IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 17, Issue 9 Ser. 1 (September. 2024), PP 48-57
www.iosrjournals.org

Species Diversity And Pollination Ecology Of Bagale Hills Forest Reserve, Girei Local Government Area, Adamawa State - Nigeria

Oluwole, M. O.[1]; Yaduma, Z. B.[2]; Adeshina, E. O.[3] And Ayuba D. K.[1]
[1](Department Of Forestry And Wildlife Management, Federal University Wukari, Taraba, Nigeria)
[2](Department Of Forestry And Wildlife Management, Modibbo Adama Univesity, Yola, Nigeria)
[3](Department Of Crop Science, University Of Abuja, Nigeria)

Abstract:
Background*: This study assessed the pollination ecology and diversity of the Bagale Hills Forest Reserve (BHFR) in Adamawa State. The aim of the study was to understand if biodiversity conservation of the reserve, as planned by the government, is achieved. The objectives were to: assess angiosperm diversity; determine pollinator diversity; evaluate the interaction between angiosperms-pollinators and assess the period of flowering of angiosperms in the transects of the study area.*
Materials and Methods*: The study adopted the systematic line transect procedure in laying out transects. Four transects of 1 km were laid and four sampled plots of 50 m x 50 m size was alternately laid along each of the transect. Three angiosperms were selected at random for data collection on phenology and the diversity of both plants and its associated pollinators. The studied reserve was traversed on foot for three months and the appearance of flower buds and the presence of pollinators on targeted tree species was observed. Data were analyzed and presented using the Descriptive statistics and the Shannon-Wiener diversity index was used for the determination of biodiversity.*
Results*: The result of the Shannon-Wiener Diversity Index indicated pollinator species diversity of 2.686 and angiosperms diversity index of 2.761591 that indicated a very high biodiversity for both the pollinators and its associated plant species in the study area. The phenology result indicated that the pollinators observed were invertebrates that were not evenly distributed and that only about 3.25 % of the tree species were flowering during the wet season. It was also observed that all sampled tree species were generalist in nature.*
Conclusion: *It was concluded that conservation education must be prioritized for the communities surrounding the study area.*
Key Word*: Phenology, Pollinators, Biodiversity, Pollination Ecology.*

Date of Submission: 13-09-2024 Date of Acceptance: 23-09-2024

I. Introduction

Biodiversity serves as a critical support system for a range of ecosystems including the reproduction functions by influencing pollination, seed dispersal, resilience and ecosystem stability1. The more diverse the communities of primary producers are, the more the ecosystems' productivity2. In recent times, there has been an increasing concern over pollinator diversity and population decline as it affects plant productivity therefore, if sustainability is the focus, there is need to understanding the validity of such pollinator population and diversity decline in different ecosystems.

The interrelationships between pollinator-flowering plants have developed physical characteristics that make them more likely to interact successfully resulting in a great diversity of angiosperms 3,4. On the other hand, the diversity of pollinators is influenced by the natural characteristics of the flowers of the angiosperm. The type, shape, structure, colour, odour or fragrance and nectar of flowers determine the type of pollinator that visits the flower. The distinctive characteristics or pollination syndrome displayed by a flower is what attracts a distinct pollinator to it 3. This syndrome can be used to predict the type of pollinator that will aid the flower in successful reproduction. The more specific the relationship between the flower and pollinator, the more likely the pollen of that species that will be successfully transferred and that the plant's pollen will not be wasted on the flower of a different species. Accordingly, that the hypothesis of co-evolution is explained by plant-pollinator interaction, such as how mutualism or antagonism can alter plant morphology or pollinator behaviour and morphology.

Sexually reproduced plants and their pollinators could either be generalist or specialist depending on their morphology 5. Plants that are generalists can be pollinated by a wide range of pollinators 6, 7.

The phenology of plants such as: bud-burst, leaf-expansion, abscission, flowering, fertilization, seed set, fruiting, seed dispersal and germination take place in due season 8. For the most part, these events are too familiar to attract any special attention. Only when the expected pattern is broken, for example by out-of-season flowering or the loss of fruit due to a late frost, is attention drawn to the importance of timing of growth and reproduction in the life of plants.

Phenological studies are as important as the spatial aspects are to understanding species interactions and community function 9, 10. To this end, this research focus on the plant phenology and biodiversity in the study area with the objectives to: assess angiosperm diversity in the study area; determine pollinator diversity in the study area; determine the interaction between angiosperms-pollinators in the study area; and assess the period of flowering of angiosperms in the transects of the study area.

II. Material And Methods

Study Area:

Bagale Hills Forest Reserve (BHFR) is located in Girei Local Government Area of Adamawa State (See Fig. 1 and 2) covers an approximately 179.746 Km^2 of land. It is situated between latitude 9º 15' and 9º 23' North and longitude 12º 31' and 12º 41' East 11. The annual rainfall is 1030 mm per annum. The maximum temperature in Bagale can reach 40 ºC particularly in April while minimum temperature can be as low as 18 ºC between December and January[12]

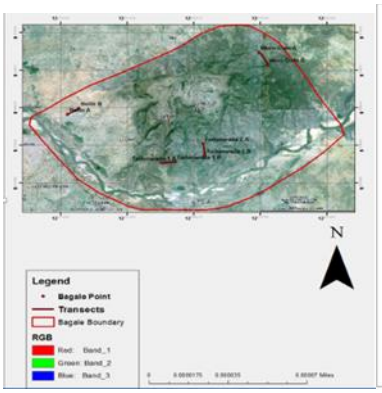

Figure 1: Map of Girei Local Government in Adamawa, Nigeria
Source: Adamawa State in Maps, 1999

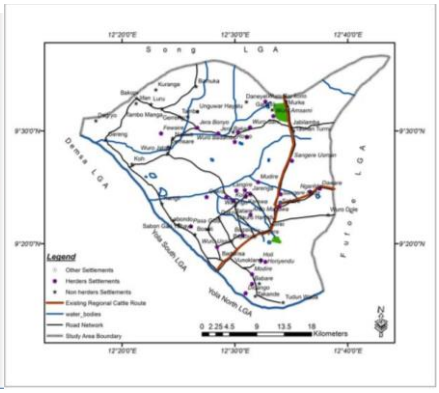

Figure 2: Map of Bagale Hills Forest Reserve.
Source: Federal College of Forestry, Jos GIS Laboratory, 2015

Study Design: This study adopts the systematic sampling in which four transects of 1 km was laid at intervals of at least 500m between each transect (Figure 4). Also, sample plots of 50 m X 50 m were laid alternately at 200 m interval as adopted by [13].

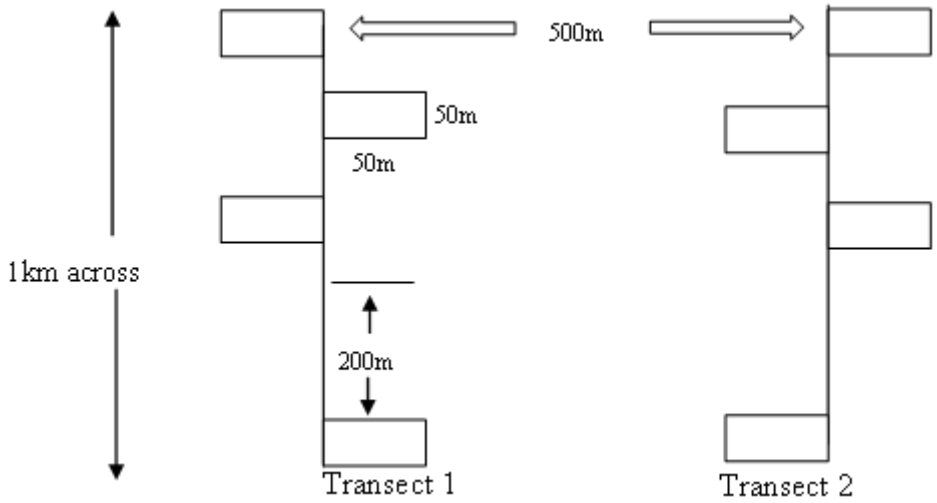

Figure 4: Plot Location using Systematic Line Transect

Study Duration: June 2022 to August 2022.

Method of Data Collection

Data were collected by direct field observation with the aid of binocular, field guide book and recorded in data collection sheet. The study area was traversed on foot for three months and the appearance of flowering buds and presence of pollinators (birds, butterflies, bees, ants, beetles, flies and rodents) on targeted tree species was observed between the periods of 6:00 am to 10:00 am and 4:00 pm to 6:00 pm daily. The number of visitation of pollinators and the occurrence of reproductive parts of the flowers were also recorded.

In each plot, all living angiosperms with diameter at breast height (dbh) ≥ 10cm were numbered and identified. Out of these trees, three trees (focal trees) were selected at random and were used for collection of data on phenology and pollination. Plant-pollinator interactions were determined by visual observation of rates of visitations to a particular tree at flowering stage for a period of 10 minutes; these were used to identify the generalist (many pollinators) and the specialist trees (single pollinator) 6. The scoring system used for the Phenology of the identified trees were "0" (for "No bud") and "1" (for "flower bud"). The information on tree species were collected by direct field observation with field guide book and recorded in data collection sheet.

Method of Data Analysis

The data collected were subjected to descriptive (Frequency, Table and Charts) and inferential statistics which was used to compare and present the species list, phenology and diversity of pollinators and plant-pollinator interactions along the transects in the study location. Shannon-Wiener index was used to determine diversity of angiosperms and pollinators of the study location as shown in equation (1). The LSD procedure was used to compare means of flowering of focal trees amongst the transects (2).

$$H' = -\sum_{i=1}^{N} Pi \ \ ln \ \ (Pi) \text{.....(1)} \quad [14]$$

Where H'= Shannon-Wiener diversity index

N = The total number of all individuals

Pi= The proportion of a species to the total number of individuals in the community.

$$LSD = t_{(0.05/2\ dferror)} \ \ x \ \ \sqrt{2}MSE/r$$

Where t = Student's t-value (i.e. t-tabulated) from the t-table at a chosen level of significance (α)

and error degrees of freedom. (α/2 implies a t

MSE = Error mean squares

r = number of observations per treatment

III. Result

Pollinators of Flowering Trees in BHFR

The result displayed in Table 1 indicated that the average pollinators in BHFR was found to be 54.4 % with mean of 71.6875. Plot 4 had the highest pollinator visitation with 125 recorded pollinators. The least number of pollinators was encountered in plot 15 (23). A total of 370 pollinators were recorded in transect 1 (Girei Laide) which was followed by transect 3 (Holin) with 293 pollinators and by transect 2 (Girei Kolere) with 249 pollinators and transect 4 (Wuro-dole) with 235 pollinators.

The Interactions between Plant and Pollinator in BHFR

The result of plant-pollinator interaction in Table 2 showed that pollinators were not evenly distributed among the angiosperms in the study area. It was further observed that three (3) pollinators were sometimes observed on the flowers of some trees and at other times, eight (8) pollinators or even more were observed on other flowers of the BHFR. Additionally, it was observed that same species of pollinators were present in all transects in the study area.

Table 1: Number of Pollinators on Flowering Trees in BHFR

	Plot No	Frequency
Transect 1	1	95
	2	68
	3	82
	4	125
	Total	370
Transect 2	5	108
	6	24
	7	56

	8	61
	Total	249
Transect 3	9	101
	10	57
	11	58
	12	77
	Total	293
Transect 4	13	51
	14	110
	15	23
	16	51
	Total	235
	Grand Total	1147

Source: Field Survey, 2022

Diversity of Pollinators in the Study Area

The result of the Table 3 showed that the Shannon-Wiener Diversity Index for pollinators in BHFR was 2.686285. Additionally, the diversity Indices for pollinators in each of the Transects were as follows: the Diversity Index for Transect 1 was 1.360977 (Table 4), that of Transect 2 (Table 5) was 1.267949, while the diversity index for Transect 3 and 4 (Table 6 and 7) were 1.357443 and 1.245903 respectively.

The Check List of Tree Species in the Study Area

Tree species in Bagale Hills Forest Reserve

The trees and shrub species in BHFR were assessed in terms of frequency, species richness, distribution and abundance (Table 8). The result showed that 34 tree species belonging to 19 families were inventoried in the study area. The numbers of species in each family were as follows: Anacardiaceae (1), Annonaceae (2), Balanitaceae (1), Bombacaceae (3), Burseraceae (2), Caesalpinioideae (5), Combretaceae (3), Loganiaceae (1), Meliaceae (1), Mimosoideae (5), Moraceae (1), Ochnaceae (1), Olacaceae (1), Polygalaceae (1), Rhamnaceae (1), Rubiaceae (2), Sapotaceae (1), Sterculiaceae (1) and Verbenaceae (1). In terms of distribution, the result shows that *Annona senegalensis, Uvaria chamae, Daniella olivera, Detarium microcarpum, Tamarindus indica* and *Sarcocephalus latifolius* occurred in all the four transects (Girei Laide, Girei Kolere, Holin and Wuro-Dole). *Prosopis african,*

Table 2: Plant-Pollinator Interaction in BHFR

S/N	Tree species	Number of pollinators	Species of pollinator	Rate of visitation
1	*Acacia senegal*	4	Wasp	**
			Mud dauber	*
			Honey bee	*
			Butterfly-	**
2	*Annona senegalensis*	4	Beetle	**
			Ants	*
			Honey bee	*
3	*Anogeissus leiocarpus*	3	Butterfly- swallowtail	**
			Tiny flies	*
4	*Combretum molle*	4	Butterfly	*
			Bug	*
			Wasp	**
			Honey bee	**
5	*Detarium microcarpum*	9	Beetles	*
			Honey bee	*
			Flies	*
			Butterfly	**
6	*Dichrostachys cinerea*	3	Butterfly -brown	**
			Tiny fly	**
7	*Entada africana*	4	Bee	**
			butterfly	*
8	*Piliostigma thonningii*	4	Honey bee	**
			Flies	*
9	*Prosopis africana*	4	Bee	**
			Butterfly	*
10	*Securidaca longepedunculata*	3	Wasp	*
			Butterfly	**
			Others: Lizard, honey bee	*
11	*Strychnos spinosa*	3	Mint green butterfly	**

			Brown butterfly	*
12	*Tamarindus indica*	8	Honey bee	**
			Wasp	*
			Soldier ant	**
			Flying bug	*
			Butterfly	*
			Small ants	*
			Flies	*
13	*Uvaria chamae*	3	Butterfly-swallowtail	*
			Glossina-tsetse fly	**
			Bee	**

*= Occasionally visited, ** Frequently visited

Lophira lanceolata, Vitellaria paradoxa, Sterculia setigera (G. Laide, Holin and Wuro-Dole), Anogeissus leiocarrpus (G. Kolere, Holin and Wuro-Dole), Combretum molle (G. Laide, G. Kolere and Holin), Haemtostaphis barteri, Strychnos spinosa and Acacia senegal (G. Laide and Holin), Adansonia digitata (Holin and Wuro-Dole), Piliostigma reticulatum (G. Kolere and Wuro-Dole), Piliostigma thonningii (G. Laide and G. Kolere) and Dichrostachys cinerea (Gi. Kolere and Holin). However, those that appeared in one (1) out of the four (4) transects include Balanites aegyptiaca, Commiphora africana, Combretum paniculatum, Entada africana, Ximenia americana and Gardenia erubescens (Girei Kolere), Bombax costatum, Khaya senegalensis, Ficus platyphlylla, Securidaca longepedunculata and Vitex doniana (Girei Laide) and Ceiba pentandra, Boswellia spp, Parkia biglobosa and Ziziphus spina-christi (Holin).

The result of tree species along the transects showed that Holin had the highest with 21 species, followed by Girei Laide (20), Girei Kolere (17) and the least was Wuro-Dole (13). The summary (frequency) of stems in each transects include: 147 stems in Girei Laide, followed by 100 stems in Holin, 95 stems in Wuro-Dole, and the least was Girei Kolere which had 85 stems.

Table 3: Diversity of Pollinators on Flowering Trees in BHFR

Plot No	Frequency	Pi	LnPi	PiLnPi
1	95	0.082825	-2.49103	0.206319
2	68	0.059285	-2.8254	0.167504
3	82	0.071491	-2.63819	0.188606
4	125	0.10898	-2.21659	0.241564
5	108	0.094159	-2.36277	0.222476
6	24	0.020924	-3.86685	0.080911
7	56	0.048823	-3.01955	0.147424
8	61	0.053182	-2.93403	0.156038
9	101	0.088056	-2.42978	0.213957
10	57	0.049695	-3.00185	0.149177
11	58	0.050567	-2.98446	0.150914
12	77	0.067132	-2.7011	0.181329
13	51	0.044464	-3.11308	0.138419
14	110	0.095902	-2.34442	0.224836
15	23	0.020052	-3.90941	0.078393
16	51	0.044464	-3.11308	0.138419
	1147			**2.686285**

Source: Field Survey, 2022

Table 4: Diversity of Pollinators on Flowering Trees in Transect 1 (Girei Laide)

Plot No	Frequency	Pi	LnPi	PiLnPi
1	95	0.256757	-1.35963	0.349095
2	68	0.183784	-1.69399	0.311328
3	82	0.221622	-1.50678	0.333936
4	125	0.337838	-1.08519	0.366618
	370			**1.360977**

Table 5: Diversity of Pollinators on Flowering Trees in Transect 2 (Girei Kolere)

Plot No	Frequency	Pi	LnPi	PiLnPi
5	108	0.433735	-0.83532	0.362308
6	24	0.096386	-2.33939	0.225484
7	56	0.2249	-1.4921	0.335573
8	61	0.24498	-1.40658	0.344584
	249			**1.267949**

Table 6: Diversity of Pollinators on Flowering Trees in Transect 3 (Holin)

Plot No	Frequency	Pi	LnPi	PiLnPi
9	101	0.34471	-1.06505	0.367133
10	57	0.194539	-1.63712	0.318484
11	58	0.197952	-1.61973	0.320629
12	77	0.262799	-1.33637	0.351197
	293			**1.357443**

Table 7: Diversity of Pollinators on Flowering Trees in Transect 4 (Wuro-dole) BHFR

Plot No	Frequency	Pi	LnPi	PiLnPi
13	51	0.217021	-1.52776	0.331556
14	110	0.468085	-0.75911	0.355328
15	23	0.097872	-2.32409	0.227463
16	51	0.217021	-1.52776	0.331556
	235			**1.245903**

Table 8: Tree Species in Bagale Hills Forest Reserve

Family	Scientific name	Hausa name	Girei Laide (n)	Girei Kolere (n)	Holin (n)	Wuro-Dole (n)
Anacardiaceae	*Haematostaphis barteri*	Jini kafri	2	0	1	0
Annonaceae	*Annona senegalensis*	Gwandar daji	6	2	10	4
	Uvaria chamae		8	2	3	5
Balanitaceae	*Balanites aegyptiaca*	Aduwa	0	2	0	0
Bombacaceae	*Adansonia digitata*	Kuka	0	0	2	9
	Bombax costatum	Gurjiya	6	0	0	0
	Ceiba pentandra	Rimi	0	0	4	0
Burseraceae	Boswellia spp	Ararabi	0	0	3	0
	Commiphora africana	Dashi	0	3	0	0
Caesalpiniodae	*Daniella olivera*	Maje	7	2	10	6
	Detarium microcarpum	Taura	33	8	7	2
	Piliostigma reticulatum	Kalgo	0	9	0	1
	Piliostigma thonningii	Kalgo	1	9	0	0
	Tamarindus indica	Tsamiya	9	3	10	35
Combretaceae	*Anogeissus leiocarpus*	Marke	0	10	6	5
	Combretum molle	Wuyan damo	10	2	7	0
	Combretum paniculatum	Kirya	0	7	0	0
Loganiaceae	*Strychnos spinosa*	Kokiyar	4	0	3	0
Meliaceae	*Khaya senegalensis*	Madaci	2	0	0	0
Mimosoideae	*Acacia senegal*	Dakwara	10	0	1	0
	Dichrostachys cinerea	Dundu	0	12	9	0
	Entada africana	Tawasa	0	3	0	0
	Parkia biglobosa	Dorowa	0	0	1	0
	Prosopis africana	Kirya	5	0	3	1
Moraceae	*Ficus platyphylla*	Ganji	1	0	0	0
Ochnaceae	*Lophira lanceolata*	Namiji kadanya	13	0	2	4
Olacaceae	*Ximenia americana*	Tsada	0	1	0	0
Polygalaceae	*Securidaca longepedunculata*	Uwar maguguna	8	0	0	0
Rhamnaceae	*Ziziphus spina-christi*	Kurna	0	0	2	0
Rubiaceae	*Gardenia erubescens*	Gaude	0	4	0	0
	Sarcocephalus latifolius	Tafashya	3	6	6	8
Sapotaceae	*Vitellaria paradoxa*	Kadanya	15	0	9	11
Sterculiaceae	*Sterculia setigera*	Bakin Kukkuki	1	0	1	4

Verbenaceae	*Vitex doniana*	Dinyar	3	0	0	0
Total			147	85	100	95
Species Richness			20	17	21	13

n= number of trees/shrubs per Transect Source: Field Survey, 2022

Tree Species Diversity

Diversity of tree and shrub species in BHFR

The result of the Shannon-Wiener Diversity Index for BHFR was 2.761591 (Table 9). The index value showed that Tamarindus indica was the highest contributor to the diversity of trees in the study area that was followed by *Detarium microcarpum* and *Vitellaria paradoxa*. Other contributors to the plant diversity in the descending order include: *Daniella olivera, Sarcocephalus latifolius, Annona senegalensis, Anogeissus leiocarpus* and *Dichrostachys cinerea, Combretum molle* and *Lophira lanceolata, Uvaria chamae, Adansonia digitata* and *Acacia senegal, Piliostigma reticulatum* and *Piliostigma thonningii, Prosopis africana, Securidaca longepedunculata, Combretum paniculatum* and *Strychnos spinosa, Bombax costatum* and *Sterculia setigera, Ceiba pentandra* and *Gardenia erubescens, Haematostaphis barteri, Boswellia species, Commiphora africana, Entada africana* and *Vitex doniana, Balanites aegyptiaca, Khaya senegalensis* and *Ziziphus spina-christi* and the least was *Parkia biglobosa, Ficus platyphylla* and *Ximenia americana*.

Phenological scoring in the study area

During the course of the study, the number of flowering and non-flowering trees were observed and presented in Fig. 3. The result showed that in June, the flowering trees were 235 while the non-flowering trees were 192 trees. In July, the number of flowering trees were 244 while the non-flowering trees were 183. Lastly, in August, the number of flowering trees were 189 while the non-flowering trees were 238.

Phenological scoring along the four transects for the period June-August in the study area

During the course of the study, the number of flowering and non-flowering trees were observed and presented in Fig. 4. The result showed that in June, Transect 1 had the highest flowering trees (17) which was followed by that of Transect 3 (15). The next was Transect 2 (13) and the least was that of Transect 4 (7). Transects 1 and 3 had the highest number of non-flowering trees (20) while Transects 2 and 4 were the least with (16) respectively. In July, the flowering trees in Transects 1 and 3 were 16 respectively. That of Transect 2 and 4 there were 14 and 7 respectively while the non-flowering trees in descending order were: 21 (Transect 1), 19 (Transect 3), 16 (Transect 4) and 15 (Transect 2). Lastly, in August, the number of flowering trees descending order were 11 (Transect 1 and 3), 10 (Transect 2) and 7 (Transect 4) while the non-flowering trees in descending order were 26, 24, 19 and 16 in Transects 1, 3, 2 and 4 respectively.

The phenological average scoring for the period June-August in Bagale revealed that an average of 48 trees were bearing flower bud during the period of study while an average of 76 trees were no flower bud as presented in Table 10. The reason for higher number of trees with no flower bud was because the study was conducted during rainy season when most trees do not flower.

Table 9: The Diversity of tree/shrub species of Bagale Hills Forest Reserve

S/N	Species	Frequency	Pi	Ln Pi	PiLnPi
1	*Haematostaphis barteri*	3	0.006036	-5.10998	0.030845
2	*Annona senegalensis*	22	0.044266	-3.11755	0.138
3	*Uvaria chamae*	18	0.036217	-3.31822	0.120177
4	*Balanites aegyptiaca*	2	0.004024	-5.51544	0.022195
5	*Adansonia digitata*	11	0.022133	-3.81069	0.084341
6	*Bombax costatum*	6	0.012072	-4.41683	0.053322
7	*Ceiba pentandra*	4	0.008048	-4.8223	0.038811
8	*Boswellia species*	3	0.006036	-5.10998	0.030845
9	*Commiphora africana*	3	0.006036	-5.10998	0.030845
10	*Daniella olivera*	25	0.050302	-2.98971	0.150388
11	*Detarium microcarpum*	50	0.100604	-2.29657	0.231043
12	*Piliostigma reticulatum*	10	0.020121	-3.906	0.078592
13	*Piliostigma microcarpum*	10	0.020121	-3.906	0.078592
14	*Tamarindus indica*	57	0.114688	-2.16554	0.248362
15	*Anogeissus leicarpus*	21	0.042254	-3.16407	0.133693
16	*Combretum molle*	19	0.038229	-3.26415	0.124786
17	*Combretum paniculatum*	7	0.014085	-4.26268	0.060038
18	*Strychnos spinosa*	7	0.014085	-4.26268	0.060038
19	*Khaya senegalensis*	2	0.004024	-5.51544	0.022195
20	*Acacia senegal*	11	0.022133	-3.81069	0.084341
21	*Dichrostachys cinerea*	21	0.042254	-3.16407	0.133693

22	*Entada africana*	3	0.006036	-5.10998	0.030845
23	*Parkia biglobosa*	1	0.002012	-6.20859	0.012492
24	*Prosopis africana*	9	0.018109	-4.01137	0.07264
25	*Ficus platyphylla*	1	0.002012	-6.20859	0.012492
26	*Lophira lanceolata*	19	0.038229	-3.26415	0.124786
27	*Ximenia americana*	1	0.002012	-6.20859	0.012492
28	*Securidaca longepedunculata*	8	0.016097	-4.12915	0.066465
29	*Ziziphus spina-christi*	2	0.004024	-5.51544	0.022195
30	*Gardenia erubescens*	4	0.008048	-4.8223	0.038811
31	*Sarcocephalus latifolius*	23	0.046278	-3.0731	0.142216
32	*Vitellaria paradoxa*	35	0.070423	-2.65324	0.186848
33	*Sterculia setigera*	6	0.012072	-4.41683	0.053322
34	*Vitex doniana*	3	0.006036	-5.10998	0.030845
		427			**2.76159**

Source: Field Survey, 2022

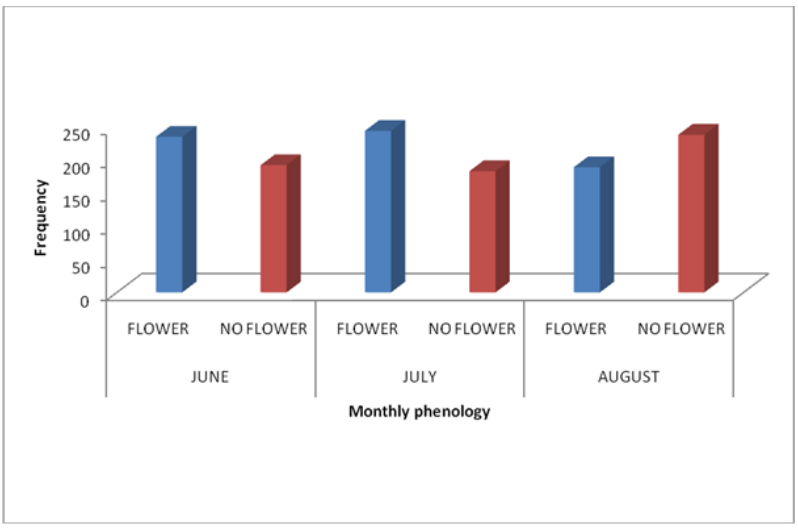

Figure 3: Phenological Scoring in Bagale Hills Forest Reserve (Yola)

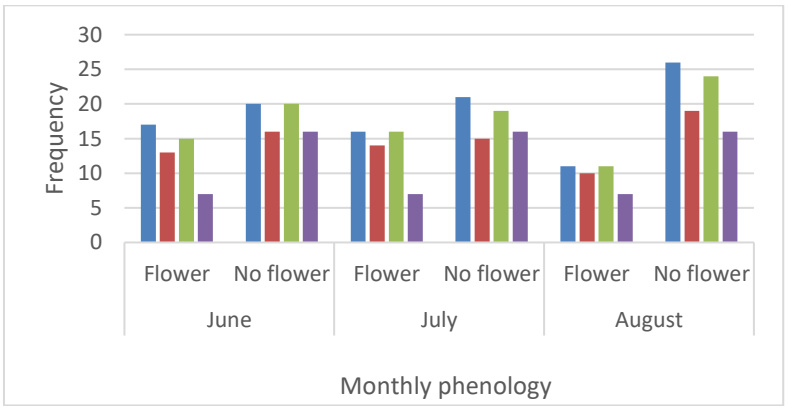

Figure 4: Phenological Scoring along the transects in Bagale Hills Forest Reserve (Girei)

Table 10: Phenological Average Scoring for the period June-August in Bagale

	Flower	No flower
Transect 1	14.67	22.33
Transect 2	12.33	16.67
Transect 3	14.0	21.0
Transect 4	7.0	16.0
Total	**48**	**76**

Source: Field Survey, 2022

IV. Discussion

The Diversity of Pollinators in the Study Area

The result of the diversity index indicated that there was high diversity of pollinators in BHFR and that the species of invertebrate pollinators encountered in all four transects were similar. The study showed that there were more bees and butterfly species than other pollinators in the study area. It is a well-known fact that Bees pollinate a wide range of plants. This agrees with the results of [15, 16]. The Bagale Hills Forest Reserve consists of several hills with death pits between some of them and showed that most of its difficult terrain limits human accessibility and consequently provides protection to the natural resources in some part of the forest. The result of this study agrees with description of the savanna ecosystem affected by human activities [17, 18]. They showed that the anthropogenic activities can incur an "extinction debt" that will not be realized for decades or centuries. Animals disappear more quickly than plants from degraded land, but plants may not last long without their mutualistic animal partners. In Bagale, Caesalpinioideae and Mimosoideae were more abundant.

The Check List of Tree Species in the Study Area

The various pollinator species identified during the course of studies include the following animals: Wasp, Mud dauber, Honey bee, Beetle, Ants, Tiny flies, Bug, Brown Butterfly, Mint green butterfly, Soldier ant, Glossina-tsetse fly and Lizard. The numerous pollinator species listed above agrees with the fact that there is high diversity of pollinators identified in the BHFR. This implies that the BHFR is capable of increased plant diversity and productivity if maintained in its current status in addition to providing significant food security, ecosystem resilience, biodiversity conservation and resilience to pesticides and disease; as a high diversity of pollinators reduces the ecosystem's dependence on any single species, like honeybees, which are vulnerable to pests like the Varroa mite or colony collapse disorder. If multiple pollinators are available, the ecosystem can still function even if some species are negatively affected by pesticides or diseases [19].

Tree Species Diversity

The total number of trees (≥ 10 cm dbh) was 427 stems ha-1. These were disproportionately distributed among 19 families, 32 genera and 34 species. The 19 families of trees encountered during the course of the study showed that the forest is very highly diverse. The distribution of trees along the transects shows similar results. This is because the location of the study area is situated in the Savanna, a belt of vegetation that extends from Senegal to Sudan [18, 20].

The Interaction between Plants and Pollinators in the Study Area

The result of plant-pollinator interaction showed that pollinators were not evenly distributed along the transects in BHFR. This may be as a result of fragmentation of habitat and may be detrimental to plant and pollinator interactions. The result agrees with 6 who reported different number of visitors for three sites in Everglades National Park in small fragments and that of [9, 16] who also reported observed variations in the distribution of pollinators attributed to the physical and environmental factors (altitude, number of plant species, forest disturbance flowering trees, rainfall and temperature). The study also revealed that the trees encountered were all generalist plants. The reason is because more than one pollinator was seen on the angiosperms in the site. In the course of this study, only 2 pollinators (wasp and butterfly) were observed on *Securidaca longepedunculata*, but only the butterfly frequently visited the flowers. The highest number of pollinators were seen on *Detarium microcarpum* (9 insects) and Tamarindus indica (8 insects). The most frequent pollinators on *D. microcarpum* were butterfly and T. indica was soldier ant. The result of this investigation agrees with 6 in a similar study at Everglades National Park, Southern Florida, which observed that plants that are generalists can be pollinated by a wide range of pollinators.

Summary

The study was on the plant diversity and pollination ecology along the transects of Bagale Hills Forest Reserve, in Girei Local Government Area of Adamawa State, Nigeria. Four transects of 1 km each were laid in the study site. The study area was assessed in terms of frequency of trees and pollinators, species richness, distribution and abundance of trees. The result of check list for BHFR showed that there were 427 stem of trees belonging to 19 families. The result of frequency of trees within each transect was in the following order: Girei Laide (147), Holin (100), Wuro-dole (95) and Girei Kolere (85). The result of species richness was in the following order: Holin (21), Girei Laide (20), Girei Kolere (17) and Wuro-dole (13). Shannon's Diversity Index was used to determine the diversity of angiosperms in Bagale was 2.761591. The diversity index of pollinators was also found to be 2.686285. The summation of all the pollinators in Bagale was 1147 non vertebrates. The highest number of pollinators was recorded in Girei Laide (370), the next was Holin (293), followed by Girei Kolere (249) and Wuro-dole (235).

V. Conclusion

Despite variation in topographical features of the studied location, plant species and pollinator diversity were found to be highly diverse. This was despite the fact that the research was conducted in raining season during which only few trees were flowering. Additionally, a wide range of pollinators were observed on a tree and this is an indication that such trees are generalist. It was concluded that conservation education for the communities surrounding the study site must be given due priority to enable the sustainability and possible improvement in the diversity, reproduction and resilience of the BHFR. In view of the findings from this study, the following recommendations were made: i) there is the need for high level of conservation education for the communities living around Bagale Hills Forest Reserve in Yola. ii) there is need for further studies that will include dry season study of pollination ecology and anthropogenic impact on pollinators in the study area.

References

[1] Loy Xingwen And Brosi, Berry J. (2022). The Effects Of Pollinator Diversity On Pollination Function. Journal Of Ecology Vol. 103 (4), E3631 April, 2022. Doi: 10.1002/Ecy.3631

[2] Duffy, J. E., C. M. Godwin, And B. J. Cardinale. 2017. Biodiversity Effects In The Wild Are Common And As Strong As Key Drivers Of Productivity. Nature 549:261-264.

[3] Carvalho, T. (2014). Honeybee Project. Plants And Environmental Protection Sciences (Peps). College Of Tropical Agriculture And Human Resources.

[4] Oluwole, M. O., Adeshina, E. O. And Ayuba, D. K. (2024). Pollination Ecology Of Some Selected Trees In Bagale Hills Forest Reserve And Jos Wildlife Park, Nigeria. Journal Of Pharmacy And Biological Sciences (Iosr–Jpbs) Vol. 19, (5) 7-14.

[5] Johnson, S.D., Steiner, K.E., (2000). Generalization Versus Specialization In Plant Pollination Systems. Trends In Ecology And Evolution, Volume 15, Issue 4, 1 April 2000, Pages 140-143.

[6] Waser, N. M. And Ollerton, J. (2007). Plant-Pollinator Interaction: From Specialization To Generalization. American Journal Of Botany 88, 128. 340-361 Pp.

[7] Maggi, T., Pardo, L. And Chreil R. (2022). Insect Pollinators: A Key To Ecosystem Resilience And Food Security. Pollinators, 2024 (1) 35-50

[8] O'brien, A. M., N. A. Ginnan, M. Rebolleda-Gómez, And M. R. Wagner. 2021. Microbial Effects On Plant Phenology And Fitness. American Journal Of Botany 108(10): 1824–1837. Https://Doi.Org/10.1002/Ajb2.1743

[9] Carter, J. S. (1997). Ecology. File Ecology.Htm Sun 19 Jan 2014. Clipart Edited From Corel Presentation 8. Carterjs@Uc.Edu

[10] Claßen-Bockhoff, R. And Silló, N. (2024). A Multitude Of Bee Pollinators In A Phenotypic Specialist - Pollinator Diversity From The Plant's Perspective. Flora, Vol.312, March 2024, 152461

[11] Adebayo, A. A. (1999). Climate I: Sunshine, Temperature, Evaporation And Relative Humidity. In Adamawa State In Map. Adebayo A. A. And Tukur, A. L, (Eds). Paraclete Publishers, Yola. Nigeria. Pp 3-5, 20

[12] Adebayo, A. A. And Nwagboso, N. K. (2005). Climate And Agricultural Planning In Adamawa State. In Agriculture In Adamawa State. Igwe, E. C., Mshelia, S. I. And Jada, M. Y., (Eds). Paraclete Publishers, Yola, Nigeria. 2005. Pp 12-13.

[13] Adekunle, V. A. J. (2010). Assessment Of Tree Species Diversity And Evenness (That Is Tree Species Composition And Distribution), Tree Quality And Quantity In Gebo Forest Reserve Kogi State. Forestry Journal. 1-5 Pp.

[14] Adekunle, V. A. J., Olagoke, A. O. And Akindele, S. O. (2013). Tree Species Diversity And Structure Of A Nigerian Strict Nature Reserve. Tropical Ecology 54(3): 275-289 Pp.

[15] Maggi, T., Pardo, L. And Chreil R. (2023). Pollinator Diversity: A Key To Ecosystem Resilience And Food Security. Pollinators, 2023 (6) 33-48

[16] Kemabonta, K. A., Ebiyon, A. S. And Olaleru, F. (2015). The Butterfly Fauna Of Three Varying Habitats In South Western Nigeria. Futa Journal Of Science Reserach. 11(1): 1-6

[17] Morrison, O. S. (1999). Savanna And The Wildfire, Mukogodo, Kenya. Apublication Of The Ministry Of Environment. Pp 1-73.

[18] Rivers, Y. (2001). Vegetation And Classification Systems. The International Union For Conservation Of Nature (Iucn), 1-43pp.

[19] Peter Hristov, Rositsa Shumkova, Nadezhda Palova, And Boyko Neov (2020). Factors Associated With Honey Bee Colony Losses: A Mini-Review. Vet Sci. 2020 Dec; 7(4): 166. Published Online 2020 Oct 30. Doi: 10.3390/Vetsci7040166

[20] Usman, H. D. (2013). Identification Of Plants Visited By The Honeybee, Apis Mellifera L. In The Sudan Savanna Zone Of Northeastern Nigeria. African Journal Of Plant Science, 7 (7), 273-284.