EFFECT OF HABITAT ALTERATION ON HERPETOFAUNAL ASSEMBLAGES OF EVERGREEN FOREST IN MIZORAM, NORTH-EAST INDIA

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It was the saying of Bion,

that though the boys throw stones at frogs in sport,

yet the frogs do not die in sport

but in earnest.

--Plutarch

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SUMMARY

The response of frogs and lizards to habitat alteration was studied in South Mizoram. Chronoseres were selected such that two successional gradients were represented- ***jhum*** fallows regenerating to mature forest, and ***jhum*** fallows converted to teak plantations. Herpetofauna were sampled by three techniques- strip transects, pitfall trapping, and systematic searching.

Species richness of herpetofauna increased along the ***jhum***-mature forest gradient. However, teak plantation had a depauperate herpetofauna, similar in composition to the 1-year ***jhum*** fallows. All frogs and lizards were classified into 6 guilds on the basis of their activity period (diurnal or nocturnal) along with whether they were terrestrial, arboreo-terrestrial, or arboreal. Analysis of the strip-transect data showed that there were distinct differences in the distribution and abundance patterns of diurnal and nocturnal species. To examine patterns, multidimensional scaling (MDS) was used for indirect gradient analysis in two ways- firstly to summarise differences between sites and secondly, to explore possible associations between herpetofaunal guilds and habitat parameters across categories. The MDS differentiated two different groups of habitat variables. One group makes up the gross structural components of the habitats, while the other represents microhabitat parameters. All guilds were more strongly associated with trends in microhabitat distribution, than macrohabitat-parameters, while species richness showed diffuse associations with habitat parameters.

The assemblages in the 1 to 10 year ***jhum*** fallows and teak plantations were dominated by a set of terrestrial and arboreo-terrestrial lizard species. Most of those species are distributed widely, either in the Indian subcontinent, or further east and south, into South-east Asia. On the other hand, a number of frogs and some lizards were restricted to mature forest. Most of these species are restricted either to North-east India, or to the study area itself, and some are apparently hitherto undescribed species. The fact that so many narrowly distributed species were found in mature forest has obvious conservation implications.

Overall, the results suggest that in a mosaic of habitats resulting from ***jhum***-cultivation, even remnants of primary forest may be of immense importance for persistence and recolonisation by mature forest herpetofauna. Teak plantations offer a very marginal habitat for a large set of herpetofauna, even after a long period of growth.

1. INTRODUCTION

Tropical forests today are undergoing rapid degradation. Under these circumstances, monitoring habitat quality or suitability at different scales is imperative. Any ecological system with high diversity, as is seen in mesic tropical forests, is bound to show a rather complex response to fluctuations in environmental variables due to disturbance- forest can appear intact, yet be biologically vitrified (ex. Phillips, 1997; Richards, 1996)

An effective approach towards gauging or monitoring habitat change is to study the response of a faunal group in terms of changes in diversity along a gradient of time and/or space. This can then be used to support conjectures about habitat degradation in terms of structural and functional attributes (Landres ***et al***, 1988; Noss, 1990). It is generally perceived that a well-defined response to disturbance (predictable, rapid, sensitive, analysable and as far as possible linear response) is desirable (***cf.*** Brown, 1991). However, an easily interpretable response may not always reveal the true extent of the situation. Therefore, what is needed is a comparative approach to actually understand the effects of habitat change on the functioning and structure of an ecological community. Assemblages of faunal groups with differing life histories are likely to show different responses to disturbance. In practice however, there has to be a compromise between the numerous limitations to attaining a true landscape approach and the need to adopt an approach broad enough to allow more than a taxon-restricted understanding of this problem (Weaver, 1995).

The conservation implications of such studies coupled with the theoretical and empirical contribution they can make to our ecological understanding (***fide*** Simberloff, 1988) are enough incentive to take up problems that deal with faunal groups that have hitherto not been examined within this framework.

1.1 Habitat alteration and herpetofauna

The majority of studies dealing with habitat alteration examine one of a limited set of faunal groups- predominantly those with well-documented biology. Literature dealing with the effect of anthropogenic habitat alteration (not natural disturbance) on herpetofauna is particularly difficult to come by (But see Bowman ***et al.***, 1990; Heang ***et al.,*** 1996; Lenart ***et al.***, 1997; Saravanakumar, 1995; Pearman, 1997).

Though the effects of anthropogenic habitat alteration on indigenous fauna have been reported for faunal groups separately (ex. for a review of effect of shifting cultivation on birds, see Shankar Raman, 1995), there have been few studies comparing the response of different faunal groups simultaneously to the same alteration pattern (But see Bowman ***et al***, 1990; Howard and Viskanic, 1998). In the latter situation, it has come to the fore that different faunal groups respond very differently to the same alteration pattern. For instance, Bowman ***et al*** (1990) reported a very different response for birds, butterflies and reptiles to the same pattern of slash and burn agriculture in Papua New Guinea. In general, the broad pattern that has been shown is that diversity increases along the successional gradient. Conversion of natural forest to single species plantations too has been shown to have negative repercussions for indigenous fauna (ex. Daniels ***et al***, 1990).

Saravanakumar (1995), and Bowman ***et al***. (1990) reported an indistinct response of herpetofaunal assemblages to habitat alteration. While the former compared frog assemblages in primary evergreen forest and teak plantations, the latter examined the effect of shifting cultivation on reptiles. On the other hand, Pearman (1997) and Gibbs (1998) working on frogs, found a distinct pattern of change in community composition along habitat gradients. These conflicting results may be because of the basic difference in approach between the studies. While Saravanakumar (1995) and Bowman ***et al***. (1990) did not attempt to examine subsets of their study taxa (either in terms of guilds or taxonomic subgroups), Pearman (1997) and Lenart ***et al.*** (1997) did, and found differences in response ***within*** certain groups of frogs. For instance, Pearman ***et al***. (1995) studying the effect of habitat alteration due to logging, found that tree frogs (Hylids) were more abundant in secondary forest, while ground dwelling Elutherodactylids preferred primary, undisturbed forest.

1.1.1 Of frogs, lizards and snakes

Correlating the distribution of assemblages with environmental factors needs a careful selection of the study group. Frogs and lizards share many attributes that makes it possible, and indeed desirable, to study them together if the questions being asked can be better answered with this approach (Toft, 1985).

It is well accepted that different approaches and methods are needed to study snakes as compared to other herpetofauna because of inherent differences in their ecology (Pianka, 1986; Lloyd ***et al***, 1968; Stamps, 1977; Seigel & Collins, 1993; Toft, 1985). Snakes ***are*** difficult to work with, as they are wide ranging, occur in apparently low densities and are difficult to observe in the field. A cumulative effect of these facts is that snakes have been away from the focus of community studies (Seigel & Collins, 1993). Therefore, the requirements of snakes as subjects for community oriented studies need to be recognised. The present study design would not be suitable for studying frogs, lizards and snakes together, and the latter group was excluded from the present study.

1.1.2 Herpetofauna in north-east India

As is the case with other faunal groups, the Western Ghats and north-east India are two major diversity hotspots for herpetofauna (Jayaram, 1974). The Andaman and Nicobar islands also show high species diversity, after correcting for the area effect (Das, 1996a). Though North-east India, one of the biodiversity hotspots of the world, is also one of the most beleaguered areas in terms of habitat degradation and loss today, little work has been done there in terms of herpetofaunal inventorying. Community oriented ecological studies of the region's herpetofauna have now begun to proliferate (ex. Inger ***et al.***, 1987; Das, 1996b; Bhupathy & Kannan, 1997; Vasudevan ***et al.***, ***under review***, Ishwar ***et al.***, ***under review***). However, they have all been concentrated in the tropical moist forests of the Western Ghats, all work in the Northeast having been restricted to scattered alpha-taxonomic work (Ex. Chanda, 1994). Moreover, most of the work that has been done is mostly restricted to more accessible areas, viz., the Brahmaputra basin, and adjoining hill ranges.

In the literature, one finds considerable speculations about the relative species richness and distribution patterns of herpetofauna in the Western Ghats and the Northeast (Ex. Jayaram, 1974; Das, 1996a). This skewed effort in terms of herpetofaunal ecology work therefore precludes meaningful comparisons between the herpetofauna of the Western Ghats and North-east India.

1.2 Habitat alteration in North-east India

There is considerable literature available on the patterns of habitat alteration in Northeast India, especially with reference to shifting cultivation (Ramakrishnan, 1992) (or ***jhum*** cultivation as it is popularly known), a widely used form of agriculture in the tropics even today (National research council, 1993). An extensive review of land use patterns in the North-east and particularly in the state of Mizoram would not be in order in a discourse of this kind. I will restrict myself to a few intriguing aspects that form the core of my study problem: habitat alteration in two forms- shifting cultivation and plantation forestry. Both lead to a dramatic, long-lasting alteration of natural habitat, and in the existing situation in Northeast India both are interrelated, a situation I will try to describe briefly here.

Jhum cultivation is probably one of the oldest farming systems in the tropics and has proven to be sustainable and ecologically sound as long as the human population density is not too high, and fallow periods are long enough to restore productivity (National Research Council, 1993). However, growing population pressure has forced the shortening of fallow periods, which combined with the erosion of traditional ***jhumming*** methods have lead to loss of productivity, resulting in clearing of new land more frequently, combined with progressive degradation of existing cultivated land. Obviously, this has led to widespread concern about the effect of shifting cultivation on biological diversity.

In Mizoram itself, the history of ***jhumming*** is relatively recent, as these hills were probably settled as recently as 300-400 years ago (Pachuau, 1994). Despite this, the state today is covered by extensive secondary growth, dominated by bamboo brakes. The policy of converting so-called degraded lands resulting from shifting cultivation to tree plantations has become increasingly popular (National research council, 1993). In most of Northeast India, extensive bamboo brakes result from ***jhumming*** (Ramakrishnan, 1992). These have often been perceived as being degraded, and tree plantations have been encouraged under new land use policies, mainly for fuel wood, timber and for environmental protection. Most tree plantations in the tropics were planted after the 1960’s, and are therefore relatively young (National research council, 1993), which means that the negative environmental effects of such plantations would not be easily apparent. The ecological effects of converting abandoned ***jhum*** fallows to tree plantations, particularly those of non-indigenous species, need to be examined.

In Mizoram, the first plantations were taken up in 1958-59 (Singh, 1992). The plantations are largely of teak (***Tectona grandis***) or teak in combination with indigenous trees such as ***Gmelina arborea.*** In recent years, indigenous tree species of timber value and combination tree plantations have been encouraged under the new land use policy and under forestry programmes (State Forestry Action Programme, 1996).

1.3 Study questions

Most species of herpetofauna in mesic tropical evergreen forests are restricted to particular microhabitats (Sexton et al, 1964; Inger et al., 1987). The effect of fire on such a poorly vagile faunal group is bound to be drastic, especially if there is a high level of habitat specificity (Pianka, 1992). Habitat specialised species can become extinct within a given habitat patch, but remain in the overall system by periodic re-invasion from adjacent or nearby patches of suitable habitat. One would, for instance envisage a drastic negative response of terrestrial herpetofauna to burning, and gradual recovery along the successional gradient in post-***jhum*** ecosystems. Also, single tree plantations offer habitat very different from natural forest, possibly inhibiting recolonisation and maintaining a low level of herpetofaunal diversity. So a broad question can be asked: ***How does conversion of primary evergreen forest to Jhum cultivation and teak plantation affect amphibian and reptile assemblages?***

Within the framework of this broad question, I will attempt to resolve the following problems:

1) Firstly, how do frog and lizard assemblages recover along a successional gradient of ***jhum*** fallows to mature forest on one hand, and what is the pattern if ***jhum*** fallows are converted to teak plantation?
2) What habitat parameters define the pattern best: how important are micro-habitats for frog and lizard persistence and recovery?
3) What subsets of herpetofaunal assemblages are more sensitive to habitat changes, and how should the problem be approached- at the level of taxonomic subsets i.e., frogs vs. lizards, or at the level of cross-taxon guilds?

2. STUDY AREA

In June-July 1998, a reconnaissance survey was undertaken in and around some protected areas of South Mizoram. Subsequently, Ngengpui wildlife sanctuary (Ngengpui WLS) and some adjacent areas were chosen as the study site. The primary concern while choosing the study area was to find a suitable combination of vegetation, climatic and topographical features, conducive to the nature of the study I had framed (See section 1).

2.1 Location, area and physical features:

Mizoram is the southernmost state in North-east India, and lies between 21°56'N – 24°31'N and 92°16'E – 93°26'E. It is bound by Myanmar and Bangladesh in the east and west respectively, and by states of Tripura, Assam and Manipur in the North. The state is divided into three administrative divisions / districts – Aizawl district in the north, Lunglei district in the centre, and Chhimtuipui district in the south.

Pachuau (1994) and Singh (1996) have given a succinct description of the physiography of Mizoram. The geomorphology of Mizoram is dominated by a series of parallel hill ranges, generally running from north to south, increasing in elevation from west to east. The numerous rivers, governed by the hill ranges flow either from north to south, or ***vice versa***, often following a tortuous course. This creates a complex drainage pattern with several parallel rivers flowing in opposite directions (Pachuau, 1994; Singh, 1996). The hill ranges can be classified into the ridge and valley province (Altitudinal range of 40 – 1550 m), occupying most of the state and the mountainous terrain province (Altitudinal range of 400-2157m), restricted to an eastern longitudinal strip adjoining Myanmar (Pachuau, 1994; Singh, 1996). The slopes range from straight (10-15 °) to, very steep (>40 °) (Singh, 1996). Flat lands cover only 2.4% of the geographical area. In addition, many of the ranges bounding river valleys along the eastern side, are low in elevation (C. 100-500 msl), having gentle slopes, with small stretches of flat land along either side of the river (***pers. obs***.).

It is such an area in Chhimtuipui district that Ngengpui WLS (92°45'12" E - 92°50'20" E and 22°21'24" N - 22°30'06" N) is situated. The area comes under the jurisdiction of the Lai Autonomous District Council*. The Sanctuary (Final notification in 1997), with an area of about 110 sq. km, encloses the valley of Ngengpui river, and adjoining hills (Fig 1&2). However, the actual extent of the study area is about 150 sq. km, as areas adjoining

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* There are three autonomous district councils in south Mizoram- viz., The Chakma, Mara and Lai Autonomous District Councils.

Figure 1: Location map of study area

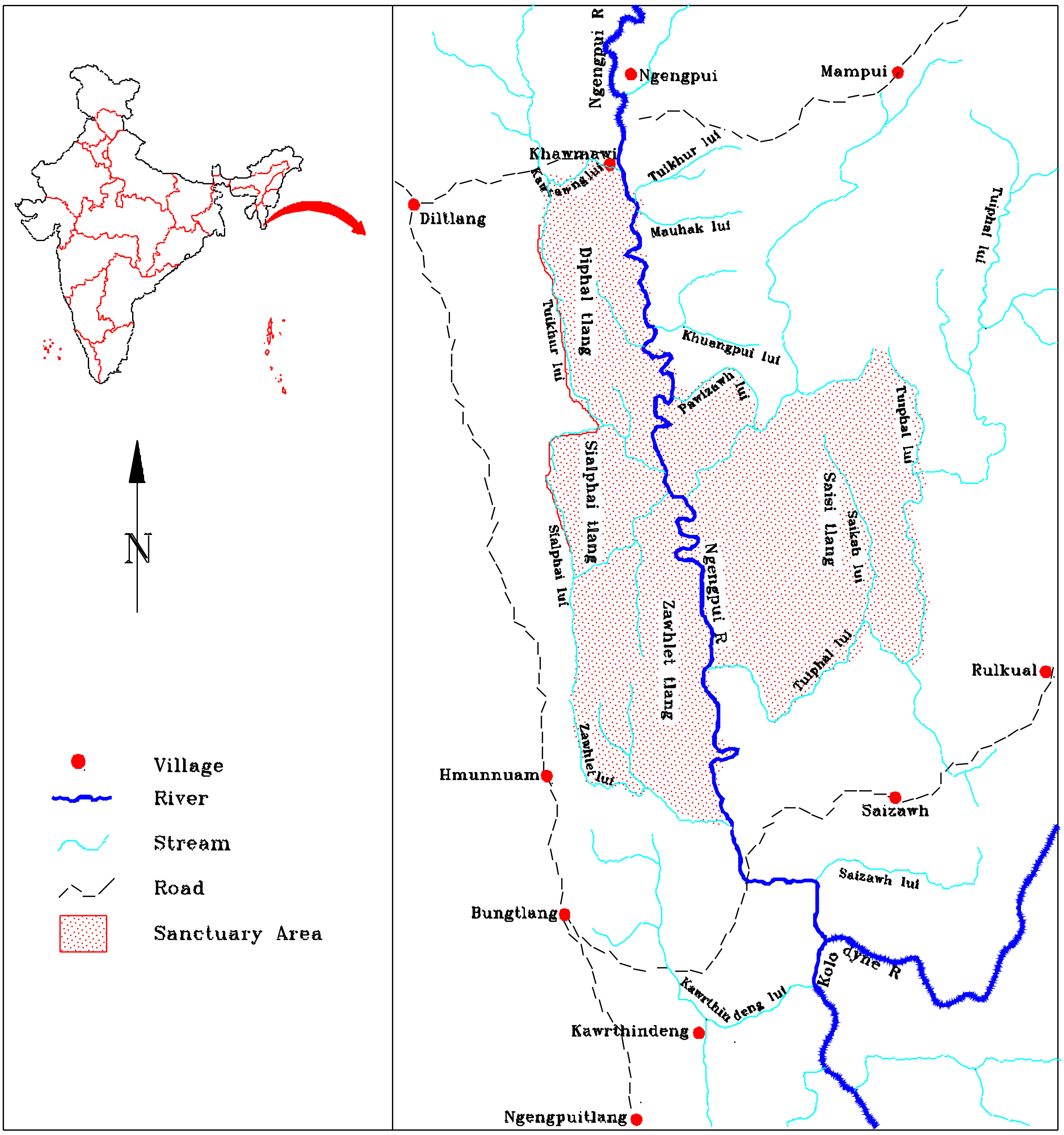
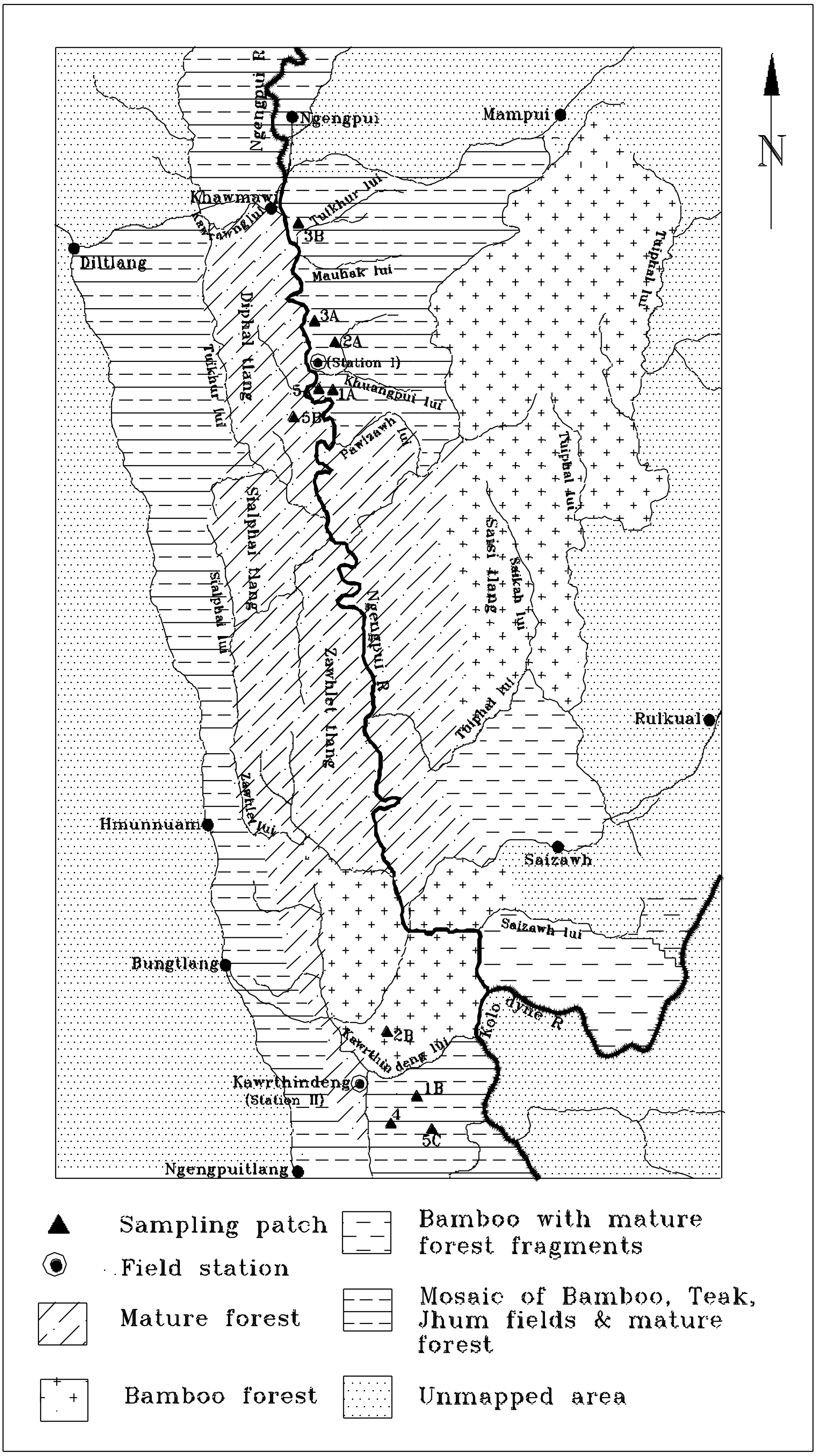


Figure 2: Location of sampling patches with respect to vegetation types



the WLS were also covered. The river Ngengpui flows from north to south, through the heart of the sanctuary. Various large and small streams (= ***Lui*** and ***Lui té***, respectively) form the actual boundary (Fig. 1). There are three main ridges (= ***tlangs***) in the sanctuary, viz. ***Zawhlet-tlang*** , ***Sialphai-tlang and Diphal-tlang*** on the western side of the river, and ***Saisi-tlang*** on the eastern side. Altitude ranges from ***c***.180 msl along the river bank to ***c***. 540 msl on ***Saisi-tlang.*** Numerous rocky as well as silted streams dissect the whole area. Generally, the former are found in the hills, while the latter are restricted to the valley and adjoining low-lying areas. All the major streams flow into the river Ngengpui.

As would be expected, topographical relief influences nature of soils considerably in Mizoram (Dept. of Agricul., Mizoram: 1993). In the study area, soil is predominantly yellowish-brown fine loam to sandy loam and moderately well drained. Soil depth ranges from deep (45-90 cm) to very deep (>90 cm). The latter factor made the study area ideal for using the pitfall trapping technique for sampling herpetofauna (See section 3.2.1.1).

2.2 Climate:

Due to lack of recording stations, information regarding temperature and precipitation are not available for all areas in Mizoram. In general, conditions range from tropical to sub-tropical, depending upon altitude. Under the direct influence of the southwest monsoon, rainfall is high (average precipitation 2752 mm), imposing humid conditions. The northwestern and southern parts receive maximum rainfall (Pachuau, 1994). Temperature fluctuations are least in mid to high altitude areas, and highest in the flatlands and valleys. Three distinct seasons can be recognized- the 6-month rainy season from mid-May to October, 4 months of winter from November to February, and 2 months of summer from March to early May. Though the temperature-range often quoted for Mizoram is 8-24 ^{o}C in winter and 11-35 ^{o}C in summer (Pachuau, 1996; Singh, 1996), the present study area, due to its location and topography has a very different climate.

In order to gauge temperature and humidity conditions in the study area, I recorded daily maximum and minimum temperature (Figure 3) and also wet-dry bulb temperatures (Fig. 4) twice a day (between 0600-0700 hrs and 1400-1500 hrs respectively), from the last week of November 1998 till the termination of fieldwork in April 1999.

As is apparent from Figure 3, the day temperature remained consistently moderate to high during the study period. On the other hand, the night temperature was low in winter months, and moderate in the summer, with more variation. Though only 5 days of rainfall were encountered throughout the study period, humidity was high throughout (Figure 4). These are very important factors, since the success of the herpetofaunal sampling techniques, and indeed the overall outcome of the study, was bound to be strongly influenced by the temperature and humidity regime at the study site.

Figure 3: Temperature changes in study area during fieldwork period

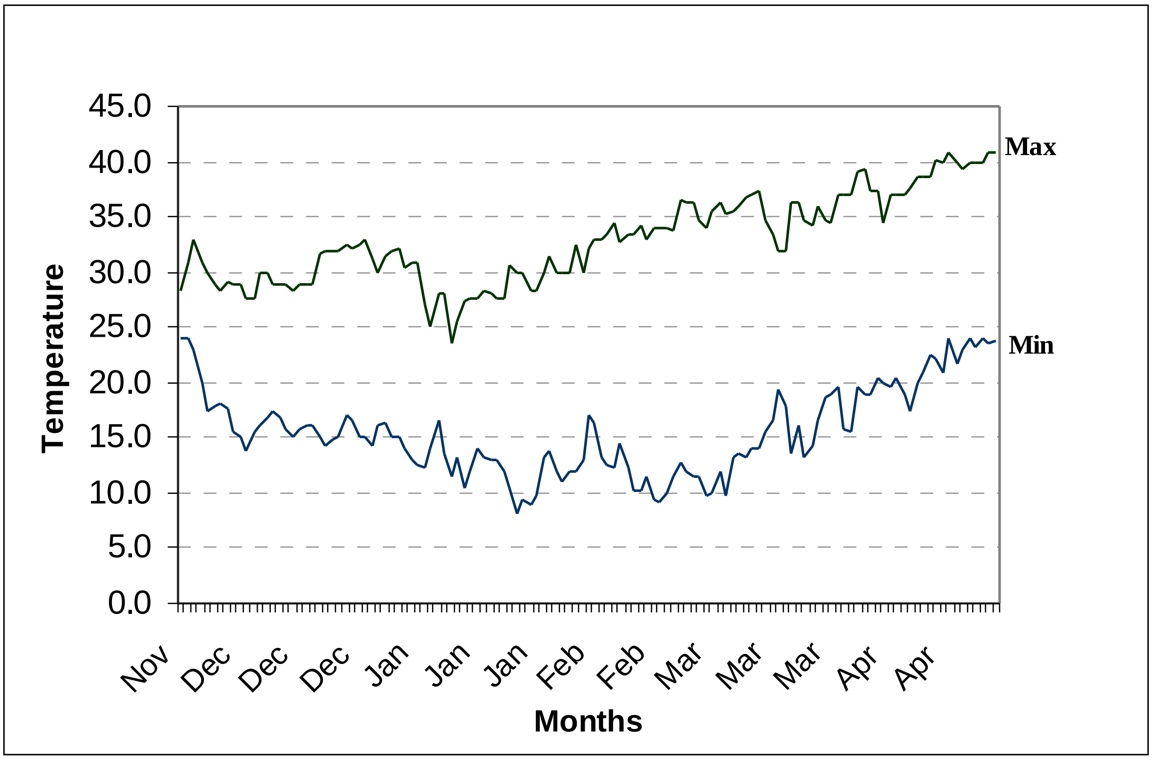
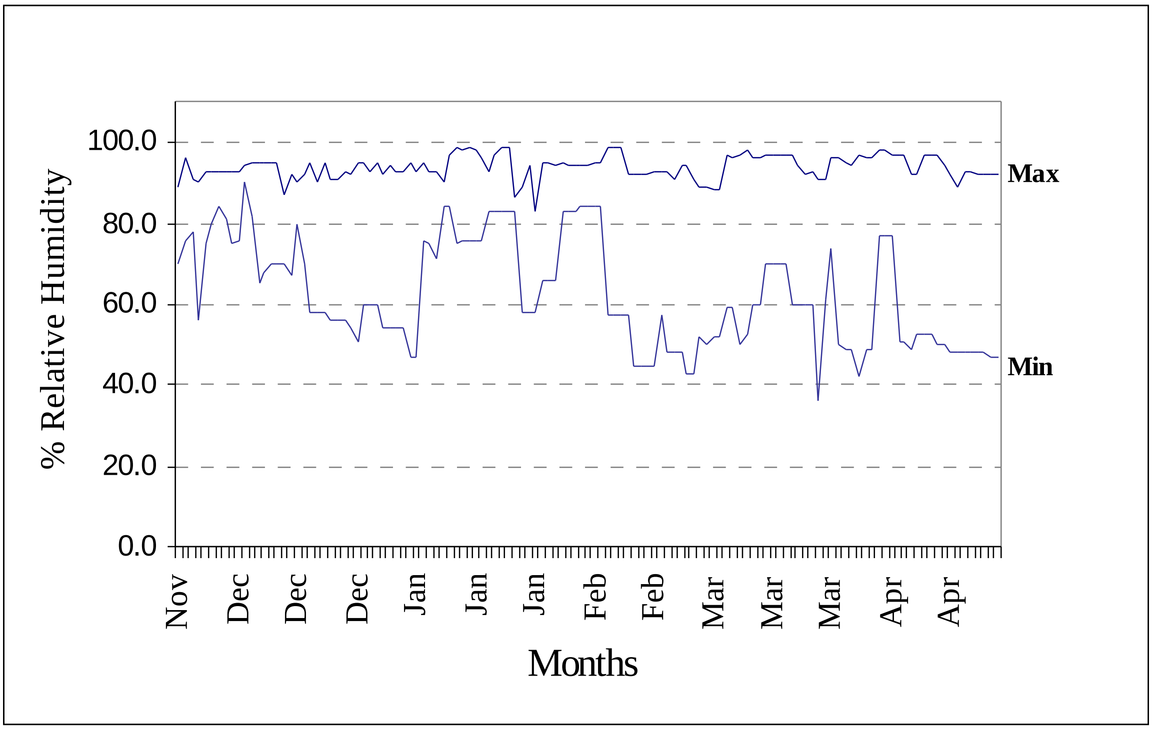


Figure 4: Trends in relative humidity levels in study area



2.3 Vegetation:

Most of the area within Ngengpui WLS is mature/primary forest, while the surrounding areas are a mosaic of bamboo-dominated patches, remnant mature forest, teak plantations and ***jhum*** fallows of varying ages (***personal observations***), mostly in adjoining areas outside the protected area. Henceforth, I shall refer to all primary forest as mature forest, because it is often difficult to determine the age of "primary" forest (Finegan, 1996), especially in an area with a poorly known history of land use and recovery.

2.3.1 Natural vegetation:

The low to mid-elevation forests of the southern limits of Mizoram have been inadequately surveyed. They show a unique composition and structure, which preclude extrapolation from better known forests further north and elsewhere, and clumping with known vegetation series (***cf.*** Champion and Seth, 1968) may not be justified (***fide*** Puri et al., 1989). The vegetation of the present study area is of the tropical (moist) Evergreen type (Wikramanayake ***et al.***, 1998), corresponding to Northern Tropical Evergreen Forest (1b/c2) and Chittagong Tropical Evergreen Forest (1b/c4). The vegetation composition changes considerably from the valley up to mid-elevations. There are 5 rainless months, but the effective dry period is much shorter, with humidity being consistently high during these months (Fig.2). The forest is characterised by a magnificent three-tiered structure, with towering, buttressed, deciduous emergents, followed by middle and tertiary canopy trees. The top canopy has ***Dipterocarpus retusus***, ***D. turbinatus***, ***Tetrameles nudiflora*** and ***Pterygota alata*** in the valley and upto an elevation of about 500 msl, beyond which ***Sterculia scaphigera*** replaces ***T.nudiflora*** as one of the dominant emergents. The middle and tertiary canopy levels are characterised by evergreen trees like ***Nephalium*** sp., ***Palaquium polyalthum***, ***Chisocheton paniculatus***, ***Polyalthia simiarum, Aporusa dieoica***, ***Hydnocarpus kurzii*** and ***Amoora*** spp., and with some deciduous ones such as ***Artocarpus*** spp. In riparian areas there are patches of moderately open forests with species such as ***Gmelina arborea*** and ***Terminalia myriocarpa.*** There are tracts of tall grassland on either side of the river, along most of its length. Palms such as ***Licuala peltata***, ***Caryota urens*** and canes (***Calamus*** spp) are seen in all areas, and many species of wild banana are found, mainly in riparian areas, moist ***nalas***, and in tree fall gaps with dense successional vegetation. Bamboos, mainly ***Bambusa tulda*** (vern.: ***Rawthing***), and ***Dendrocalmus longispathus*** (vern.: ***Rawnal***), often occur along moist ***nalas*** and in the understorey in some places, along with patches of ***Phrynium pubinerve.*** In disturbed mature forest, along with shrubs, ***Alpinia allughas*** and ***Phrynium pubinerve*** grow profusely as understorey.

2.3.2 Secondary vegetation:

The Jhum fallows

A comprehensive account of post-***jhum*** ecosystems in Northeast India has been given by Ramakrishnan (1992). However in Mizoram, there are subtle differences in successional patterns in ***jhum*** fallows (Singh, 1996). In the study area, seral stages follow two different patterns, depending on the vegetation in the area where the ***jhum*** was cut (***pers. obs***.).

In general, abandoned fields that were cut from bamboo brakes initially give rise to a prodigious growth of herbaceous weeds like ***Ageratum conyzoides***, ***Mikania scandens***, and ***Eupatorium adenophorum***, along with seedlings of trees such as ***Macaranga*** spp. and ***Trema orientalis***. In many areas tall grass species like ***Saccharum bengalense***, ***Erianthus longisetosus*** and ***Thysanolaena maxima*** also establish themselves. This early seral vegetation quickly overruns surviving crop plants. Thereafter, shoots of the bamboo ***Melocanna baccifera*** (Vern.: ***Mautak***) soon appears from surviving rhizomes, and in a matter of 3-4 years forms a dense stand, overpowering most other early seral stages. In a couple of years more, a closed canopy bamboo forest is formed in which other bamboos (***B. tulda*** and ***D. longispathus***) also establish themselves. A prolonged ***jhum*** fallow ultimately gives rise to a mixed bamboo and broad-leaved forest, in which bamboo gradually loses ground, leading to a mature forest approaching the stature of primary forest.

The second pattern of secondary succession is seen in ***jhums*** that have been cut from mature forest, and not bamboo brakes. In this case, after the initial proliferation of weeds, tree species establish themselves, there being no bamboo rhizomes to start with. In a matter of 3-4 years a dense growth of saplings of pioneering tree species such as ***Macaranga*** spp., along with mature forest tree species and some herbaceous weeds is seen. The latter are gradually choked out by progressive closure of the canopy by established saplings. Thereafter the vegetation reverts to mature forest if left undisturbed.

The results of an approximate ground mapping of vegetation that I carried out during and before the study in Ngengpui WLS and surrounding areas is represented in Fig 2. The sanctuary itself is largely covered by mature forest, while surrounding areas have a mosaic of bamboo forest, ***jhum*** fallows and tree plantations.

Plantations

The oldest teak plantation in Ngengpui valley and adjoining areas is about 23 years old (***Pu*** Lalnunngila, ***pers. comm***.). Most of the teak plantations are in the valley flatlands or moderately sloping slopes, while a few are on upper slopes, mostly along the roadsides. Some plantations of ***Gmelina arborea*** and ***Michelia champaca*** are also present in the reserve forest, which is at the northern end of the sanctuary. The teak plantations show a monotonous, uniform structure so characteristic of monocultures, with little undergrowth, mostly consisting of tall grass and ***Lantana.***

2.4 Changes in the Ngengpui valley- some insights

In the wake of socio-economic changes that have taken place in Mizoram in the last decade or so (For a succinct discourse on these aspects, see Singh, 1996) broad changes have taken place in the land use patterns in Ngengpui valley and surrounding areas. Almost all villages surrounding the sanctuary are situated along the metalled road that surrounds it (See Fig 1.). Most of the people are of the ***Pawi***, ***Bawm***, ***Pang*** or ***Bru*** tribes, with a few ***Mizo***, ***Mara*** and ***Châkma***. Among the villages, Mampui, Khawmawi, Hmunuam, Saizawh, and Rulkual are either ***Pawi***, or ***Pawi-Bawm-Pang*** dominated. Kawrthindeng is the only ***Bru*** village, while Ngengpui, Diltlang and Bungtlang have people of different tribes living together. Only Ngengpui and Khawmawi villages are situated near the sanctuary boundary. In the study area, most of the areas outside the boundary of Ngengpui WLS are notified by the Lai Autonomous District Council as village council reserves (E&F Dept., Mizoram, 1998) with each village exercising rights over a fixed area of forest near it. However, there are significant differences in land use patterns in Chimmtuipui district from other parts of the state, and elsewhere in the Northeast (***pers. obs***.). Among the three districts in Mizoram, it has the highest percentage of its land under mature natural forest cover, a large portion of it legally unprotected. Consequently, in many areas, along with bamboo brakes, people have the option to cut mature or primary forest for ***jhum*** cultivation, a situation seldom seen in most of northeast India (Ramakrishnan, 1992), and a greater portion of Mizoram itself. This results in different successional patterns in the post-***jhum*** fields, as described above (section 2.3.2), and a mosaic of remnant mature forest patches, abandoned ***jhum*** fields in different stages of succession, plantations, and bamboo brakes results. A similar pattern is seen in the present study area, making it eminently suitable for the framework of the present study.

3. METHODS:

Throughout this dissertation, I use the following terminology. The term 'Patch' is used to refer to the sampling areas only. The terms 'Habitat category' and 'Vegetation type' I use interchangeably with reference to broad successional stages, which may include more than one 'Patch'. 'Macrohabitat' refers to the broad structural aspect of the habitat, while 'Microhabitat' refers to lower level, micro-structural attributes, to a large extent dependent upon the former. 'Refuge' is a subset of a 'Microhabitat'. For instance, a buttressed tree is a microhabitat while its structural attributes which are actually utilised by resting animals such as hollows, buttress enclosures, bark, etc are refuges. A frog or lizard species was considered 'Terrestrial', 'Arboreo-terrestrial', or 'Arboreal' depending upon the proportion diel time it spent (based on personal observations), or its species group was known to spend (based on personal observations and existing information) on the ground and at above ground-level at different height classes. Similarly, a species was considered 'Nocturnal' or 'Diurnal' depending upon its ***modal diel-activity period***, again based on personal observations and existing information of its species group (especially in the situation where there were very few records for the species).

In general, I strictly adhered to the golden rule of herpetology- "a species in hand is better than two in the bush". All individuals detected by any of the techniques described below were caught whenever possible, identified ***in*** hand, and then released. All those "that got away" were identified to a justifiable level as far as possible. However, the percentage of completely unidentified individuals was negligible (See section 4). Whenever an individual posed identification problems, or belonged to a taxon documented for the first time in the study, a voucher specimen was preserved in 10 % buffered formalin, for later reference.

3.1 Defining patches:

At the initiation of fieldwork, the primary concern was to identify and delineate habitat patches in concordance with the study design. During the first week of the study period, a rapid reconnaissance was done in the potential areas that had been - identified during the preliminary survey in June-July 1998. Habitat patches (See Fig. 2 & Table 1) were then delineated, with 4 main criteria for selection- vegetation of the patch, surrounding vegetation, topography of the area, and distance from perennial water (At least 200 m from patch edge). Both sets were easily accessible from makeshift field stations- an abandoned ***jhum*** hut in the northern part and the village Kawrthindeng in the southern part of the study area (Henceforth referred to as station– I and station– II respectively). Altitude was not a major consideration as and the intensive study area was within an altitudinal range of 200-350 m.s.l., and the study area itself lies within a range of 180-500 m.s.l.

A combination of small streams and habitat edges were used to define the limits of patches 2a, 2b, 3a, 4a, 5a, 5b and 5c, while the boundary of patches 1a and 1b were easily identifiable without marking. Only one area was available for the 30-35 year

jhum fallow class (Patch 4), so a larger patch area was taken to compensate for it. All patches except the mature forest patches were selected so that they were more or less comparable with respect to surrounding vegetation.

This type of spatial design allows the choice of comparison between habitat categories by combining similar patches if necessary.

Table 1: Details of sampling patches

Patch code	Patch details	Information source	Approx. size
1a	1 year fallow, cultivated and abandoned in 1998	Ngengpui village council	3-4 ha.
1b	1 year fallow, cultivated and abandoned in 1998	Ngengpuitlang & Kawrthindeng village councils	3-4 ha.
2a	4-5 year fallows, two fields cultivated and abandoned in 1994 & 1996 respectively, indistinguishable from each other.	Ngengpui village council	4-6 ha.
2b	7-10 year fallows, 3 fields cultivated and abandoned between 1988 & 1991, indistinguishable from each other.	Kawrthindeng village council	4-6 ha.
3a	4 year old teak plantation, planted in 1994	Ngengpui village council	3-4 ha.
3b	22 year old teak plantation, planted in 1977	Ngengpui village council	4-6 ha.
4a	30-35 year fallows, 5-6 fields cultivated and abandoned between 1963 & 1969, indistinguishable from each other.	Ngengpuitlang & Kawrthindeng village councils	8-10 ha.
5a	Mature forest, slightly disturbed	-	4-6 ha.
5b	Mature forest, undisturbed	-	4-6 ha.
5c	Mature forest, undisturbed	-	4-6 ha.

3.2 Sampling methods

To effectively distribute sampling effort between techniques and patches, sampling was carried out in sampling ‘sessions’ of 10 days each. Two such sessions were completed every month (=20 days), starting from 15th December 1998 to the end of April 1999. During each session, time was allocated to each of the sampling techniques described below.

3.2.1 Herpetofauna: a sampling conundrum

There are many problems associated with amphibian and reptile sampling. Though a number of techniques are known (Heyer ***et al.***, 1994), lack of standardized sampling methodology has been a major concern (Pearman ***et al.***, 1995). Though diversity is high in wet tropical forest habitats (Scott, 1976), densities are low (Inger, 1980(b); Inger & Voris, 1993). This problem is particularly apparent in S. Asia, where densities of tropical terrestrial herpetofauna are the lowest in the world (Inger, 1980a & b). The sampling problem is rendered more acute by the apparently patchy distribution of herpetofauna in tropical forest, which has led to experimentation with new techniques to improve detection rate (Vasudevan ***et al.***, ***under review,*** Ishwar ***et al.***, ***under review***).
It is obvious then that any one method is not sufficient to effectively document herpetofaunal diversity and micro-distribution patterns in an area. In fact, multiple techniques in conjunction have been recommended even for relatively well studied faunal groups such as birds, especially if characterisation of community structure is the primary objective (Terborgh ***et al.*** 1990). This is particularly true for short duration studies, such as this one, where the species inventorying effort needs to be maximised. Moreover, the sampling then needs to be focussed on a particular sub-group, as it would not be possible to sample fossorial, terrestrial as well as arboreal frogs and lizards satisfactorily.
Taking these problems into consideration, I decided to use three techniques for sampling herpetofauna, each derived from existing techniques, but modified to suit the objectives of the study - (i) pitfall trapping, (ii) strip transects and (iii) systematic searching. All techniques were primarily oriented towards effectively sampling low-level arboreal, terrestrio-arboreal, and terrestrial species.

3.2.1.1 Pitfall trapping

The primary objective of pitfall trapping was to maximize the species inventorying effort in a comparable manner across patches. I used the 'Y'- shaped pitfall array design (***cf.*** Corn, 1994; See appendix 1) with minor modifications. ***This technique is effective primarily for sampling terrestrial and arboreo-terrestrial forms***. Each array had four cylindrical aluminium pitfall traps buried into the ground so that the rim of each cylindrical trap is flush with the ground. Diameter of each of the three terminal traps was 30 cm and the depth was 60 cm, while the single central pit had a diameter of 50 cm, and a depth of 70 cm. Each trap also had a funnel made of aluminium at the rim, to reduce the probability of trapped animals escaping. The traps were connected with three 40-cm tall opaque plastic sheet drift fences 5 meter in length, held up by thin bamboo stakes.

All arrays were established within a period of 14 days, from 29th November to 12th December. In all, 22 arrays were established, each patch having 2 arrays, except for patch 4, where 4 arrays were established. Each array was situated such that it was well inside of the patch edge or boundary and on gentle or no slope with as much distance between arrays as possible.

Throughout the period of patch delineation and establishment of pitfall traps, intensive searching was carried out to catch and identify as many species of herpetofauna as possible. However, the process of familiarisation continued throughout the duration of the study, as new species were detected at every sampling session till the termination of fieldwork.

To allow the traps to ‘settle down’, systematic trapping at each array was initiated 10 days after the traps were established. Traps were left open for 5-10 consecutive days. They were checked at different intervals in different habitats, ranging from every alternate day in patches like the I year fallows, to every third day in mature forest patches, the checking frequency being proportionate to the level of exposure trapped animals were subjected to. Most specimens (95.2 %) obtained from pitfall trapping were released in the same or a similar patch, a minimum of 200 m away from the array in which they were trapped. The remaining were retained as voucher specimens.

3.2.1.2 Strip transects

The second method that I used for sampling herpetofauna was a technique that I can best describe as a synthesis of belt transect and a quadrat techniques (***cf.*** Jaeger, 1994; Jaeger & Inger, 1994, Pearman ***et al,*** 1995). The objective for using this technique was to estimate the abundance of frogs and lizards and proportional abundance of diurnal and nocturnal species per unit area for each patch. I discuss the reasons for using this approach later in this thesis. ***This technique primarily sampled terrestrial, arboreo-terrestrial and low-level arboreal species***.

Each strip was walked only once, and typically 50m long, but cut short if the edge of the patch was in sigh. Using one of the pitfall arrays in the target patch as the starting point, a random number was generated with a calculator, using the first digit to fix direction, and a number of steps were taken corresponding to remaining random digits. The point reached was used as the base point from which the strip was initiated. Because of the patch sizes, and the placement of the pitfall traps, seldom did any base point fall out of the patch. In the latter circumstance, the point was abandoned, and a new one generated using the same procedure. Strips were walked and thread-marked using a hip chain. Each strip was unique, and if a random base-point fell on or near an existing strip, a new random point was generated.

Each strip was walked once in both directions by two observers, between 1000-1400 hrs during winter and 0900-1300 during summer. At the beginning and end of each strip, air and soil temperature were recorded. On the first walk, all active animals within 1.5 metres on either side of the strip line and up to a height of 3 m were recorded as ‘strip searched- active’. Any animal seen leaving the search area was recorded as being present in the strip area. Henceforth I shall refer to this, the first part of the strip walk, as the ‘active animal walk’. ***No microhabitat searching was done during this walk***. On the way back, using the thread marker as reference line, all possible microhabitats within the area defined for active animals were intensively searched for resting animals. This included raking leaf litter, rolling and ripping logs, probing holes, checking tree buttresses, banana sheaths, etc., and all animals found were recorded as 'strip searched- resting '. ***All active animals seen during this walk were not enumerated***, but their behaviour and position was noted. This part of the strip I shall henceforth refer to as the ‘resting animal walk’.

The active animal walk was carried out at a slow and steady pace, fixed for all patches at about 20min / 50m (Fig. 5).

However, the time for the resting animal walk varied across vegetation types, but was more or less constant ***within*** any given vegetation type (Fig.6). This was because each vegetation type had a different structural complexity and hence the time needed for searching all possible microhabitats within the search area varied. I argue that just as sampling in the habitats need to be proportional to habitat heterogeneity scale at a broader spatial scale, so does higher microhabitat complexity call for proportional effort, either spatially or as in this case, in terms of time spent searching. Without this approach, it would not be possible to saturate the microhabitat search effort.

A total of 192 strip transects were completed. In general, the mean time needed for each strip transects and the number of strip transects done in each patch increased from the 1-year fallows and teak patches to the mature forest patches (Fig. 6).

Figure 5: Mean time (± 95% C. I.) spent per strip transect across patches (Sample size in parentheses)

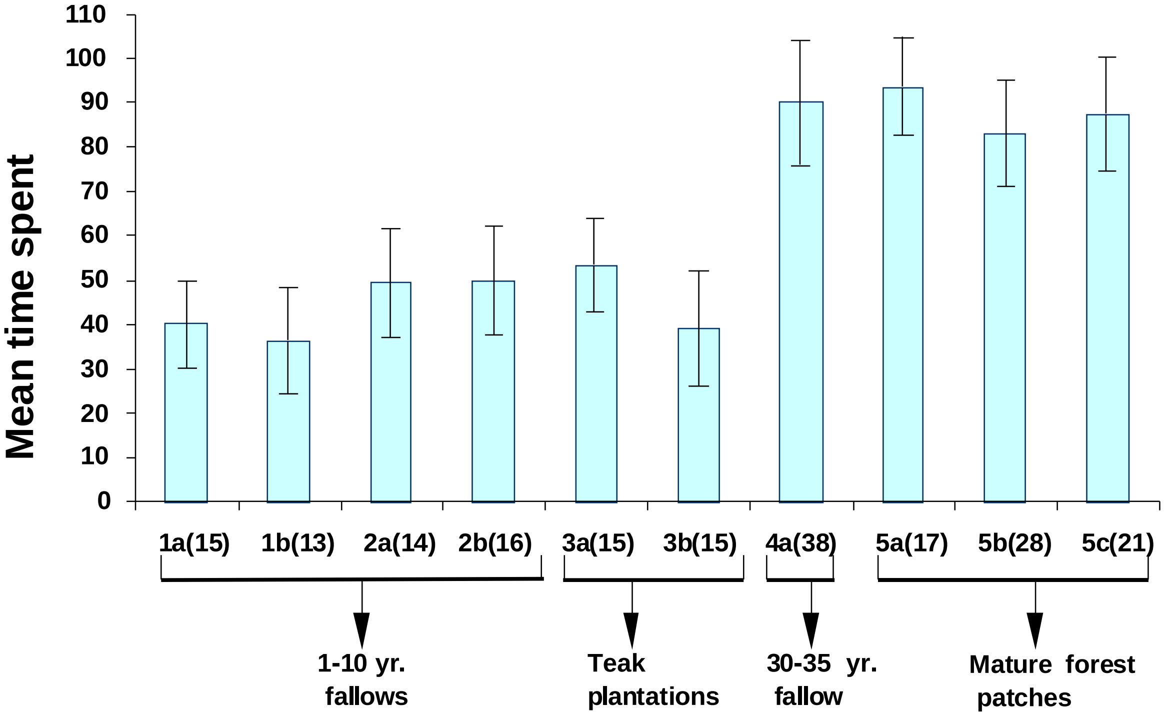
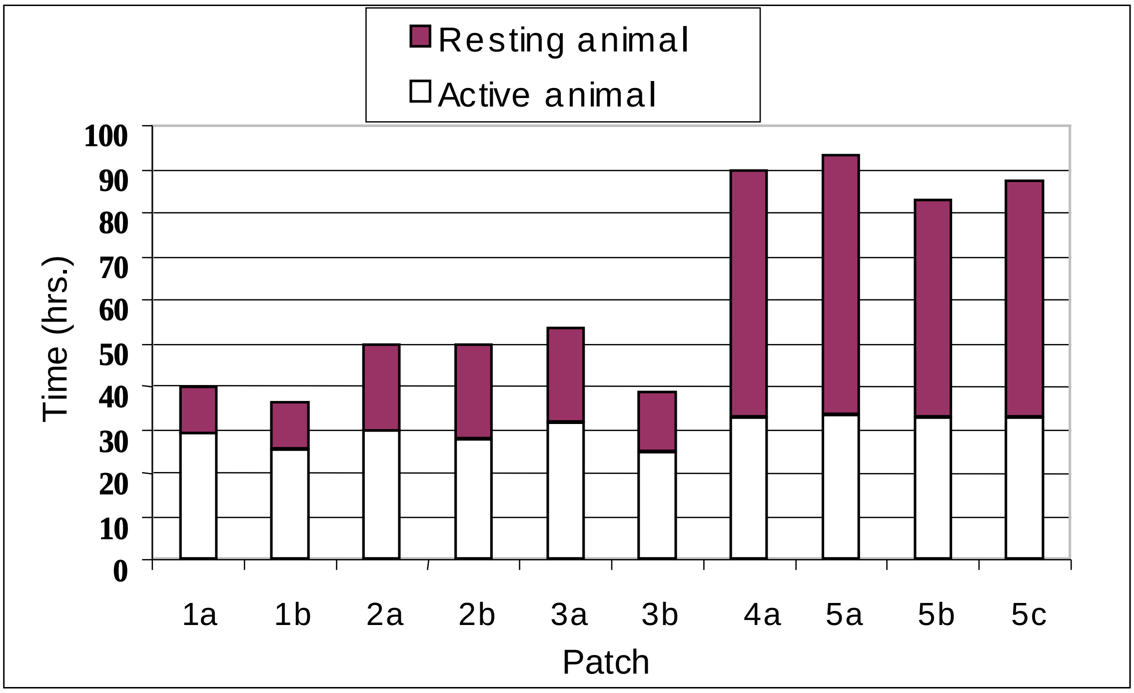


Figure 6: Proportion of sampling time spent on resting and active animal strips across patches



3.2.1.3 Systematic searching

To maximise species inventorying, and provide additional information (which formed the basis for an ***a-posteriori*** guild classification), far ranging searching was carried out at the end of each sampling session in each patch. All animals found were recorded, with ***special focus on resting animals***. Details of the refuge and microhabitat they were found associated with were noted. ***This technique sampled terrestrial, arboreo-terrestrial as well as arboreal species***.

Periodically, nocturnal searches were made to collect information about the nocturnal refuge of diurnally active animals, and also to strengthen the results in terms of presence or absence of species in different patches. This information added crucial information to the microhabitat characterisation of the herpetofauna in the study area.

3.2.2 Confirming species presence: how many individuals?

In a study of this nature, it is important to have a criterion for accepting the presence of a species in a given habitat from the set of habitats being investigated (patches in this case). The question here is whether the species was found by chance- how does one decide that the species was not a vagrant from another patch type, or that it is absent from other patches?

As discussed in section 1, the patterns of micro and macro-distribution of herpetofauna are intriguing. As herpetofauna show notable changes in terms of richness and abundance along habitat gradients (***cf.*** Bowman ***et al.***, 1990; Woinarski and Gambold, 1992), the abundance factor in particular needs to be considered before setting rejection / acceptance classes. However, it has been documented time and again that in tropical mature forests, herpetofauna occur at high diversity but in low abundance (Ex. Inger, 1980a; Ishwar ***et al.***, 1997). So a uniform species rejection criterion for all habitats in this case is not suitable. This problem is more crucial in the mature forest patches, and it would be an unnecessary loss of information to reject species presence in a habitat because of a rigid, uniform rejection level across patches. With these considerations, I set habitat specific rejection levels for confirming species presence across patches in the following way, ***after pooling all species and individuals from all the herpetofaunal sampling techniques*** -

Patch	Group	Acceptance level
1a, 1b, 2a, 2b, 3a, 3b	I	A total of 3 or more individuals, after pooling samples from all techniques
4, 5a, 5b, 5c	II	A total of 1 or more individuals, after pooling samples from all techniques, provided it does not appear in any of the patches of the above group. If appearing in any patch of the above group (I), 2 more individuals have to be detected for the species to be included in the study. In other words, the acceptance levels jumps to 3 or more individuals

3.2.3 Guild classification

While examining changes in communities of animals in response to habitat change, a well-directed investigation of changes in guild composition is likely to improve the resolution of such studies to a great extent (ex. Bowman ***et al.,*** 1990; Shankar Raman, 1995). However, before defining guilds for an amphibian-lizard assemblage, an important factor needs to be considered- Amphibians and lizards are governed by habitat structure at least as much and maybe more than food limitation in terms of quality, as most of them are feeding generalists (Toft, 1985). So a habitat structure-oriented guild classification (as against foraging mode) would be an effective way to examine changes in herpetofaunal community composition across habitats in a study of this kind. Also, nocturnality and diurnality needs to be considered while examining community organisation for herpetofauna (Duellman and Pianka, 1990). I used this approach while assigning species to guilds in this study.

Based on available information and personal observations (See beginning of this section), species were assigned to guilds, firstly on the basis of their activity period- diurnal or nocturnal. Secondly, each diurnal and nocturnal species was further classified as terrestrial, arboreo-terrestrial and arboreal. Thus six guild classes were identified- nocturnal terrestrial (NT), nocturnal arboreo-terrestrial (NAT), nocturnal arboreal (NA), diurnal terrestrial (DT), diurnal arboreo-terrestrial (DAT) and diurnal arboreal (DA).

3.2.4 Habitat / Vegetation sampling

Vegetation sampling was done with an ***a priori*** selection of vegetation and habitat attributes for sampling that would best relate to patterns of herpetofaunal species richness and composition, albeit indirectly. For vegetation sampling, I adopted the methods of Bowman ***et al***. (1990), but with considerable modification. All vegetation sampling was done in 10 meter wide strip transects, usually of 25 m length, but shorter if the edge of the patch was reached. Tree density and tree species richness was sampled on the whole area of each strip. All trees >20cm GBH were enumerated, while the rest were classified as shrubs. Six circular plots of 2-m radius at 5-m intervals on the strip were used for sampling bamboo, shrub, palm, banana, and tall grass clump density. Percentage cover of herbaceous forms and leaf litter, dead woody matter abundance and abundance of lianas were visually estimated. A hand-held canopy densiometer was used to estimate percentage canopy cover at 5 metres from ground level at the centre of each of the 6 circular plot on every strip. Litter depth was gauged by pressing a blunt rod of 0.5-cm diameter on the surface of the leaf litter and then counting the number of leaves that were trapped under it, at 5 random points in each circular plot. I used this method for gauging litter depth rather than the popular practice of using a needle for impaling leaves, because leaf litter in different vegetation types is unlikely to be impaled with the same success.

Strips were located randomly in the same manner as that for strip transects for herpetofaunal sampling. The number of strips sampled in each patch are as follows- 6 each in patch 1a, 1b, 2a, 2b and 4a; 5 each in patch 3a, 3b, 5a, 5b and 5c.

3.3 Data analysis:

To gauge herpetofaunal species richness across habitat categories, records were pooled from all three techniques to get a single estimate of species richness in each habitat category. ***Only data from strip transects were used for abundance estimation***, after pooling all strips in each patch. To reveal initial patterns of richness in broad guilds, abundance of all frogs and lizards, and for diurnal and nocturnal species were compared separately using the Kruskal-Wallis H test for independent samples.

I used Multi-dimensional scaling (MDS) to obtain a distinct, graphical representation of differences between the habitat categories and describe chronosere gradients. Compositional dissimilarity can be considered an effective measure of ecological distance, and this technique is used to geometrically represent similarities between sites or variables as faithfully as possibly, according to their dissimilarities in a graphical, low-dimensional space (***fide.*** Johnson and Wichern, 1992; Minchin, 1987). Despite its proven robustness for indirect gradient analysis, it has not been used much in ecological studies for various reasons (Jongman ***et al.***, 1995). Various habitat attributes (See section 3.2.4) were used to calculate similarities (Euclidean distance) between habitats. For the MDS solution, the Euclidean distance-scaling algorithm (***fide.*** Norušis, 1997) was used. I then tested differences between four macro-habitat parameters to summarise broad differences between the habitat categories, using one-way Analysis of Variance (ANOVA). All the test variables were normally distributed, but the assumption of homoscedasticity was not satisfied (Levene's test, $p<0.001$). So Tamhane's T2 (conservative pair wise comparisons test based on a t test) was used as a post-hoc multiple range test.

To explore possible habitat parameters influencing patterns of total species richness and richness of guilds I used MDS again. In this case, separate similarity matrices (Euclidean distance) for each patch were simultaneously used for MDS analyses, using the Euclidean distance-scaling algorithm. In both the MDS solutions, the number of dimensions were accepted after examining of stress and RSQ values (See Norušis, 1997). Pearson's product-moment correlation coefficients were then calculated to judge the strength of the association patterns suggested by the MDS.

The SPSS software program (Version 8.0) was used for all analyses.

4. RESULTS

In all, 68 species of herpetofauna were recorded during the study, out of which 32 are included in this work. (See Appendix II). The remaining species are mainly snakes and turtles, which were excluded due to the reasons discussed before (See Section 1). Some amphibians and lizards were also excluded because were sighted opportunistically, and did not appear in the samples of any of the three herpetofaunal sampling techniques.

The three herpetofaunal sampling techniques yielded results as follows-

	Number of individuals	Species of total	Exclusive species*
Pitfall trapping	277	17	2
Strip transects	158	16	1
Systematic searching	175	29	8

* Species discovered exclusively by that technique; not found by the other two.

It is not surprising that systematic searching yielded the most number of species, as all effort was concentrated on maximizing searching and scanning effort. I encountered a mortality percentage of 1.4 % during pitfall trapping.

4.1 Herpetofauna: initial patterns

Simple richness measures provide a good broad indication of whether the target group differentiates between habitats (Verner, 1985; Pearman, 1997). Fig 7 shows species accumulation curves across habitats (patches similar in broad features and/or age pooled). The trends are very distinct indeed. While all the early successional stages and teak plantations reach an asymptote very soon, the 30-35 year fallow stopped yielding new species only by the 8th sampling session. Mature forest on the other hand continued to yield new species till the final sampling session, in the 3rd week of April 1999.

It would be interesting to examine if the trends are similar for frogs and lizards. Figs. 8, 9, 10, 11, 12 show separate species accumulation curves for frogs and lizards. Accumulation curves in the early ***jhum*** fallows and in teak plantations show a very early asymptote. But towards the older ***jhum*** fallow and mature forest patches the frog curves are very different, with no apparent asymptote in the mature forest. The Lizard accumulation curves on the other, show a more gradual difference between patches, but here too the curves show much more accumulation towards the mature patches. At the outset, this patterns is not very surprising, considering the fact that frogs and lizards differ notably in their ecology. These initial patterns are interesting, but speculating about explanations at this point would lead nowhere- a closer examination is necessary.

Figure 7: Species accumulation across patches, frogs and reptiles pooled: (a) 1 yr. ***Jhum*** fallows (b) 4-10 yr. ***Jhum*** fallows (c) Teak plantations (d) 30-35 yr. ***Jhum*** fallow (e) Mature forest patches

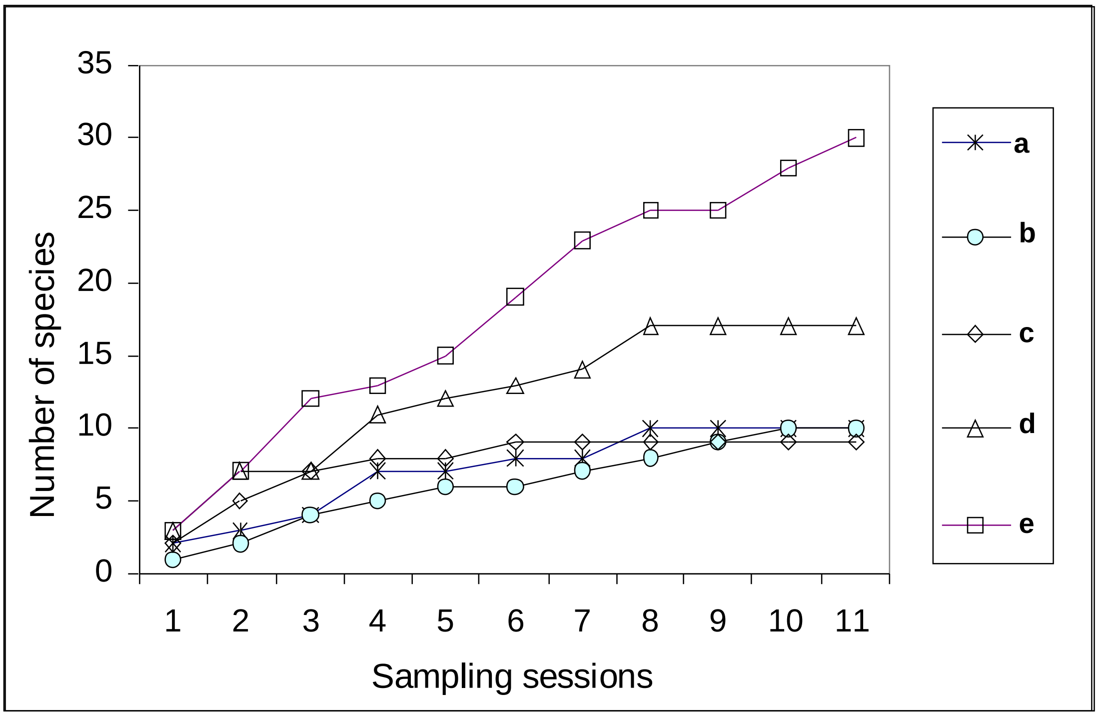


Figure 8: Separate species accumulation curves for frogs and lizards: 1-yr ***jhum*** fallows

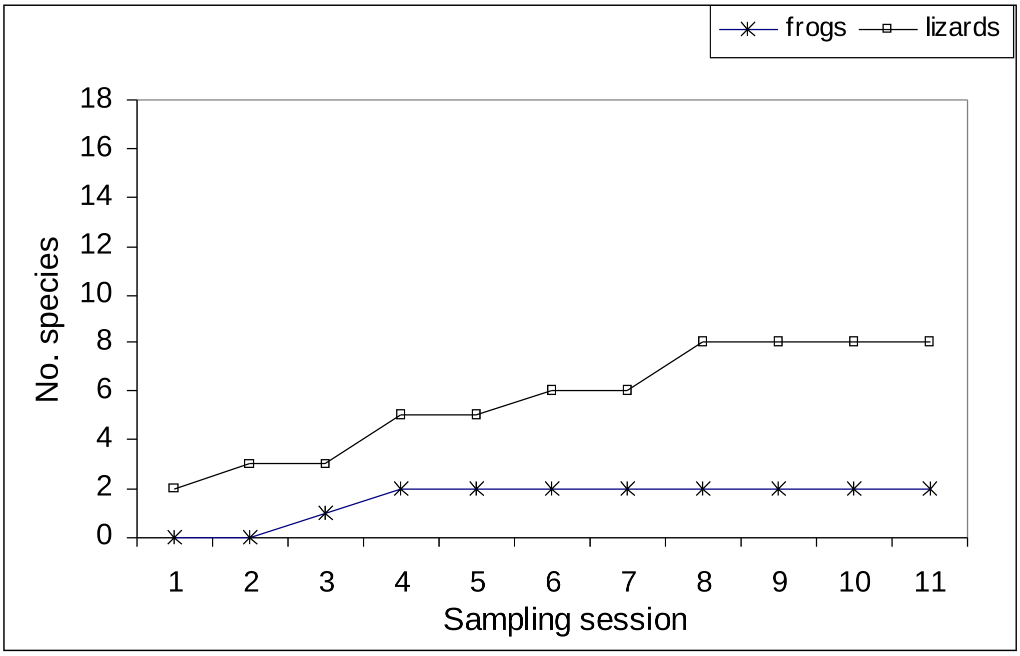


Figure 9: Separate species accumulation curves for frogs and lizards: teak plantations

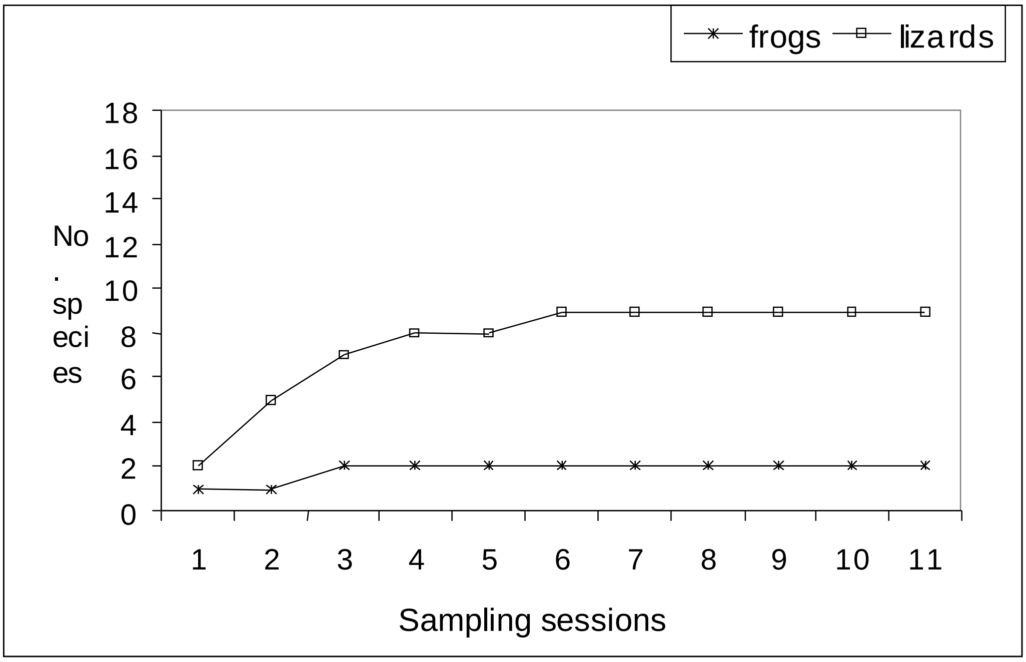


Figure 10: Separate species accumulation curves for frogs and lizards: 4-10yr ***jhum*** fallows

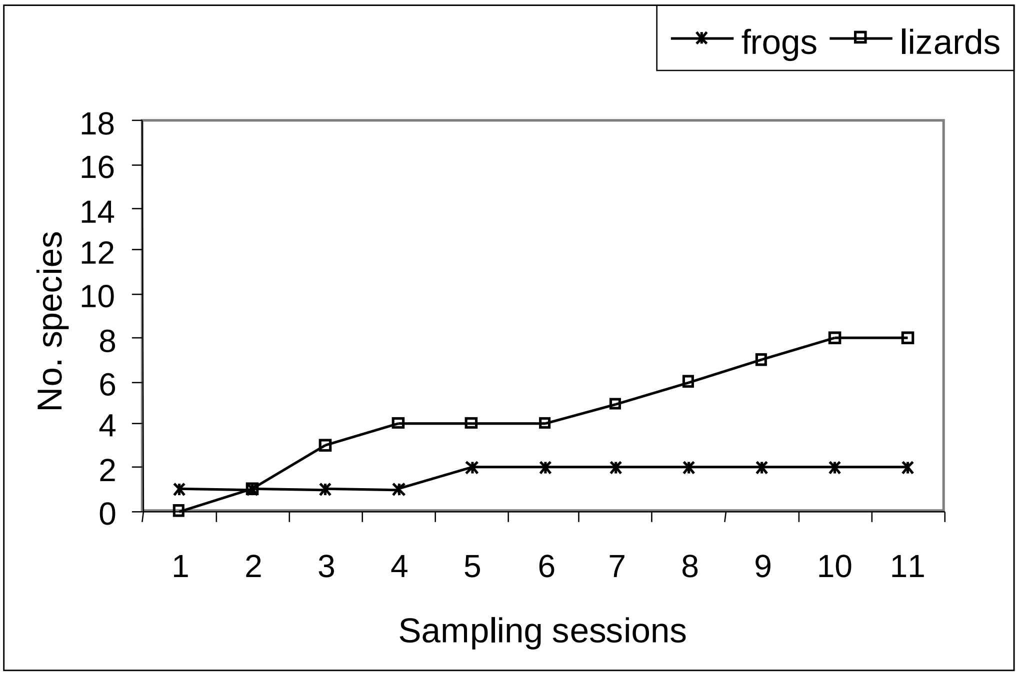


Figure 11: Separate species accumulation curves for frogs and lizards: 30-35yr ***jhum*** fallows

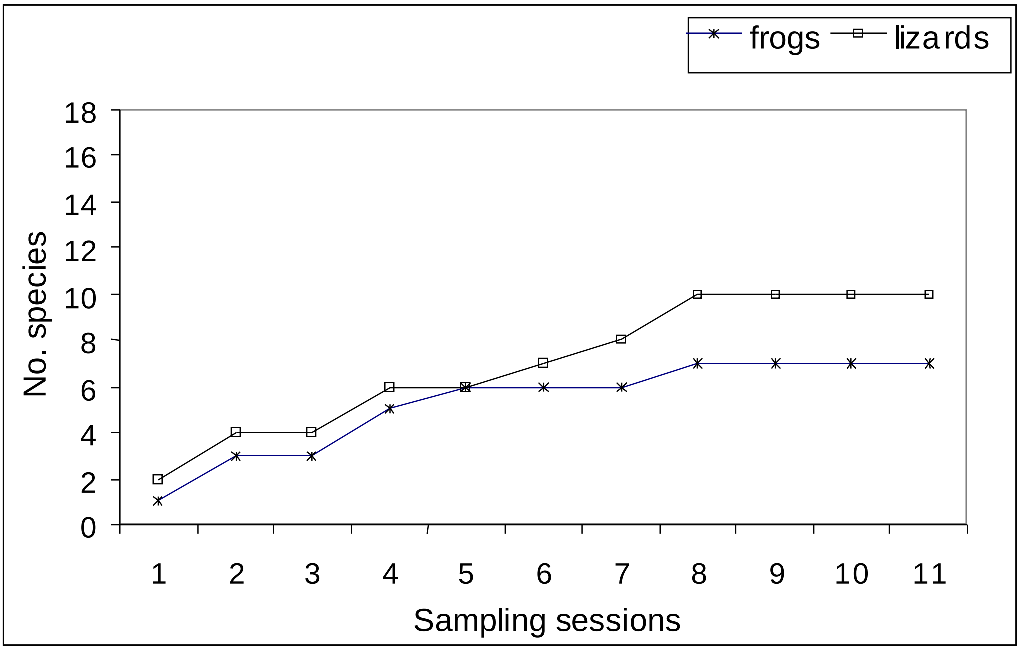
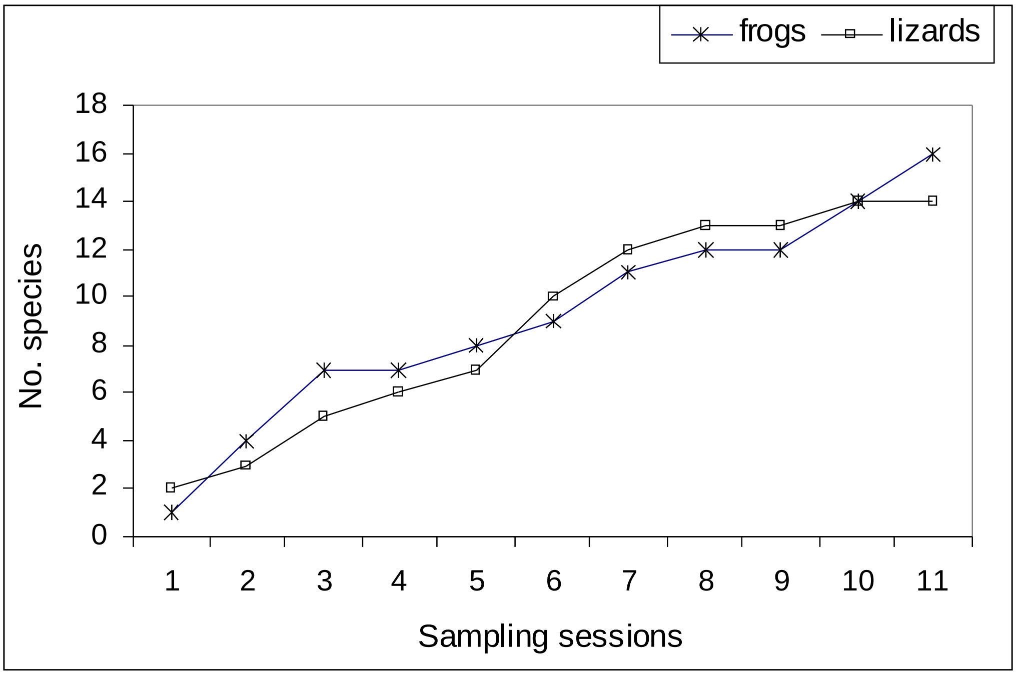


Figure 12: Separate species accumulation curves for frogs and lizards: Mature forest



4.1.1 Of nocturnal and diurnal species

Having said that there are many differences in the ecology of frogs and lizards, the fact remains that many lizards do share ecological affinities with frogs (*cf.* Heatwole 1977). The most convergent ecological characteristic between the two groups is nocturnality- there are many nocturnal lizards, especially in the Infraorder Gekkonomorpha (Geckoes) (Duellman and Pianka, 1990). So to examine ecological patterns among assemblages of these two groups, a taxonomic basis may not be the right approach. To compare abundance of frogs and lizards in different habitat categories, I pooled all animals on the strip transects in each patch (frogs and lizards together), and then recalculated abundance in two categories- diurnal and nocturnal, separately (Figs. 13, 14 and 15 respectively).

Though pooled abundance did not differ significantly across habitat categories (Kruskal-Wallis H, $\chi^2 = 4.672$, $p = 0.862$), abundance of both nocturnal and diurnal animals were significantly different ($\chi^2 = 32.740$, $p < 0.000$ and $\chi^2 = 22.414$, $p = 0.008$ respectively). The distinction between the two broad groups is evident- diurnal species are more abundant in the post-***jhum*** fallows and in teak plantations, and less abundant in the 30-35 yr. fallow and mature forest patches, while nocturnal species show an opposite trend. Therefore the two categories, viz., nocturnal and diurnal, must respond to inter-habitat contrasts differently.

Figure 13: Pooled abundance of frogs and lizards (per 100 m^2) across patches (Refer to table 1 for patch label identities)

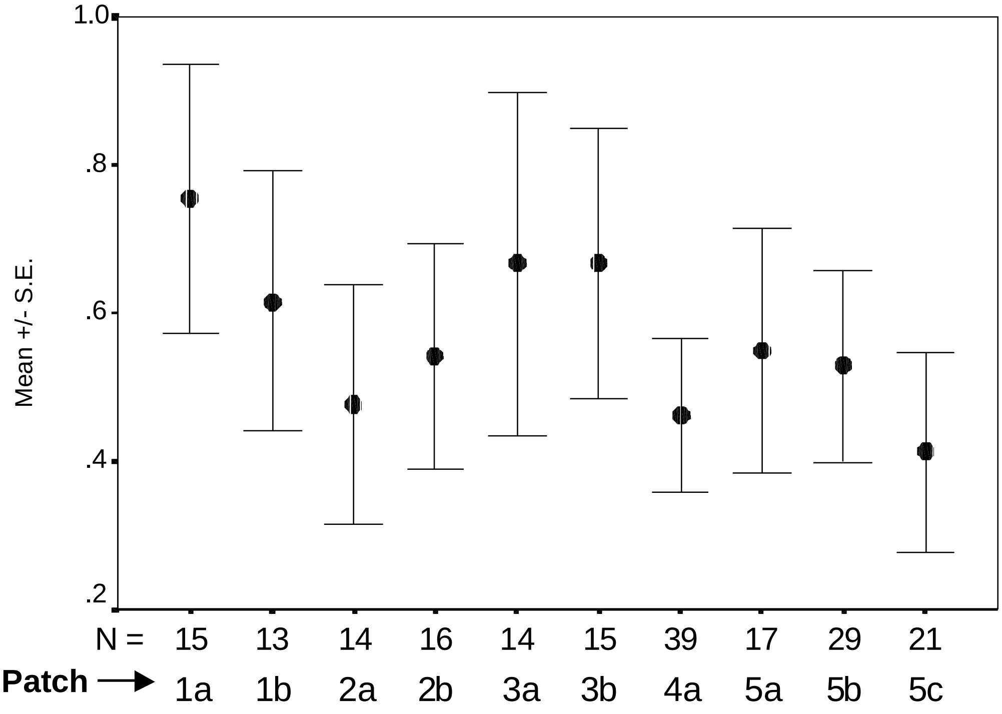


Figure 14: Abundance of diurnal species (per 100 m^2) across patches
(Refer to table 1 for patch label identities)

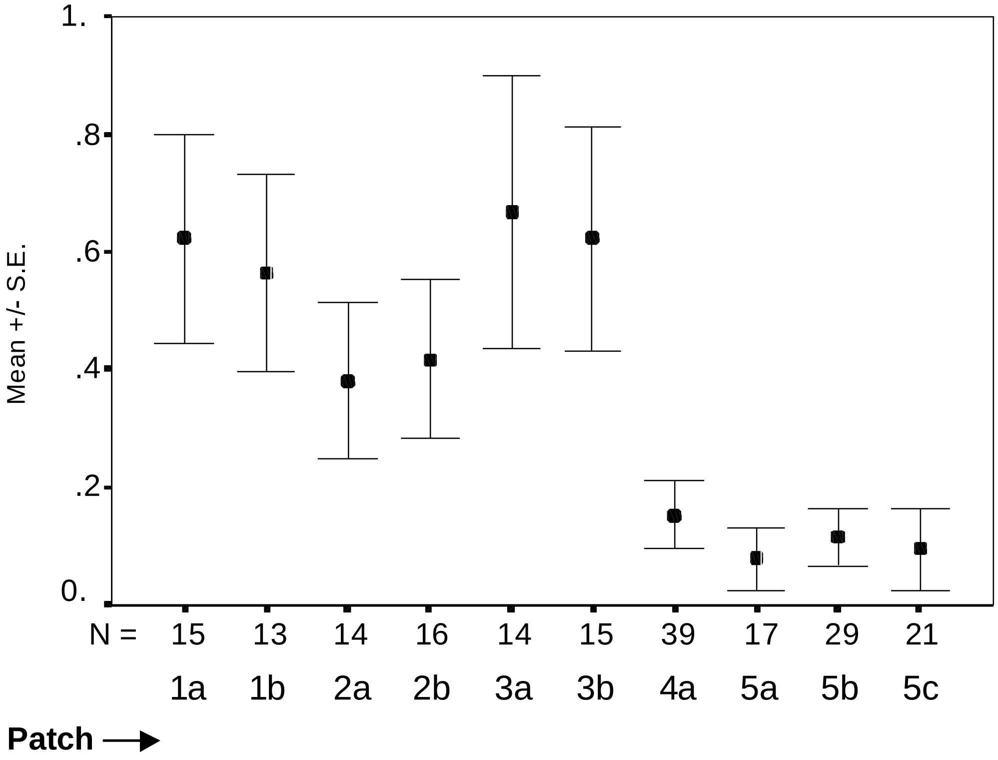
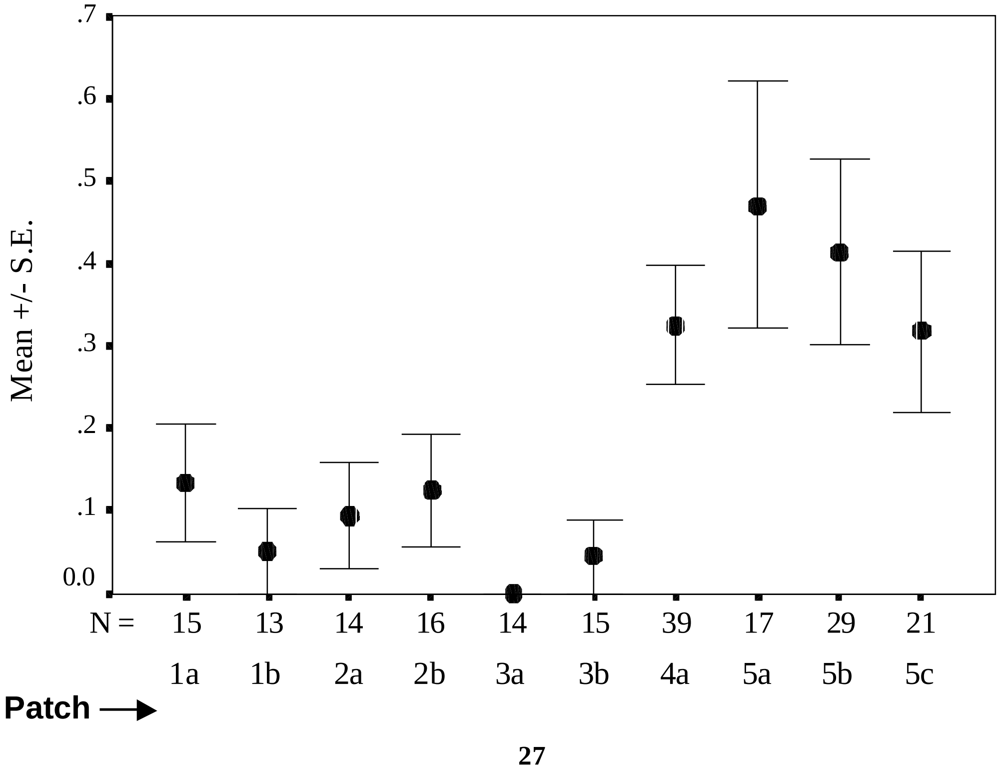


Figure 15: Abundance of nocturnal species (per 100 m^2) across patches
(Refer to table 1 for patch label identities)



4.1.2 Looking at guilds

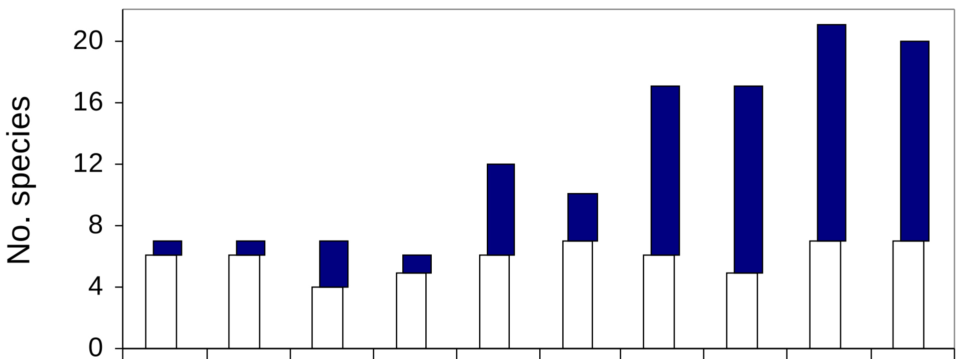
From figures 14 & 15, it is clear that the ***abundance*** of nocturnal species (estimated only from strip transects) increases towards the 35-40 year ***jhum*** fallows and mature forest, while that of diurnal species decreases in the same direction.

But it is not yet apparent how species ***richness*** changes in these categories. Fig. 16 shows the proportion of diurnal and nocturnal species after pooling individuals from ***all the three***-herpetofaunal sampling techniques. Here again, the pattern is distinct. The contribution of nocturnal species to the total species list increases dramatically in patches 4a to 5c, while it is quite steady in the case of diurnal forms.

In the case of the nocturnal vs. diurnal species ***richness*** patterns (Figure 16), as the proportions have been derived from the total species list (Pooling samples from all three techniques), species that did not appear in strip-transects, including arboreal forms such as ***Draco maculatus*** add an important aspect to the pattern. The proportion of arboreal and terrestrial species also changes significantly across habitat categories (Kruskal-Wallis H, $\chi^2 = 28.64$, p= 0.001 and $\chi^2 = 44.87$, p < 0.000 respectively). ***So, it is mainly nocturnal and arboreal species that account for the differences in species richness across habitat categories***.

With these preliminary patterns, it is now possible to examine species richness among and within guilds. Table 2 shows all species included in this study, and their guild classification. Again, the increase in frog species towards mature patches is apparent. Lizards on the other hand, mainly represented by the diurnal terrestrial (DT) guilds in the early 1 year, 4-5 year, 7-10 ***jhum*** fallows**,** and in teak plantations. The increase in the representation of lizards in more mature patches is because of increase in diurnal arboreal (DA) and arboreo-terrestrial (DAT) lizard species. Also, though there are 5 lizards in nocturnal guilds (3 in NA, one each in NAT and NT), there are no diurnal frogs in the diurnal guilds. This is not surprising, as the majority of frogs are known to be nocturnal (Toft, 1985; Duellman and Pianka, 1990).

Figure 16: Change in nocturnal-diurnal species proportion across patches
(Refer to Table 1 for patch code identity)



Patch	3a	3b	1a	1b	2a	2b	4a	5a	5b	5c
■ Nocturnal spp.	1	1	3	1	6	3	11	12	14	13
□ Diurnal spp.	6	6	4	5	6	7	6	5	7	7

Table 2: Guild* classification and species composition across patches

Guild	Species	Frog/ Lizard	PATCH (Present = 1; Absent = 0)									
			1a	1b	2a	2b	3a	3b	4a	5a	5b	5c
DA	***Draco maculatus***	L	0	0	0	0	0	0	0	1	1	1
DAT	***Calotes versicolor***	L	1	1	1	1	1	1	0	0	0	0
DAT	***C. emma***	L	0	0	0	1	0	0	1	1	1	1
DAT	***Ptyctolaemus gularis***	L	0	0	0	0	0	0	1	0	1	1
DT	***Takydromus sexlineatus***	L	0	1	1	1	1	1	1	0	1	0
DT	***Mabuya multifasciata***	L	1	1	1	1	1	1	0	0	0	0
DT	***Mabuya macularia***	L	1	1	1	1	1	1	0	0	1	0
DT	***Mabuya sp.***	L	1	0	1	1	1	0	1	1	0	1
DT	***Sphenomorphus indicus***	L	0	0	0	0	0	0	1	1	1	1
DT	***Sphenomorphus maculatum***	L	1	1	1	1	1	1	0	1	0	1
DT	***Sphenomorphus courcyanum***	L	0	0	0	0	0	0	1	0	1	1
NA	***Bufoides meghalayana ?***	F	0	0	0	0	0	0	0	1	1	0
NA	***Philautus sp.***^{2}	F	0	0	0	0	0	0	0	0	1	1
NA	***Philautus sp.***^{3}	F	0	0	0	0	0	0	1	1	1	1
NA	***Philautus sp.***^{4}	F	0	0	0	0	0	0	0	0	1	0
NA	***Chirixalus vittatus***	F	0	0	0	0	0	0	0	1	1	0
NA	***Rhacophorus sp.***	F	0	0	0	0	0	0	0	0	0	1
NA	***Cosymbotus platyurus***	L	1	0	0	0	0	0	1	1	1	0
NA	***Ptychozoon lionotum***	L	0	0	0	0	0	0	0	0	0	1
NA	***Gekko gecko***	L	0	0	0	0	0	0	1	1	1	1
NAT	***Rana sp.***^{4}	F	0	0	0	0	0	0	0	0	0	1
NAT	***Kaloula pulchra***	F	0	0	0	0	0	0	0	1	1	1
NAT	***Philautus sp.***^{1}	F	0	1	0	1	0	1	1	1	1	1
NAT	***Hemidactylus garnoti***	L	1	1	0	1	0	0	1	1	0	0
NT	***Microhyla berdmorei***	F	0	0	0	0	0	0	0	1	1	0
NT	***Megophrys parva***	F	0	0	0	0	0	0	1	1	0	0
NT	***Bufo melanostictus***	F	1	0	0	0	1	1	0	0	1	0
NT	***Occidozyga sp.***	F	0	0	0	0	0	0	1	1	1	1
NT	***Pterorana khare***	F	0	0	0	0	0	0	1	0	0	1
NT	***Rana sp.***^{2}	F	0	0	0	0	0	0	1	1	1	1
NT	***Rana sp.***^{3}	F	0	0	0	1	0	0	1	0	0	1
NT	***Tropidophorus assamensis***	L	0	0	0	0	0	0	1	0	1	1
	Total frogs		1	1	0	2	1	2	7	9	11	10
	Total lizards		7	6	6	8	6	5	10	8	10	10
	POOLED TOTAL		8	7	6	10	7	7	17	17	21	20

* NT= Nocturnal Terrestrial; NAT= Nocturnal Arboreo-Terrestrial; NA= Nocturnal Arboreal; DT= Diurnal Terrestrial; DAT= Diurnal Arboreo-Terrestrial; DA= Diurnal Arboreal

4.2 Recovering gradients: a multidimensional scaling of habitats

I used trends of abundance in categories of habitat parameters along with patch ages (Mature forest patches were arbitrarily given a age value of 100 years) as as criteria for multidimensional scaling to obtain a explicit representation of similarities between habitat categories, which could then be interpreted in terms of possible gradients of succession. This ‘chronosere’ approach is a practical way to study succession (***cf.*** Bowman ***et al.***, 1990). The results of the scaling are represented in Fig. 17 and Table 3.

To assist interpretation, I drew directional lines indicating two gradients. The distance between any two habitat points in the MDS depiction reflects actual dissimilarities(or similarities) between the two categories in terms of the indicator variables (Structure and time in this case). The results of the MDS model suggest that the changes in terms of structure with increasing successional age are drastically different from ***jhum*** to mature forest, compared to ***jhum*** to teak forest. ***In general, there is a gradual change towards a tree dominated habitat in both cases, but vey different qualitatively.***

4.2.1 Habitats: differences and changes

I chose four habitat attributes which would best indicate differences between habitat categories, which I call macro-habitat parameters - tree density, bamboo density, shrub density, and canopy cover (Table 4). Tree density was highest in teak plantations, 30-35 year ***jhum*** fallow, and in mature forest. Bamboo density was highest in the 4-5 year ***jhum*** fallow, and decreased steadily along the bamboo forest to mature forest gradient. Shrub density was highest in mature forest. Canopy cover increased towards the mature forest categories. While interpreting these results, it needs to be remembered that all habitat parameters recorded were with the intention of using them as surrogates of spatial resources for herpetofauna. So canopy cover was measured at 5 metres above ***ground*** level, and shrub density actually represents density of shrub***-forms***, as all tree saplings < 20 cm G.B.H**.** were included in this category.

Tall grass, herbaceous forms, shrub forms, and bananas dominated the 1-year ***jhum*** fallows. Litter cover and depth was poor, dominated by herb and grass leaves. Bamboos were absent, reflecting the fact that the ***jhums*** had been cut from primary forest, and not bamboo brakes. Canopy cover was low, and insolation levels were extremely high.

Figure 17: Derived patch similarity (distance) model

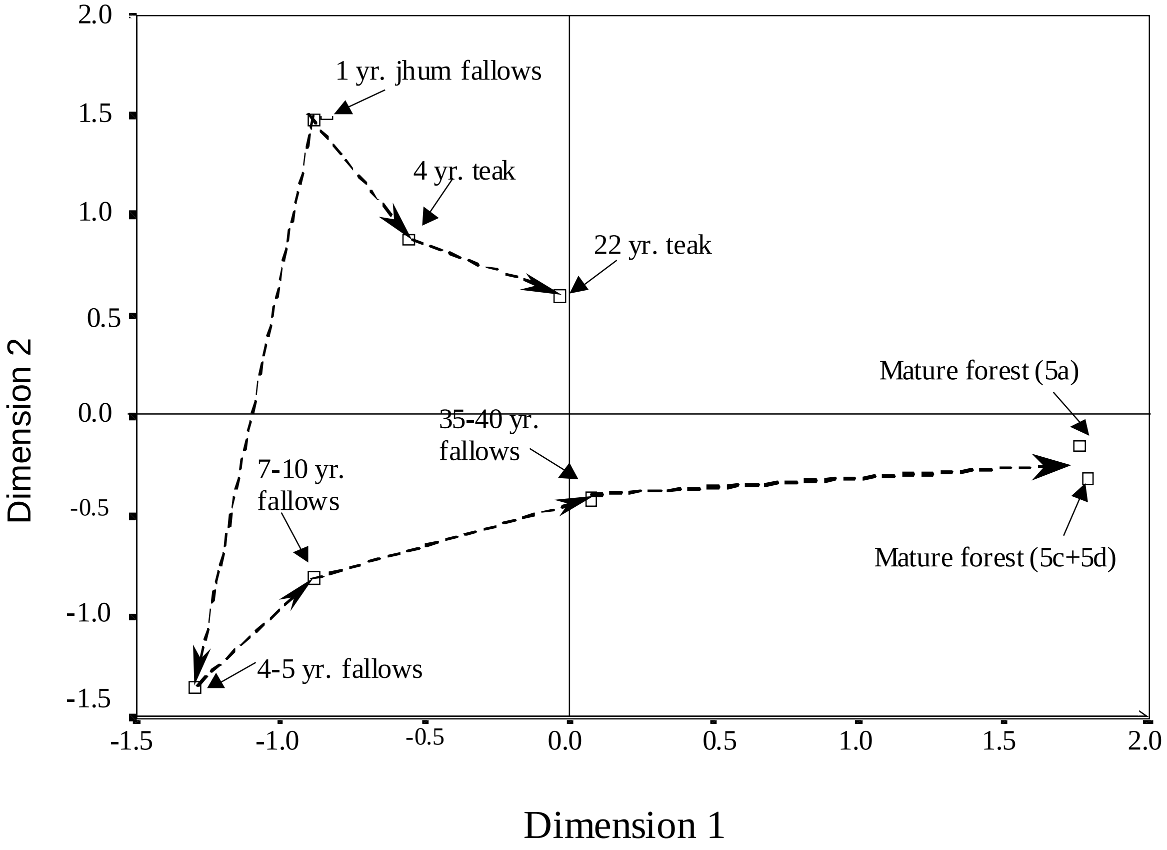


Table 3: Stimulus coordinates for Fig. 17

Habitat type (Patch)	Dimension 1	Dimension 2
1 Yr. jhum fallows (1a+1b)	-.8407	1.5127
4-5 yr fallows (2a)	-1.2977	-1.3492
7-10 yr. fallows (2b)	-.8863	-.8068
4 yr. teak plantation (3a)	-.5587	.8859
22 yr. teak plantation (3b)	-.0379	.6091
30-35 yr. teak plantation (4a)	6.0685	-.4087
Mature forest (5a)	1.7643	-.1379
Mature forest (5b+5c)	1.7885	-.3051

The 4-5 and 7-10 year ***jhum*** fallows had high bamboo culm density, dominated by a single species, ***Melocanna baccifera.*** herb-form density, and very low tree density. The understorey was sparse. Litter depth and cover was high, but almost exclusively bamboo leaves.

The teak plantations had very few tree species other than teak. The understorey was sparse, with some tall grass, shrubs and leaves. Litter depth and cover was moderate, dominated by teak leaves.

The 30-35 year ***jhum*** fallow had moderate tree as well as bamboo culm density. This reflects the fact that bamboo here was slowly giving way to trees. Apart from ***Melocanna baccifera***, clumps of ***Bambusa tulda*** and ***Dendrocalamus longispathus*** were also present. Litter depth and cover were moderate to high, with bamboo as well as tree leaves.

The mature forest patches had high tree density and shrub from density. Bamboo density was insignificant, as bamboos were restricted to moist ***nullahs*** and in the understorey of disturbed forest. Litter depth and cover was moderate to high, dominated by tree leaves. Herbs were rare in the mature ***jhum*** and forest patches.

Table 4: Differences in four macro-habitat parameters across habitat categories (** ⇒ p< .005; * ⇒ p< .05; - ⇒ Not significant; F ⇒ F-ratio of one-way parametric ANOVA)

(a) TREE DENSITY (F=79.232)

	Category	Mean / 250 m^2± S.E.	1	2	3	4	5	6	7	8
1	1 Yr. ***jhum*** fallows (1a+1b)	00.41 ± 0.26								
2	4-5 yr fallows (2a)	01.52 ± 0.96	-							
3	7-10 yr. fallows (2b)	03.38 ± 0.95	-	-						
4	4 yr. teak plantation (3a)	34.05 ± 3.04	**	**	**					
5	22 yr. teak plantation (3b)	24.45 ± 0.87	**	**	**	**				
6	30-35 yr. teak plantation (4a)	15.32 ± 1.30	**	**	**	**	**			
7	Mature forest (5a)	27.67 ± 2.05	**	**	**	-	-	**		
8	Mature forest (5b+5c)	20.33 ± 1.76	**	**	**	**	-	-	-	

(b) BAMBOO CULM DENSITY (F=194.30)

	Category	Mean / 25 m^2 ± S.E.	1	2	3	4	5	6	7	8
1	1 Yr. ***jhum*** fallows (1a+1b)	00.00								
2	4-5 yr fallows (2a)	96.36 ± 5.05	**							
3	7-10 yr. fallows (2b)	62.86 ± 4.85	**	**						
4	4 yr. teak plantation (3a)	00.00	-	**	**					
5	22 yr. teak plantation (3b)	00.00	-	**	**	-				
6	30-35 yr. teak plantation (4a)	30.26 ± 3.85	**	**	**	**	**			
7	Mature forest (5a)	00.01 ± 0.21	-	**	**	-	-	**		
8	Mature forest (5b+5c)	01.14 ± 0.15	-	**	**	-	-	**	-	

(c) CANOPY COVER (F=139.38)

	Category	Mean (%) ± S.E.	1	2	3	4	5	6	7	8
1	1 Yr. ***jhum*** fallows (1a+1b)	12.07 ± 1.67								
2	4-5 yr fallows (2a)	67.91 ± 2.79	**							
3	7-10 yr. fallows (2b)	69.79 ± 1.71	**	-						
4	4 yr. teak plantation (3a)	37.25 ± 2.58	**	**	**					
5	22 yr. teak plantation (3b)	51.33 ± 4.61	**	**	**	**				
6	30-35 yr. teak plantation (4a)	76.70 ± 1.62	**	-	-	**	**			
7	Mature forest (5a)	72.64 ± 2.03	**	-	-	**	**	-		
8	Mature forest (5b+5c)	80.68 ± 1.86	**	**	*	**	**	-	-	

(d) SHRUB DENSITY (F=12.21)

	Category	Mean / 25 m^2 ± S.E.	1	2	3	4	5	6	7	8
1	1 Yr. ***jhum*** fallows (1a+1b)	25.85 ± 2.86								
2	4-5 yr fallows (2a)	25.59 ± 3.31	-							
3	7-10 yr. fallows (2b)	19.58 ± 2.29	-	-						
4	4 yr. teak plantation (3a)	11.28 ± 1.19	**	-	-					
5	22 yr. teak plantation (3b)	13.99 ± 2.08	**	-	-	-				
6	30-35 yr. teak plantation (4a)	27.58 ± 3.21	-	-	-	*	-			
7	Mature forest (5a)	45.24 ± 4.26	**	**	**	**	**	*		
8	Mature forest (5b+5c)	39.37 ± 4.04	*	-	**	**	**	-	-	

4.3 Uncovering herpetofauna-habitat relationships

What then is the nature of underlying relationships between herpetofaunal guilds and habitat parameters that result in the observed patterns of amphibian and reptile species richness and distribution along the habitat gradients?

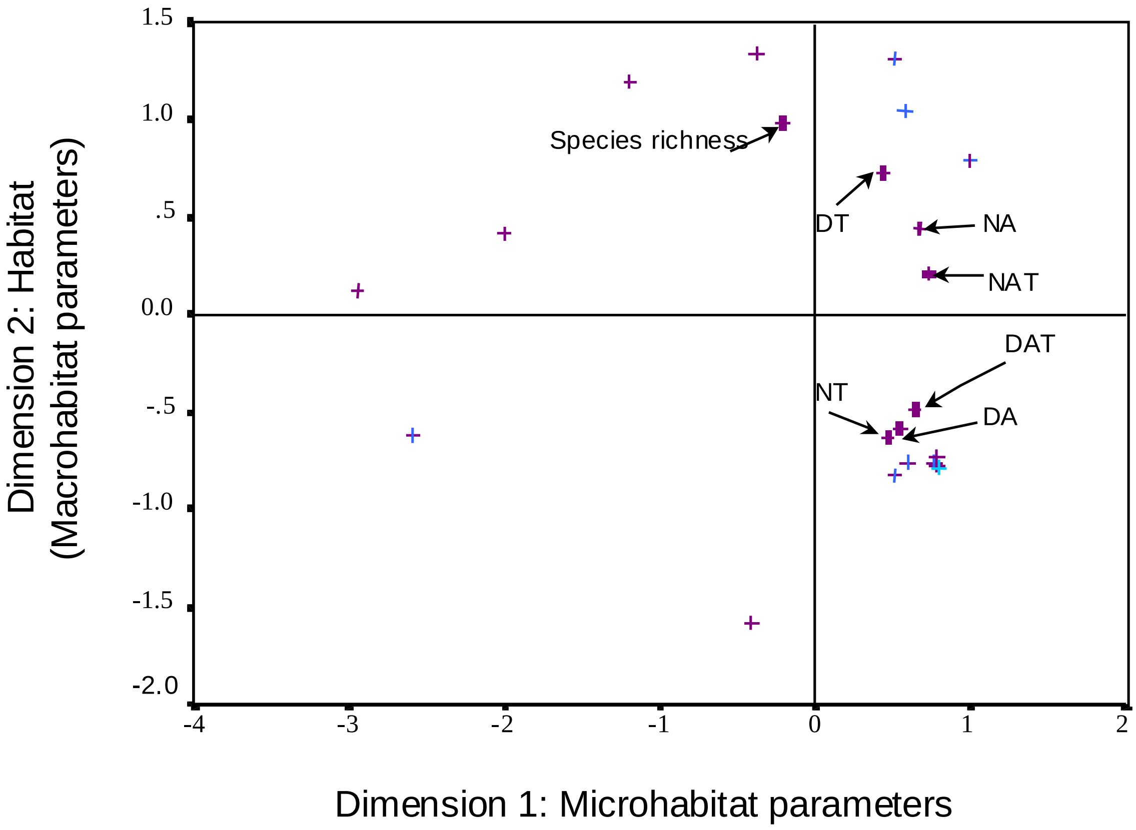
To help answer this question, I used MDS once again, now using similarities between habitat variables, richness in guilds, and total species richness across patches for the MDS algorithm (See sec. 3.3, Data analysis). The similarities were expressed in two dimensions (Fig 18, Table5) and a very clear pattern is seen. I suggest that dimension 1 expresses microhabitat parameters, and dimension 2 expresses macro-habitat parameters (Refer to Table 5). On the two dimensions of the derived MDS model, all the guilds associate closely with microhabitat parameters, and ***not*** the macro-habitat parameters. On the other hand, total species richness associates more closely with 'crude' macrohabitat parameters such as tree density, canopy cover and shrub density. I argue that guilds associate more closely with microhabitat parameters, while total species is a less discriminating indicator, associating weakly with broad macrohabitat parameters.

To explore this apparent relationship between herpetofauna and habitat parameters further, I calculated Pearson's product-moment correlation coefficients between total species richness, richness in each of the six guilds and all the variables in both the habitat dimensions. The results support the pattern revealed by the MDS model well. Total species richness was significantly correlated with ($p<0.05$, two tailed) with some microhabitat (Palm density, liana abundance) as well as macrohabitat factors. Four guilds viz., Diurnal arboreal, Nocturnal arboreal, Nocturnal arboreo-terrestrial and Nocturnal arboreal, were correlated mainly with microhabitat factors. For example, both diurnal arboreal (DA) and Nocturnal arboreal (NA) guilds were strongly correlated ($p<0.01$, two tailed) with liana abundance, shrub density, palm density and basal area of trees.

However, the diunal terrestrial and diurnal terrestrio-arboreal guilds were not strongly correlated with any parameter in particular, which suggests that they probably do not depend so strongly on microhabitat structural characteristics, but are more dependent on other microclimatic conditions imposed by macrohabitat factors such as canopy cover. Similar patterns have been observed for diurnal terrestrial herpetofauna (which are largely lizards) elsewhere (ex. Heatwole, 1977).

Figure 18: Derived habitat-microhabitat-herpetofauna* dimensions

(For macrohabitat and microhabitat stimulus (parameter) coordinates, refer to table 5; Averaged (RMS) stress over each patch matrix = 0.08615, RSQ = 0.9037; Euclidean distance model)



*Guild identities: DA= Diurnal –arboreal; DAT= Diurnal-arboreo-terrestrial; DT= Diurnal –terrestrial; NA = Nocturnal-arboreal; NAT= Nocturnal-arboreo-terrestrial; NT= Nocturnal terrestrial

4.4 Herpetofauna and successional gradients

A question that remains to be addressed is whether the overall community composition of herpetofauna is a good indicator of habitat differences or gradients. Fig. 19 represents a dendrogram of similarities between habitat categories based on shared community elements (species). All mature patches and the 30-35 year fallow form a group distinct from all other patches. Moreover, all secondary habitat patches are arranged according to age, except the 22-year teak plantation. This reiterates the above results- the assemblages did not seem to differentiate between teak plantations and 1-year ***jhum*** fallows, despite a time gradient of 1 year to 22 years.

Fig. 20 shows species richness patterns along the two successional gradients - one from ***jhum*** to mature forest, and another from ***jhum*** to Teak plantation. Species richness changes in very different ways along the two gradients. While it increases from ***jhum*** to mature forest, it apparently ***decreases*** marginally on conversion to teak, remaining low even after a period of 22 years.

Figure 19: Dendrogram of site similarities according to herpetofaunal species composition (Bray-Curtis single-link agglomeration)

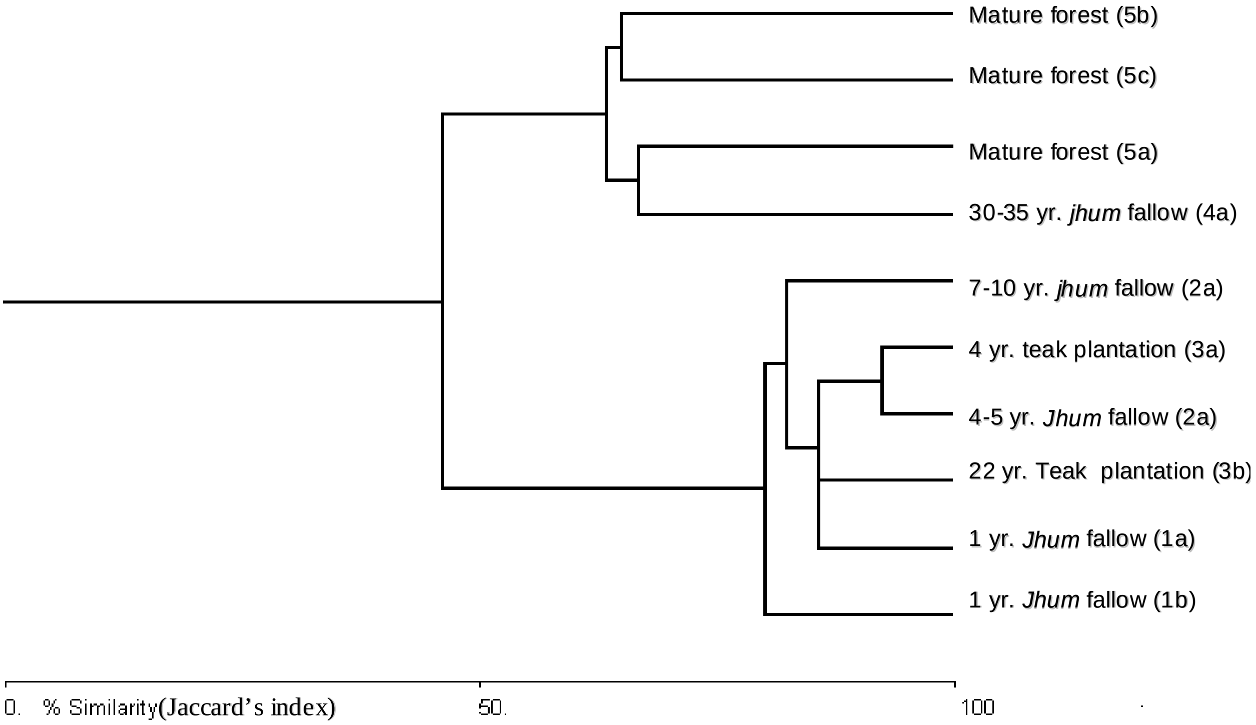
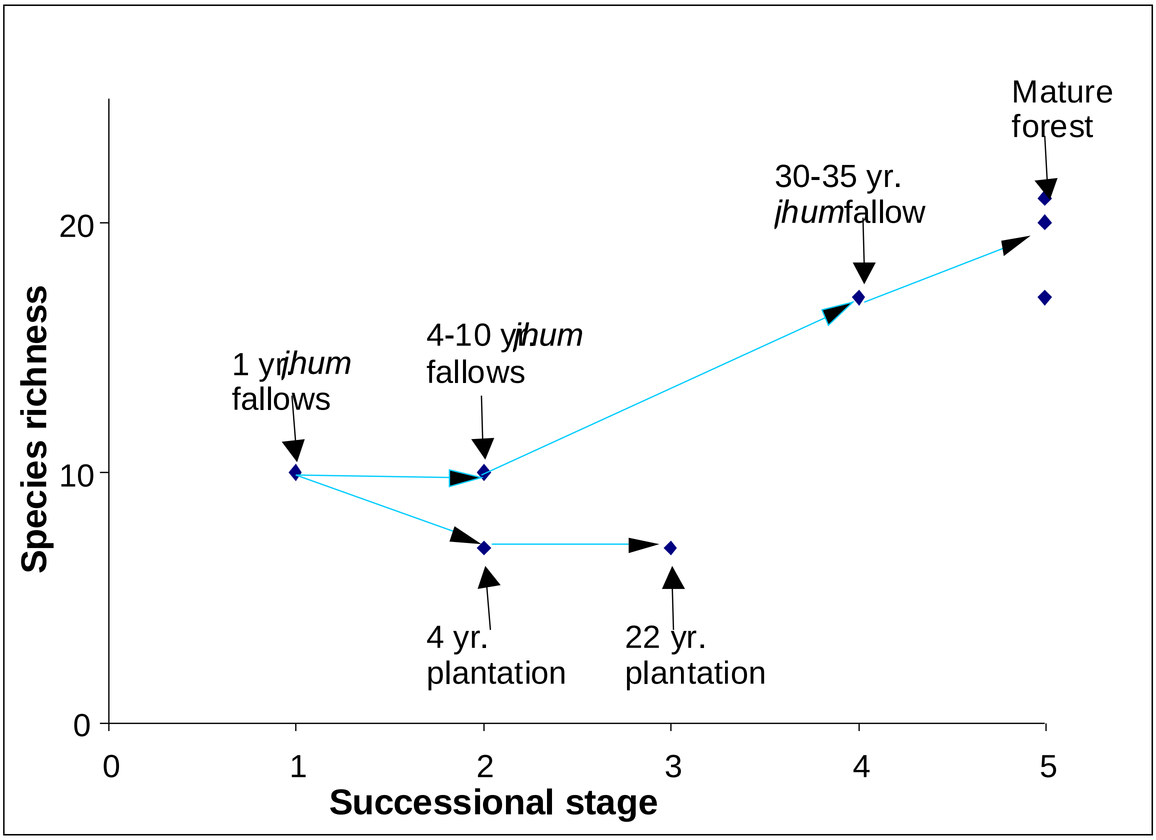


Figure 20: Trends in species richness along successional gradients



5. DISCUSSION

Broadly, the results of this study concur with earlier work addressing similar problems (Bowman ***et al***, 1990; Shankar Raman, 1995). However, the approach has been different from earlier work of similar nature, not so much in the way the questions were addressed, but more so because of the faunal group under scrutiny here- herpetofauna. Shankar Raman (1995) studied the effect of ***jhum*** cultivation on bird communities in Mizoram, and found very distinct trends- bird species richness increases as a logarithmic function of the successional age after ***jhumming***. ***The focus of this study has been more towards exploring spatial correlates of herpetofaunal community patterns across chronoseres***- spatial factors are likely to be a definitive predictor of herpetofaunal community structure. For a given time span, a gradient of succession from 1 year ***jhum*** fallow to teak plantation compared to 1 year ***jhum*** fallow to mature forest is likely to have a very different pattern of change in habitat structure, on which the response pattern of frogs and lizards is likely to depend.

5.1 The habitat gradients

The MDS derived a model of patch similarities (distances) in two dimensions, using time (patch age) and space (structural features) as criteria (Fig. 17; Table 8). The two successional gradients are clearly defined- the 1 year ***jhum*** fallow to teak plantation, and the 1-year ***jhum*** fallow to mature forest gradient. Tables 4-7 summarise differences between 4 macro-habitat parameters. There are striking differences between the young ***Jhum*** fallows, teak plantations, the old 30-35 year ***jhum*** fallow and mature forest. The 30-35 year ***jhum*** fallows and mature forest patches were the only ones with high tree density as well as canopy cover, and overall structural heterogeneity was high. Though teak plantations had high tree density, canopy cover was low, and the overall structure of the forest was monotonous. The 4-10 year ***jhum*** fallows were dominated by bamboo. Canopy cover was moderate, and overall structural heterogeneity was monotonous. The 1-year ***jhum*** fallows were extremely exposed, with very little vertical structural heterogeneity.

5.2 Recovery patterns- looking at sleepy frogs and running lizards

The gross pattern of community change is very evident in terms of species richness (Fig 7) and abundance (Fig. 13). Frogs and lizards show very different trends (Fig. 8-12). Though there are many lizards in the 1-year ***jhum*** fallows, 4-10 year ***jhum*** fallows and in the teak plantations, there are almost no frogs.

But does examination at this level of distinction explain the pattern of recovery satisfactorily? A close examination of Table 3 suggests that it may not be so. 5 of the 16 lizards have a characteristic that they do not share with the others- they are nocturnal. ***Gekko gecko, Hemidactylus garnoti, Cosymbotus platyurus*** and ***Ptychozoon horsfieldi*** are all nocturnal geckoes, and strongly arboreal in their habitat-structural affinities. The 5th species is ***Tropidophorus assamensis***, a crepuscular-nocturnal terrestrial skink. However, there are no diurnal frogs. Therefore the 5 lizards and the sixteen frogs have one thing in common- they are nocturnal. This then suggests that maybe the distinction has to be made at a different level- the subgroups need to be redistributed before studying response patterns.

After redistributing frogs and lizards into two groups, viz., diurnal and nocturnal species, a trend similar to the frog-lizard pattern is seen- the diurnal group is more abundant (Figs. 14 & 15) and represented by more species (Figure 16) than the nocturnal one in the early post-***jhum*** successional stages and in the teak plantations. Also, the nocturnal group surpasses the diurnal group in abundance and richness in the 35-40 year ***jhum*** fallow and mature forest. However this, the diurnal-nocturnal pattern, seems much clearer than the frog-lizard one.

5.3 Frogs sleep in mature forest….

Fig. 18 shows the second MDS distance model- similarities of richness in guilds, species richness, and habitat variables in two dimensions. The associations are very clear- all the guilds follow the distribution of microhabitat parameters, while species richness does not associate strongly with any parameter in particular. Formal correlation tests support the association pattern suggested by the MDS model (section 4.3).

It is obvious that macro-habitat parameters are bound to govern the distribution and quality of microhabitats, apart from influencing the microclimate. This would be an important consideration while searching for micro- vs. macro-habitat correlates of amphibians and reptiles. I will cite an example from the study to stress this point.

Banana plants were an important refuge for tree frogs- throughout the study, banana leaf-sheaths yielded a number of tree frogs. However, though banana plants were extremely abundant in the 1-year ***jhum*** fallows, ***no*** frogs were found on searches there. All frogs in banana sheaths were found in plants in 30-35 year ***jhum*** fallows and mature forest. The reason for this anomaly is simple. Banana plants in ***jhum*** fallows are exposed to constant insolation during the day. As a result, the stem and the sheaths get heated, making it impossible for frogs to take refuge there. On the other hand, in the mature forest and old ***jhum*** fallow, banana plants are at least partially shielded by the forest canopy. In this case then, the refuge (banana sheath) is unutilisable for frogs if the microhabitat (banana plant) is in an unsuitable macro-habitat (with low canopy cover).

Most of the frogs reported during this study were found in mature-forest, and some in 30-35 year ***jhum*** fallows (Table 3). An interesting fact is that most of them are either restricted to Northeast (these include some apparently undescribed species) or if more widely distributed, probably occur only marginally further into Southeast Asia. ***Bufo melanostictus*** is the only anuran that is widely distributed elsewhere in the Indian subcontinent. This species, along with ***Philautus sp.***[1] ***(identification pending)*** were the only anurans in the 1-year ***jhum*** fallows and teak plantation.

5.3.1 ….and lizards run in open spaces

Among the lizards, ***Calotes versicolor, Mabuya macularia, Mabuya multifasciata, Spenomorphus maculatus*** and ***Takydromus sexlineatus*** are all widely distributed lizards. While the first two range from the Indian subcontinent way across to South-east Asia, Northeast India is the western-most range of the latter three (Das, 1996a). In all, skinks accounted for 7 of the 16 species of lizards. In the bamboo-dominated fallows as well as the 30-35 year old fallow ***Mabuya*** sp. (***description pending***; Pawar, ***unpubl. data***) a skink, was the most abundant. It was rarely seen outside of bamboo-dominated forest. Towards the 30-35 year ***jhum*** fallow and the mature forest patches, a number of arboreal and arboreo-terrestrial lizards, both nocturnal and diurnal, appeared in the samples. But the most interesting lizard that appeared in the mature forest samples was ***Trophidophorus assamensis,*** a terrestrial skink that lives under stones in moist ***nullahs*** and hills streams. Apart from its amphibian-like preference of microhabitats, it is also crepuscular-nocturnal (***pers. obs)***.

During the height of the dry season, a few lizards of the relatively open habitats were occasionally seen in mature forest. These included ***Mabuya macularia*** and ***Sphenomorphus maculatum.*** However, others such as ***Calotes versicolor*** and ***Mabuya multifasciata*** were never seen in mature forest. This suggests that during dry periods, certain open-habitat species may temporarily invade the mature forest. But it never happened that a characteristic mature forest species appeared in any of the open habitats, this holding true even in the case of lizards. For instance, ***Trophidophorus assamensis*** and ***Draco maculatus*** were never found in any of the early ***jhum*** categories or teak plantations. So, though there were a lot of lizards in the relatively open habitats, there were also many that were restricted to the 30-35 yr. ***jhum*** and mature forest patches.

5.4 Of diversity indices and species abundance models

The idea that a habitat with higher structural complexity will support more species is an intuitively appealing one. Apart from other faunal groups, this idea has been supported by community ecologists studying herpetofauna (ex. Pianka, 1986; Schoener, 1974, 1977). Forest structure has been proven to be an important determinant of herpetofaunal diversity and community structure (Sexton ***et al***., 1964; Voris, 1977; Scott, 1976) and probably have a strong influence on their re-colonisation success (ex. Petren and Case, 1998).

The results of this study suggest that a simple temporal-structural oriented guild classification may reveal patterns that would have been hidden in the gross response pattern seen if a pooling approach is taken. To make such studies more effective, such an approach is necessary. Density may be an effective measure of differences in multi species populations, but a niche-oriented approach may yield clearer results (Pianka, 1986).

The substantial difference in response of diurnal-nocturnal classified guilds, leads one to speculate whether the analysis of diversity patterns in combined amphibian and reptile studies have been satisfactorily dealt with, especially in the framework of species–abundance models. This problem becomes more acute if a biological or resource-apportioning model (***cf***. Magurran, 1988) has been used to attach a biological meaning to the observed species-evenness pattern (ex. Lloyd ***et al.***, 1968). As the results of this study suggest, I argue that in at least one niche dimension, (microhabitat- refuge), nocturnal and diurnal species are likely to be relatively non-interacting. This then means that pooling of frogs and lizards and then exploring their richness-abundance patterns may not be justified, as they may be following two different patterns of richness-abundance, a difference which is likely to remain hidden by the 'pooling' approach. In this situation, attributing a biological meaning in terms of niche apportioning may not make real biological sense. Though niche-oriented models are more relevant to small communities of related species sharing the same kind of resources (Tokeshi, 1993). Herpetofauna do occur in small assemblages, but it is important to consider the possibility that subsets (or guilds) of the target community may be following very different patterns, which need to be examined separately.

6. CONCLUSIONS

A note of caution…

A note of caution is necessary here - the insights that this study has provided have to be viewed keeping in mind that herpetofauna are strongly influenced by seasonal patterns, and this study was restricted to the 5 months of dry season. This is also the reason why I refrain from predicting the time-scale of herpetofaunal recovery in such situations by fitting a curvilinear distribution to the apparent herpetofaunal recovery patterns along successional gradients (Figure 20), as has been effectively attempted in similar situations before (Ex. Shankar Raman, 1995). Though such a projection has considerable practical conservation value, it would be presumptuous in this case. This again stresses the point that a short-term herpetofaunal community study of this scope has limitations. The picture would be more complete with information from the wet season. But that the study was conducted in the dry season also means that the microhabitat-herpetofauna association was viewed at its most crucial period- ***a large set of amphibians and lizards was studied in its summer refuge***. Obviously, the availability of habitat as refuge affects the distribution of herpetofauna, and indeed, their very persistence.

In conclusion

To summarise, in the situation where ***jhum*** fallows are allowed to succeed to mature forest, herpetofauna showed a distinct positive response along the gradient towards maturity. However, the response was more clearly defined if subsets of the community were examined separately. In general there were strong indications that a combined effect of habitat structure at the macro- and micro- level will define the pattern of herpetofaunal recovery in such situations. In the case where ***jhum*** fallows are converted to teak plantation, even a long period of succession from 1 year ***jhum*** fallow to teak plantation did not result in an appreciable change in herpetofaunal species richness. In fact, there seems to be a marginal decrease in species richness. In terms of herpetofaunal composition, even the 22-year teak plantation is similar to the 1-***jhum*** fallows (See fig. 19). Here again the importance of habitat-structural aspects of succession for herpetofaunal recovery comes to the fore- herpetofaunal recovery follows a habitat recovery gradient in terms of structure more closely than in terms of time. While a 30-35 year ***jhum*** fallow regained a substantial number of mature forest frogs and lizards, the 22 – year teak plantation did not show any appreciable improvement in terms of herpetofaunal species richness.

Mature forest is an important refuge for herpetofauna. A number of species of frogs and lizards were found to be mature forest specialists in the dry season, and at least some of them are likely to be restricted to mature forest even in the wet season. In this short study itself, hitherto undecided species were discovered, all in mature forest (See appendix II). Only a set of terrestrial, sun-loving lizards inhabited ***Jhum*** fallows and teak plantations, a pattern that is probably more pronounced in the dry season. Teak plantation therefore must be a poor dry-season habitat for herpetofauna, and even after many years of growth may not accrue features that may make it suitable for re-colonisation by herpetofauna of primary forest. Pure bamboo stands too are marginal habitats for most frogs and a number of arboreal lizards, but over a period of time, when woody plants slowly begin to dominate, many species may be able reinvade the forest as it approaches the structural dimensions of primary forest

Therefore, in a mosaic of secondary habitats resulting from ***jhum***ming, mature forest patches probably play a very important role, in the survival and persistence of a large number of frog and lizard species. One would envisage a very depauperate herpetofauna in areas where ***jhum***ming has resulted in extensive bamboo brakes. The situation would probably be worse if natural regeneration is arrested and ***jhum*** fallows are planted with single tree plantations.

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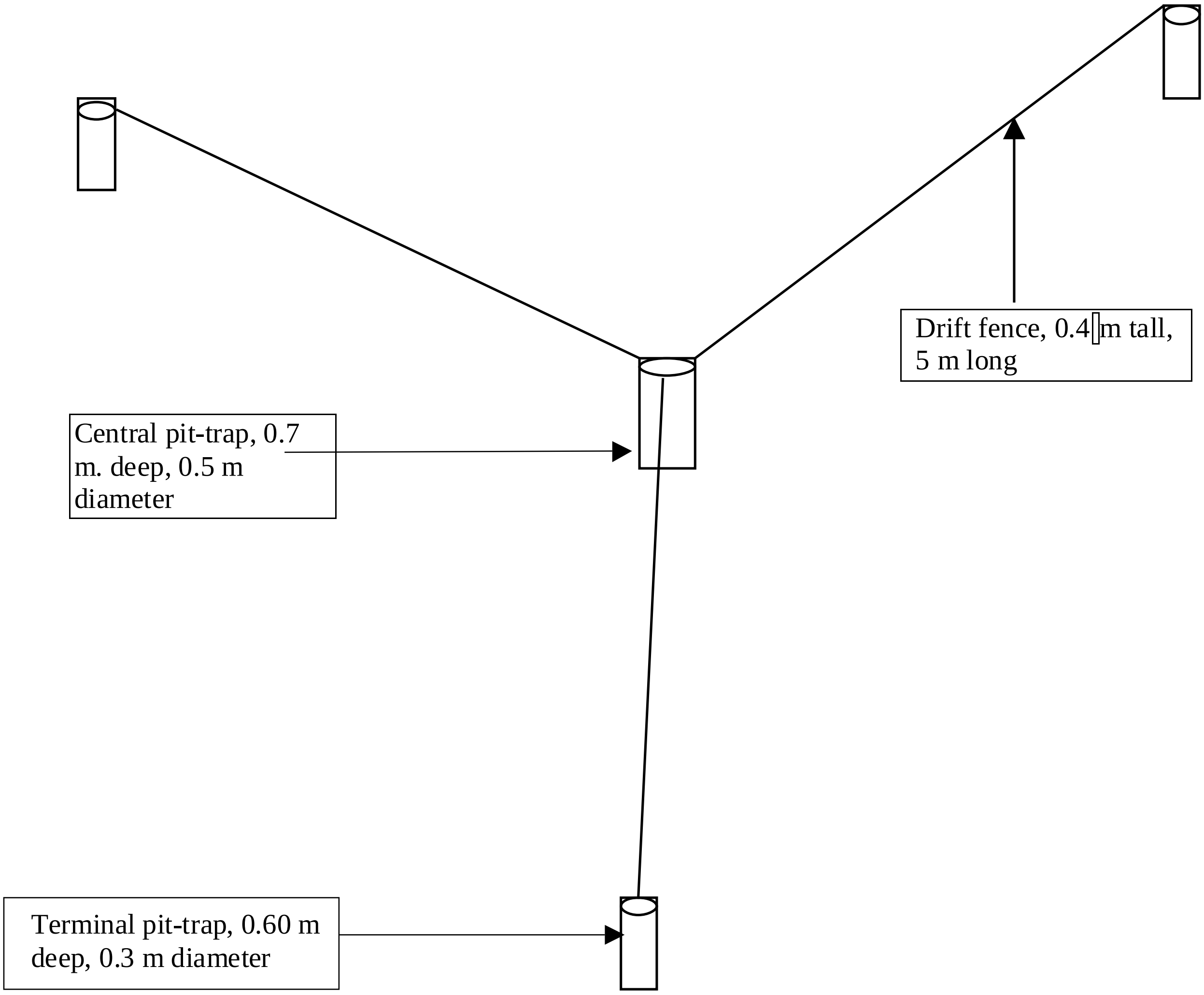
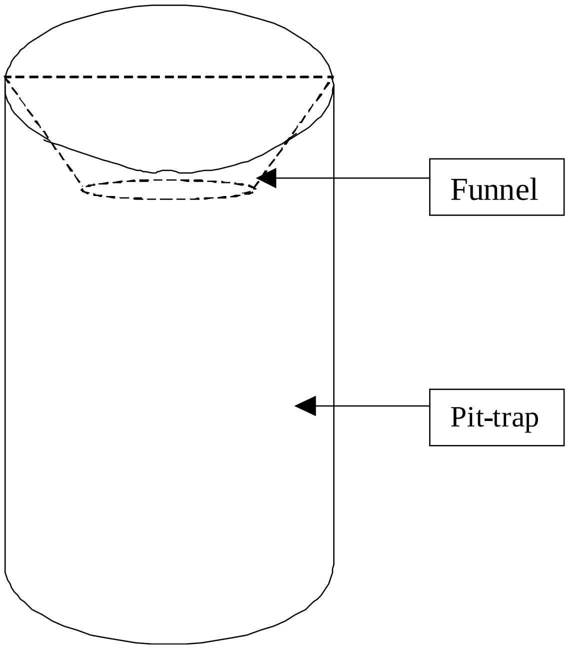
APPENDIX I :

'Y' pitfall array (Diagrammatic) –



PIT-TRAP



APPENDIX II : LIST OF AMPHIBIANS AND REPTILES RECORDED FROM NGENGPUI WLS AND ADJOINING AREAS DURING PRESENT STUDY, 1998-1999

(Species from preliminary survey in June included; Flagged (*) species are included in analyses- 16 frogs and 16 lizards; Taxa with a '?' in superscript are those with definite identification / description pending)

AMPHIBIANS

		COMMON NAME
	Family: Ichthyophidae	
1	***Ichthyophis sp.***	-
	Family: Megophryidae	
2*	***Megophrys parva***	MYANMAR PELOBATID TOAD
	Family: Bufonidae	
3*	***Bufo melanostictus***	COMMON ASIAN TOAD
4*	***Bufoides meghalayana*** $^{?}$	KHASI-HILLS TREE TOAD
	Family: Microhylidae	
5*	***Microhyla berdmorei***	BERDMORE’S NARROW-MOUTHED FROG
6	***Microhyla ornata***	ORNATE NARROW-MOUTHED FROG
7*	***Kaloula pulchra***	PAINTED KALOULA
8	***Uperodon cf. systoma***	MARBLED BALLOON FROG
	Family: Rhacophoridae	
9*	***Philautus sp***^{1}**.**	-
10*	***Philautus sp***^{2}**.**	-
11*	***Philautus sp***^{3}**.**	-
12*	***Philautus sp***^{4}**.**	-
13*	***Philautus sp***^{5}**.**	-
14	***Philautus sp***^{6}**.**	-
15*	***Chirixalus vittatus***	BOULENGER'S TREE FROG
16	***Polypedates leucomystax***	WHITE MOUSTACHED TREE FROG
17*	***Rhacophorus maximus***	LARGE GREEN TREE FROG
18	***Rhacophorus bipunctatus***$^{?}$	TWIN-SPOTTED TREE FROG
	Family: Ranidae	
19	***Limnonectes cf. limnocharis***	CRICKET FROG
20	***Hoplobatrachus tigerinus***	INDIAN BULL FROG

21	***Euphlyctis cyanophlyctis***	INDIAN SKIPPING FROG
22*	***Occidozyga sp.***	-
23*	***Pterorana khare***	-
24*	***Rana laticeps***	-
25*	***Rana sp*** ^{3}	-
26	***Rana sp*** ^{4}	-
27	***Rana sp*** ^{5}	-

REPTILES

	Family: Testudinidae	
28	***Indotestudo elongata***	YELLOW TORTOISE
29	***Manouria emys***	ASIAN GIANT TORTOISE
	Family: Bataguridae	
30	***Melanochelys trijuga***	BLACK TURTLE
31	***Kachuga sylhetensis***	ASSAM ROOFED TURTLE
32	***Cyclemys oldhami***	ASIAN LEAF TURTLE
	Family: Trionychidae	
33	***Amyda cartilaginea***	-
	Family: Gekkonidae	
34*	***Hemidactylus frenatus***	SPINY-TAILED HOUSE GECKO
35*	***Hemidactylus garnoti***	GARNOT'S GECKO
36*	***Cosymbotus platyurus***	FLAT TAILED GECKO
37*	***Ptychozoon lionotum***	SMOOTH BACKED GLIDING GECKO
38*	***Gekko gecko***	TOCKAY
	Family: Agamidae	
39*	***Calotes versicolor***	COMMON CALOTES / GARDEN-FENCE LIZARD
40*	***Calotes emma***	SPINY-HEADED FOREST CALOTES
41*	***Draco maculatus***	ASIAN GLIDING LIZARD
42*	***Ptyctolaemus gularis***	BLUE-THROATED FOREST LIZARD
	Family: Lacertidae	
43*	***Takydromus sexlineatus***	LONG-TAILED LIZARD
	Family: Varanidae	
44	***Varanus bengalensis***	COMMON INDIAN / BENGAL MONITOR

	Family: Scincidae	
45*	***Mabuya multifasciata***	MANY-LINED SUN SKINK
46*	***M. macularia cf. macularia***	COMMON LITTLE SKINK
47*	***Mabuya sp.***	-
48*	***Sphenomorphus maculatus***	STREAMSIDE FOREST SKINK
49*	***S. indicus***	LARGE FOREST SKINK
50*	***S. courcyanum***	NORTHEAST INDIAN PIGMY FOREST SKINK
51	***Tropidophorus assamensis***	TWO-BANDED WATER SKINK
	Family: Boidae	
52	***Python molurus bivittatus***	BURMESE PYTHON
53	***P. reticulatus***	REGAL / ROYAL PYTHON
	Family: Colubridae	
54	***Oligodon cf. cinerus***	-
55	***Oligodon cf. cyclurus***	-
56	***Lycodon zawi***	ZAW’S WOLF SNAKE
57	***Psammodynastes pulverulentus***	COMMON MOCK VIPER
58	***Ahaetulla prasina***	ORIENTAL VINE / WHIP SNAKE
59	***Dendrelaphis pictus***	PAINTED BRONZEBACK
60	***Chrysopelea ornata***	GOLDEN TREE SNAKE
61	***Elaphe radiata***	COPPERHEADED RACER
62	***Ptyas korros***	INDO-CHINESE RATSNAKE
63	***P. mucosus***	COMMON INDIAN RATSNAKE
64	***Rhabdophis subminiata***	RED-NECKED KEELBACK
65	***Xenochrophis piscator***	CHECKERED KEELBACK
	Family: Elapidae	
66	***Bungarus fasciatus***	BANDED KRAIT
67	***Naja kaouthia***	MONOCELLATE COBRA
68	***Ophiophagus hannah***	KING COBRA
	Family: Viperidae	
70	***Trimeresrus cf. stejnegeri***	STEJNEGER’S GREEN PIT VIPER