ASSESSMENT OF HABITAT FRAGMENTATION IMPACT ON COMMUNITY TABOO SPECIES FOR ADOPTION AS CONSERVATION PORTFOLIOS IN LOWLAND RAINFOREST ECOLOGICAL ZONE OF DELTA STATE, NIGERIA

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Abstract

This study examined the impact of forest loss by fragmentation along four communities that taboo the species of primates and reptiles. Data by survey at three sighting regimes in a3×2×5 factorial experiments were square root-transformed before the analysis of variance and significant means separated at 5% level of probability with the Duncan multiple range tests. The fineness/coarseness of forest corridors and edges, availability of propagules and a-subjective habitat-matrix score for 7 key attributes of forest fragmentation along with soil samples analyzed for CEC, exchangeable cations and Ca-Mg ratio. Results showed higher mean population sighted in corridors than that of the edges. Propagule availability was Ugili Amai-Olloh Ossisa (18.5 kg/ha) >Ugono-Orogun (16.8 kg/ha)>Umute-Nsukwa (15.2 kg/ha)>Emu Uno (10.8 kg/ha) and underpinned intact fragment as Umute-Nsukwa>Ugili-Ossisa>Ugono-Orogu> Emu-Uno for the protection of IUCN Red List vulnerable white-throated guenon (*Cercopithecus erythrogaster*) and threatened West African dwarf crocodile (*Osteollaemus tetraspis*).

Key words: Habitat fragmentation; Taboo species; Forest corridors and edges; Propagules.

INTRODUCTION

Habitat fragmentation and increased edge effects constitute endemic alteration on landscape integrity and sources of biodiversity leakages from protected areas to free community forest areas with varying degrees of threats and extinction (Almond *et al*. 2020, Noss 1987). Fortunately, the communities that taboo biodiversity often create safe landing for sustained viable population even though with minimal knowledge of likely disturbance regimes that are critical to habitat protection and sustainability. These communal fragments of special scientific interest represent strategic framework for the conservation of remnant forest ecosystem patches among increasing ecosystem degradation by fragmentation.

The earlier legislation and gazette of forest estates with different needs to constitute forest reserves was particularly carried out in the colonial and military administrations across Nigeria to particularly control forest fragmentation. These defined forest fragments were constituted, managed and sustained for uniquely different habitats, biotas with target taxa in the different ecological zones to serve as sources of forest minor produce, ecological and environmental shields until the last two decades when the effects of edges and isolation set deforestation and dereservation, respectively crept into undermine the various objective of sustainable forest management (Rodriguez *et al.* 2021, Akansanmi 2006). Unfortunately, the significant anthropogenic land bridges in the last three decades led to severe incursions on existing defined fragments of forest estates at an alarming rate since no new constituted forest reserves have either been created or reconstituted by redefinition to enclose diminishing fragments.

Even though fragment ages are often not relied upon in the administration of critical forest resources in the Nigeria, the documented evidence reported in Onochie (1984) on the distribution of forest reserves across the six geopolitical zones of approximately 99,991.92 km^2 with the south-south, south-west, north-east and south-east representing 15.61%, 16.69%, 6.55% and 1.63%, respectively creates a uniform assessment of the coarse and fine-filter fragmentation nature. In Delta State, the proportion of forest reservation along the ecological divide range from 60%, 10% and 30% in the lowland rainforest, swamp forest, and freshwater, respectively (FAO 2020) land cover status has significantly declined to 48.2%, 51% and 43.2% due to increased anthropogenic land bridges in 2008, 2012 and 2016, respectively for infrastructures, agriculture, poor management owing to boundary disputes and inconsistent forest regulatory framework that had no bearing with suitable scientific policies (Egwunatum *et al.* 2014). Consequently, protected habitats for the survival of wildlife and biological diversities were lost by internalized fragmentation approach that accounted for the migration of endemic species in various ecological zones to seemingly safer regions for survival, especially in the terrains with difficulty in forest resources exploitation, especially lumbering.

Accordingly, the 24 species of mammals, 23 species of primates, 839 bird species endemic to renowned ecological fragments in Nigeria (Oni 2006), risk various scale of threats as may be allowed by the features of fragmented communities as influenced by individual vulnerabilities. The survival of migrating species, especially terrestrial species have been reportedly anchored on the receipt of individual community forest fragments that have been designated as either "evil forest or tabooed sacred forest" in local areas. The distribution of taboo and sacred forests vary in cultural belief often ascribed to the ancient historical folk tales and events that individual community hold strongly. The viable populations of bio-diversity have been reported in these community forests and have been relied upon as pragmatic framework for the realization of *in-situ* conservation in documented climes (World Resources Institute 2005). In addition, there are other communities that strictly taboo different wild life species. There are forest areas, often relatively intact, that are referred to as "evil forest" and restrictions are enforced to maintain "sanctity of the spirit" and thereby avoid de-reservation by "mortal men". Documentation of these have been absolutely oral, even though these proliferate the numerous ecological zones of the tropical forest area as tradition often hold way in the face of modern religion.

Traditional ecological knowledge therefore creates a driving platform for the integration of local sites of special scientific interest into existing conservation portfolio. Although traditional ecological knowledge has been relatively exploited in land-use practices for high agricultural production as in shifting cultivation, seed storage, local soil mineralization and mulching techniques, its engagement and conservation barely contradicts in negative sense vulnerability as the risk communities are faced due to transformation by extractive uses (Margules and Pressey 2000). The intensive use of forest trees species especially the roots, barks and trunks by direct extraction and collection for fifty medicinal purposes has been reported as a major source of biodiversity loss leakage that breed both threat and extinction in Nigeria ecosystem due to habitat loss (Umar *et al*. 2013, Odugbemi *et al.* 2017).

Approximately, 17 groups of wildlife species have reportedly witnessed population changes over the last ten decades (NBSAP 2001) with significant decline among the primates notably adduced to hunting for bush meat, international trade and the crocodiles (Crocodylidae) attributed to overharvesting. The

purported lost benefits were basically tied to tourism, genetic diversity and skins which to a large extent constitute the sources of economic revenue to the nation. However, the critical issues of habitat defense for the conservation by reduction of ecological distortions within fragmented forests and engagement of alternative products of forest origin to minimize pressure on the habitat encroachment linked to protected reserves and national parks within individual ecological zones. Article 8(a) of the Convention on Biological Diversity succinctly relies on the precautionary principle that the absence of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize observable threats of the significant reduction or loss of biological diversity. Therefore, the availability of communal interest expressed as taboo for these threatened species affords a safer protection route that must find intersection along the ecological zones where original habitat existed to act as possible fragmentation corridors for conservation.

Delta State in the Niger-Delta region which is Africa's largest delta, provides habitat to 6 endemic wildlife species on the IUCN Red List among which are the vulnerable white-throated guenon (*Cercopithecus erythrogaster*) and threatened West African dwarf crocodile (*Osteollaemus tetraspis*) even though significant population has been lost (SPWA 2010, Mittermeir 2010) due to intense hunting pressure, crude oil and gas exploration activities, massive deforestation in the mangrove forest and unabated harvest of key ecosystem goods and products (Olowoye and Onwuteaka 2012). The complex cultural taboo of some communities along the outer chain of barrier islands lowland rainforest ecological zone has therefore largely contributed to the sustenance of viable populations in the face of unperceived forest fragmentation threats due to the common relationship that exists between the species and host community. The delta therefore appears to be the last stronghold of these species.

Consequently, increasing fragment size as habitat protection for the conservation of these wildlife species cannot be overemphasized in the course of proposing *in-situ* conservation portfolios, especially in developing climes where forest resources are key sustainable livelihood options. It is against this backdrop that relatively intact habitat corridors and edges of forest fragments in the selected littoral communities that tabooed white-throated monkey and West African dwarf crocodile which were studied as novel formwork for the design of conservation portfolios for habitat protection and restoration. Thus the objectives of this work were to study the impact of fragmentation on the habitat and population of endemic taboo species in communities with a view to identifying suitability for inclusion *viz-a-viz* adoption as conservation portfolios in the lowland rainforests ecological zone of Delta State for functional conservation in Nigeria.

MATERIAL AND METHODS

Description of study areas

The study was conducted in Umute-Nsukwa, Ugili Amai-Olloh Ossisa, Emu-Uno and Ugono-Orogun communities in the lowland rainforest ecological zone of Delta State in the Niger Delta region of Nigeria. The average temperature range (18.10-33.6^{o}C), rainfall (>2762 mm/annum) and relative humidity (96% annually) are well documented as almost uniform although with minimal difference on the increase with the deeper littoral communities in the mangrove forest region (Egwunatum *et al.* 2014).

Umute-Nsukwa is in Aniocha South LGA on Lat. 6^{o}7´N and Long. 6^{o}29´E. It encloses a long stretch of water habitat that runs towards the boundary with Nsukwa, with standing forest connections at

Nsukwa junction along the Kwale-Warri Road. The stream forest transverses the heavy traffic route that has high crown cover which permit the aboreal movement of white-throated monkey population. The sacred forest around this transverse road accounts for approximately 6-10 ha of intact indigenous forest tree species. The Umute-Nsukwa community forest is bounded in the eastern axis by Isheagwu Forest Reserve and south by the Olloh-Ossisa grass-plain vegetation. Major species tabooed in this community is vulnerable white-throated guenon (*Cercopithecus erythrogaster*) which is protected, even though the population constitutes a significant level of pest to agricultural fields especially maize (*Zea mays*) and cassava (*Manihot esculenta*).

Ugilli-Osissa community is located in Ndokwa West LGA on 5°46´N and 6°24´E. The UgiliAmai-OllohOssisa community shares boundary on the west and east by Nsukwa and Isheagwu, respectively. Existing vegetation is denser along the Isheagwu boundary and sparse at Nsukwa axis. It narrows off in Olloh-Ossisa with significant grass-plain in Ugili-Amai, dotted with different patches of *Daniella oliveri*, *Khayas enegalensis*, and *Lophira alata* tree species that serve as habitat for the IUCN Red List Vulnerable white-throated guenon (*Cercopithecus erythrogaster*) and as nesting ground for several migratory bird species.

Emu-Uno community is situated between 5°38´-4°2´N and 6°13- 6°25´E in Ndokwa West LGA. The vegetation is highly degraded by agriculture with a lot of secondary forest and agroforestry practices especially *Hevea brasilensis* species. But, the tabooed IUCN threatened West African dwarf crocodile (*Osteolaemus tetraspis*) enjoys the habitat along marshy and protected areas of the community.

Ugono-Orogun is mixed habitat grassland with relatively intact vegetation in Ughelli North LGA on 5°31´N and 6°48´E. Crude oil exploration is the major bane to tabooed Iguana/alligator reptile population although a significant number of adjoining communities that also taboo has contributed to the conservation.

Data collection

Empirical data on the movement of tabooed species within delineated patches in fragment were collected using a total of thirty local persons in each community. These were employed to conduct the survey at the rate of ten persons per sighting regime of 2, 4 and 6 ha by transect method as employed in Legault *et al*. (2013) in each forest beat at two days interval for two weeks. The number of each tabooed species per team per ha in different beats was taken every other day for two weeks and expressed in percentages.

Focus group interviews were conducted for 15 persons in each community to assess seven key anthropogenic-habitat framework attributes capable of affecting forest fragmentation for conservation portfolios using factor scores (1-4). Mean of each attribute was taken and the final total score per community was adjudged accordingly as the relative conservation value as well as protection from habitat degradation potential.

Available propagules and soil samples from 0-15 cm depth were studied with the collection from ten strategically located points within a quadrat of 0.10 sqm at intervals within 1ha plot size in the corridors and edges of fragmented habitats in each community area. Soil samples were then bulked and analyzed for cation exchange capacity CEC, essential exchangeable cations of Ca, Mg and Mg-Ca ratios, respectively.

Data analysis

The numbers of sighted taboo species of interest per sighting regime of 2, 4 and 6 ha in two different habitat fragments per community were expressed as percentages of total species in a3×2×5 factorial design experiment. Square root transformation was carried out by taking the square root of each observation before conducting the analysis of variance (ANOVA). Significant means were separated using the Duncan multiple range test at 0.05 probability level.

RESULTS AND DISCUSSION

The status of communities for proposed conservation activities was ranked for existing forest remnant relying on vegetation maps and ground trotting information (Table 1). Umute-Nsukwa had the highest habitat diversity of 4 while Emu-Uno the least (1). The Ugili-Ossisa and Ugono-Orogun had the same habitat diversity of two. Estimated size was largest at Ugono-Orogun and least at Emu-Uno of 315 ha and 10.5 ha, respectively. Umute-Nsukwa had 28 ha.

The forest type at Umute-Nsukwa, Ugili-Ossisa and Ugono-Orogun, respectively is the mixed forest. Emu-Uno was agroforestry in nature. Endemic wildlife species with the addition of tabooed species were 3 in Umute-Nsukwa and 2 at Ugili-Ossisa.

The Umute-Nsukwa community has a relatively pristine forest while Ugili-Ossisa and Ugono-Orogun have modified. The Emu-Uno is degraded with agriculture. Ugili-Ossisa and Ugono-Orogun have an occurring grass-plain that is regular in shape even though intercepted by anthropogenic activities at different points along the different ecological zones of the State.

Table 1. Ranking of relative values of existing forest remnants for community conservation.

Ecological criteria	Umute-Nsukwa	Emu-Uno	Ugili-Ossisa	Ugono-Orogun
Habitat diversity	4	1	2	2
Estimated size (Ha)	28.00	10.50	305	315
Matrix type	Mixed-forest	Agro-forest	Mixed-forest	Mixed-forest
Endemic species	3	1	2	1
Disturbance	Relatively pristine	Degraded	Modified	Modified
Slope	Intermediate	Irregular	Regular	Regular

Effect of forest fragments on the distribution of tabooed species

The effect of different forest fragments on the mean distribution of different tabooed species is shown in Table 2. There were significant differences in the means of sighted tabooed species within and among the forest edges and corridors of the habitat fragments in different communities at different sighting regimes ($p \leq 0.05$). The highest mean (44.40) at 6.0 ha sighting regime was significantly different along forest fragments and sighting regime in Umute-Nsukwa.

In Emu-Uno, there were significant differences among the sighting regime and within forest fragments. The forest corridor at 4 ha sighting regime recorded the highest mean of 33.30 while the least mean (9.99) was recorded in the forest edge at 2 ha sighting regime. There was however no significant difference between the mean of sighted tabooed species in the forest corridors at 2 ha and 6 ha sighting regimes in Ugili-Ossisa. The highest mean of 35.0 was recorded in the forest corridor at 4 ha sighting regime while the least of 10.00 was along the forest edge habitat fragment.

Table 2. Effects of habitat corridors and edges on the distribution of Tabooed species.

Sighting Regime (ha)	Habitat fragment	Umute-Nsukwa	Emu-Uno	Ugili-Ossisa	Ugono-Orogun
2.00	Edge	11.10±0.23^{d}	9.99±1.33^{e}	10.00±1.03^{d}	14.28±1.00^{d}
	Corridor	4.44±1.02^{e}	13.32±1.00^{d}	20.00±1.05^{b}	19.04±0.75^{c}
4.00	Edge	17.76±1.11^{c}	19.98±0.72^{c}	15.00±1.24^{c}	14.28±0.52^{d}
	Corridor	39.96±0.55^{b}	33.30±1.10^{a}	35.00±1.83^{a}	23.80±2.05^{b}
6.00	Edge	44.40±2.11^{a}	23.31±0.32^{b}	20.00±0.63^{b}	38.08±0.31^{a}
	Corridor	43.56±1.45^{a}	23.45±0.85^{b}	34.75±1.56^{a}	18.98±1.38^{c}

Means ± Std Error in the same column with the same superscript are not significantly different ($p \geq 0.05$).

The 6 ha sighting regime recorded the highest mean (38.08) along the corridor in Ugono-Orogun. There was no significant difference ($p \geq 0.05$) between the mean of sighted tabooed species in the forest edges at 2 ha and 4 ha sighting regimes with the least means of 14.28, respectively. Generally, the highest mean population of tabooed species in the various communities was sighted in the third sighting regime of 6 ha. But, in Ugili-Ossisa, there was no significant difference between the population of tabooed species sighted at first and third sighting regimes. This may probably be due to the existing grass-plain vegetation that was more homogenous with dotted tree species which allowed wider movement of species. Yet, this observation was also tied only to the corridor fragments that increase protection and reduce migration as these deepen towards the center of each corridor. The populations of sighted species at the forest edge fragments were generally low in all the communities probably as a result of the degradation often associated with forest edges due to deforestation for agriculture (Putz *et al.* 2001). This underpins the need to reduce agricultural activities within the individual forest edges to accommodate more taboo species cannot be overemphasized. This may have accounted for the poor population of species sighted in Emu-Unor community even with the intact corridor forest (Ogar *et al.* 2016).

The protection of taboo species in the respective fragments showed higher potential in the corridors probably as a result of the available forest patches particularly in the study areas with a high proximity to sacred forest fragments, such as in Nsukwa axis with some pristine forest located within a topo-edaphically heterogeneous community. Significantly, the combination of these characteristics may have contributed to creating safer habitats by acting as forts against intrusions of anthropogenic activities (Sundqvist *et al*. 2013, Méndez-Toribio *et al.* 2016, Jucker *et al*. 2018). Furthermore, the running streams that are well connected between Umute-Nsukwa-Iseagu provide another foraging route with evergreen canopy tree species. Even though intercepted by roads, the several connecting culverts on ground as well as the wide-band canopy connectivity make arboreal movements easy, especially for the primates.

Matrix of habitat and anthropogenic activities on conservation

The disturbance regimes within the fragments in various communities are depicted in Fig. 1. It was Umute-Nsukwa>Ugili-Ossisa = Ugono-Orogun> Emu-Uno for fire. With respect to hunting and poaching for wildlife it was Ugono-Orogun>Ugili-Ossisa = Umute-Nsukwa = Emu Uno. Agriculture was Umute-Nsukwa = Ugili-Ossisa>Ugono-Orogun> Emu Uno while fuel-wood collection was Ugili-Ossisa = Emu Uno = Ugono-Orogun. The presence of exotic species was highest in Emu-Uno and uniform in the other communities.

The matrix of anthropogenic influence showed that Umute-Nsukwa, Ugono-Orogun and Ugili-Ossisa were revealed to have the highest values for fire/agriculture, hunting/poaching and fuel-wood

harvesting, respectively. The combination of fire and agriculture in Umute-Nsukwa may not be unconnected with the acquisition for new forest area for farming as well as the maintenance of the same overtime by burning to elicit for soil nutrients. Furthermore, fuel-wood harvesting was depicted in the Ugili-Ossisa communities as a crucial anthropogenic issue on habitat formwork and this finding is lined with Egwunatum and Nwafor (2014) that reported poor sighting of migratory bird species in grass-plain as a result of an increasing loss of standing forest trees species to fuel-wood extraction merchants.

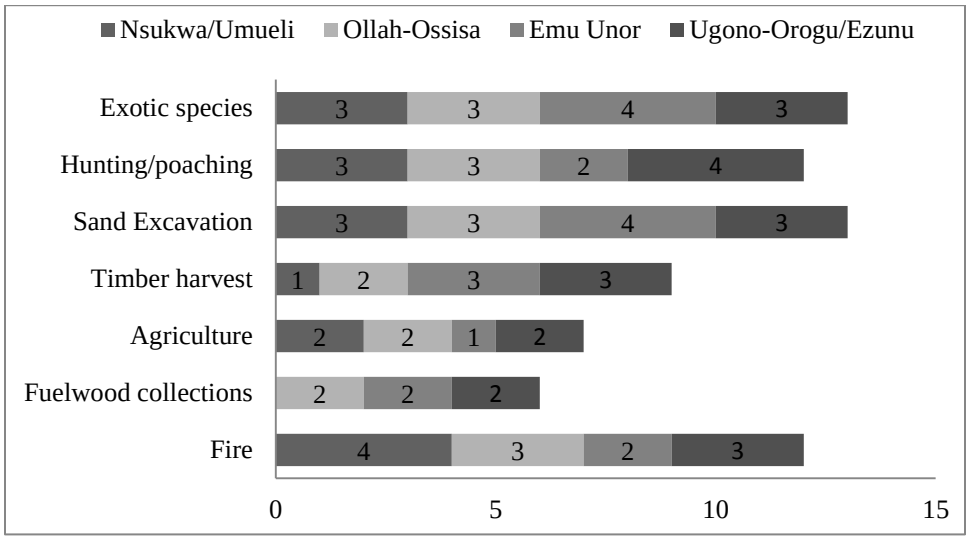

Fig. 1. Anthropogenic impact matrix of contemporary habitat fragmentation attributes in studied communities.

Evaluation of forest soil-fragment restoration potential

The forest soil habitat matrix for the various communities is shown in Table 3. The highest and least cation exchange capacity (CEC) of 18.30 meq/100g soil and 5.25 meq/100g soil at the forest edges was recorded in Ugono-Orogun and Umute-Nsukwa, respectively. The forest corridors in Ugono-Orogun and Emu-Uno had CEC of 20.40 and 12.11meq/100gsoil, respectively. The highest and least Ca along forest edge habitat was recorded in Ugono-Orogun (13.50) and Umute-Nsukwa (2.43) while it was Ugili-Ossisa (16.52) and Emu-Uno (8.77), respectively at the corridors. Magnesium recorded the highest value along the forest edges at Umute-Nsukwa (1.83) and least (1.14) at Emu-Uno. The forest corridors had the highest Mg (2.83) at Ugono-Orogun and least (0.93) at Emu-Uno.

The Ca-Mg ratio along the forest edges of communities was widest (10.23) and narrowest (1.33) at Ugono-Orogun and Umute-Nsukwa, respectively. The available propagules were least (10.8 kg/ha) and highest (18.50 kg/ha) at Emu-Uno and Ugili-Ossisa, respectively. Within each community habitat fragment, the corridors showed wider value except in Ugono-Orogun where it was reversed. Whereas between the two habitat fragments in each community, all forest corridors showed higher CEC and exchangeable cations as well as wider Ca-Mg ratio except in Ugono-Orogun. The higher CEC in corridors may not be unconnected with the richer nutrient capacities and compositions due to more remnant forest tree vegetation than in the edges of the same habitat in various communities. This is because forest litters represent the pool potential sources of soil nutrient enrichment in forest ecosystem (McDonald 2003) particularly for the restoration of degraded habitat fragments. Forest litters at the

edges of fragmented habitats provide nutrient for interaction with wildlife wastes for the initiation of natural forest successions in less disturbed forests.

Table 3. Forest soil habitat matrix for restoration of degraded communities.

Community	Habitat fragment	CEC (Meq/100g soil)	Ca^{2+}	Mg^{2+}	Ca/Mg ratio	Propagules available (kg/ha)
Umute-Nsukwa	Edge	5.25	2.43	1.83	1.33	15.20
	Corridor	13.10	10.12	2.40	4.23	
Ugili-Ossisa	Edge	14.60	10.14	1.67	6.07	18.50
	Corridor	18.33	16.52	1.33	12.42	
Emu-Uno	Edge	11.20	5.63	1.14	4.94	10.80
	Corridor	12.11	8.77	0.93	9.43	
Ugono-Orogun	Edge	18.30	13.50	1.32	10.23	16.83
	Corridor	20.40	15.31	2.83	5.41	

Furthermore, the nutrient retention capacities as expressed by the CEC and Ca-Mg ratio suggested the type of habitat grains in the different forest fragments. Higher nutrient retention capacity could typify luxuriant forest structure and fine-grained habitat patches compared to a more degraded coarse-grained fragments that loss nutrient both to the environment and internally due to downward leakages as a result of narrow Ca/Mg ratio. This finding is in line with Asadu and Akamigbo (1990) that reported a correlation between soil nutrient retention and exchangeable cations in degraded forest ecosystems. Although the forest edges showed lower values, the usual nutrient compensations from boundary corridors often serve as leeway for the transfer of energy resources from medians especially by remnant wildlife population for restoration and regeneration activities. Consequently, the corridors in each fragmented habitat may have contributed to greater proportion of available propagules estimated in the different fragments in view of community restoration and succession (Scheffer *et al.* 2001). Ugili-Ossisa habitat parchments, with notably over two habitats had the highest propagules compared to the least in Emu-Uno probably as a result of heavy degradation and deforestation which has been modified to accommodate agroforestry practices to the detriment of the root rhizosphere region (Dupuch and Fortin 2013). Hence, the coarse-grained habitat in Emu-Uno represented the least with conservation value among the communities studied for selection as sites of special interest as a result of fragmented forest landscape ages, varying degrees of connectivity alter and then reduce population matrix to present an ecosystem interlaced with bio-anthropogenic processes to initiate discontinuities and accounted for low sighted species even within a wider fragment.

The four communities have potentiality as conservation portfolios for white-throated monkey and dwarf crocodile with Umute-Nsukwa as the best for these tabooed and IUCN threatened species in Delta State. Habitat fragmentations in the communities, however, revealed that Emu-Uno had the least characteristics to sustain viable population although with the highest available propagules for habitat restoration and forest succession. The choice of conservation location within community is critical to the survival of existing taboo species. The corridors demonstrated the most enriched and suitable habitat fragment for the possible erection of conservation portfolios in the respective communities. Consequently, all the communities have notable sites for conservation and the rich corridors mapped for possible intersection on remnant rich ecological zones with perceived relics of endemic species for adoption as local sites of special scientific interests in the State for wider protection of biodiversity in Nigeria.

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