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DIVERSITY OF FRUIT TREES AND FRUGIVORES IN A NIGERIAN MONTANE FOREST AND ADJACENT FRAGMENTED FORESTS

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ABSTRACT : The study was conducted to examine and compare the species composition, diversity, and richness of both fruit trees and frugivores between a protected natural forest – Main Forest (MF), and unprotected forest fragments (A, B, and C) within a Nigerian montane forest ecosystem. Five 20m x 20m quadrats were randomly distributed in each of the sites for the enumeration of fruit trees while the identification and enumeration of frugivores was carried out using the Random Walk/Watch method. Alpha diversity was measured using both Simpson and Shannon-Wiener indices while similarity or otherwise dissimilarity in species composition between each pair of the sites was measured using Sorenson's index. Pearson's correlation coefficient (r) was used to examine the correlation between the diversity of fruit trees and frugivores. The highest number of fruit tree species was encountered in MF (46), followed by Fragment A (24) while 21 species were encountered in each of fragments B and C. The highest number of frugivorous species was encountered in MF (39), followed by each of Fragments A and B (26) while 25 species were encountered in C. Birds accounted for over 70 per cent of the frugivorous species observed within the five taxonomic groups in all the sites. Both the fruit trees and frugivore species composition varied more between the main forest and each of the fragments than between each pair of the fragments. However, the level of dissimilarity in species composition between the main forest and the fragments was more with the fruit trees than the frugivores. A total of 36, 34, and 33 fruit tree species found in MF were not found in fragments C, B, and A respectively while 26 frugivorous species were common to MF & A and MF & B, while MF & C have 24 species in common. The diversity of fruit trees and that of frugivores were highly correlated. Both the number and diversity of fruit trees and frugivores were higher in the protected main forest than in each of the forest fragments.
Key words: Montane Ecosystem; Forest Fragmentation; Fruit Trees; Frugivores; Diversity

INTRODUCTION

Frugivores (fruit-eating animals) depend on pulp of fleshy fruits, which is the soft, edible, nutritive tissues surrounding the seeds, as primary food resource [15]. Frugivores apart from depending on fruits to satisfy their nutrient requirements also double as seed dispersers. Seed dispersal determines the spatial arrangement and physical environment of seeds and thus is an important step in the reproductive cycle of most plants [9,16,30,26]

The importance of seed dispersers and dispersal cannot be overemphasized. Many tropical trees bear fruits adapted for consumption and dispersed by animals, and many tropical animals depend on fruits for food for at least part of the year [14]. Consequently, local extinction of fruit-eating birds, bats or primates might reduce recruitment of fruiting trees dependent upon frugivore-mediated dispersal for reproduction, and consequently increase the chance of local extinction of the focal trees, of other animals that eat their fruits, and ultimately of other trees dispersed by members of the initial assemblage [12].

The general consequence could be a widening circle of extinctions, precipitated by the disappearance of one pivotal species [13]. In fact, the local extinction of some animal populations, or their reduction to the point of becoming functionally extinct, can have dramatic consequences in terms of regulating and supporting ecosystem services, especially in mutualisms, such as pollination and seed dispersal [22,27]. Therefore, seed dispersal through frugivory is important in maintaining levels of genetic diversity. In addition, seed dispersal by frugivores plays an important role in bringing seeds of forest species into degraded landscapes, and this helps in forest restoration.

Stretched along the Nigerian/Cameroon border are most of the Nigeria's montane/sub-montane forests. Historically, these forests were located in expansive sweeps along escarpment edges in the Gotel Mountains and Mambilla Plateau (Taraba State), and on Vogel Peak and the Kirri Plateau (Adamawa State). Montane forest also occurred as stream fringing forest meandering across the Jos (Plateau State), Obudu (Cross River) and Mambilla plateaus. Almost all the stream fringing forest has been lost from Jos Plateau, and it is now confined to small fragments on Obudu and Mambilla Plateaus. On Mambilla, there remains one significant sub-montane forest, Ngel Nyaki. The forest (approximately 7.2 $km^{2)}$ falls within Ngel Nyaki Forest Reserve which is 46 km^2 in area. The reserve is located on the western escarpment of Mambilla Plateau, in the bowl of an old volcanic crater from 1400-1600m elevation. It was gazetted a Local Authority Forest Reserve in 1969. Outside the reserve boundary is an unofficial 'buffer zone', comprising grassland and stream fringing forest. The forest reserve is known for its high diversity in fauna and flora [3].

It has become common knowledge in the world that serious conflicts arise in the uses of bio-edaphic resources and there is undue pressure on marginal lands in the arid zone States of Nigeria, which are characterized by fragile ecosystems [6]. Ngel Nyaki Forest Reserve is currently beset with problems of fragmentation and exploitation (especially in the riverine forest strips of the buffer zone). The fragmentation of forest habitat is widely considered to be one of the main threats to biodiversity while it has been established that habitat loss has large, negative effects on biodiversity [23]. There is therefore, the need to restore and sustainably manage the reserve and its resources. However, sustainable restoration and management of the reserve require a thorough understanding of the influence of habitat fragmentation and exploitation on the processes that shape genetic variation and other ecological processes. The study therefore, evaluated the impact of habitat fragmentation and exploitation on fruit trees and fruit-eating animals by ascertaining and comparing their composition, diversity and richness or otherwise rarity, between unprotected forest fragments and the protected climax vegetation - the main forest (MF) within the reserve.

MATERIALS AND METHOD

Description of the Study Area

The study was conducted at Ngel Nyaki Forest Reserve, located towards the western escarpment of the Mambilla plateau, Taraba State, Nigeria (Figure 1).The plateau is located between longitude $11^0\,00^1$ and $11^0\,30^1$ East and latitude $6^0\,30^1$ and $7^0\,15^1$ North. It is drained by numerous water courses which unite to form the main rivers to discharge eventually into the Benue River. Ngel Nyaki Forest Reserve can be reached on foot from Yelwa village past the Mayo Jigawal, from where it is less than an hour's walk to the upper edge of the forest. It comprises approximately 46km^2 of impressive sub-montane to mid-altitude forest, lying between 1400 – 1500m [3]. The forest vegetation is continued to the South-west facing slope where mist may lie for days, and sometimes a week at a time, during the rainy season. Heavy rainfall is recorded from April to October while the dry season is from approximately November to March.

Ngel Nyaki Forest Reserve and Game Sanctuary, is the most species diverse forest on Mambilla plateau [3]. Over 146 vascular plant species have been recorded, many of which are trees, and (near-) endemic to the Afromontane Region [28,4]. Four tree species are Red Data listed, and several, such as *Anthonotha nolddii* are new to West Africa and others new to Nigeria [3]. This high floristic diversity is reflected in the high number of primates and other animal species in the forest [8,5]. There is a small, but thriving population of the Red Data listed Chimpanzee (*Pantroglodytes* subsp *vellerosus),* as well as the Putty-Nosed monkeys (*Cercopithecus nicitans)* and the black and white colobus *(colobus guereza occidentalis)*. The forest is also rich in bird life, more than 200 species were documented in 2003 (Disley, personal communication). Ngel Nyaki was formally gazetted a local authority Forest Reserve under Gashaka - Mambilla Native Authority Forest order of April 1969, but at present it is under the management of the Taraba State Government and the Nigerian Conservation Foundation (NCF), with the Nigerian Montane Forest Project (NMFP) as a project partner.

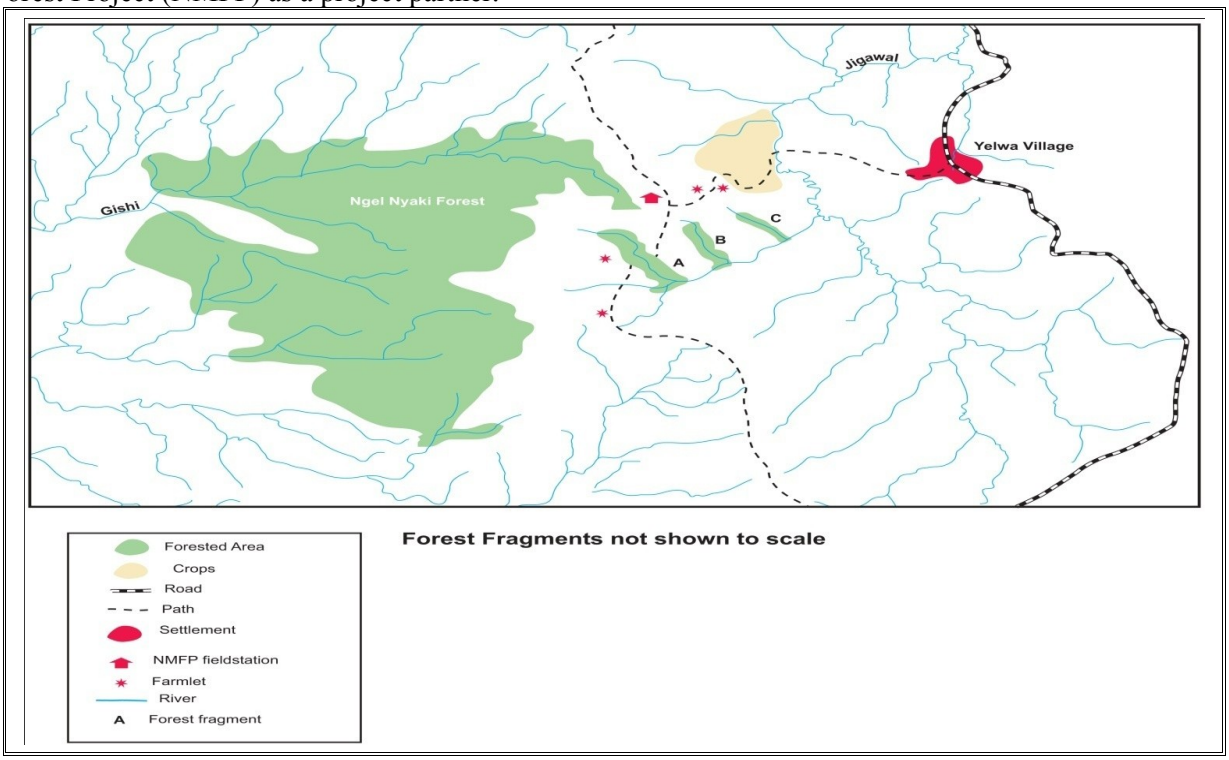

Figure 1: Ngel Nyaki Forest and the adjacent forest fragments.

Method of Data Collection

Identification and Enumeration of Fruit Trees

To gain an insight into the fruit tree species composition of the sites, five 20m x 20m quadrats were randomly distributed in each of the sites. This quadrat size falls within the range specified in literature for vegetation sampling by White and Edwards [29]. Narrow cut lines were made to demarcate the plot boundaries. All fruit trees within the plots were identified to species level and counted. Fruit tree species were identified using Keay *et al*., [21] and Chapman and Chapman [3]. A tree in this study was regarded as a woody plant of erect posture with a minimum breast circumference of 10cm and a minimum height of 5m.

Identification and Enumeration of Frugivores

The identification and enumeration of frugivores was carried out using the Random Walk/Watch method (Disley pers. Com.). Random walks were carried out between 6.00 am and 6.00 pm once a week in each study site, for a period of twenty weeks, to ascertain the frugivorous species present. During each random walk, the number of individual frugivorous species sighted was recorded for the respective sites. This was then summed accordingly for the twenty days of random walk. The identification of birds in the field was done with the aid of Borrow & Demey [2]

Method of Data Analysis

Measurement of Alpha Diversity

Two common approaches for measuring alpha diversity are species richness and evenness/heterogeneity [24]. Species richness simply refers to the number of species in the community while evenness/heterogeneity refers to the distribution of individuals among the species. In this study, species richness was computed for the fruit trees and frugivores as the total number of fruit tree species and frugivores encountered in each site respectively. For the measurement of evenness/heterogeneity, Simpson and Shannon-Wiener indices were computed for each of the sites using the PAlaeontological STatistics (PAST) software.

Measurement of Beta Diversity

Sorensen's similarity index was used to measure beta diversity. Wolda [31] suggested the use of similarity indices for measuring beta diversity. Jansen and Vegelius [20] had earlier opined that, of the many similarity indices, only three of them (the Ochiai, the Jaccard and the Sorensen) are worth considering.

Sorenson's index is expressed as:

RI = 100 * a / a + b + c

Where:

a = number of species present in both sites under consideration

b = number of species present in Site 1 but absent in Site 2

c = number of species present in Site 2 but absent in Site 1

Measurement of Correlation between Diversity of Fruit Trees and Diversity Frugivores

Pearson's correlation coefficient (r) was used to examine the correlation between the diversity of fruit trees and frugivores. This was done using the PAlaeontological STatistics (PAST) software.

RESULTS

Fruit Tree Species Composition of Different Sites

The fruit tree species present at the various sites and the number of individuals encountered is presented in Table 1. The highest number of fruit tree species was encountered in MF (46), followed by Fragment A (24) while 21 species were encountered in each of fragments B and C. A total of 12 unknown fruit tree species were encountered with 6 occurring only in MF; 1 in each of fragments A and B; and 4 in fragment C.

Table 1: Fruit Tree Species Composition of the enumerated sites and number of individuals encountered

Species	MF	A	B	C
Isolona deightonii	1	0	0	0
Anthocleista vogelii	1	1	1	1
Nuxia congesta	0	1	1	0
Maesa lanceolata	0	1	1	1
Rapanea melanophloeos	1	1	1	1
Voacanga bracteates	1	1	0	0
Tabernaemontana contorta	1	0	0	0
Rauvolfia vomitoria	0	1	1	0
Allophylus africanus	1	1	1	1
Deinbollia crossonephelis	1	0	0	0
Diospyros monbuttensis	1	0	0	0
Zanthoxylum leprieurii	1	0	0	0
Clausena anisata	1	1	1	1
Chrysophyllum albidum	1	0	0	0
Entandrophragma angolense	1	0	0	0
Carapa grandiflora	1	0	0	0
Synsepalum sp.	1	0	0	0
Pouteria altissima	1	0	0	0
Albizia gummifera	1	1	1	1
Newtonia buchananii	1	0	0	0
Dalbergia heudelotti	1	1	1	1
Anthonotha noldeae	1	0	0	0
Hannoa klaineana	1	0	0	0
Psychotria schweinfurthii	1	0	0	0
Celtis gomphophylla	1	0	0	0
Trema orientalis	1	1	1	1
Olax subscorpoidea	1	0	0	0
Chionanthus africanus	1	0	0	0
Santiria trimera	1	0	0	0
Garcinia smeathmannii	1	1	1	0
Psorospermum corymbiferum	1	1	1	1
Symphonia globulifera	1	0	0	0
Discoclaoxylon hexandrum	1	0	0	0
Bridelia micrantha	1	1	1	1
Croton macrostachyus	0	1	1	1
Polyscias fulva	1	1	1	0
Memecylon afzelii	0	1	0	0
Beilschmiedia mannii	1	0	0	0
Dombeya ledermannii	0	1	1	1
Syzygium guineense	0	1	1	1
Eugenia gilgii	0	1	1	0
Canthium vulgare	0	1	1	1
Rothmannia urcelliformis	1	0	0	0
Pavetta owariensis	1	0	0	0
Oxyanthus speciosus	1	0	0	0
Trilepisium madagascariensis	1	0	0	0
Ficus sp.	1	1	1	1
Ritchiea albersii	1	0	0	0
Zymalos monospora	1	0	0	0
Unknown sp.1	1	0	0	0
Unknown sp.2	1	0	0	0
Unknown sp.3	1	0	0	0
Unknown sp.4	1	0	0	0
Unknown sp.5	1	0	0	0
Unknown sp.6	1	0	0	0
Unknown sp.7	0	1	0	1
Unknown sp.8	0	1	1	1
Unknown sp.9	0	0	0	1
Unknown sp.10	0	0	0	1
Unknown sp.11	0	0	0	1
Unknown sp.12	0	0	0	1

Frugivore Species Composition of Different Sites

The frugivores present at the various sites and the number of individuals encountered is presented in Table 2 while Table 3 shows the number of frugivorous species observed within each of the five taxonomic groups at the different sites. The highest number of frugivorous species was encountered in MF (39), followed by each of Fragments A and B (26) while 25 species were encountered in C. Birds were the most predominant frugivorous species among the five taxonomic groups with 29 species encountered in MF and 22 species in each of fragments A, B and C.

Table 2: Frugivores at different sites and number of individuals encountered

Species	Family	MF	A	B	C
Andropadus tephrolaemus	Pycnonotidae	4	2	1	1
Andropadus gracilirostris	Pycnonotidae	3	0	0	0
Pycnonotus barbatus	Pycnonotidae	5	5	5	5
Chlorocichla simplex	Pycnonotidae	1	3	5	4
Francolinus bicalcaratus	Phasianidae	1	3	5	4
Treron calvus	Columbidae	4	1	1	3
Turtur tympanistria	Columbidae	2	1	1	1
Turtur afer	Columbidae	1	2	1	1
Columba sjostedti	Columbidae	4	2	1	1
Streptopelia semitorquata	Columbidae	5	5	5	5
Streptopelia hypopyrrha	Columbidae	2	1	3	5
Gymnobucco calvus	Capitonidae	4	0	0	0
Lybius bidentatis	Capitonidae	5	5	5	5
Pogoniulus bilineatus	Capitonidae	5	0	0	0
Buccanodon duchaillui	Capitonidae	4	0	0	0
Turdus pelios	Turdidae	3	2	5	5
Sylvia borin	Sylviidae	5	5	5	5
Phylloscopus trochilus	Sylviidae	5	5	5	5
Corythaeola cristate	Musophagidae	1	0	0	0
Tauraco persa	Musophagidae	5	0	0	0
Tauraco leucolophus	Musophagidae	1	4	4	4
Crinifer piscator	Musophagidae	0	0	0	2
Bycanistes fistulator	Bucerotidae	5	0	0	0
Platysteira cyanea	Platysteiridae	4	2	1	1
Ploceus bannermani	Ploceidae	2	4	5	5
Ploceus baglafecht	Ploceidae	2	5	5	5
Ploceus nigricollis	Ploceidae	1	1	1	1
Linurgus olivaceus	Fringillidae	3	3	1	0
Zosterops senegalensis	Zosteropidae	1	3	1	1
Colius striatus	Coliidae	4	5	5	5
Cephalophus monticola	Antelopinae	2	0	0	0
Cephalophus rufilatus	Antelopinae	1	1	1	1
Funisciurus anerythrus	Sciuridae	5	5	5	5
Tadarida spp	Pteropodidae	1	1	1	0
Papio Anubis	Cercopithecinae	4	0	0	0
Cercopithecus nicitans	Cercopithecinae	4	0	0	0
Cercopithecus aethiops	Cercopithecinae	5	5	5	4
Cercopithecus mona	Cercopithecinae	2	0	0	0
Colobus guereza	Cercopithecinae	2	0	0	0
Pantroglodytes vellerosus	Hominidae	1	0	0	0

Table 3: Number of frugivore species observed within each of the five taxonomic groups at the different sites

Taxon	MF	A	B	C
Birds	29	22	22	22
Primates	6	1	1	1
Ungulates	2	1	1	1
Rodents	1	1	1	1
Bats	1	1	1	0
Total	**39**	**26**	**26**	**25**

Similarity and Dissimilarity of Sites in terms of Fruit Tree Species Composition

The similarity or otherwise dissimilarity in fruit tree species composition between each pair of the enumerated sites is shown in Table 4. MF and fragment C are the most dissimilar, followed by MF & B and MF & A respectively. A total of 36, 34, and 33 fruit tree species found in MF were not found in fragments C, B, and A respectively. 13, 12, and 10 fruit tree species were common to MF & A, MF & B, and MF & C respectively. Fragments A & B are the most similar in terms of fruit tree species composition, followed by fragments B & C and fragments A & C respectively. A total of 21 fruit tree species were common to fragments A & B, while 17 species were common to fragments A & C, and 16 common to fragments B & C.

Table 4: Sorensen's similarity indices for fruit trees at different sites

	MF	A	B	C
MF	*	22.81	21.82	17.54
A	22.81	*	87.50	60.71
B	21.82	87.50	*	61.54
C	17.54	60.71	61.54	*

Similarity and Dissimilarity of Sites in terms of Frugivorous Species Composition

The similarity or otherwise dissimilarity in frugivore species composition between each pair of the enumerated sites is shown in Table 5. Frugivore species similarity was higher between the protected forest and each of the fragments, and between each pair of the fragments than that of the fruit trees in the respective sites. MF and fragment C are the most dissimilar, followed by both MF & A and MF & B. 13 frugivore species found in MF were not found in fragments A and B, while 15 species found in MF were not found in fragment C. 26 frugivore species were common to MF & A and MF & B, while MF & C have 24 species in common. Fragments A & B are the most similar in terms of frugivores with all the 26 species common to both sites. 24 frugivore species were common to both fragments A & C, and B & C.

Table 5: Sorensen's similarity indices for frugivores at different sites

	MF	A	B	C
MF	*	66.67	66.67	60.00
A	66.67	*	100.00	88.89
B	66.67	100.00	*	88.89
C	60.00	88.89	88.89	*

Diversity of Fruit Trees at different Sites

The alpha (within-site) diversity of fruit trees at different sites is shown in Table 6. Both Simpson and Shannon-Wiener diversity indices show that MF is the most diverse of all the sites, followed by fragment A while fragments B and C have the same diversity index.

Table 6: Alpha diversity indices for fruit trees at different sites

Variable	MF	A	B	C
Simpson index (1-D)	0.9783	0.9583	0.9524	0.9524
Shannon-Wiener index	3.829	3.178	3.045	3.045
Species richness	46	24	21	21

Diversity of Frugivores at different Sites

The alpha (within-site) diversity of frugivores at different sites is shown in Table 7. Both Simpson and Shannon-Wiener diversity indices show that MF is the most diverse of all the sites, followed by fragments A, C, and B respectively.

Table 7: Alpha diversity of frugivores at different sites

Variable	MF	A	B	C
Simpson index (1-D)	0.9679	0.9514	0.9476	0.9490
Shannon-Wiener index	3.519	3.115	3.052	3.057
Species richness	39	26	26	25

Correlation between Diversity of Fruit Trees and Diversity of Frugivores

The correlation coefficient (r) for the diversity of fruit trees and the diversity of frugivores for all the sites was 0.987776 and 0.99678 for Simpson and Shannon-Weiner diversity indices respectively.

DISCUSSIONS

The highest number of fruit tree species - about double the number found in each of the fragments, was found in MF. More of the unknown fruit tree species were found in MF and fragment C which represent both extremes in terms of protection and exploitation respectively. This may be as a result of unhindered evolutionary processes in the main forest and disturbance-induced successional changes in fragment C. Both phenomena could alter the species composition of the forest ecosystem over time.

The level of dissimilarity in fruit tree species composition was very high between the main forest on one hand and the fragmented forests on the other. This may be as a result of anthropogenic activities in the unprotected fragments. Habitat disturbance and alteration can lead to changes in species composition by inducing the germination of seeds of pioneer tree species in the soil seedbank. The highest dissimilarity in fruit tree species composition between the protected main forest and the least protected fragment C and the high level of similarity between each pair of the fragments, lends credence to this assertion.

The fruit tree diversity showed a declining trend from the main forest through fragment A to fragments B and C. The observed trend could be attributed to the differences in the level of protection being given to the main forest and the fragmented sites. Anthropogenic impacts of habitat fragmentation and/or degradation causes biodiversity decay worldwide. Harris and Silva-Lopez [10] observed that habitat fragmentation is one of the most serious causes of diminishing biological diversity, while its main consequence – habitat loss- is responsible for biodiversity loss and ultimate extinction of species [19]. However, it should be noted that the level of disparity between the main forest and fragment C, in terms of the diversity of fruit tree species was relatively low when compared with the diversity of the entire tree species between the two sites as observed by Ihuma *et al* [18]. It seems that the rural dwellers spare the fruit trees in the course of exploitation of resources in the unprotected fragment C since the fruits are most likely to contribute to their livelihoods.

Higher number and diversity of frugivores recorded in the main forest than each of the fragments is attributable to the higher number and diversity of fruit tree species found in the former. Most frugivorous animals rely heavily on fruits, particularly in the tropics [7]. In a number of fine-scale field studies, it has been shown that the richness of frugivorous animals is largely dependent on fruit availability [e.g. 11, 7, 1]. One possible explanation for a positive relationship between food plant and animal species richness is that a greater number of plant species could potentially provide more niches for the coexistence of animal species ('niche assembly hypothesis'; [17]). Perrins *et al.,* [25] equally asserted that the distribution of any species is restricted by the distribution of its habitat and within that habitat the availability of food and other resources. Our result also showed a very high correlation between the diversity of fruit trees and that of frugivores.

However, the higher similarity observed between the frugivores found in the main forest and each of the fragments than with fruit trees is attributable to the migratory nature of the frugivores especially the birds which accounted for over 70 per cent of the frugivorous species observed within the five taxonomic groups in all the sites.

CONCLUSIONS

The diversity of fruit trees and that of frugivores were highly correlated. Both the number and diversity of fruit trees and frugivores were higher in the protected main forest than in all the forest fragments. Birds accounted for over 70 per cent of the frugivorous species observed within the five taxonomic groups in all the sites. Both the fruit trees and frugivore species composition varied more between the main forest and each of the fragments than between each pair of the fragments. However, the level of dissimilarity in species composition between the main forest and the fragments was more with the fruit trees than the frugivores.

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