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Ecological impacts of fragmentation on the diversity and distributions of indigenous tree species in tropical rainforest of Nigeria

Ndakara Ofudjaye Emmanuel[*1], Atuma, Ifeanyi Morrison[1],
Iwegbue Chukwujindu Maxwell Azubuike[2]

[1]*Department of Geography and Regional Planning, Delta State University, Abraka, Nigeria*
[2]*Department of Chemistry, Delta State University, Abraka, Nigeria*

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Abstract

This study investigated the ecological impacts of fragmentation on diversity and distributions of indigenous tree species in Nigerian rainforest, with the aim to ascertain how fragmentation impacted on the species of *Ceiba pentandra, Irvingia gaboneensis, Piptadeniastrum africanum, Milicia excelsa, Musanga cecropioides,* and *Pentaklepta macrophylla.* The study was carried out in 42 randomly selected matured rainforest fragments above 80 years within the 7 States of the Niger Delta region (grouped into 21 small and big fragments respectively). Data collected were on fragments sizes and tree species populations, through quadrats of 10m × 10m. Statistical analysis of data involved the descriptive, regression, t-test, similarity and diversity indices. Results showed that population of trees, population density and species populations differed among the fragments and significantly varied between the small and big fragments groups. Population densities were higher in big fragments. Populations of trees were significantly related with fragments sizes, with correlation values of 0.90 and 0.79 for the small and big fragments. High similarity index of 91% for the tree species was observed between the small and big fragments. With calculated t-value of 0.265 < table t-value of 2.228, the diversity index between small and big fragments was not significant at 5% level of confidence. Species diversity was higher in small fragments. Fragmentation had higher impact on species richness than their relative abundance. In conclusion, fragmentation has impact on diversity and distributions of tree species. Ecosystem-based management is recommended as an approach to ensure sustainability of indigenous tree species in the rainforest, for the purpose of biodiversity conservation.

***Corresponding Author:** Ndakara, Ofudjaye Emmanuel ✉ ndakaraoe@delsu.edu.ng

Introduction

Disturbances in forest ecosystem have resulted to fragmentation at different scales by highly reducing the larger contiguous tropical forested areas into smaller forest relics (Liu, Wilson, Hu, Liu, Wu & Yu, 2018; Fahrig, 2013; Laurance, Camargo, Luizao, Laurance, Pimm, Bruna, Stouffer, Williamson, Benitez-Malvido, Vasconcelos, Van Houtan, Zartman, Boyle, Didham, Andrade & Lovejoy 2011). Fragmentation involves the process of reducing contiguous forest habitats to relatively smaller and spatially distinct island habitats (Ojoyi, Mutanga, Odindi, Aynekulu & Abdelrahman, 2015; Collinge, 2009). In many tropical rainforest regions, the originally contiguous moist rainforest cover has been greatly destroyed due to long term human and other anthropogenic activities (Ndakara, 2012a; Ndakara, 2011). The original forest cover rich in tree species have been reduced to island habitats and forest fragments with resultant effects on diversity of species contained (Ndakara & Ofuoku, 2020; Ojoyi, *et al.,* 2015; Struebig, Kingston, & Petit, 2011), size of habitats (Galanes & Thomlinson, 2009), species distribution (Struebig *et al*, 2011), tree populations and edge effects (Chapman, Myers, Burky &cmEwan, 2015; Fahrig, 2003).

As fragmentation process develops, its ecological effects change (Wu, 2013). According to Farmilo, Melbourne, Camac & Morgan (2014), there has been increasing concern about species loss, ecosystem diversity and reduction in genetic diversity of trees. This concern arose because of the implications of large-scale forest degradation. For instance, studies by Arroyo-Rodríguez, Cavender-Bares, Escobar, Melo, Tabarelli (2012), and Arroyo-Rodríguez, Rös, Escobar, Melo, Santos, Tabarelli (2013) reported that "rate of tropical forest degradation led to extensive reduction of forest landscape".

Although some forest habitats are naturally patchy in terms of the organisms and abiotic conditions as reported by Fahrig (2013), the actions of man according to Haddad, *et al* (2015) have immensely fragmented landscapes in many world forest ecosystems thereby altering the essential quality and connectivity patterns of habitats. Therefore, the understanding of the root causes and resultant impacts of fragmentation is very critical to preserving the functioning of ecosystems and biodiversity (Ndakara, 2016a; Fahrig, 2013; Alexander *et al.*, 2012).

Different researches have revealed that loss and fragmented habitat has negative impacts on biodiversity. According to Haddad, Brudvig, Clobert, Davies, Gonzalez, Holt, Lovejoy, Sexton, Austin, Collins, Cook, Damschen, Ewers, Foster, Jenkins, King, Laurance, Levey, Margules, Melbourne, Nicholls, Orrock, Song & Townshend (2015) and Wu (2013), habitat loss and forest fragmentations are seen as the main cause of biodiversity loss globally. One major path-way by which habitat fragmentation affects biodiversity is through reduction in the suitable habitats for organisms. As the remaining patches of habitat get smaller, they obviously support fewer populations of species thus, leads to species loss and extinction (Funkami, 2015; Peng, Hu, Yu, 2014; Laurance *et al.*, 2011; Ndakara, 2009).

Habitat fragmentation has implications on population dynamics which is concerned with differences in species numbers and changes in their relative proportion (Riitters, Coulston & Wickham, 2011; Didham, Kapos, Ewers, 2012). However, Jules (1998) reported that smaller fragments contain smaller population while larger fragments contain larger population (Yu, Hu, Feeley, Wu, Ding, 2012). Therefore, reduction in size of habitat fragments leads to high risk of species extinction.

One outstanding problem associated with forest fragmentation as reported in researches carried out by Ndakara (2016b), Funkami (2015), and Fahrig (2013) is "loss in species diversity"; while Liu *et al.* (2018) opined that loss in species diversity results from large-scale degradation of habitats and trees, leading to extensive reduction in species diversity. Species extinction is another major problem associated with forest fragmentation (Wu, 2013). As the natural rainforest cover is being converted to different use by humans, the trees are exposed to extinction risks thus, Jules (1998) and Martinez-Morales (2005) opined that most species of forest trees affected in the course of fragmentation may probably not be found again in such habitat fragments, while a few of such tree species may occur only in the interior parts due to edge effects associated with reduced size of forest (Didham *et al*, 2012).

Expectedly, several studies have been carried out to investigate forest fragmentation and the resultant impacts. Liu, *et al.* (2018) studied how fragmentation affects biodiversity and the functioning of ecosystem; Haddad, *et al.* (2015) examined fragmentation of habitat and its impacts on earth's ecosystems; Ojoyi, *et al.* (2015) studied how forest fragmentation affect tree species diversity and abundance in Tanzania; Chapman *et al.* (2015) studied edge effects of forest fragmentation on biodiversity; Dechoum, Castellani, Zalba, Rejmánek, Peroni, Tamashiro (2015) investigated community structure and succession in the deciduous forest fragments in southern Brazil;

Lima, Lima, Santos, Tabarelli & Zickel, (2015) investigated fragmentation and herb assemblages in Brazilian Atlantic forest; Farmilo, *et al.* (2014) investigated fragmented forest landscape and changes in plant species density; Magnago, Edwards, Edwards, Magrach, Martins, Laurance (2014) examined the change in functional attributes of Brazilian Atlantic forests after fragmentation; Fahrig (2013) investigated patch-size and the isolation effects; Hu, Feely, Wu, Xu, & Yu (2011) examined the determinant factors of nestedness and species richness in fragmented landscapes; Ndakara (2009) investigated rainforest fragments and the diversity of tree species in South-Southern Nigeria; Collins, Holt, & Foster (2009) studied patch-size and decline of plant species within fragmented landscape; Leach and Givnish (1996) examined species loss and the ecological determinant factors in remnant prairies; Jules (1998) studied fragmentation of habitat and demographic change for Trillium in old-growth forest; Other studies conducted by Golden and Crist (2000); Carlson and Hartman (2001), Summerville and Crist (2001), Virgos (2001) and Fuller (2001) examined fragmentation and loss of habitats.

From the studies above, the ecological impacts of fragmentation on the diversity and distributions of indigenous tree species in tropical rainforest within Nigeria have not been adequately documented; where as within this region, fragmentation has resulted to extinction of most indigenous rainforest tree species, reduced habitat size for species habitation, increased indices of diversity, and increased impact on species richness than their relative abundance (Ndakara, 2009).

Nigerian rainforest ecosystem has long been exposed to numerous problems due to fragmentation. The originally contiguous rainforest cover has been highly reduced to island forest thus leading to high risk of species extinction. Many indigenous species are hardly found within the rainforest relics. There is loss of species diversity leading to extensive reduction in species diversity. This study therefore, examines the diversity and distributions of *Ceiba pentandra, Irvingia gaboneensis, Piptadeniastrum africanum, Milicia excelsa, Musanga cecropioides,* and *Pentaklepta macrophylla* within fragments of Nigerian moist rainforest cover. The choice of these species was determined following a reconnaissance survey which revealed that they are tree species that featured commonly within the Nigerian rainforest fragments; while the rainforest fragments investigated are those that are confined to conserved areas where logging and other related human activities which can cause ecosystem degradation are not carried out, in line with observations in studies by Liu, Wilson, Hu, Liu, Wu & Yu (2018), Ndakara (2012b).

The focus of this study was to ascertain the ecological effects caused by fragmentation of rainforest on diversity and distribution of indigenous species of trees within the Nigerian moist rainforest cover. In other that the primary aim of the study was achieved, The following specific objectives were treated: (i) examine size of fragments and group them into small and big fragments; (ii) investigate populations of trees of rainforest origin found in the fragments; (iii) investigate individual tree species populations between the small and big fragments groups; (iv) determine density of trees within the rainforest fragments; (v) determine the proportional index of similarity for tree species between the two fragments groups; and (vi) ascertain the species diversity indices for tree species between the two fragments groups.

Materials and methods

The study area

Nigeria is located between latitudes 4°N and 14°N and also between longitudes 3°E and 15°E (fig 1). The vegetation cover comprises the forest and grassland. The Nigerian rainforest region covers about 25,900 km2 (Ndakara, 2011); within a land area coverage of about 75,000 km2 (Ndakara, 2012a). Defined in this way, the region comprises seven states which are: Abia, Bayelsa, Edo, Akwa-Ibom, Cross River, Delta and Rivers (Fig 1); and fall within similar conditions of climate and topo-sequence. This region falls within the humid sub-equatorial climate with annual temperature averaging about 30°C, and annual rainfall ranging between 2800mm and 4000mm (Ndakara and Eyefia, 2021). The vegetation is of moist tropical rainforest type which has tree forms that range in strata from the shrubs to the exceedingly tall members (Ndakara, 2011). Besides, the luxuriant rainforest ecosystem is made up of herbs, lianas, epiphytes, sciophytes and parasites. This vegetation has been highly degraded and at present, mainly relics of the original contiguous rainforest cover are observed within sacred and other conserved areas. The landscape is a low-lying deltaic plain interspersed with water-logged depressions, and formed from sedimentary deposits. The soils are hydromorphic and alluvial. These soils are mainly derived from coastal deposits and support effective growth and development of rainforest trees.

Methodology

This research was conducted in the seven rainforest States within Nigeria (Fig 1). The selection of the seven States was based on conditions that they fall within same vegetation belt, similar conditions of climate and topo-sequence, as adopted in a study by Amiolemen, Iwara, Ndakara, Deekor & Ita (2012). This study involved 42 rainforest fragments. In each State (which will subsequently be called zone), 6 rainforest fragments were selected (3 each for the small and big fragments groups respectively). Small fragments group comprises fragments with areas between 10,000m² and 40,000m², while big fragments group comprises fragments with areas between 40,401m² and 90,000m². Selection of fragments was based on conditions that the vegetations are matured and above 80 years in history; they fall within same ecological region; the selected fragments are those that are confined to conserved areas where logging and other activities that lead to ecosystem degradation are not carried out (Ndakara and Ofuoku, 2020); and species of trees investigated are of rainforest origin. Each fragment was shared into quadrats of 10m×10m as considered effective for sampling trees in the tropical rainforest. Tree species examined were *Ceiba pentandra, Irvingia gaboneensis, Piptadeniastrum africanum, Milicia excelsa, Musanga cecropioides, and Pentaklepta macrophylla*. The choice of these species was determined following a reconnaissance survey which revealed that they were the indigenous ecological species that featured commonly within the forest fragments. Data collection exercise involved field assistants; while data collected were on forest fragments sizes, individual tree species population, and population distribution of trees.

Fragment sizes were ascertained using ranging poles and arrows to establish the points before measuring with measuring tape. Data analysis involved the descriptive statistics, independent samples t-test, regression analysis, similarity index, and diversity index. The descriptive statistics was employed to compute the mean, standard deviation and density of trees populations. Bar graph was used to show populations of the tree species in the fragments. Independent-samples t-statistics was used to test the differences in tree populations between small and big fragments, and the differences in populations of each species of trees between small and big fragments at 5% levels of confidence respectively. Regression analysis was employed to test the possible relationships between population of trees and fragments sizes at the 5% level of confidence. Tree species similarity was computed using the community similarity index in line with Brower and Zar (1984); while species diversity for the trees was computed using index of species diversity following Simpson (1949).

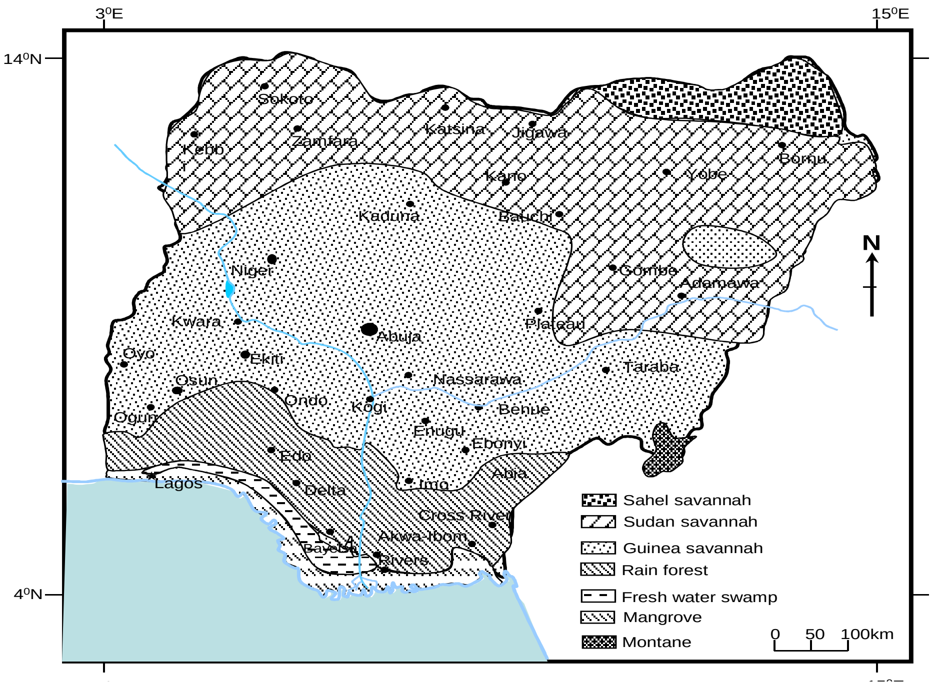

Fig. 1. Vegetation Map of Nigeria showing the Rainforest Distribution.
Source: Ministry of Lands, Survey and Urban Development, Asaba, Nigeria (2020).

Results and discussion

Fragment sizes and tree populations

The fragments vary in sizes between 10,000m² and 40,000m² (small fragments), and between 40,401m² and 90,000m² (big fragments). The tree populations also varied across the fragments (Fig 2).

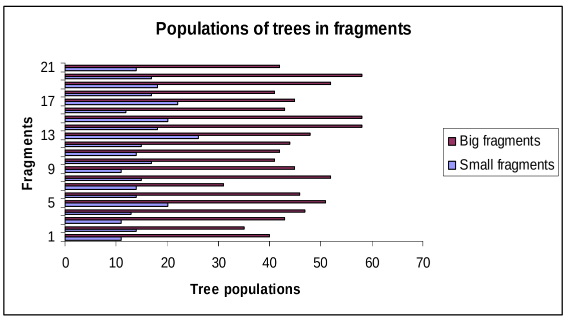

Fig. 2. Trees populations in fragments.

Tree populations varied in response to fragments sizes. Big fragments had more trees than the small fragments. The highest tree population of (58) was seen in fragments with areas measuring 88,000m² and 90,000m² while the smallest population of trees (11) was seen in fragments with areas measuring 25,200m² and 28,000m².

From Fig. 3, the density of trees populations varied across the fragments. The smallest population density (0.00039) was observed within the small fragments group with area measuring 28,000m² and tree population of 11, while the highest density (0.00089) was observed within the big fragments group with area measuring 46,180m² and tree population of 41. The observed differences in trees populations and density of their populations in response to fragments sizes has marked impacts on distribution levels of trees and species of trees in the fragments. As the trees populations reduce in response to reduced size of fragments, some species that are indigenous to rainforest ecosystem were no longer found. Such species have become endangered and threatened.

This finding is in line with finding that was reported in the study by Fahrig (2013). The observed pattern of variation in tree densities can possibly be due to loss of biodiversity, which corroborates the observation reported in studies by Farmilo *et al.* (2014), and Soons, Mescaline, Jongejans and Heil (2005) which reported that trees populations in fragmented ecosystems are more exposed to become extinct due possibly to effects that are associated with sizes of remnant habitat. Studies by Fahrig (2013), Jongejans and de Kroon (2005), and Haddad *et al.* (2015) reported that greater isolation from neighbouring population reduces trees populations in fragments; while increased amount of "edge" habitat reduces the distribution levels of trees and tree species as reported by Liu *et al.* (2018); Chapman *et al.* (2015); Ojoyi *et al.* (2015); Saunders, Hobbs & Margules, (1991); Jules, (1998).

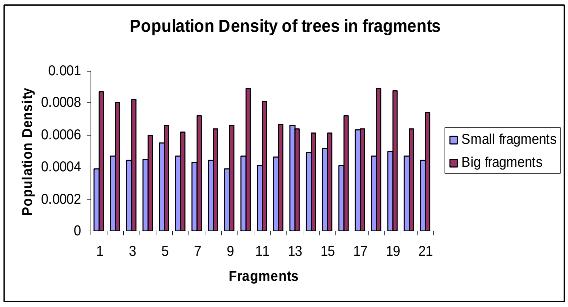

Fig. 3. Density of trees populations in different fragments.

Table 1 of supplementary materials presents test results of independent-samples t-statistics on the differences in populations of trees between small and big fragments. With means of 15.86 and 45.81 respectively for the small and big fragments, the small fragments contained less population of trees than the big fragments. The standard deviation values of 3.88 and 7.15 respectively for the small and big forest fragments show that tree populations is higher in the big fragments, but varied across the two fragments groups. However, with t-values of 16.88 and significant 2-tailed value of 0.00, the observed difference of 29.95 in trees populations between the small and big fragments groups is significant at the 5% level of confidence. Therefore, there is significant difference in populations of trees between the small and big fragments.

Relationship between forest fragments sizes and populations of trees

Regression results for relationships between forest fragments sizes and population of trees are presented in table 2 of the supplementary materials. In both small and big fragments, the standardised beta coefficients of 0.895 for the small fragments group and 0.789 for the big fragments revealed that there is strong positive relationship between fragments sizes and trees populations in them.

Table 1. Independent-Samples T-statistics Results for the Population of trees between small and big fragments.

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Recall	1.00	21	15.8571	3.87667	.84596
	2.00	21	45.8095	7.14576	1.55933

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Recall	Equal variances assumed	5.039	.030	-16.884	40	.000	-29.95238	1.77403	-33.53782	-26.36694
	Equal variances not assumed			-16.884	30.834	.000	-29.95238	1.77403	-33.57132	-26.33344

** 1- Trees populations in small fragments

2- Trees populations in big fragments

This shows that significant relationships occur between sizes of fragments and trees populations in them at the 5% level of confidence. In this regards, changes in fragments sizes impact on the populations of trees. This finding corroborates findings that were reported in studies by Farmilo *et al.* (2014), and Arroyo-Rodriguez *et al.* (2013). Although some earlier studies conducted by Zimmerman and Bierregard (1986), Dzwonko and Loster (1989), Doak and Mills (1994), Elliott & Swank (2008) reported that results of studies about plant communities and fragment attributes are often not clear because different rates of selective logging take place in forests thus, makes statistical interpretation quite complicated. This study has presented clearer results on the account that this research was conducted on rainforest fragments which were mainly conserved and within sacred places where logging activities have not taken place within living memory.

Table 2. Regression Results for relationships between fragments sizes and population of trees in Sites.

Sites	Dependent variable	Predictor variable	Model	Sum of squares	df	Mean square	Adjusted R square	Std Beta Coeff	F	Sig.
Smaller fragments	Tree population	Fragment size	Regression Residual Total	240.951 59.620 300.571	1 19 20	240.951 3.138	.791	.895	76.787	.000
Larger fragments	Tree population	Fragment size	Regression Residual Total	635.601 385.637 1021.238	1 19 20	635.601 20.297	.603	.789	31.316	.000

**Since P<0.05 for all the relationships, our overall models are therefore significant.

Tree species distributions in fragments

Due to fragmentation effects, tree species maintained discontinuous distribution pattern. Trees populations for individual species varied across the fragments. While some species were distributed across the fragments, some other species were not found in some fragments. Such species that were not commonly distributed are obviously being threatened and becoming endangered in the rainforest ecosystem. The endangered species were commonly observed within the small fragments, as reported in studies by Fahrig (2013) and Haddad *et al.* (2015). In both small and big fragments, populations of *Piptadeniastrum africanum* were highest, while the least population observed were from *Irvingia gaboneensis* and *Milicia excelsa* respectively for the small and big fragments.

The populations of individual species of the trees in big fragments show that the species vary in populations across the fragments (Fig 4). While *Piptadeniastrum africanum* was highest in population (320) in all the big fragments, *Milicia excelsa* has the least population (88). Stands of *Milicia excelsa* and *Pentaklepta macrophylla* were not found in some of the big fragments. *Ceiba pentandra* had population of 129, *Musanga cecropioides* had population of 165, *Pentaklepta macrophylla* had population of 140 while *Irvingia gaboneensis* had population of 120. These show a marked variation in the total populations of the species of trees found in the big fragments. The distributions of the population of tree species also show high diversity owing to relative evenness in the total populations of species contained.

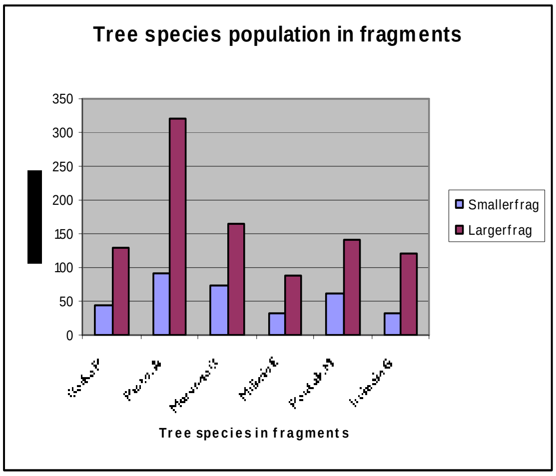

Fig. 4. Tree populations for each species in small and big fragments.

Populations in big fragments were more than the observed populations in small fragments for all the tree species. The populations of species in small fragments also vary across the fragments (Fig 4). Population of *Piptadeniastrum africanum* (90) was highest, while Irvingia gaboneensis with a population of 32 was the smallest. *Ceiba pentandra* had population of 43, Musanga cecropioides's population was 74, *Milicia excelsa*'s population was 33, *Pentaklepta macrophylla*'s population was 61 while *Irvingia gaboneensis*'s population was 120. However, stands of *Ceiba pentandra*, *Milicia excelsa, Pentaklepta Macrophylla* and *Irvingia gaboneensis* were not seen in a few fragments.

Inferring from the distributions of species in both small and big fragments, *Irvingia gaboneensis, Milicia excelsa* and *Pentaklepta macrophylla* are becoming endangered and much threatened. They were not found in many fragments, which probably could be as a result of reduced size of habitat, as reported in studies by Liu *et al.* (2018), Yu *et al.* (2012), and Fahrig (2002). However, the population distribution for the tree species shows high diversity owing to evenness in the total population of each tree species. Fig. 4 is a bar graph of each species populations in big and small fragments. Species populations were generally higher across the big fragments. While *Piptadeniastrum africanum* was observed to have the highest population, stands of *Irvingia gaboneensis* had the least population.

The implication of the observed lower population across the small fragments has earlier been attributed to reduced forest area which accounts for the impact of habitat fragmentation on population of tree species. In assessing the negative impacts of reduced size of habitat, study by Fahrig (2002) reported that at certain point, small fragments would become too small to sustain their local populations. Species which are unable to cross the non-habitat section of the forest landscape will then be confined to higher number of very small fragments, thereby reducing the overall population size and the persistence probability (Duguay *et al*., 2007).

The differences in species populations were tested with independent-samples t-statistics. Table 3 of supplementary materials presents the independent-samples t-statistics results for the differences in species populations between small and big fragments. With t-values of 3.004 and significant 2-tailed value of 0.013 and 0.025, the observed difference of 104.83 in species populations between the small and big fragments was significant at the 5% level of confidence. However, the mean population values of 55.5 and 160.3 with standard deviation values of 23.57 and 82.18 for the small and big fragments respectively revealed that reduced forest areas and sizes has negative impacts on populations of species contained. This finding corroborates result reported in the studies by Haddad *et al.* (2015).

Table 3. Independent-Samples T-Statistics Results for Populations of each tree species between Small and Big Fragments.

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Recall	1.00	6	55.5000	23.56905	9.62202
	2.00	6	160.3333	82.18191	33.55063

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Recall	Equal variances assumed	2.296	.161	-3.004	10	.013	-104.83333	34.90312	-182.602	-27.06434
	Equal variances not assumed			-3.004	5.817	.025	-104.83333	34.90312	-190.894	-18.77281

** 1- population of each tree species in small fragments

2- population of each tree species in big fragments

Fragmentation impacts on biodiversity

Fragmentation leads to habitat loss which negatively affects species distribution and biodiversity. Therefore the need to ascertain the species similarity levels for trees in the two different communities (small and big fragments) becomes necessary.

Tree species similarity

Similarity assessment is one important way to compare pairs of communities. Table 1 presents the proportional index for species similarity between the small and big fragments. The index for the species similarity shows that there is high similarity in the species between the small and big fragments. This indicates that species in both small and big fragments are similar. Despite the fact that the two communities studied maintained discontinuous pattern of distribution, being fragmented forest areas, the species studied were not endemic at any level.

In both small and big fragments, *Piptadeniastrum africanum* had the highest proportion followed by *Musanga cecropioides*. While *Irvingia gaboneensis* and *Milicia excelsa* had the smallest proportion in the small fragments, *Milicia excelsa* had the smallest proportion in the big fragments.

Table 4. Proportional Index of Species Similarity between the Small and Big Fragments.

SN	Tree species	Small fragments		Big fragments		Percentage Similarity (PS)
		Population	Proportion	Population	Proportion	
1	*Ceiba pentandra*	43	13%	129	13%	13
2	*Piptadeniastrum africanum*	90	27%	320	33%	27
3	*Musanga cecropioides*	74	22%	165	17%	17
4	*Milicia excelsa*	33	10%	88	9%	09
5	*Pentaklepta macrophylla*	61	18%	140	15%	15
6	*Irvingia gaboneensis*	32	10%	120	13%	10
	Total	333	100%	962	100%	91%

PS = 91%: High index of similarity

Species diversity

Habitat loss has been observed to impact negatively on species diversity with respect to trees in the rainforest, which emphasized richness and species abundance (Chapman *et al.*, 2015; Fahrig, 2013; Best, Bergin and Freemark, 2001). Table 2. presents the Simpson's indices for species diversity between small and big fragments.

Table 5. Simpson's Indices for Species Diversity between Small and Big Fragments.

SN	Fragments	Species populations	Simpson's Index (S.I)	Variance (S^2)	Calculated t-value	Table t-value	Decision
1	Small fragments	333	0.8107	0.0018			
2	Big fragments	962	0.7977	0.0006	0.265	2.228	N.S

** N.S = Not Significant.

Although species populations were higher in the big fragments, the calculated t-test results from the variance (S^2) of the Simpson's indices show that the differences the species diversity between the small and big fragments was insignificant at the 5% level of confidence. Therefore, in terms of evenness and richness, fragmentation has higher effect on richness than relative abundance of species as opined by Funkami (2015). Indeed, it has been reported in several studies that species diversity reduces as size of habitat reduces, while larger forest areas contain more diverse tree species as reported by Laurance *et al.* (2011); Yu *et al.* (2012); Arroyo-Rodriguez (2013). However, this study observed that species of trees are more at variant with higher index of diversity in small fragments. This can be due to the fact that relative abundance could still be maintained by the few species contained in the fragments irrespective of size. The effect of fragmentation on species diversity can be linked with the trend in successional trajectories which its effects are higher in small fragments than larger fragment areas (Dechoum *et al.*, 2015).

However, study by Cook, Yao, Foster, Holt & Patrick (2005) revealed that succession impacts on woody vegetation occur slowly in small habitats than in big habitats.

Conclusion and recommendation

Results of investigations in this study showed that population of trees, population density, and species population differed among the fragments and significantly differed between the big and small fragments groups. Population densities were higher in big fragments. Populations of trees were significantly related to fragment sizes. High similarity index was observed for species of trees between the big and small fragments groups. The diversity index between the big and small fragments was insignificant.

Tree species were more at variant with higher index of diversity within small forest fragments. Although, several studies revealed that fragmentation threatens biodiversity, while species diversity reduces with reduced fragments size. This study observed that species contained in smaller-size fragments have higher index of diversity. This is possible because, talking about evenness and richness, fragmentation had higher effect on species richness than their relative abundance. Therefore, this research is of immense importance in biodiversity conservation. The conservative measures for tree species need identifying the species within that region that are vulnerable to loss of habitat.

Since fragmentation has impact on diversity and distributions of tree species. Ecological approach towards biodiversity conservation is required. Therefore, "Ecosystem-based management" is recommended as an approach to ensure sustainability of indigenous tree species in the rainforest.

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