC2 is most strongly correlated with bamboo density, and sites with high bamboo density can be expected to have high PC2 values.

To depict these relationships graphically, I calculated the PC1 and PC2 scores for each site and ordinated them in PC1 - PC2 space (Fig. 8). The trends in vegetation succession are lucidly summarised in this graph. As succession proceeds from 1 to 25 years, there is an increase in woody plant species richness, tree density, canopy cover, depth of the leaf litter (PC1 variables), and a concurrent increase in bamboo density (PC2 variable). After 25 years, bamboos are succeeded entirely by woody plants (presumably after flowering and death of bamboos), and bamboo density plunges to low values in mature forest. This is represented as an initial increase and then a decrease on the PC2 axis. Horizontal heterogeneity is higher in early seral stages and show a declining trend through succession (on PC1, see Fig. 8). Overall, I suggest that PC1 represents the changes in woody plant succession while PC2 reflects the effects of bamboo succession.

4.2.4 *Vegetation and birds - bird species richness, abundance. and diversity*

Having grouped the original eight vegetation variables to two meaningful components, I calculated simple Pearson product-moment correlation coefficients to examine the relationship between bird community attributes and PC1 (which is taken to reflect woody plant succession) and

Table 3: Principal Components Analysis of vegetation variables: final statistics

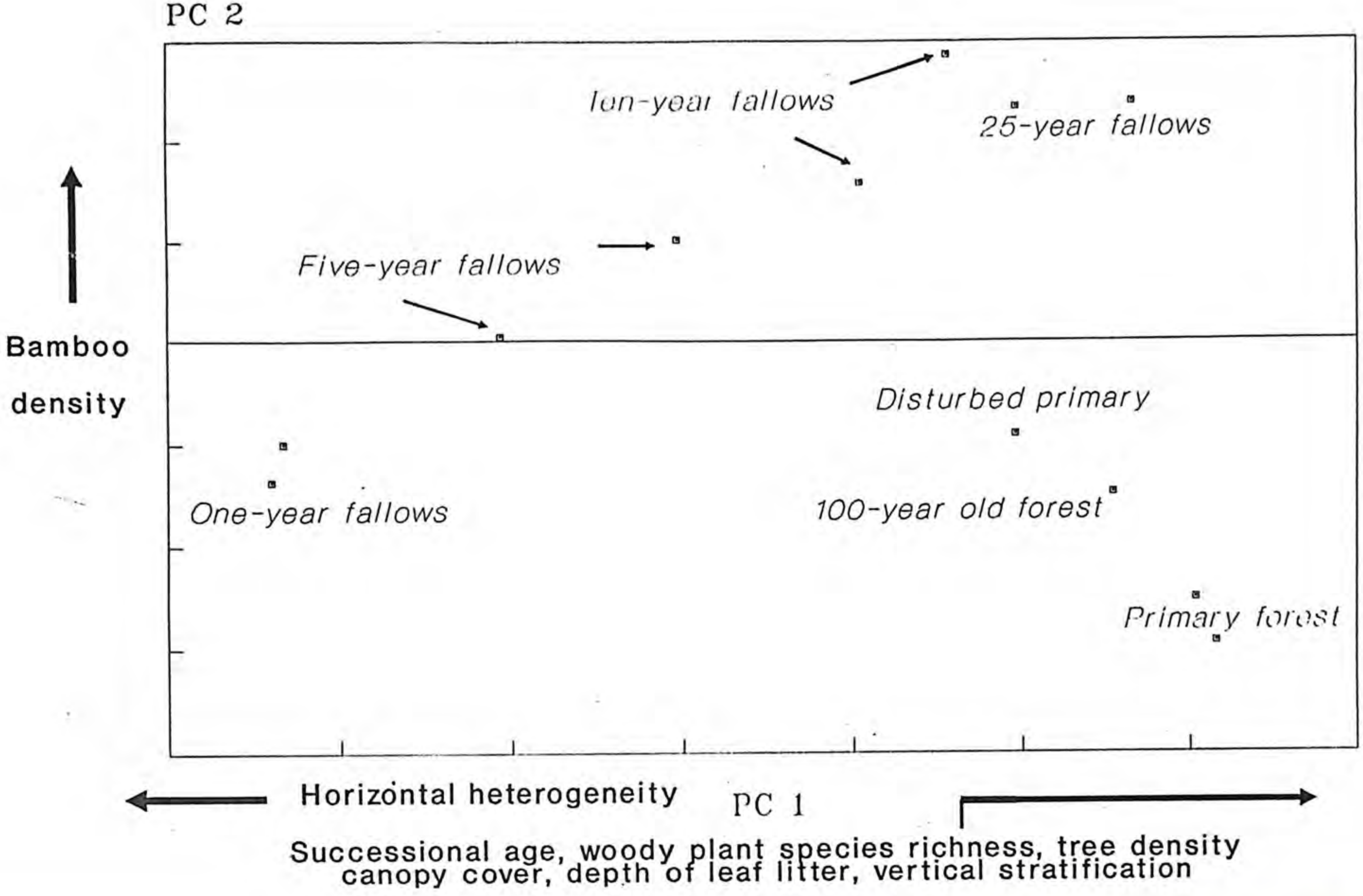
Variable	Multiple R^2	Factor	Eigenvalue	% of Variance	Cum. %
Age	0.8908	1	5.9831	74.8	74.8
Tree density	0.9509	2	1.3699	17.1	91.9
Bamboo density	0.9604				
Woody plant species richness	0.8836				
Canopy cover	0.9402				
Leaf litter	0.9285				
Vertical stratification	0.9698				
Horizontal heterogeneity	0.8288				

Rotated Factor Matrix (Pearson product-moment correlation coefficients)

	PC1	PC2
Age	0.6335*	-0.6996*
Tree density	0.7800**	-0.5853*
Bamboo density	0.0284	+0.9796**
Woody plant species richness	0.8342**	-0.4334
Canopy cover	0.9637**	+0.1070
Leaf litter	0.9528**	-0.1435
Vertical stratification	0.9430**	-0.2838
Horizontal heterogeneity	- 0.8877**	+0.2019

* 2-tailed $p<0.05$
** 2-tailed $p<0.01$

Fig. 8: Vegetation changes from 1-year *jhum* fallow to primary forest: results of Principal Components Analysis (PCA)



PC2 (which represents bamboo succession). This analysis was first performed for the overall characteristics such as bird species richness and abundance. Then birds were categorised into broad feeding guilds and the effects were considered guild-wise. The results are presented below.

Bird species richness, abundance, the exponential Shannon-Weiner and reciprocal Simpson's diversity measures were all positively related to PC1 ($p < 0.05$, Table 4). Only bird abundance showed a negative relationship with PC2 that was statistically significant ($r = -0.59$, $p < 0.05$). To test whether bird species richness and abundance were significantly related with PC2 when the effects of PC1 were removed, I calculated partial correlation coefficients. Significantly, both bird species richness and abundance emerged as negatively correlated with PC2 (Partial $r = -0.65$ and -0.77, respectively, $p < 0.05$).

Table 4: Relationship between bird species attributes and vegetation components

	Principal Components	
	PC1	PC2
Bird species richness	0.77^{**}	-0.41
Bird species abundance	0.63^{*}	-0.59^{*}
Exponential Shannon Diversity Measure, $e^{H'}$	0.75^{**}	-0.22
Reciprocal Simpson's Index, D	0.73^{**}	-0.29

2-tailed p values
$+ \Rightarrow p < 0.1$
$* \Rightarrow p < 0.05$
$** \Rightarrow p < 0.01$

Thus bird species richness, abundance, and diversity were positively influenced by succession of woody plants (represented by PC1). Bamboo density (PC2) has a significant negative influence on bird richness and abundance when the effects of woody plant succession are removed by partial correlation.

4.2.5 *Vegetation and birds - Guild structure, composition, and vegetation changes*

Moving from the level of the entire community to the level of guilds, I now consider the impact of *jhum* on different feeding guilds of birds. Fourteen foraging-guild classes were recognised for the purpose of this study (Table 5). The early successional stages (1-,5-, and 10-year fallows) had fewer guilds (9, 11, and 10, respectively), than later successional stages from 25-year fallow to primary forest (11-12 guilds). The 25-year fallow had the highest number of guilds represented (12), which was only one guild more than the number of guilds in the mature forest sites (11). The *extra* guild in the 25-year fallow was represented by the rufous piculet, a diminutive woodpecker that forages primarily on bamboo substrates. This species occurred in the 10-year old fallow also and was absent from the mature forest sites. The 1- and 5-year fallows either lack or are deficient in guilds such as bark feeders, frugivores, canopy insectivores, and nectarivore-insectivores that are well-represented in later successional stages (see Table 5). The granivore guild is unique in that it is represented only in the 1-year fallow by three species (whitebacked munia, spotted dove, and rufous turtle dove). These species were seen only in the current and 1-year fallows and close to roads and human habitation throughout the study period. The mean number of species per guild increased from 2.6 in the 1-year fallow to 5.0 in the mature forest sites with intermediate values in the 10- and 25-year fallows.

Correlations between the number of species in a guild in a particular fallow and the average of the two PC scores for each successional fallow are presented in Table 6. This table indicates that there

are significant positive correlations between number of species in the frugivore. nectarivore-insectivore, bark-feeder, and terrestrial and canopy insectivore guilds, and PC1 (which represents woody plant succession). As one may expect, the bamboo-substrate feeding guild is positively

Table 5: Guild composition in successional *jhum* fallows and primary forest

Guilds	1-year fallow	5-year fallow	10-year fallow	25-year fallow	Disturbed & 100-year forest	Primary forest
Frugivore	1	5	4	5	7	9
Frugivore - nectarivore	-	1	-	2	2	2
Nectarivore - insectivore	5	8	8	9	12	10
Granivore	3	-	-	-	-	-
Bark-feeder	-	1	2	2	3	5
Bamboo	-	0	1	1	-	-
Omnivore	2	2	1	-	-	-
Diurnal carnivore	3	1	-	2	1	2
Nocturnal carnivore	-	-	-	1	2	1
Terrestrial granivore - insectivore	1	1	-	3	4	2
Sallying insectivore	1	6	4	7	6	6
Terrestrial insectivore	1	2	3	2	3	4
Understorey insectivore	6	9	8	12	10	7
Canopy insectivore	-	4	3	5	5	7
Total number of species	23	40	34	51	55	55
Number of guilds present	9	11	10	12	11	11
Number of species/guild Mean (± S.E.)	2.56 (0.63)	3.64 (0.90)	3.78 (0.88)	4.25 (1.05)	5.00 (1.05)	5.00 (0.92)

related to PC2 (bamboo density). However, this result is based on the occurrence of a single species (Table 5, but see Discussion). Omnivores are negatively correlated with PC1. Notably, other than the bamboo-substrate foraging guild, no other guild is significantly related to PC2.

Table 6: Relationship between guild structure and vegetational components

	Principal Components	
	PC1	**PC2**
Frugivore	0.85^{*}	-0.39
Frugivore - nectarivore	0.74^{b}	-0.26
Nectarivore - insectivore	0.84^{*}	-0.18
Granivore	-0.80^{b}	-0.28
Bark-feeder	0.88^{*}	-0.43
Bamboo	0.31	0.86^{*}
Omnivore	-0.93^{*}	0.09
Diurnal carnivore	-0.35	-0.46
Nocturnal carnivore	0.68	-0.33
Terrestrial granivore	0.52	-0.25
Sallying insectivore	0.77^{b}	0.17
Terrestrial insectivore	0.84^{*}	-0.30
Understorey insectivore	0.48	0.57
Canopy insectivore	0.89^{*}	-0.19
Number of Guilds	0.71	0.24
Mean number of species/guild	0.93^{*}	-0.24

$* \Rightarrow$ Probability of Type I error $p < 1/32$ comparisons = 0.03
$a \Rightarrow p < 0.05$. $b \Rightarrow p < 0.1$

Thus, the number of species in several guilds appears to be closely related with woody plant succession, and bamboo appears to play a comparatively insignificant role.

4.3 *Are primary forests more important for birds that are habitat-specialists or rare?*

In earlier sections, I have considered the impact of *jhum* on birds at the community level and at the level of feeding guilds. In the following sections, I consider the impact of *jhum* at the species level by categorising each species in terms of their abundance and rarity in different habitats.

4.3.1 *Habitat specialists*

To say that a bird species is specialised to a habitat type or to say that one bird species is more specialised than another requires that the habitat types under consideration be defined from a bird's point of view. At first thought, it seems possible that the number of transects a bird was seen in can be used as a simple index of habitat specialisation (i.e. fewer transects = more specialised). However, this is not appropriate in the case of this study as the sites sampled were deliberately chosen by the observer and do not necessarily represent the chief habitats that bird species may be distinguishing. Despite this apparent limitation, a meaningful way of comparing habitat specialisation can be devised. I argue that if two habitats are perceived by the birds as alike, then the overall bird community composition of the two sites should be very similar. Therefore, using the similarity indices of bird community composition to demarcate very similar sites (and hence, habitats) one can then proceed with determining the degree to which bird species in the defined habitats are specialised. In results presented earlier (see section 4.1.3, Table 1), I highlighted the fact that the 5- and 10-year fallows were nearly identical in terms of bird community composition. Similarly, the mature forest sites (disturbed primary, 100-year forest and primary forest) are very similar in bird community composition. Even in terms of vegetation these sites are very similar (see Section 4.2.1 and 4.2.2, Table 2). The two pairs of sites (5 to 10-year bamboo forest and mature forest) can justifiably be clubbed together as describing very similar to near-identical habitats for birds. With this assumption, I proceed to describe habitat specialisation in birds in the following four definable habitat types:

(i) One-year fallow (open field),

(ii) 5- to 10-year fallow (bamboo forest - number of individuals of each bird species occurring was taken as an average of the number in the two sites),

(iii) 25-year fallow (secondary 'tree-and-bamboo' forest), and

(iv) 100-year to primary forest (mature forest - number of individuals was averaged as in the case of bamboo forest).

Each bird species was placed in one of the following classes for each habitat type: Unique and Characteristic, Abundant, Frequent, Infrequent, Vagrants or Rare birds (Methods, section 3.3). The results given in Table 7 show the number and proportional representation of species in the first four categories. Vagrants and rare birds are considered later.

Table 7: Habitat specialists and bird-abundance categories in four main habitats

Successional Habitat category	Unique & Characteristic species	Abundant species	Frequent species	Infrequent species
1-year fallow (open field)	13 (56.5)	0 (0)	1 (4.3)	9 (39.1)
5- & 10-year fallow (Bamboo forest)	3 (6.7)	2 (4.4)	12 (26.7)	28 (62.2)
25-year fallow (mixed tree-and-bamboo secondary forest)	5 (9.6)	3 (5.8)	16 (30.8)	28 (53.8)
Mature forest	12 (19.0)	4 (6.3)	19 (30.2)	28 (44.4)

N. B. : Tabled values are number of bird species and percentages (in parentheses).
For definitions of specialisation and abundance categories see Methods.

Unique and characteristic species:

Open 1-year fallow had the highest number of unique bird species (13). Unique species dominated the community comprising 56.5% of the total species (Table 7). The unique species included insectivores such as tailor bird, Indian tree pipit, Beavan's wren-warbler, redbreasted flycatcher, and dark grey bush chat, granivores such as spotted dove, whitebacked munia, and rufous turtle dove, and omnivorous redvented bulbuls. Four of these species (redvented bulbul, tailor bird, Beavan's wren-warbler, and redbreasted flycatcher) also occurred in the 5-year fallow but at much lower densities and generally close to the edge near adjacent open fields or small clearings.

After 1-year fallow, the number of unique and characteristic was highest in mature forest, where 12 species were found (these comprised 19.0% of the total species, Table 7). This included species which typically occurred only in the mature moist forest in the study area, eg. imperial pigeon, peacock-pheasant, Indian pied hornbill, great hill barbet, blacknecked tailor bird, whitetailed blue flycatcher, and blackbreasted sunbird, as well as others such as plaincoloured flowerpecker, and lesser yellownaped woodpecker which were noted to occur sporadically in late secondary forest during casual observations.

The number of unique species in the 5-10 year fallows and 25-year fallows were three and five, respectively. The unique species in the former habitat were quaker babbler, blackheaded oriole, and white-eye. Blackheaded orioles and white-eyes were seen in the disturbed primary forest on some occasions (casual observations) but were absent from other mature forest areas. The quaker babbler occurred solely in *jhumed* areas and its distribution can be said to match that of *Melocanna bambusoides*, the bamboo that colonises abandoned *jhum* fields, almost exactly. In the mature forest areas it was completely replaced by a congeneric species the Nepal babbler. The quaker babbler was noted in a portion of the disturbed primary forest where *Melocanna* had invaded the understorey, but otherwise occurred only in *jhumed* areas outside of mature forests. In the 25-year fallow, five species were classified as unique or characteristic. They were: fairy bluebird, collared broadbill, Tickell's babbler, whiteheaded shrike-babbler, and larger goldenbacked woodpecker. The term characteristic (implying higher abundance in the 25-year fallow) is probably more appropriate to these species as they also occurred quite regularly in primary forest areas, though not frequently on the transects (all five species were detected 1-3 times in primary forest transects). Two things are to be noted regarding these five species. Firstly, they were all detected on less than 11 occasions over 10 km of transect (implying infrequent occurrence compared to 19 other species which were classified as abundant and frequent). Secondly, the 25-year fallow transects were in the moist Tuichar valley and was surrounded on three sides by tall primary, evergreen riverine vegetation. Four species (fairy bluebird, Tickell's babbler, larger goldenbacked woodpecker, and collared broadbill) were noted frequently in the primary forest areas immediately surrounding the 25-year fallow.

Overall, it is clear that the open 1-year fallow that represents a drastically different habitat, has a number of specialised, open-country species occurring solely in these areas. At the other extreme, the primary forest has an almost equal number (but much lower proportion) of highly specialised bird species of interior forest. The 5-10 year fallow has three species that are rare or absent elsewhere and the 25-year fallow appears to have five species that occur infrequently but at higher rates than in the primary forest transects. An important aspect that clearly emerges from this is that *jhuming* causes an *increase in the overall bird species richness* by the addition of several disturbance- and open-country adapted species particularly in the 1- and 5-year fallows.

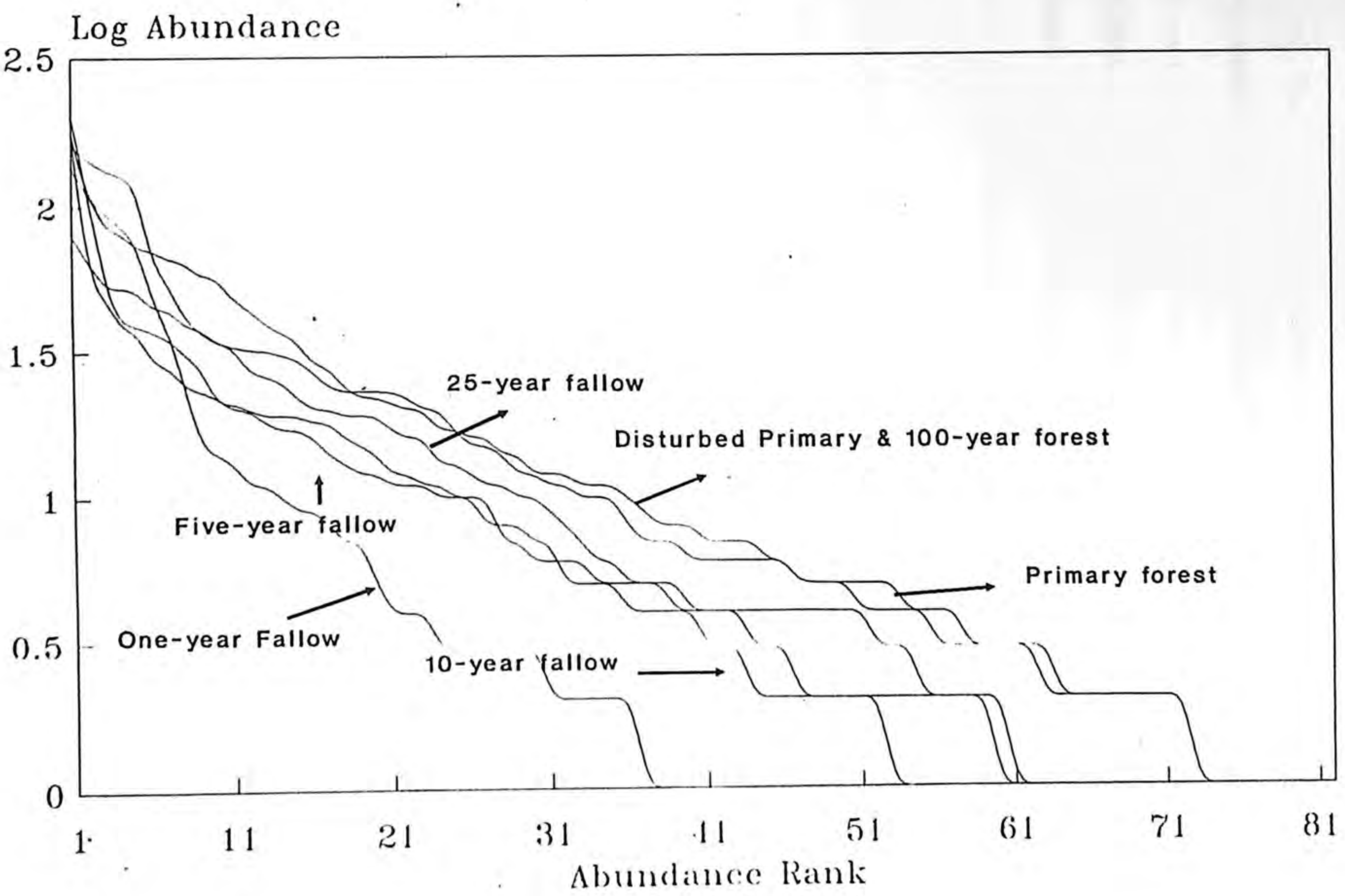
Other abundance categories:

Another striking aspect in Table 7 is that birds in the abundant and frequent categories constitute a relatively small proportion in the 1-year fallow (5.3%), whereas they constitute nearly one-thirds of the 25-year fallow and mature fallow sites. The 5-10 year fallows are intermediate. This implies a much steeper species-abundance graph (Fig. 9) in young fallows compared to late-successional fallows and mature forest. Infrequently occurring species dominate the 5-and 10-year bamboo forests (62.2% of species, Table 7), the proportion declining to 44.4% in the mature forest sites. The implications of these patterns are elaborated in the Discussion.

4.3.2 *The question of rarity: Apparently rare vagrants and intrinsically rare birds:*

Numerous species were detected less than three times in each of the four identified habitat categories, i.e. 1-year fallow, 5-10 year fallow, 25 year fallow, and mature forest. These species have been excluded from the earlier analyses in this section as they could not be justifiably attributed to that habitat based on just one or two observations. However, an alternative approach

Fig 9: Bird species–abundance patterns during succession after *jhum* cultivation



has been pursued here. In Table 8, I have placed each of these vagrant/rare species in four broad categories, i.e.:

(i) species common in early succession (species that were seen frequently in 1-10 year fallows on transects and casual observations),

(ii) species common in late succession (species that were frequently seen in 25-year fallows and mature forest),

(iii) other (birds found near water, near human habitation, passage migrants etc.), and finally

(iv) intrinsically rare birds (birds that were overall very scarce in the study area and were rarely seen in transects or during casual observations). These species are the ones that are most important from a conservation point of view.

The results presented in Table 8 are revealing. In the successional forests (1- to 10-year fallows), 44-47% of the apparently rare birds are species that are common in late successional forests (Table 8). For instance, species like whitecheeked hill partridge, bluethroated barbet, green magpie, and blacknaped woodpecker, which were very common in mature forest occurred at very

Table 8: Numbers (and percentages) of vagrant/rare species in different categories in the identified habitat types

Habitat Category	Common birds in early succession (1-10 yrs.)	Common birds in late succession (25-100+ yrs)	Other	Intrinsically rare bird species
1-yr fallow (open field)	6 (24.0)	11 (44.0)	4 (16.0)	4 (16.0)
5-10 yr fallow (bamboo forest)	12 (26.7)	21 (46.7)	3 (6.7)	9 (20.0)
25-yr fallow (mixed tree-and-bamboo secondary forest)	3 (12.0)	15 (60.0)	1 (4.0)	6 (24.0)
Mature forest	12 (32.4)	4 (10.8)	1 (2.7)	20 (54.1)

Tabled values are numbers of vagrant/rare species in different categories and percentages to totals (in parentheses).

low densities in the bamboo forests and *jhum* habitat mosaic. These species were thus detected at low frequencies. In the 25-year fallows, the vagrants were similarly largely (60.0%) composed of species common in mature forest, such as blueeared barbet, blackthroated babbler, redeared bay woodpecker etc. The intrinsically rare birds are clearly confined largely to mature forest both in terms of total number of species (20) as well as proportion (54.1%, see Table 8). This includes species that were entirely absent in early successional habitats, such as pintailed green pigeon, bluenaped pitta, collared broadbill, great slaty woodpecker, streaked wren-babbler, as well as others that were seen only once or twice in *jhumed* areas during casual observations spanning the entire study period, eg. blackbrowed leaf warbler, thickbilled green pigeon, and orangeheaded ground thrush.

Finally, from the above analyses (Tables 7 and 8), I would like to conclude the following:

(i) A large majority of the birds that occur very infrequently in *jhumed* areas as vagrants/apparently rare species, are actually species that are abundant or frequent in mature forest.

(ii) Mature forest contains the largest number and proportion of intrinsically rare bird species (20/100 species detected in mature forest transects).

4.4 *Do altitudinal migrants tend to prefer mature forest habitat while long-distance migrants prefer open, disturbed habitats?*

Fourteen species of altitudinal migrants were seen at least three times in one of the four habitats. The number of species of altitudinal migrants in the 1-fallows, the 5-10 year fallows, the 25-year fallows, and mature forest were 4, 3, 6, and 8, respectively. Interestingly, the 4 species in the 1-year fallow did not occur in the later successional stages, i.e. rubythroat, greybacked shrike, Indian tree pipit, and dark grey bush chat. All four species were earlier classified as 'unique' to the 1-year fallow. In contrast, except for one species (whitetailed blue robin) the altitudinal migrants that occurred in the 5-25 year fallow also occurred in mature forest transects but at lower frequencies in the habitat. Among the altitudinal migrants that occurred in mature forest, shortbilled minivets and whitetailed blue flycatcher were not seen in early successional habitats at all, whereas rufousbreasted blue flycatchers occurred at lower frequencies in the *jhumed* areas (30 detections in mature forest *vs.* 17 and 4 in 25- and 10-year fallows, respectively). Overall, primary forest is the main habitat for at least 8 of the 14 species of altitudinal migrants, while four are exclusive to the 1-year *jhum* fallow is the exclusive habitat for four species. The remaining species (whitetailed robin and blackbrowed flycatcher-warbler) which were seen at least thrice in 10-25 year old bamboo forest only, were detected in primary forest also during casual observations.

Only two species of long-distance migrants were detected on transects, the redbreasted flycatcher (a winter migrant from the Palaearctic zone), and the bluethroated flycatcher (a summer breeding migrant that spends the winter in south India). Redbreasted flycatcher were detected only in 1- and 5-year fallows (37 and 7 times, respectively). This again was a species classified as 'unique or characteristic' in the 1-year fallow. During casual observations, the species was detected only once in mature forest during the entire study period. Bluethroated flycatchers were detected only in the 5- and 25-year fallow, 3 and 4 times, respectively. The low sightings can be attributed to the fact that this species appeared in the study area only in March 1995. Casual observations confirmed that the species was most frequently encountered in bamboo forests that were 5- to 10-years old in the study area. Both species of long-distance migrants can thus be said to benefit from *jhuming*, as it creates suitable habitat for them.

5. DISCUSSION

The major findings of this study are clear. To briefly recapitulate, there are distinct trends of increase in bird species richness and abundance through succession from open 1-year *jhum* fallow to primary forest (Table 1). Similarity indices reveal that the changes are sequential, with species turnover occurring as vegetation succession proceeds. The 5- and 10-year old bamboo forests are very similar to each other in terms of bird community composition (Fig. 5). By 25 years, the mixed tree-and-bamboo forest in the valley has species richness values close to that found in primary forest (Table 2 and Fig. 3) but near-complete convergence as indicated by the similarity index seems to have occurred only by 100 years (Fig. 5). Vegetation succession has been characterised by PCA into components reflecting woody plant succession (PC1) and bamboo succession (PC2) (Fig. 8). Overall, bird species richness, abundance, and guild attributes appear to be most closely tied to PC1. In terms of habitat specialisation, the 1-year fallow has the largest number of unique species adapted to open-country. Mature forest has the second largest number of unique or characteristic species and the largest number (and proportion) of intrinsically rare birds. In terms of migrants, the limited data indicates that most altitudinal migrants are predisposed to use of mature forests whereas the two species of long-distance migrants prefer open habitats. I now discuss these results further and attempt to answer the five questions raised in the Introduction and outline their implications for the conservation of birds in the lower altitude hills of north-east India.

5.1 *Trends in bird species richness and abundance - the timescale of ecosystem recovery*

Bird species richness showed a relationship with successional age of vegetation that was not linear, but asymptotic, i.e. there was a rapid initial increase from 1-year fallow to 25-years after which there was only a slight increase between 25- and 100-years (Fig. 3). By 100 years, bird species richness had attained values practically identical to primary forest. The functional response curve in Fig. 3 is a model of diminishing returns over time. This curve parallels the well-known patterns of change that occur during plant secondary succession in terms of increase in plant biomass over time, decrease in plant production/respiration ratio to unity in mature climax forest, in production/ biomass ratio and net primary production from high to low values, and so on (Odum 1971). An examination of Table 2 clearly indicates that even vegetation succession in *jhum* fallows in the study area shows asymptotic changes in tree density (which can be taken to reflect woody biomass), woody plant species richness, canopy density and so on. Such changes during secondary succession of plant communities in abandoned *jhum* fallows in north-east India have earlier been documented by Toky and Ramakrishnan (1983, see also Ramakrishnan 1992). The important aspect in these trends is the rate of change over time. According to Odum (1971), the rates of change in communities (whether they be plant or animal communities) are initially rapid but decrease to zero as the ecosystem matures giving rise to a stable climax formation. The equilibrium assumptions of this model was criticised by others (see Connell and Slatyer 1977), but the overall trends are generally supported by field observations of not only plant communities (Toky and Ramkrishnan 1983, Sprugel 1985, Brown and Lugo 1990), but also of bird communities along a successional gradient of vegetation (Smith and MacMahon 1981). I suggest that the trends seen in this study in both bird community attributes (such as species richness and abundance), as well as plant community attributes (such as woody plant species richness, tree density) reflect that secondary succession in both bird and plant communities following shifting cultivation in north-east India show similar changes over succession.

The functional response equations fitted to the changes in mean and cumulative bird species richness (Fig. 3) are now easy to interpret - V represents the asymptotic value of bird species richness, and k is a variable that represents the rapidity of the initial recovery phase. A caveat that needs to be added here is that the curve is an empirically-derived fit deliberately chosen for the biological interpretations that it offers. It needs to be validated by further studies; of particular interest would be the factors that affect k. For instance, different areas and different disturbance factors may affect the value of k. In higher altitudes, where vegetation succession and recovery is slower (Ramakrishnan 1992), k is likely to be higher; for the same value of k, recovery in species richness will be faster in less species-rich habitats (lower V). The potential value of the equation is that if one knows the values of species richness in mature forest and can predict the value of k it will be possible to assess how long the ecosystem will take to recover from disturbances such as *jhuming*. I suggest the variable k in the equation is analogous to the z value that has found much utility in studies of island biogeography (MacArthur and Wilson 1967), and may perhaps yield insights into general principles underlying recovery of tropical forest ecosystems as more information becomes available in the future.

Another implication of the patterns found here is that as recovery in bird communities is rapid (by 25 years the species richness is only slightly less than in primary forest), the impact of *jhuming* on birds is unlikely to manifest itself until disturbance levels are drastic - i.e. repeated *jhuming* under a short *jhum* cycle of 5 or ten years. Studies on another form of habitat disturbance in tropical rainforests (logging) suggest a similar conclusion - species loss may be a logarithmic function, i.e. species may be able to persist in moderately to highly disturbed areas but further increases in disturbance rates would cause disproportionately more losses than at low disturbance levels (Johns 1992). In this study, bird species richness is linearly related to the logarithm of the successional age of the fallow ($r = 0.91$, $df = 10$, $p < 0.001$). I have also mentioned that the greater the difference in the logarithm of the ages between two fallows, the less the similarity ($r = -0.75$, $p<0.001$). This linear relationship disappears if the arithmetical age difference is used ($r = -0.13$, $p = 0.29$). These logarithmic relationships suggest that species accumulation and convergence toward mature forest conditions is related more closely to the ratio of difference in fallow ages through succession than to simple arithmetical differences in age. In terms of *jhuming*, one can predict that in a hypothetical case where *jhum* cycle declines from 100 years to, say, 50 years (a 2-fold difference in age), the loss in species will be much less than, say, a decline in *jhum* cycle from 25 to 5 years (a 5-fold difference).

I mentioned earlier that the patterns of change in bird community appear to parallel changes in plant succession. If this is true one would expect to find close relationships between bird community attributes and vegetation attributes. It is to this aspect that I now turn as a prelude to answering my second question.

5.2 *Vegetation succession and birds*

5.2.1 *Recovery of forest vegetation*

Succession in vegetation from 1-year fallow to primary forest shows three main trends: (i) an increasing trend in tree density, woody plant species richness, canopy cover, depth of leaf litter, and vertical stratification. (ii) declining trend in horizontal patchiness of the vegetation, and (iii) an increase in bamboo density upto 25 years followed by a decline to nearly zero values in primary forest (Table 2, Fig. 7). These trends have been lucidly summarised by PCA in figure 8.

Bamboos are well known to be colonisers of secondary habitats in north-east India (Rao and Ramakrishnan, 1988). In areas where *jhuming* is carried out repeatedly under fallow cycles of 5-10 years, succession is arrested at this stage and dense, near-monotypic stands of bamboo become the predominant vegetation (Ramakrishnan 1992). But if succession is allowed to take its course, it is likely that bamboos would initially dominate and then decline to very low values in mature forest because woody plants are quick to replace them follow the death of bamboos after periodical mass-flowering. My observations showed that many shrubs and tree saplings of primary forest woody plants (e.g. *Artocarpus chaplasha, Mesua ferrea, Cinnamomum obtusifolium*) were growing profusely in the dense, dark understorey of the 25-year fallow. Rainforest plants which are known to be shade-adapted (Richards 1952) presumably grow well under the dense bamboo forests that are 10 or more years old and replace them after the flowering and death of *Melocanna bambusoides* bamboo. However, recovery of the original mature forest plant community may take either a much longer time, or, alternatively, the original composition may never recover due to interplay of other chance factors.

Studying temporal processes in tropical rainforests is notoriously difficult in the absence of indices such as growth rings. An interesting recent attempt by Riswan *et al.* (1985) at modelling the recovery processes predicted a minimum period of 60-70 years for stabilization of secondary species (plants) and replacement of primary species by 105-150 years. After 220-250 years, the model predicts, biomass will stabilize while individual trees may exist for over 500 years (Riswan *et al.* 1985). In Dampa TR, the 100-year old forest site that has regenerated on village-land abandoned in 1895-1900 on Dampatlang and Pathlai Lunglen Tlang is very similar to primary forest in terms of vegetation. This appears to validate the model of Riswan *et al.* (1985). However, some differences do exist in terms of the apparent scarcity of large emergents and other floristic differences and structural differences: for instance, *Cinnamomum tamala* one of the commonest tree species in primary forests was practically absent in the 100-year old forest; tree density, woody plant species richness, and depth of leaf litter were significantly lower in the 100-year forest than in the primary forest (t-tests, $p<0.05$, see Results). Assuming the patterns of change are asymptotic, we can predict that complete recovery of original vegetation and biomass may well take at least 200-250 years as suggested by Riswan *et al.* (1985).

5.2.2 *Birds and vegetation - correlated changes:*

So now, we can ask the question, 'How are bird community attributes related to vegetation succession and maturity of the forest?'. In a study of the bird communities in the Western Ghats hill ranges in south India, Daniels *et al.* (1992) found a negative correlation between bird species richness and woody plant species diversity and vertical stratification. They argued that this result was because the Western Ghats was relatively impoverished in evergreen forest bird species compared to the Eastern Himalayas, Drier, open forest habitats and plantations in the Western Ghats had higher bird species richness as they were colonised by birds from the large source pool of species of more open forest habitats in the Indian sub-continent (Daniels *et al.* 1992). Stating the same argument in the reverse one would predict that in the bird-species-rich tropical forests of the Eastern Himalayas and north-east India bird species richness is likely to be positively correlated with woody plant species diversity and vertical stratification. This is clearly borne out by my findings as there are significant positive correlations between bird species richness and abundance, and PC1, which represents woody plant succession ($r = 0.77$ and 0.63, $p < 0.05$, Table 4). This trend of increase in bird species richness with woody plant species richness, vertical stratification, tree density, and other traits reflecting woody plant succession on PC1, thus represents the more common trend that has been found earlier in tropical forest habitats (Terborgh 1985, Wiens 1989). The tropical forests of north-east India may thus be saturated with bird species compared to the species-deficient Western Ghats (Daniels *et al.* 1992).

Another notable aspect is that bamboo succession (PC2) shows a negative relation with bird species richness and abundance when the effects of woody plant succession (PC1) are removed by partial correlation. This is perhaps because the 10-25 year bamboo forests appear as dense monotypic stands of *Melocanna bambusoides* bamboo (40-46 culms per 25 m^2). These dense stands are possibly uniform both in terms of space and availability of resources compared to 5-year old bamboo forests which had the highest values of horizontal heterogeneity (Table 2). Hence species that reach high abundance in the more heterogeneous early-successional habitats may decline in abundance (eg. quaker babbler, little spiderhunter).

The positive correlation between bird species richness and woody plant succession (PC1) is easier to understand when we consider individual guilds. It is seen that the number of species in several guilds is positively related to woody plant succession (Table 6): frugivores (egs. barbets, hornbills, bulbuls), bark-feeders (egs. woodpeckers, nuthatches, speckled piculet), nectarivore-insectivores (e.g. chloropsises, bronzed and racket-tailed drongos), terrestrial insectivores (egs. laughing thrushes, dull slatybellied ground warbler), and canopy insectivores (egs. shortbilled minivet, large greenbilled malkoha). Frugivores occur at higher numbers in the mature forests probably because fruiting trees are more abundant in this habitat. Tree species such as *Ficus sp.*, families such as Lauraceae and Myristicaceae, which are known to be important for frugivorous birds (Ali and Ripley 1983) were well represented in mature forest and scarce in the *jhumed* countryside. In Neotropical habitats where fruit abundance is higher in secondary forest (25 years old) greater frugivore abundance and diversity may be seen in the disturbed habitats (Martin 1985). Bark is also a resource that is available more in late successional stages as tree density increases (Table 2). Canopy cover and depth of leaf litter are also highest in the mature forest and this may account for the fact that terrestrial and canopy insectivores are well-represented here. The availability of food resources may be an important determinant of habitat selection by birds. The distribution of granivores too appeared to reflect this as they occurred only in the open 1-year fallow where fallen grain, grass seeds etc. were an obviously available resource. The overall trends of change in guild composition and structure (such as increase in canopy insectivores and bark feeders with succession) closely parallel those found in studies of shifting cultivation and bird communities by Bowman *et al.* (1990) in Papua New Guinea and Blankespoor (1991) in Africa suggesting that similar factors underlying these patterns exist.

The bamboo-substrate feeding guild, represented by a single species (rufous piculet) appeared to show a significant relationship with PC2 (bamboo density). In the study area, three bird species were seen feeding on bamboo substrates - rufous piculet, paleheaded woodpecker, and slatyheaded scimitar babbler. The paleheaded woodpecker has been noted to be *partial* to bamboo forests (Ali and Ripley 1983, *pers. obs.*). The occurrence of such species which are highly specialised on bamboo - a characteristic feature of successional habitats (Rao and Ramakrishnan 1988), suggests that some species may have evolved exclusively to exploit the bamboo niche in the forests of north-east India. Such species may benefit from *jhuming* which creates large areas of secondary successional bamboo forests. Within the *natural* vegetation zones of Dampa TR these species are likely to occur chiefly or entirely on the more open, steep-slope forests on the western aspects of the main ridges, where *Dendrocalamus longispathus* (another preferred substrate, *pers. obs.*) is dominant in the understorey.

Overall, the fact that bird community traits such as species richness, and number of species in several guilds are most closely related to PC1 gives credibility to the suggestion made earlier that avian succession is closely related to succession of woody plants in the tropical forests of Mizoram. With this is mind, we can see that *jhuming*, particularly at low cycles such as 5-10 years, by maintaining an arrested successional vegetation of bamboo (*Melocanna bambusoides*) and suppressing woody plant succession results in impoverishment of the tropical forest bird communities of the region - a consequence that is clearly important in terms of conservation.

5.3 *Habitat specialists and rare birds - implications for conservation*

I have argued above that *jhuming*, particularly at cycles of 5-10 years, has an overall negative impact on birds when viewed at two levels - that of the entire community and that of guilds. I now consider how the impacts reach down to the level of individual species and the implications therein for the conservation of bird species in north-east India.

Table 1 indicates that birds are more abundant in mature forest. In contrast, a large proportion (over 50%) of the birds in the 5-25 year fallow occur infrequently or as vagrants (Tables 7 and 8). In Table 8, I document that about 44-60% of these species are common in mature forest areas. This suggests that numerous species of mature forest birds occur very sparingly and infrequently in *jhumed* areas. As succession proceeds, these species are likely to increase in abundance to levels comparable in mature forests. This would imply that the species-abundance curve (Fig. 9) will gradually even out as the fallow ages and the proportion of species in intermediate abundance classes would increase. The 10- and 25-year fallow transects were all adjacent (generally, < 150 m away from) to mature forests. Thus many species that occurred in the 10-25 year fallows may simply represent birds that stray occasionally out of adjacent mature forest. Thus there were no true *unique* species in the 25-year fallow, the species that emerged as unique (according the arbitrary criteria I adopted) were also present in mature forests. The colonisers of *jhum* fallows aged 5-25 years appear to be primarily derived from the species pool of mature forest. If this is true then these birds may not persist in the *jhum* habitat matrix if primary forests are removed. During casual observations forest-interior species such as great slaty woodpeckers and longtailed broadbills were seen a few times on tall trees in *jhumed* areas and in wooded ravines. These sightings were invariably adjacent to mature forest sites. It is likely that if mature forest was absent from the vicinity of these areas these species would simply not occur and local extinctions or declines in abundance may occur (Askins and Philbrick 1981, Kricher and Davis 1990). In terms of intrinsically rare birds also, mature forest is the most important habitat, with 20% of the species detected in mature forest habitats characterised thus. The fact that mature tropical forests harbour a large proportion of rare species has been documented in two other recent studies (Terborgh *et al.* 1990, Thiollay 1994).

Thirteen species of birds were characterised as unique to the 1-year fallow, and 3 to the 5-year fallow. While this clearly suggests that *jhuming* results in higher overall species richness of birds in the study area (i.e. these thirteen species would be absent if *jhuming* were not carried out), the importance of this fact from a conservation point of view is dubious. Species such as tailor bird, redvented bulbul, spotted dove, Indian tree pipit, rufous turtle dove, blackheaded oriole, whitebacked munia, white-eye, shikra etc. are birds that are very common in the Indian sub-continent (Ali and Ripley 1983, *pers. obs.*) and are of limited interest from a conservation point of view. Other open-country and disturbance-adapted species such as rubythroat, redbreasted flycatcher, dark grey bush chat, and Beavan's wren-warbler (in 1-year fallow) and quaker babbler, yellowbellied flycatcher-warbler (in bamboo forests) are very common and widespread in heavily disturbed habitats such as roadsides, valley agriculture, village bamboo reserves (Vern.: *Mauhak*), ravines in disturbed areas, and gardens in the study area (*pers. obs.*). As it is unlikely that these habitats will become scarce in the foreseeable future, I argue that these species are also not under threat of local extinction even in the absence of *jhum*. It is the avifauna of mature forest that clearly deserves priority in terms of conservation. The importance of protecting undisturbed mature forest habitat cannot therefore be overemphasized for conservation of birds in north-east India.

5.4 · *Altitudinal and latitudinal migrants - a final consideration:*

Many tropical forest bird species show substantial movements following temporal and spatial changes in availability of food resources. Nomadic frugivorous green pigeons (*Treron spp.*), water-dependent species such as the threetoed kingfisher that exhibits monsoon-related movements, are examples (Ali and Ripley 1983). While the above movements may be temporally and spatially erratic (Loiselle and Blake 1992), for many species, movements may be in the form of very regular, seasonal, altitudinal and latitudinal migration. Such species can be expected to move through or over different habitat types and in cases where mature forest habitat has been lost due to human pressures, their survival may hinge upon their ability to make use of disturbed vegetation. Studies in the Neotropics have shown that latitudinal migrants frequently occur at high densities in disturbed areas while residents and altitudinal migrants chiefly occur in mature forests (Lynch 1989, 1990, Loiselle and Blake 1992). The findings in this study appear to support the above patterns, with one exception, the highly disturbed one-year fallow had four species of altitudinal migrants. These species along with the two latitudinal migrants are likely to benefit from habitat conversion due to *jhum*. However, all species are relatively common and widespread birds in India (Ali and Ripley 1983), perhaps as a result of their ability to survive in highly modified habitats. As they are likely to persist in modified habitats in the future, they cannot be considered to be significant from a conservation point of view in comparison to the birds of late-successional (>25 years) and mature forests, many of which occur only in the north-east parts within India.

5.5 *Conclusions: reconciling conservation with human needs*

The mature tropical forest ecosystem in north-east India is characterised by bird species richness levels that seem to have reached saturation levels. Disturbance of this ecosystem by *jhuming* has overall negative results such as drastic alteration of the mature forest bird community, decline in species richness and abundance of forest birds, particularly habitat specialists and rare birds. If however, one considers *all* birds and not just *forest* birds, then *jhum* does have an effect of increasing species richness, as hypothesised by Gadgil and Guha (1992), by the entry of several specialised open-country birds. I argue that conservation objectives that simply desire to *maximise* bird diversity are inappropriate to this situation. The birds of the open fallows and highly disturbed habitats are generally common species, most with large ranges in the Indian subcontinent, and precisely *because* they are disturbance-adapted they may very likely persist or increase in numbers in the future in the face of habitat conversion.

The emphasis therefore has to be on conservation of mature forests. This may be quite important considering the fact that primary and mature forest conversion rates are proceeding apace in most parts of the tropics (Myers 1980, 1988). In Mizoram itself, it was estimated in 1981 that nearly 80% of the land area was already affected by *jhum* cultivation (FAO 1981). Nevertheless, it could be argued that as secondary succession is quite rapid, *jhum* cycles with long fallow periods (25 years or more) will help in maintaining the diversity of forest bird communities while meeting the needs of the people who continue to subsist almost entirely from *jhum*. However, this suggestion is likely to be of more academic than practical interest in areas around Dampa TR and parts of Mizoram I saw. Here, as in other parts of north-east India (Ramakrishnan 1992), practically all available land is already under very short *jhum* cycles of 5-8 years. The 10- and 25-year fallows that I describe in this study were areas within the protected area. As far as I know there exists no comparable area outside the protected area that is allowed to regenerate for such long periods. Mizoram's population has increased by nearly 850% from about 82,000 people in 1901 to 6,89,000 in 1991 (Anon. 1992). There have been remarkable historical and demographic changes even in the villages around Dampa TR (T. R. S. Raman, *unpubl. data*). These are likely to have caused increases in the total magnitude of human impact on the forest ecosystems in Mizoram. Until these factors are properly understood and more scientific information becomes available, it is difficult, and perhaps premature, to offer any conclusive prescriptions on how to reconcile human needs and conservation goals. Over most of north-east India, the viable options appear to be to stabilize *jhum* at cycles of 5-10 years and develop village industries, agroforestry, horticulture and so on as partial alternatives to *jhum* (Ramakrishnan 1992). This study indicates that in terms of conservation, 5-10 year cycles are likely to be inadequate to maintain the bird and woody plant species diversity of the tropical forests of the region. For conservation goals to be achieved, the maintenance of mature tropical forests is essential.

REFERENCES

ALI, S. 1977. Field guide to the birds of the eastern Himalyas. Oxford University Press, Delhi. 265 pp.

------, AND S. D. RIPLEY. 1983. Handbook of the birds of India and Pakistan. Compact edn. Oxford University Press, Delhi, 737 pp.

ANDRADE, G. I. AND H. RUBIO-TORGLER. 1995. Sustainable use of the tropical rain forest: Evidence from the avifauna in a shifting-cultivation habitat mosaic in the Colombian Amazon. Conserv. Biol. 8:545-554.

ANON. 1992. Statistical hand book Mizoram. Department of Economics and Statistics, Government of Mizoram, Aizawl. 259 pp.

ASKINS, R. A., AND M. J. PHILBRICK. 1987. Effect of changes in regional forest abundance on the deline and recovery of a forest bird community. Wilson Bull. 99:7-21.

BLANKESPOOR, G. W. 1991. Slash-and-burn shifting agriculture and bird communities in Liberia. West Africa. Biol. Conserv. 57:41-71.

BOWMAN, D. M. J. S., J. C. Z. WOINARSKI, D. P. A. SANDS, A. WELLS, AND V. J. MCSHANE. 1990. Slash-and-burn agriculture in the wet coastal lowlands of Papua New Guinea: Response of birds, butterflies and reptiles. J. Biogeog. 17:227-239.

BROWN, S. AND A. E. LUGO. Tropical secondary forests. J. Trop. Ecol. 6:1-32.

CHAMPION, H. G, AND S. K. SETH. 1968. A revised survey of the forest types of India. Manger of Pubication, Government of India, Delhi. 404 pp.

CONKLIN, H. C. 1969. An ethnoecological approach to shifting agriculture. Pages 221 - 233 *in* A. P. Vayda, ed. Environment and cultural behaviour, Academic Press, New York.

CONNELL, J. H., AND R. O. SLATYER. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. Amer. Natur. 111:1119-1144.

DANIELS, R. J. R., AND M. HEGDE. 1990. Is there a good season and time for sampling tropical forest birds. Blackbuck 6:3-7.

----------------, N. V. JOSHI, AND M. GADGIL. 1992. On the relationship between bird and woody plant species diversity in the Uttara Kannada district of south India. Proc. Natl. Acad. Sci. USA 89:5311-5315.

DWIVEDI, A. P. 1993. Forests: The ecological ramifications. Natraj Publishers, Dehradun. 328pp.

EDEN, M. J. 1987. Traditional shifting cultivation and the tropical forest system. Trends Ecol. Evol. 2:340-343.

FAO. 1981. Forest resources of tropical Asia. FAO, Rome. 475 pp.

GADGIL, M., AND R. GUHA. 1992. This fissured land: An ecological history of India. Oxford University Press, Delhi. 274 pp.

GOI. 1987. The state of the forest report 1987. Government of India, Ministry of Envir. and Forest, Forest Survey of India, Dehradun, 84 pp.

GUHA, R. 1994. Fighting for the forest: State forestry and social change in tribal India. Pages 20-37 *in* O. Mendelsohn and U. Baxi, eds. The rights of subordinated peoples. Oxford University Press, Delhi.

HAGAN, J. M., AND W. JOHNSTON, eds. 1990. Ecology and conservation of Neotropical migrant landbirds, Smithsonian Institution Press, Washington. 609 pp.

HORST, O. H. 1989. The persistence of milpa agriculture in highland Guatemala. J. Cult. Geog. 9:13-29.

JOHNS, A. D. 1992. Vertebrate responses to selective logging: Implications for the design of logging systems. Phil. Trans. R. Soc. Lond. B. 335:437-442.

JOHNSTON, D. W., AND E. P. ODUM. 1956. Breeding bird populations in realtion to plant succession on the piedmont of Georgia. Ecology 37:50-62.

KARR, J. R. 1971. Structure of avian communities in selected Panama and Illinois habitats. Ecol. Monogr. 41:207-233.

KATTI, M. V. 1989. Bird communities of lower Dachigam valley, Kashmir. M. Sc. Dissertation, Saurashtra University, Rajkot. 58 pp.

-----------, P. SINGH, N. MANJREKAR, D. SHARMA, AND S. MUKHERJEE. 1992. An ornithological survey in eastern Arunachal Pradesh, India. Forktail 7:75-89.

KRICHER, J. C., AND W. E. DAVIS. 1990. Patterns of avian species richness in disturbed and undisturbed habitats in Belize. Pages 240-246 *in* J. M. Hagan and D. W. Johnston, eds., Ecology and conservation of Neotropical migrant landbirds, Smithsonian Institution Press, Washington.

LAL, J. B., AND R. C. PRAJAPATHI. 1990. Space-borne monitoring of shifting cultivation in north-eastern region of India. Van Vigyan 28:125-126.

LECK, C. F. 1979. Avian extinctions in an isolated tropical wet-forest preserve, Ecuador. Auk 96:343-352.

LOISELLE, B. A., AND J. G. BLAKE. 1992. Population variation in a tropical bird community. BioScience 42:838-845.

LYNCH, J. F. 1989. Distribution of overwintering nearctic migrants in the Yucatan Peninsula. I: General patterns of occurrence. Condor 91:515-544.

-----------. 1990. Distribution of overwintering Nearctic migrants in the Yucatan Peninsula, II: Use of native and human-modified vegetation. Pages 178-195 *in* J. M. Hagan and D. W. Johnston, eds., Ecology and conservation of Neotropical migrant landbirds, Smithsonian Institution Press, Washington.

MACARTHUR, R. A. AND E. O. WILSON. 1967. The theory of island biogeography. Princeton University Press, Priceton, New Jersey. 203pp.

MAGURRAN, A. E. 1988. Ecological diversity and its measurement. Croom Helm, London. 179 pp.

MANI, M. S., ed. 1974. Ecology and biogeography of India. Dr. W. Junk Publ., The Hague. 773pp.

MARTIN, T. E. 1985. Selection of second-growth woodlands by frugivorous migrating birds in Panama: An effect of fruit size and plant density? J. Trop. Ecol. 1:157-170.

MAY, P. G. 1982. Secondary succession and breeding bird community structure: Patterns of resource utilization. Oecologia 55:208-216.

MISHRA, C., T. R. S. RAMAN, AND A. J. T. JOHNSINGH. 1994. Survey of primates, serow, and goral in Mizoram. Wildlife Institute of India, Dehradun, 30 pp.

MYERS, N. 1988. Threatened biotas: "Hot spots" in tropical forests. Environmentalist 8:187-208.

--------. 1990. The biodiversity challenge: Expanded hot-spots analysis. Environmentalist 10:243-256.

NORUŠIS, M. J. 1990. SPSS/PC+ Statistics 4.0. SPSS Inc., Chicago.

ODUM, E. P. 1950. Bird populations of the highlands (North Carolina) plateau in relation to plant succession and avian invasion. Ecology 31:587-605.

----------. 1971. Fundamentals of ecology. 3rd edn. W. B. Saunders Co., Philadelphia. 574 pp.

PACHUAU, R. 1994. Geography of Mizoram. R. T. Enterprise, Aizawl.

PICKETT, S. T. A., AND P. S. WHITE. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, Inc., Orlando. 472 pp.

PIELOU, E. C. 1984. The interpretation of ecological data. John Wiley and Sons, New York. 263pp.

RAMAKRISHNAN, P. S. 1992. Shifting agriculture and sustainable development: An interdisciplinary study from north-eastern India. MAB Series, Vol. 10. UNESCO, Paris. 424pp.

RAO, K. S. AND P. S. RAMAKRISHNAN. 1988. Role of bamboos in secondary succession after slash and burn agriculture at lower elevations in north-east India. Proc. Intl. Bamboo Workshop Nov.:59-65.

RAO, R. R., AND P. K. HAJRA. 1986. Floristic diversity of the eastern Himalaya - in a conservation perspective. Proc. Ind. Acad. Sci. (Anim. Sci./Plant Sci.) Suppl. Nov. 1986:103-125.

RICHARDS, P. W. 1952. The tropical rainforest: An ecological study. Cambridge University Press, Cambridge. 450 pp.

RIPLEY, S. D. 1959. Zoogeographic considerations on the Indian avifauna. J. Bombay nat. Hist. Soc. 56:72-81.

RISWAN, S., J. B. KENWORTHY, AND K. KARTAWINATA. 1985. The estimation of temporal processes in tropical rainforest: A study of primary mixed dipterocarp forest in Indonesia. J. Trop. Ecol. 1:171-182.

SHUGART, H. H., AND D. JAMES. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90:62-77.

SINGH, P. 1994. Recent bird records from Arunachal Pradesh. Forktail 10:65-104.

SMITH, K. G., AND J. A. MACMAHON. 1981. Bird communities along a montane sere: Community structure and energetics. Auk 98:8-28.

SPRUGEL, D. G. 1985. Natural disturbance and ecosystem energetics. Pages 335-352 *in* S. T. A. Pickett and P. S. White, eds. The ecology of natural disturbance and patch dynamics. Academic Press, Inc., Orlando. 472 pp.

TERBORGH, J. W. 1985. Habitat selection in Amazonian birds. pages 311-340 *in* M. L. Cody, ed. Habitat selection in birds. Academic Press, Inc., Orlando. 558 pp.

----------, AND S. K. ROBINSON. 1986. Guilds and their utility in ecology. Pages 65-90 *in* J. Kikkawa and D. Anderson, eds. Community ecology: Pattern and process. Blackwell Sci. Publ., Melbourne.

----------, S. T. ROBINSON, T. A. PARKER, III, C. A. MUNN, AND N. PIERPONT. 1990. Structure and organisation of the amazonian forest bird community. Ecol. Monogr. 60:213-238.

TEWARI, D. N. 1991. Shifting cultivation in India. Indian Forester 117:91-104.

THIOLLAY, J-M. 1994. Structure, density and rarity in an Amazonian rainforest bird community. J. Trop. Ecol. 10:627-32.

TOKY, O. P., AND P. S. RAMAKRISHNAN. 1983. Secondary succession following slash and burn agriculture in north eastern India: I - Biomass, litter fall and productivity. J. Ecol. 71:735-745.

USHER, M. B. 1986. Wildlife conservation evaluation: Attributes, criteria and values. Pages 3-44 *in* M. B. Usher, ed. Wildlife conservation evaluation. Chapman and Hall, London. 394 pp.

VERNER, J. A. 1985. Assessment of counting techniques. Curr. Ornithol. 2:247-302.

VON FÜRER-HAIMEDORF, C. 1982. Tribes of India: The struggle for survival. Oxford University Press, Delhi. 342 pp.

WIENS, J. A. 1989. The ecology of bird communities. Vol. I.: Foundations and patterns. Cambridge University Press, cambridge. 539 pp.

WOLDA, H. 1981. Similarity indices, sample size and diversity. Oecologia 50:296-302.

ZAR, J. H. 1984. Biostatistical analysis. 2nd edn. Prentice-Hall Inc., New Jersey. 718 pp.

APPENDIX 1

Birdlist of Dampa Tiger Reserve and nearby areas in Mizoram

FAMILY: ARDEIDAE

1.	38	Little Green Heron	*Ardeola striatus*
2.	53	Tiger Bittern	*Gorsachius melanolophus*

FAMILY: ACCIPITRIDAE

3.	125	Blyth's Baza	*Aviceda jerdoni*
4.	127	Blackcrested Baza	*A. leuphotes*
5.	130	Honey Buzzard	*Pernis ptilorhyncus*
6.	139	Shikra	*Accipiter badius*
7.	151	Besra Sparrow Hawk	*A. virgatus*
8.	165	Rufousbellied Hawk-Eagle	*Hieraaetus kienerii*
9.	185?	Vulture	*Gyps* sp.
10.	196	Crested Serpent Eagle	*Spilornis cheela*

FAMILY: FALCONIDAE

11.	205	Whitelegged Falconet	*Microhierax melanoleucos*
12.	209	Peregrine Falcon	*Falco peregrinus*
13.	215	Oriental Hobby	*F. severus*
14.	222	Kestrel	*F. tinnunculus*

FAMILY: PHASIANIDAE

15.	272	Whitecheeked Hill Partridge	*Arborophila atrogularis*
16.	274	Bamboo Partridge	*Bambusicola fytchii*
17.	294	Kaleej Pheasant	*Lophura leucomelana lathami*
18.	299	Red Junglefowl	*Gallus gallus*
19.	310	Peacock-Pheasant	*Polyplectron bicalcaratum*

FAMILY: RALLIDAE

20.	343	Whitebreasted Waterhen	*Amaurornis phoenicurus*
21.	349	Purple Moorhen	*Porphyrio porphyrio*

FAMILY:COLUMBIDAE

22.	493	Pintailed Green Pigeon	*Treron apicauda*
23.	495	Thickbilled Green Pigeon	*T. curvirostra*
24.	496	Greyfronted Green Pigeon	*T. pompadora*
25.	510	Imperial Pigeon	*Ducula badia*
26.	526	Bartailed Cockoo-Dove	*Macropygia unchall*
27.	530	Rufous Turtle Dove	*Streptopelia orientalis*
28.	537	Spotted Dove	*S. chinensis*
29.	542	Emerald Dove	*Chalcophaps indica*

FAMILY: PSITTACIDAE

30.	566	Indian Lorikeet	*Loriculus vernalis*

FAMILY: CUCULIDAE

31.	573	Common Hawk-Cuckoo	*Cuculus varius*
32.	576	Indian Cuckoo	*C. micropterus*
33.	578	The Cuckoo	*C. canorus*
34.	585	Rufousbellied Plaintive Cuckoo	*Cacomantis merulinus*
35.	587	Violet Cuckoo	*Chalcites xanthorhynchus*
36.	588	Drongo-Cuckoo	*Surniculus lugubris*
37.	593	Large Greenbilled Malkoha	*Rhopodytes tristis*
38.	600	Coucal	*Centropus sinensis*
39.	605	Lesser Coucal	*C. toulou*

FAMILY: STRIGIDAE

40.	612	Spotted Scops Owl	*Otus spilocephalus*
41.	617	Scops Owl	*O. scops*
42.	623	Collared Scops Owl	*O. bakkamoena*
43.	633	Brown Fish Owl	*Bubo zeylonensis*
44.	635	Collared Pigmy Owlet	*Glaucidium brodiei*
45.	636	Jungle Owlet	*G. radiatum*
46.	639	Barred Owlet	*G. cuculoides*
47.	642	Brown Hawk-Owl	*Ninox scutulata*

FAMILY: CAPRIMULGIDAE

48.	669	Great Eared Nightjar	*Eurostopodus macrotis*
49.	671	Indian Jungle Nightjar	*Caprimulgus indicus*
50.	675	Longtailed Nightjar	*C. macrurus*

FAMILY: APODIDAE

51.	683/ 684	Himalayan/ Black-Nest Swiftlet	*Collocalia brevirostris/* *C. maxima*
52.	691/ 690	Large Brownthroated/ Cochinchina Spinetail Swift	*Chaetura gigantea/* *C. cochinchinensis*
53.	699	Large Whiterumped Swift	*Apus pacificus*
54.	703	House Swift	*A. affinis*
55.	707	Palm Swift	*Cypsiurus parvus*

FAMILY: TROGONIDAE

56.	715	Redheaded Trogon	*Harpactes erythrocephalus*

FAMILY: ALCEDINIDAE

57.	722	Common Kingfisher	*Alcedo atthis*
58.	727	Threetoed Kingfisher	*Ceyx erithacus*
59.	730	Storkbilled Kingfisher	*Pelargopsis capensis*
60.	735	Whitebreasted Kingfisher	*Halcyon smyrnensis*

FAMILY: MEROPIDAE

61.	748	Bluetailed Bee-Eater	*Merops philippinus*
62.	753	Bluebearded Bee-Eater	*Nyctyornis athertoni*

FAMILY: CORACIIDAE

63.	755	INDIAN ROLLER	*Coracias benghalensis*
64.	759	BROADBILLED ROLLER	*Eurystomus orientalis*

FAMILY: UPUPIDAE

65.	763	HOOPOE	*Upupa epops*

FAMILY: BUCEROTIDAE

66.	772	WREATHED HORNBILL	*Rhyticeros undulatus*
67.	774	INDIAN PIED HORNBILL	*Anthracoceros malabaricus*
68.	776	GREAT PIED HORNBILL	*Buceros bicornis*

FAMILY: CAPITONIDAE

69.	778	GREAT HILL BARBET	*Megalaima virens*
70.	784	LINEATED BARBET	*M. lineata*
71.	788	BLUETHROATED BARBET	*M. asiatica*
72.	789	BLUE-EARED BARBET	*M. australis*
73.	792	CRIMSONBREASTED BARBET	*M. haemacephala*

FAMILY: PICIDAE

74.	798	SPECKLED PICULET	*Picumnus innominatus*
75.	800	RUFOUS PICULET	*Sasia ochracea*
76.	804	RUFOUS WOODPECKER	*Micropternus brachyurus*
77.	809	BLACKNAPED GREEN WOODPECKER	*Picus canus*
78.	813	LARGE YELLOWNAPED WOODPECKER	*P. flavinucha*
79.	815	SMALL YELLOWNAPED WOODPECKER	*P. chlorolophus*
80.	827	PALEHEADED WOODPECKER	*Gecinulus grantia*
81.	828	HIMALAYAN GREAT SLATY WOODPECKER	*Mulleripicus pulverulentus*
82.	850	GREYCROWNED PIGMY WOODPECKER	*Picoides canicapillus*
83.	856	HEARTSPOTTED WOODPECKER	*Hemicircus canente*
84.	857	REDEARED BAY WOODPECKER	*Blythipicus pyrrhotis*
85.	861	LARGER GOLDENBACKED WOODPECKER	*Chrysocolaptes lucidus*

FAMILY: EURYLAIMIDAE

86.	864	COLLARED BROADBILL	*Serilophus lunatus*
87.	865	LONGTAILED BROADBILL	*Psarisomus dalhousiae*

FAMILY: PITTIDAE

88.	866	BLUENAPED PITTA	*Pitta nipalensis*
89.	871	BLUE PITTA	*Pitta cyanea*

FAMILY: HIRUNDINIDAE

90.	923	REDRUMPED/STRIATED SWALLOW	*Hirundo daurica*
91.	930	HOUSE MARTIN	*Delichon urbica*

FAMILY: LANIIDAE

92.	945	Greybacked/Tibetan Shrike	*Lanius tephronotus*
93.	949	Brown Shrike	*L. cristatus*

FAMILY: ORIOLIDAE

94.	958	Blackheaded Oriole	*Oriolus xanthornus*
95.	961	Maroon Oriole	*O. traillii*

FAMILY: DICRURIDAE

96.	965	Grey/Ashy Drongo	*Dicrurus leucophaeus*
97.	970	Crowbilled Drongo	*D. annectans*
98.	971	Bronzed Drongo	*D. aeneus*
99.	972	Lesser Racket-tailed Drongo	*D. remifer*
100.	973	Haircrested/Spangled Drongo	*D. hottentottus*
101.	977	Greater Racket-tailed Drongo	*D. paradiseus*

FAMILY: STURNIDAE

102.	987	Greyheaded Myna	*Sturnus malabaricus*
103.	1015	Grackle/Hill Myna	*Gracula religiosa*

FAMILY: CORVIDAE

104.	1023	Green Magpie	*Cissa chinensis*
105.	1038	Himalayan Tree Pie	*Dendrocitta formosae*
106.	1054	Jungle Crow	*Corvus macrorhynchos*

FAMILY: CAMPEPHAGIDAE

107.	1065	Pied Flycatcher-Shrike	*Hemipus picatus*
108.	1068	Large Wood Shrike	*Tephrodornis virgatus*
109.	1072	Large Cuckoo-Shrike	*Coracina novaehollandiae*
110.	1077	Smaller Grey Cuckoo-Shrike	*C. melaschistos*
111.	1081	Scarlet Minivet	*Pericrocotus flammeus*
112.	1084	Shortbilled Minivet	*P. brevirostris*

FAMILY: IRENIDAE

113.	1098	Common Iora	*Aegithina tiphia*
114.	1103	Goldfronted Chloropsis	*Chloropsis aurifrons*
115.	1106	Orangebellied Chloropsis	*C. hardwickii*
116.	1108	Goldmantled Chloropsis	*C. chochinchinensis*
117.	1109	Fairy Bluebird	*Irena puella*

FAMILY: PYCNONOTIDAE

118.	1115	Blackheaded Yellow Bulbul	*Pycnonotus melanicterus*
119.	1120	Redwhiskered Bulbul	*P. jocosus*
120.	1128	Redvented Bulbul	*P. cafer*
121.	1140	Whitethroated Bulbul	*Cringer flaveolus*
122.	1141	Olive Bulbul	*Hypsipetes viridescens*
123.	1147	Browneared Bulbul	*H. flavalus*
124.	1148	Black Bulbul	*H. madagascariensis*

FAMILY: MUSCICAPIDAE

Subfamily: Timalinae

125.	1154	Spotted Babbler	*Pellorneum ruficeps*
126.	1166	Tickell's Babbler	*Trichastoma tickelli*
127.	1173	Slatyheaded Scimitar Babbler	*Pomatorhinus horsfieldii*
128.	1185	Large Scimitar Babbler	*P. hypoleucos*
129.	1194	Streaked/Short-tailed Wren-Babbler	*Napothera brevicaudata*
130.	1195	Small Wren-Babbler	*N. epilepidota*
131.	1198/1199	Scalybreasted/Brown Wren-Babbler	*Pnoepyga albiventer/P. pusilla*
132.	1209	Redfronted Babbler	*Stachyris rufifrons*
133.	1214	Blackthroated Babbler	*S. nigriceps*
134.	1228	Yellowbreasted Babbler	*Macronous gularis*
135.	1247	Greater Redheaded Parrotbill	*Paradoxornis ruficeps*
136.	1275	Necklaced Laughing Thrush	*Garrulax moniligerus*
137.	1277	Blackgorgeted Laughing Thrush	*G. pectoralis*
138.	1283	Whitecrested Laughing Thrush	*G. leucolophus*
139.	1347	Whiteheaded Shrike-Babbler	*Gampsorhynchus rufulus*
140.	1365	Whitebrowed Yuhina	*Yuhina castaniceps*
141.	1368	Yellownaped Yuhina	*Y. flavicollis*
142.	1375	Whitebellied Yuhina	*Y. xantholeuca*
143.	1390	Quaker Babbler	*Alcippe poioicephala*
144.	1392	Nepal Babbler	*A. nipalensis*

Subfamily: Muscicapinae

145.	1408	Brownbreasted Flycatcher	*Muscicapa muttui*
146.	1411	Redbreasted Flycatcher	*M. parva*
147.	1414	Orangegorgeted Flycatcher	*M. strophiata*
148.	1417	Rufousbreasted Blue Flycatcher	*M. hyperythra*
149.	1419	Little Pied Flycatcher	*M. westermanni*
150.	1432	Rufousbellied Niltava	*M. sundara*
151.	1434	Whitetailed Blue Flycatcher	*M. concreta*
152.	1436	Brook's Flycatcher	*M. poliogenys*
153.	1440	Bluethroated Flycatcher	*M. rubeculoides*
154.	1445	Verditer Flycatcher	*M. thalassina*
155.	1449	Greyheaded Flycatcher	*Culicicapa ceylonensis*
156.	1450	Yellowbellied Fantail Flycatcher	*Rhipidura hypoxantha*
157.	1455	Whitethroated Fantail Flycatcher	*R. albicollis*
158.	1461	Paradise Flycatcher	*Terpsiphone paradisi*
159.	1465	Blacknaped Flycatcher	*Hypothymis azurea*

Subfamily: Sylviinae

160.	1471	Dull Slatybellied Ground Warbler	*Tesia cyaniventer*
161.	1472	Slatybellied Ground Warbler	*T. olivea*

162.	1501	BEAVAN'S WREN-WARBLER	*Prinia rufescens*
163.	1503	FRANKLIN'S WREN-WARBLER	*P. hodgsonii*
164.	1525	YELLOWBELLIED WREN-WARBLER	*P. flaviventris*
165.	1538	TAILOR BIRD	*Orthotomus sutorius*
166.	1540	BLACKNECKED TAILOR BIRD	*O. atrogularis*
167.	1556	BLYTH'S REED WARBLER	*Acrocephalus dumetorum*
168.	1592	YELLOWBROWED/PLAIN LEAF WARBLER	*Phylloscopus inornatus*
169.	1605	DULL GREEN LEAF WARBLER	*P. trochiloides*
170.	1607	LARGE CROWNED LEAF WARBLER	*P. occipitalis coronatus*
171.	1609	BLYTH'S LEAF WARBLER	*P. reguloides*
172.	1612	BLACKBROWED LEAF WARBLER	*P. cantator*
173.	1615	BLACKBROWED FLYCATCHER-WARBLER	*Seicercus burkii*
174.	1622	YELLOWBELLIED FLYCATCHER-WARBLER	*Abroscopus superciliaris*
175.	1624	BLACKFACED FLYCATCHER-WARBLER	*A. schisticeps*
176.	1627	BROADBILLED FLYCATCHER-WARBLER	*A. hodgsoni*

Subfamily: TURDINAE

177.	1643	RUBYTHROAT	*Erithacus calliope*
178.	1659	WHITEBROWED BUSH ROBIN	*E. indicus*
179.	1661	MAGPIE-ROBIN	*Copsychus saularis*
180.	1665	SHAMA	*C. malabaricus*
181.	1671	BLACK REDSTART	*Phoenicurus ochruros*
182.	1677	DAURIAN REDSTART	*P. auroreus*
183.	1679	PLUMBEOUS REDSTART	*Rhyacornis fuliginosus*
184.	1681	WHITETAILED BLUE ROBIN	*Cinclidium leucurum*
185.	1685	BLACKBACKED FORKTAIL	*Enicurus immaculatus*
186.	1687	LESCHENAULT'S FORKTAIL	*E. leschenaulti*
187.	1688	SPOTTED FORKTAIL	*E. maculatus*
188.	1697	STONE CHAT	*Saxicola torquata*
189.	1705	DARK-GREY BUSH CHAT	*S. ferrea*
190.	1716	WHITECAPPED/RIVER REDSTART	*Chaimarrornis leucocephalus*
191.	1726	BLUE ROCK THRUSH	*Monticola solitarius*
192.	1729	BLUE WHISTLING THRUSH	*Myiophonus caeruleus*
193.	1733	ORANGEHEADED GROUND THRUSH	*Zoothera citrina citrina*
194.	1741	GOLDEN/SMALLBILLED MOUNTAIN THRUSH	*Z. dauma*
195.	1746	LESSER BROWN THRUSH	*Z. marginata*
196.	1758	GREYHEADED THRUSH	*Turdus rubrocanus*

FAMILY: PARIDAE

197.	1789	SULTAN TIT	*Melanochlora sultanea*

FAMILY: SITTIDAE

198.	1830	CHESTNUTBELLIED NUTHATCH	*Sitta castanea*
199.	1838	VELVETFRONTED NUTHATCH	*S. frontalis*

FAMILY: MOTACILLIDAE

200.	1852	Indian Tree Pipit	*Anthus hodgsoni*
201.	1874	Forest Wagtail	*Motacilla indica*
202.	1884	Grey Wagtail	*M. cinerea*
203.	1885	White Wagtail	*M. alba*

FAMILY: DICAEIDAE

204.	1895	Yellowvented Flowerpecker	*Dicaeum chrysorrheum*
205.	1902	Plaincoloured Flowerpecker	*D. concolor*
206.	1904	Scarletbacked Flowerpecker	*D. creuntatum*

FAMILY: NECTARINIIDAE

207.	1906	Rubycheek	*Anthreptes singalensis*
208.	1925	Blackbreasted Sunbird	*Aethopyga saturata*
209.	1927	Yellowbacked Sunbird	*A. siparaja*
210.	1931	Little Spiderhunter	*Arachnothera longirostris*
211.	1932	Streaked Spiderhunter	*A. magna*

FAMILY: ZOSTEROPIDAE

212.	1933	White-Eye	*Zosterops palpebrosa*

FAMILY: PLOCEIDAE

213.	1942	Tree Sparrow	*Passer montanus*
214.	1968	Whitebacked Munia	*Lonchura striata*

FAMILY: FRINGILLIDAE

215.	2013	Common Rosefinch	*Carpodacus erythrinus*

N. B.: Names of species and taxonomic classification follows:

Ali, S. and Ripley, S. D. 1983. A pictorial guide to the birds of the Indian subcontinent. Bombay natural History Society, Bombay.

The numbers following the serial numbers in the above list refer to the individual species reference numbers in Ali and Ripley (1983).