Bat Community Response to Forest Loss and Habitat Conversion in Southern Cameroon

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INTRODUCTION

One of the major challenges of wildlife ecology is to understand the interactions between animals and their environment. For many species, survival and distribution depend on abiotic and biotic factors. To date, habitat loss of native forest habitat, agriculture and various development projects are a primary threat to the long-term persistence of many species (Whitmore 1997). It affects species richness and abundance (Cosson et al. 1999), forest structure (Echeverria et al. 2007), and can result in species extinction (Laurance et al. 2002; Turner 1996). In Central Africa, the rate of habitat loss due to human activities is particularly fast (Brooks et al., 2002). Indeed, the requirements of increased food production in the last half of the twentieth century have led to major changes in land use, frequently involving fragmentation and loss of forest habitats (Racey and Entwistle, 2005). If animal community responses to habitat conversion have been largely studied in many tropical areas, the negative effects of gradual loss of African forests on animals are poorly documented. Such studies are needed in Africa to develop conservation strategies of many species.

Bats are the only group of mammals with powered flight, which allows them access to various habitat types. They are characterized by a remarkably long lifespan and a low reproduction rate which makes them suitable indicators of the state of ecosystem (Medellin et al., 2000). It is well known that many populations of bats have declined in their natural habitat for reasons that are poorly understood (Racey and Entwistle 2003). With some 1300 species, bats are the second most diverse group of mammals (Simmons 2005). Despite their high diversity, they are currently the most persecuted group of vertebrates in the world. Because of their abundance, diversity and range of responses to habitat change, bats have been recognized as an ideal group with which to study the effects of fragmentation in tropical forests (Meyer *et al*., 2010).

Cameroon occupies a unique geographical position between west and Central Africa. This country is characterized by different phyto-geographic zones and 48% of Africa's known mammals. The bat fauna of Cameroon has been investigated for many decades. However, despite the huge collection material deposited in various museums, our knowledge about the ecology, distribution and biology of the bat fauna of this country is still very fragmentary. Indeed, most of the recent studies in this country have yielded new faunistic records (Sedlacek 2006; Bakwo fils 2009; Bakwo Fils et al 2012; 2014; LeBreton et al 2014) and even new species (Hassanin et al, 2014). Yet, bats are animals that rarely make it onto the agenda of policy makers. Therefore, there is a real need for a policy environment that recognizes their fundamental role in seed dispersal, pollination, and pest insect's suppression. The lack of knowledge about most species hinders s the development of such conservation plans. In Cameroon, bats face a high risk of extinction due to hunting, persecution and habitat destruction.

Objectives

The goal of this project was to evaluate the effects of habitat conversion on a bat assemblage in the Dja reserve in order to predict future trends in the distribution and abundance of bat species with regard to increasing deforestation.

Specifically, the work aimed at:

- Providing a checklist of bat species encountered within different habitats of Southern Cameroon and which can be compared to the distribution patterns of bats found in the north of the country;
- Determining bats roosting and foraging habitats in Cameroon;
- Analyzing changes in species abundance and distribution across a land-use gradient in southern Cameroon.
- Predicting potential range shifts for the bat species found in southern Cameroon (including present and future models);

- Providing recommendations to the authorities in charge of wildlife protection in order to elaborate and orient conservation strategies for these species.

MATERIAL AND METHODES

Study Site

With its 526 000 hectares, the Dja Biosphere Reserve (figure 1) is the largest protected area in Cameroon and is an UICN biosphere reserve (UICN, 1987). The vegetation is described as a semi-deciduous lowland tropical rainforest (Letouzey, 1968) elevated between 400 and 800 m. The climate is characterized by two wet and two dry seasons, with major and minor rainfall peaks generally occurring in October and May respectively. Four main habitat types occur in this reserve: Upland forest; *Rapphia* swamp; *Uapaca* swamp and the inselberg associated forest. During the last decades, activities such as continued human migration to the area, deforestation resulting from unsustainable commercial logging activities, clearance of the natural vegetation to provide land for commercial and subsistence agriculture, illegal hunting and trapping, and uncontrolled bush burning have led to a serious degradation of the vegetation. These changes have inevitably affected the resident fauna including bats.

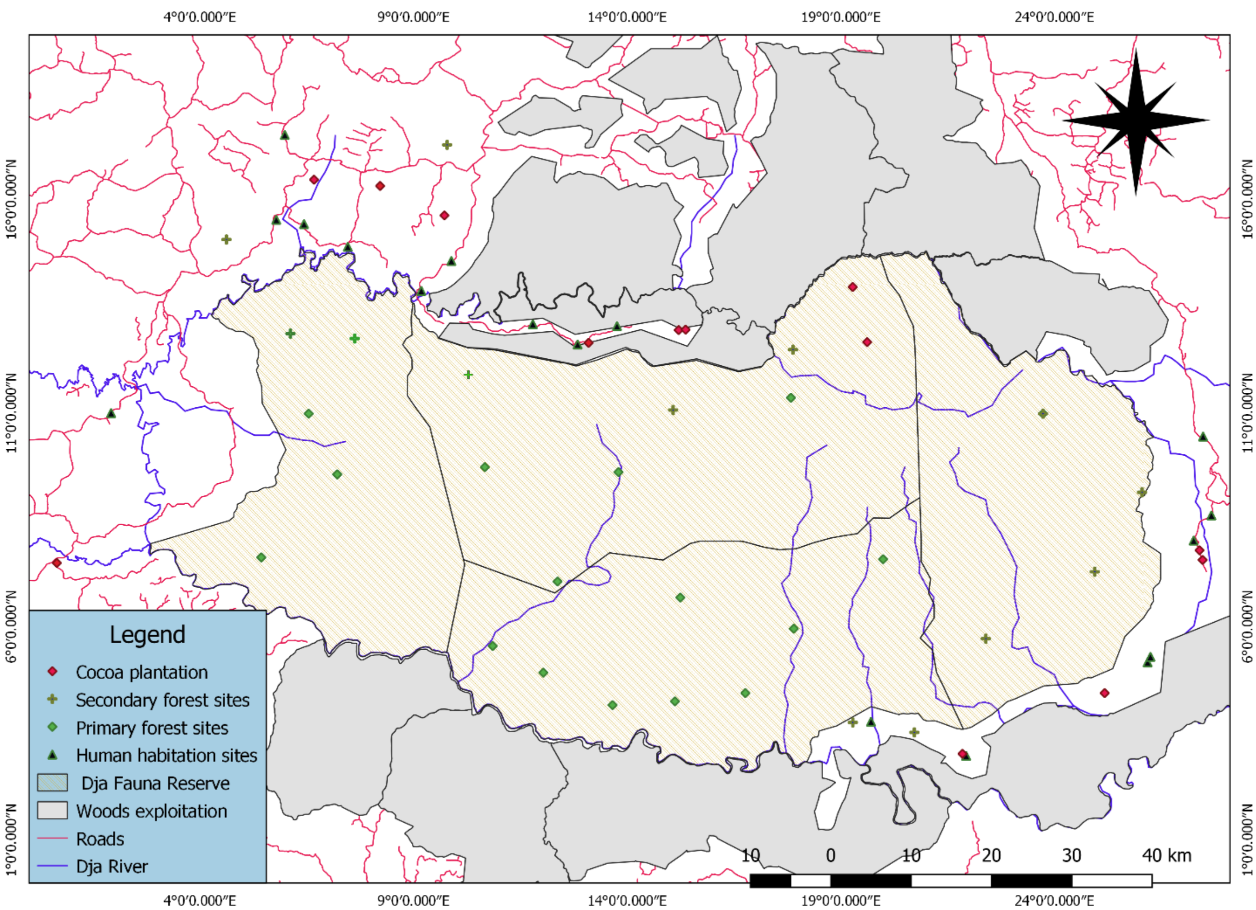

Figure 1: *Map of Dja biosphere reserve showing sampling sites*

Field Work

Sampling was conducted over 24 months. Each habitat (: primary forest, secondary forest, agriculture clearing and human settlement) was sampled monthly for bats species and their abundances (figure 2 and table 1). Each sampling event was consisted of capturing bats during seven consecutive nights using ten mist nets per site (ground-level nets and canopy nets). Mist nets were checked every fifty minutes from 6: 00 pm to midnight. Each individual caught was kept in cloth bags and subsequently weighed (Pesola balance, nearest 0.5 g), measured (forearm, nearest mm), aged (adult or juvenile based on ossification of phalanges) and sexually identified before being released. We did a punch mark (with a code in the left wing) to each individual before release (Bonaccorso and Smythe, 1972) in order to identify bats that would be captured more than once. We also investigated caves located at the Swarm, Mintoum, Somalomo, kompia and Nemeyong villages in the northern and southern part of the Dja Biosphere Reserve and in eight trees located in the Nsimalen (western part), Mintoum (easthern part) and Malen I (northern part) villages. These roosting sites were investigated during the day where five species (*Doryrhina cyclops*, *Hipposideros ruber*, *Hipposideros caffer*, *Nycteris hispida* and *Nycteris thebaica*) were observed. Identification was done on the basis of morphometrics. We used identification keys of Rosevear (1965), Hayman and Hill (1971), and Paterson and Webala (2012) for morphometric identification. Skin samples from the wing membrane were collected for genetic analyses. This was done on living bats using non-lethal Stieffel 3mm biopsy punches (Pierce and Keith, 2011).

Figure 2*: A view of some different habitats investigated in the Dja biosphere reserve*

Data Analysis

Monthly abundance indices of each bat species were determined. Species diversity estimations were calculated with Estimate S 9.0 (Colwell, 2009). We constructed Rank-abundance curves to compare the number of species, their relative abundances, the number of rare species and the equitability in each habitat type (Stoner, 2005). Species richness was compared among habitats by calculating rarefaction null models, (Gotelli & Colwell, 2001). Species composition was compared with a nonmetric multidimensional scaling (NMDS) and analysis of similarity ANOSIM, (McCune et al., 2002). To analyze individual species responses to the disturbance gradient, we compared the abundance of each habitat. At the spatial scale, we considered each habitat as a resource state available for bats and assumed that capture rates reflected resource use by each species. To investigate the effects of habitat and season (big dry, small dry, big wet and small wet) on the abundance and richness of bats, we used generalized linear models (GLM). Habitat, season, and their interaction were considered the explanatory variables. Abundance and richness of bats were pooled by season and used as dependent variables in separate models. The minimum adequate models were obtained by the exclusion of the non-significant variables from the full models. Models were then subjected to residual analyses to determine the adjustment of the error distribution and then compared with a null model. Models with statistically significant differences were subjected to a contrast analysis, pooling the qualitative terms that were not significant (amalgamation; Crawley 2007). All models used to test abundance and richness were adjusted to a quasi-Poisson error distribution. To model potential present and future (30 years later) bat distributions in the Dja Biosphere Reserve, maximum entropy modelling (Maxent) was used to highlight habitat suitability in order to determine which Eco-geographical variables influence their distributions. Predictive maps have been generated using our fieldwork data, and a suite of potential environmental predictor variables (including geological, topographic, land cover physical and climatic data).

RESULTS

Bat Assemblages

A total of 549 bat individuals belonging to four Families, 16 Genera and 25 species were captured (Table 1). Of these, 19 species were captured in primary forest. Despite the high number of species in primary forest, more individuals were captured in human habitations (n=206), mainly due to the high abundance of *Megaloglossus woermanni* (n=61). Overall, *Megaloglossus woermanni*, a nectarivorous bat was also the most common (23.31%, n=117), followed by *Epomops franqueti* (19.497%, n=107) and *Roussettus aegyptiacus* (16.39%, n=90). Insectivorous bats represented 33.15 % of the total sample, while frugivorous represent 66.85%. Nevertheless, at the species level, the insectivorous represent 68% of the sample while the frugivorous represent 32%. Primary forest was the habitat type with the highest number of species (19 species) followed by Agricultural clearing (15 species), Human habitation (11 species) and Secondary forest (8 species) (Table 1).

Table 1: *occurrences within the four habitat types and the four seasons the Dja biosphere reserve.*

Espèces	BWS				BDS				SWS				SDS		
	PF	SF	HH	AC	PF	SF	HH	AC	PF	SF	HH	AC	PF	HH	AC
Frugivores															
Casinycteris argynis	0	0	0	0	0	1	1	1	1	0	1	0	0	0	**0**
Epomops buettikoferi	1	0	1	0	0	0	0	0	0	0	0	0	1	0	**0**
Epomops franqueti	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**
Hypsignathus monstrosus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**0**
Megaloglossus woermanni	0	1	1	1	1	1	1	1	0	0	1	1	1	1	**1**
Myonycteris angolensis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**0**
Myonycteris torquata	1	1	0	1	1	1	1	1	1	0	1	1	1	1	**0**
Roussettus aegyptiacus	0	1	1	1	1	1	1	1	0	1	1	1	1	1	**0**
Insectivores															

Doryrhina cyclops	0	1	0	1	1	1	0	1	0	1	0	1	0	0	**0**
Glauconycteris albogutata	0	0	0	0	1	0	0	0	1	0	0	0	0	0	**0**
Glauconycteris argentata	0	0	0	0	1	0	0	0	1	0	0	0	0	0	**0**
Glauconycteris sp.	0	1	0	0	0	1	1	0	0	0	0	0	0	0	**0**
Hipposideros cf caffer	0	0	0	0	1	0	0	1	1	0	0	0	1	0	**0**
Hipposideros cf ruber	0	1	0	1	1	1	0	1	0	0	1	1	1	1	**0**
Macronycteris gigas	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**0**
Myotis bocagei	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**0**
Neoromicia nana	0	0	0	0	1	0	1	1	0	0	0	0	0	1	**0**
Nycteris grandis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**0**
Nycteris hispida	0	0	0	1	1	0	0	1	0	0	0	0	0	0	**0**
Nycteris thebaica	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**0**
Pipistrellus capensis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**0**
Pipistrellus nanulus	0	0	0	0	0	0	1	0	0	0	1	1	1	1	**0**
Pipistrellus sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**0**
Scotoecus hirundo	0	0	0	0	1	0	0	0	0	0	0	0	1	0	**0**
Scotophilus dingani	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**0**
Total number of species	**3**	**7**	**4**	**8**	**15**	**7**	**7**	**11**	**6**	**3**	**6**	**8**	**9**	**8**	**2**

Species diversity estimator (Chao 1) indicated species averages: 20, 20, 11.33 and 8.21 for Primary forest, Agricultural clearing, Human habitation and Secondary forest respectively. These results show that we sampled up to 90.48%, 75%, 97.09% and 97.44% of species in Primary forest, Agricultural clearing, Human habitation and Secondary forest respectively. Rarefied curves truncated at 65 individuals also suggested the same order in most species' richness (figure 3).

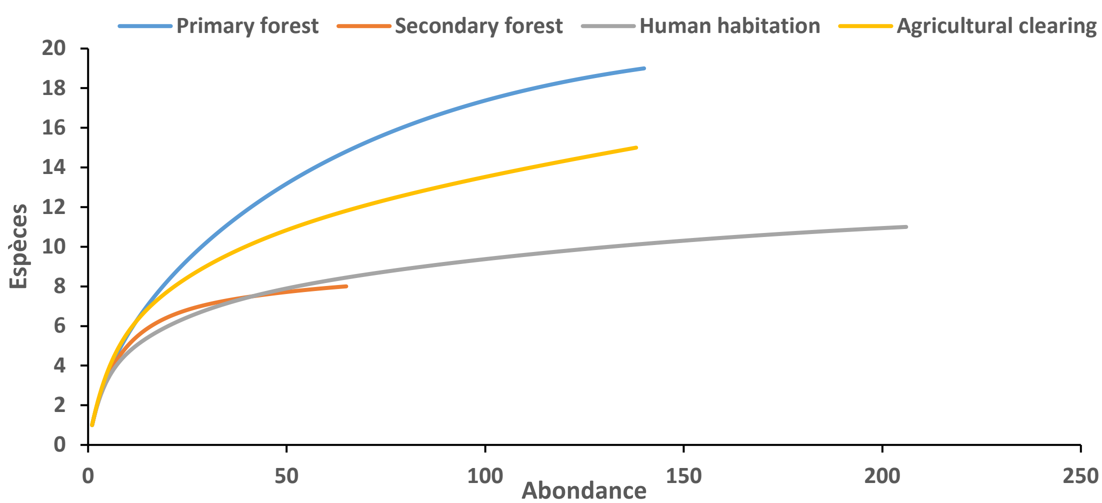

Figure 3: *Rarefaction curves of observed species richness at each habitat.*

Species diversity estimator (Chao 1) indicated species averages: 21.5, 14.5, 13 and 11.75 for the big dry season, the small wet season, the big wet season and the small dry season respectively. These results show that we sampled up to 93.62%, 93.02%, 89.66% and 76.92% of species during the small dry season, the big dry season, the big wet season and the small dry season respectively. Rarefied curves truncated at 85 individuals suggested the big dry season to be the richest season, followed by the small wet season and the small dry season. The big wet season is the poorest season in terms of species diversity (figure 4).

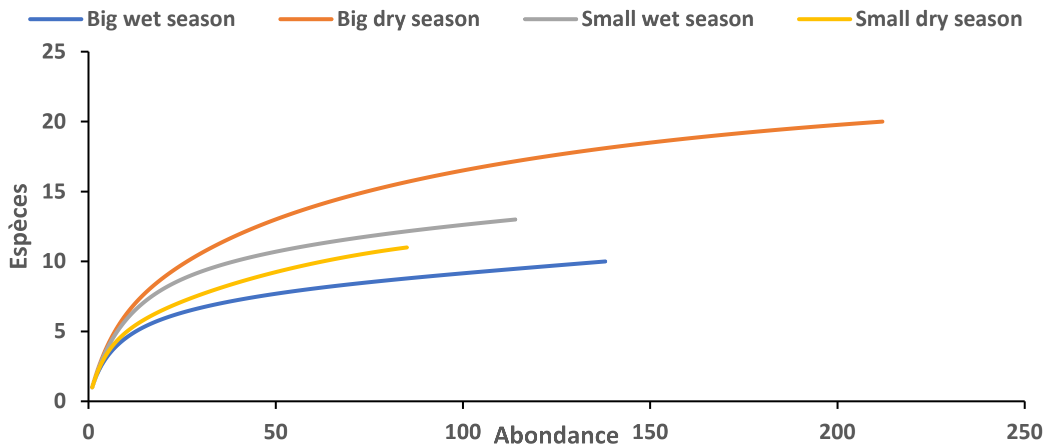

Figure 4: *Rarefaction curves of observed species richness at each season.*

Nevertheless, considering the combination between habitats and seasons, NMDS indicated that composition of species assemblages in all the four habitats was distinct (Figure 5).

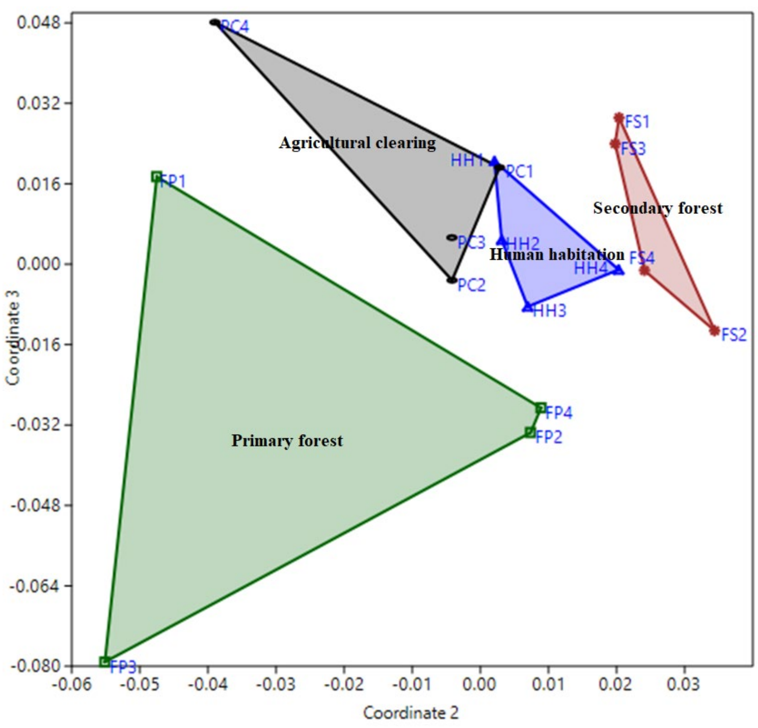

Figure 5: *Bat species assemblages of four habitat types combined by seasons along the first two axes of Non-metric Multidimensional Scaling (NMDS) ordination in the Dja Biosphere reserve.*

Differences in overall species composition were statistically significant among habitats (ANOSIM, R = 0.347, P = 0.0002), but we observed a similarity between Primary forest and Secondary forest (table 2).

Table 2: *ANOSIM test showing pairwise similarity between habitats combined by seasons*

	Primary forest	Secondary forest	Human habitation	Agriculture clearing
Primary forest	-	0.125	**0.635**	0.302
Secondary forest		-	**0.698**	0.093
Human habitation			-	0.375
Agriculture clearing				-

Rank-abundance graphs for habitats show different group of species dominating each assemblage (figure 6). *Hipposideros* cf. *ruber* was the dominant species in Primary forest with 53 individuals followed by *Epomops franqueti* (21 individuals) and *Hipposideros* cf. *caffer* (20 individuals). In Secondary forest, *Megaloglossus woermanni* was the dominant species with 23 individuals, followed by *Hipposideros* cf. *ruber* (13 individuals). *Megaloglossus woermanni* (61 individuals) was dominant in Human habitation, followed by *Epomops franqueti* (49 individuals). Agricultural clearing was dominated by *Epomops franqueti* (32 individuals) and *Megaloglossus woermanni* (29 individuals).

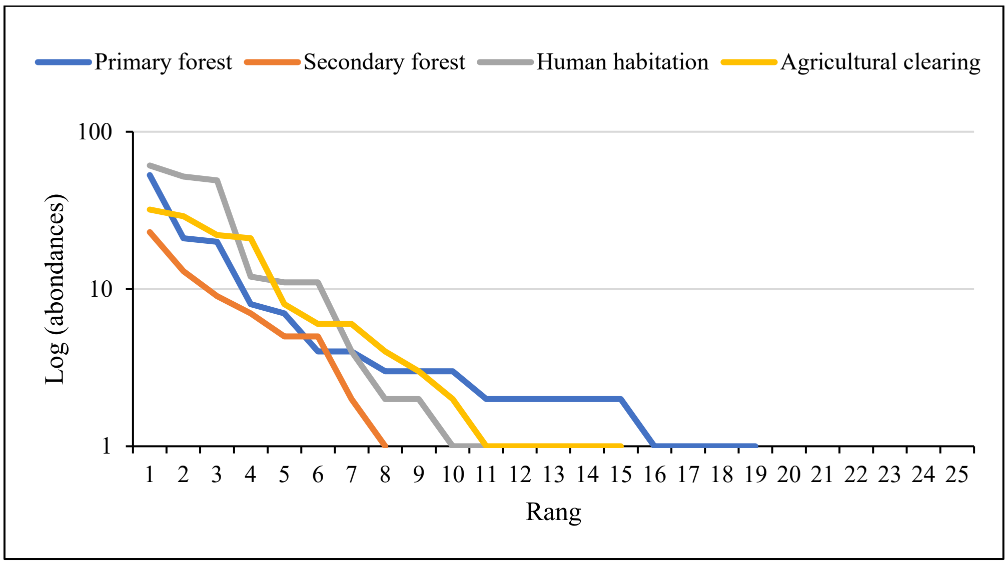

Figure 6: *Rank abundance curves for each habitat.*

Rank-abundance graphs for seasons show different group of species dominating each assemblage (figure 7). *Megaloglossus woermanni* (60 individuals) was the dominant species during the big dry season followed by *Epomops franqueti* (25 individuals) and *Rousettus aegyptiacus* (20 individuals). During the big dry season, *Epomops franqueti* (36 individuals) was the dominant species, followed by *Rousettus aegyptiacus* (34 individuals) and *Megaloglossus woermanni* (33 individuals). During the small wet season, *Epomops franqueti* was the dominant species (35 individuals), followed by *Rousettus aegyptiacus* and *Hipposideros* cf. *caffer* with 15 individuals respectively. *Hipposideros* cf. *ruber* (28 individuals) was the dominant species during the small dry season, followed by *Rousettus aegyptiacus* (21 individuals).

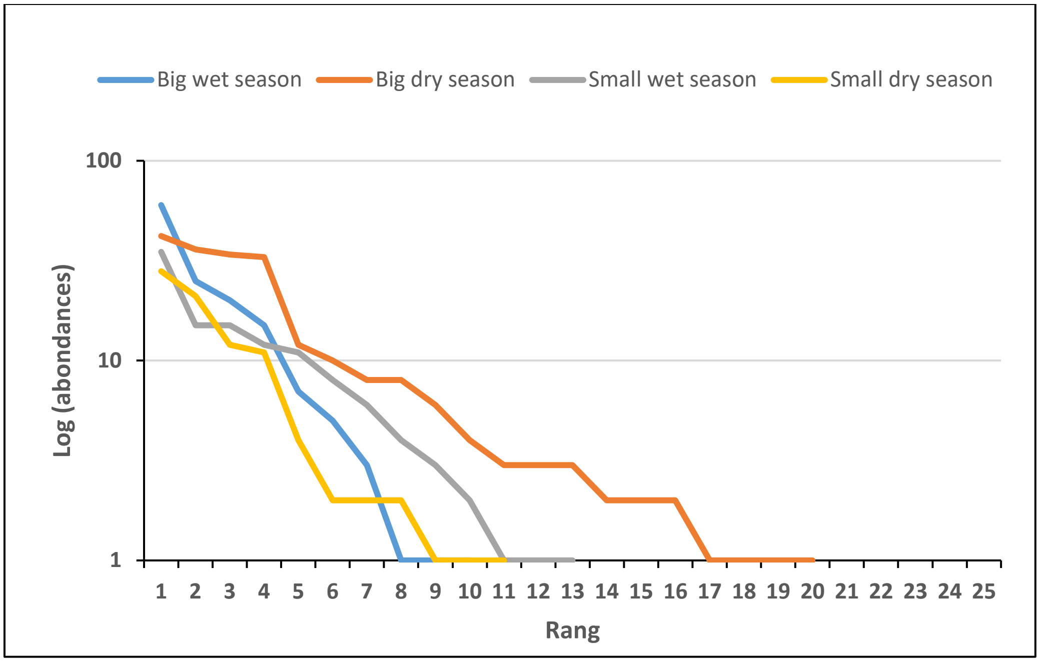

Figure 7*:* *Rank abundance curves for each season.*

Diversity of Bat Species

The Kruskal-Wallis test showed that there is no significant statistical difference in the species richness variation between different habitat types (H (chi2) = 7.28; *P*= 0.058). However, a high variability of the species richness in the primary forest can observed (figure 8). Regarding bat abundances, the difference between the four habitat types is statistically significant (H (chi2) = 10.52; *P*= 0.01419). Pairwise comparison (U test of Mann-Whitney) showed statistical differences between Human habitation and Secondary forest (*P*= 0.0028) and between Secondary forest and Agricultural clearing (*P*= 0.0197).

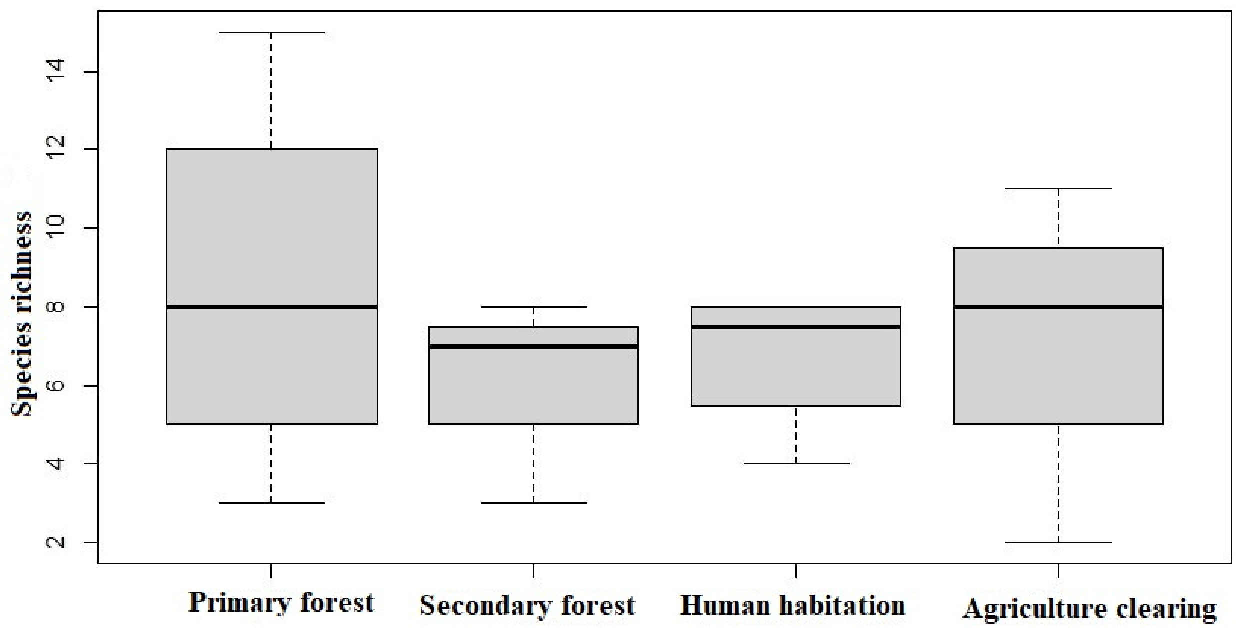

Figure 8: *Species richness variation between the four habitat types*

Using Maximum Entropy Species Distribution Modeling for Long-Term Conservation Planning

We predicted the present range and projected the range onto 2050 for 11 species of the Dja Biosphere Reserve. The presence of each bat was mostly influenced by precipitation, which determines water availability, prey abundance, mortality, and natality. Future projected ranges became more fragmented, except for *Myonycteris torquata* and *Neoromicia nana* for which an increase of their distribution could be observed in 2050.

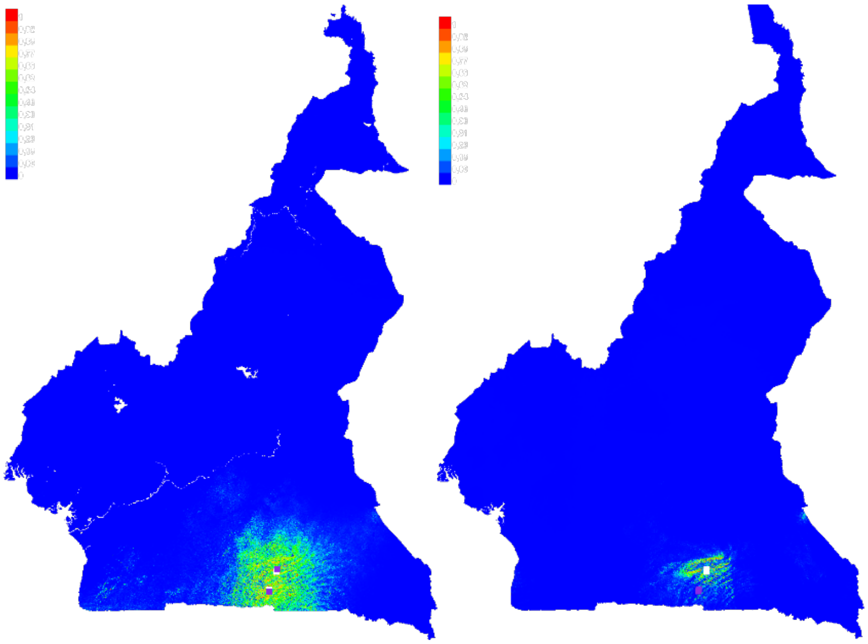

Figure 9: *present and future (2050) MaxEnt models of Casinycteris argynis. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

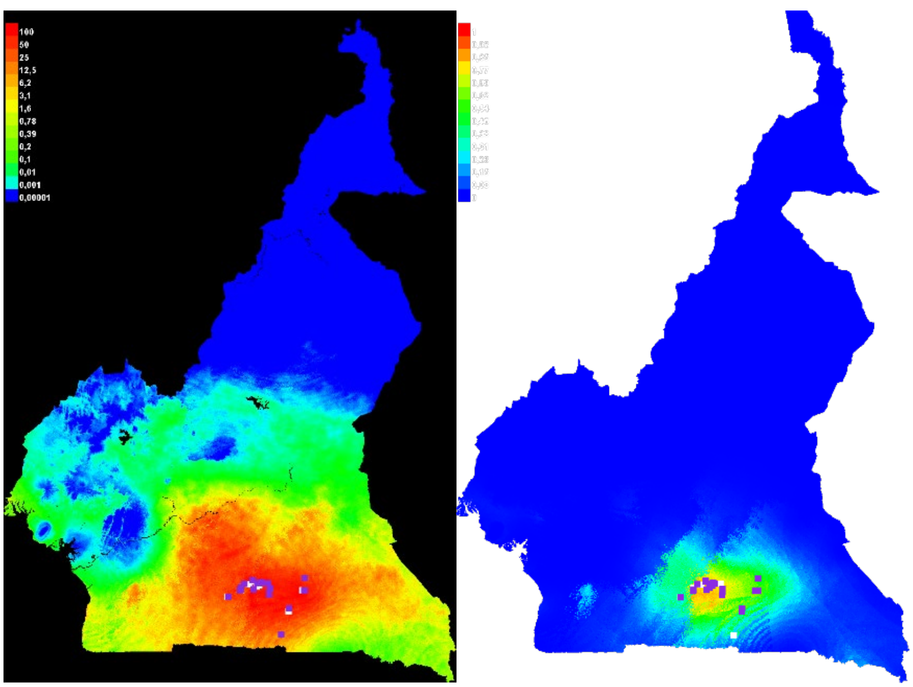

Figure 10: *present and future (2050) MaxEnt models of Epomops franqueti. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

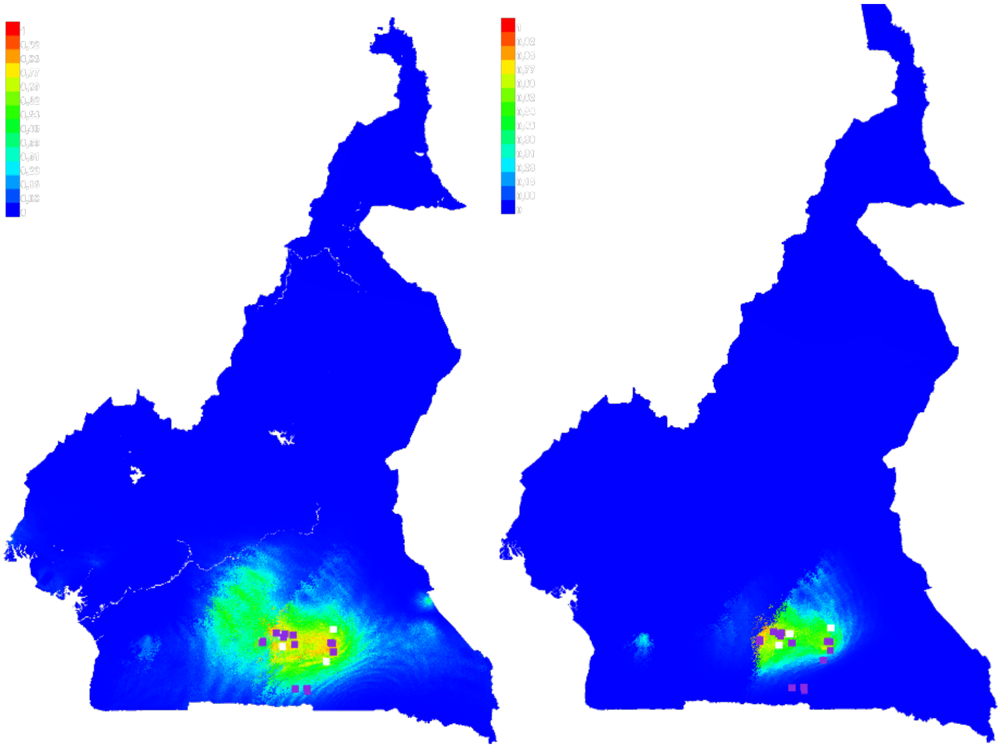

Figure 11: *present and future (2050) MaxEnt models of Megaloglossus woermanni. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

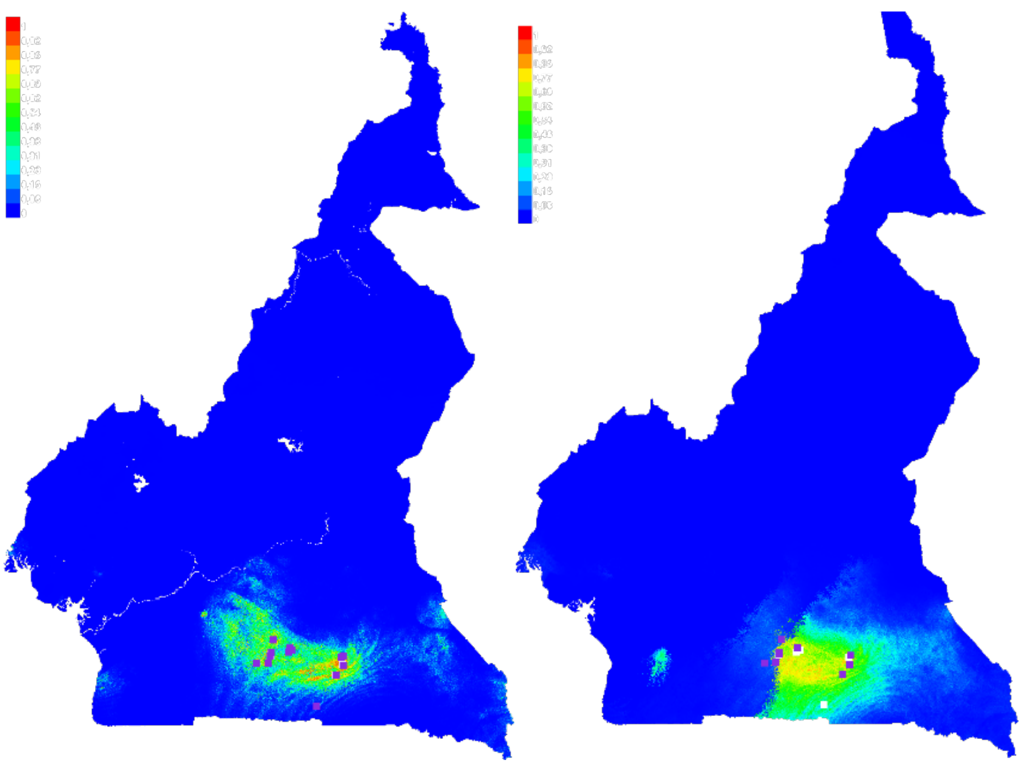

Figure 12: *present and future (2050) MaxEnt models of Myonycteris torquata. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

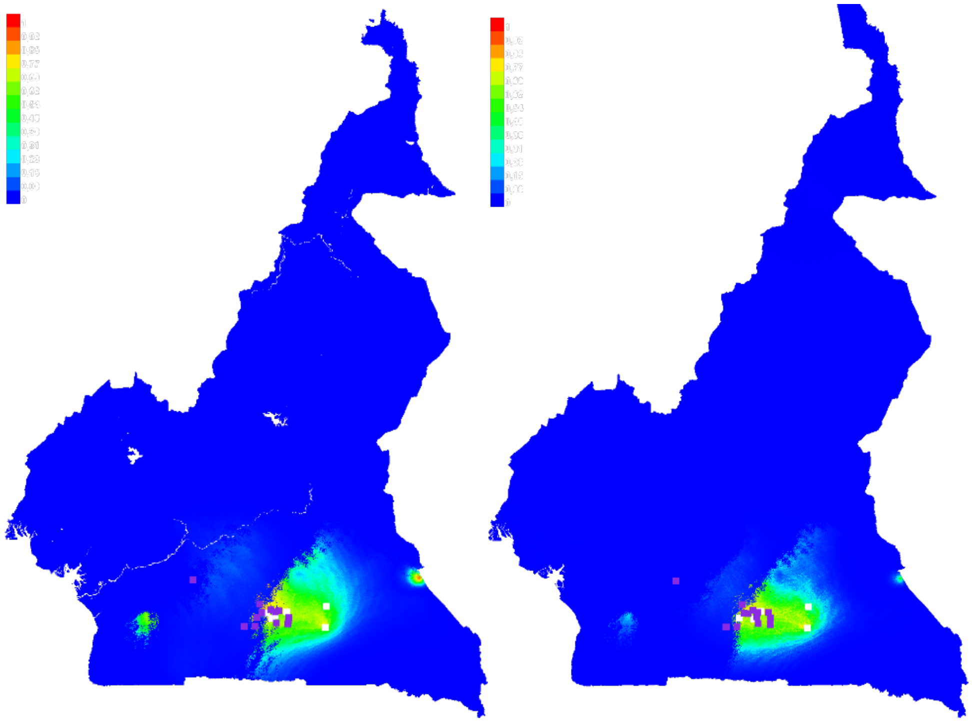

Figure 13: *present and future (2050) MaxEnt models of Rousetus aegyptiacus. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

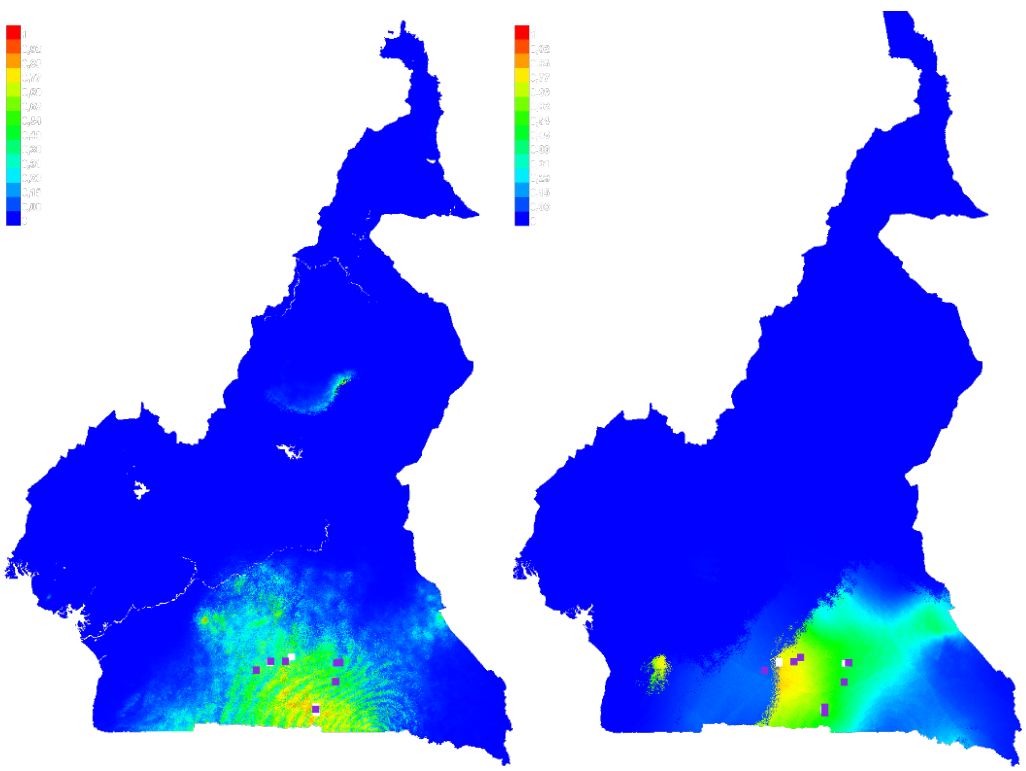

Figure 14: *present and future (2050) MaxEnt models of Dorirhyna cyclops. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

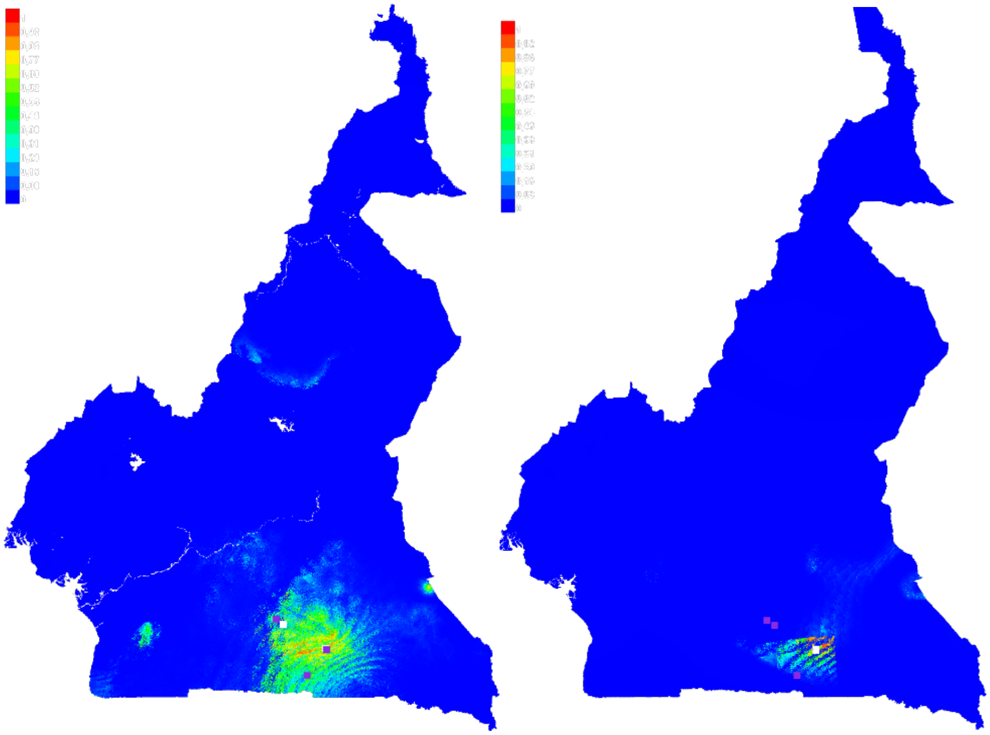

Figure 15: *present and future (2050) MaxEnt models of Hipposideros cf. caffer. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

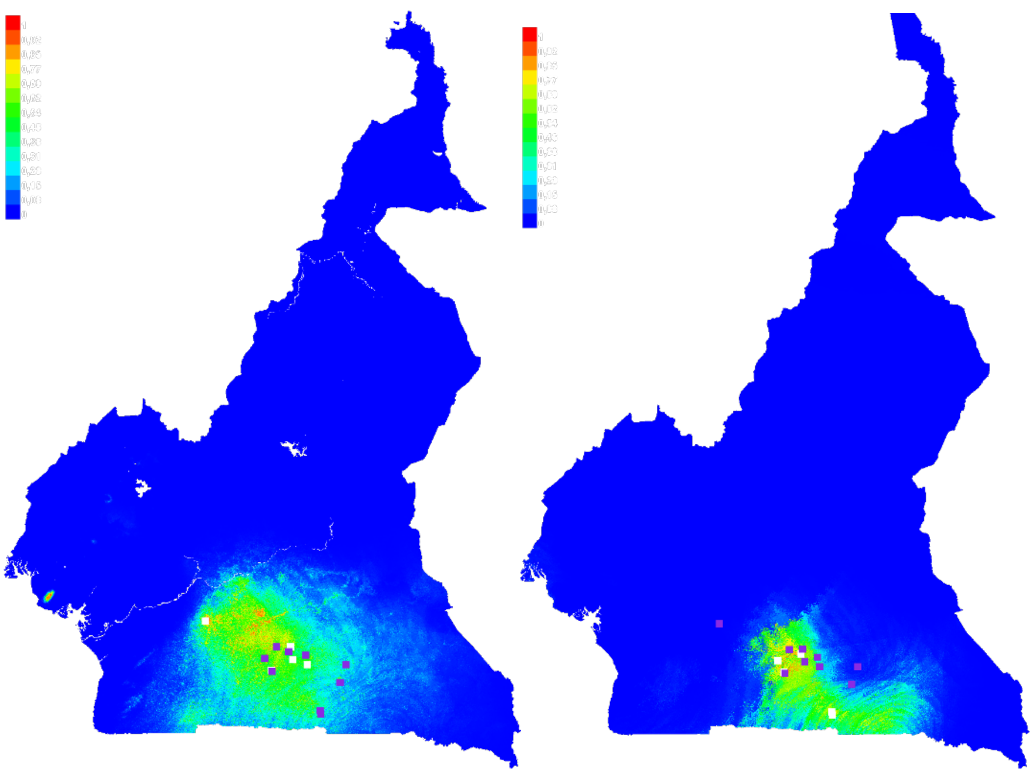

Figure 16: *present and future (2050) MaxEnt models of Hippisideros cf. ruber. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

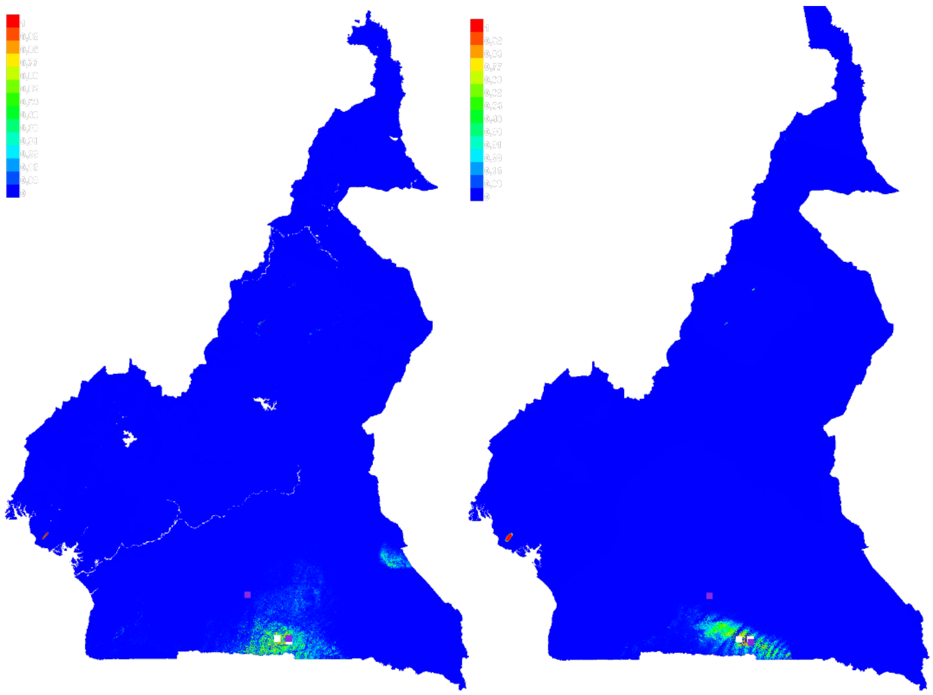

Figure 17: *present and future (2050) MaxEnt models of Nycteris hispida. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

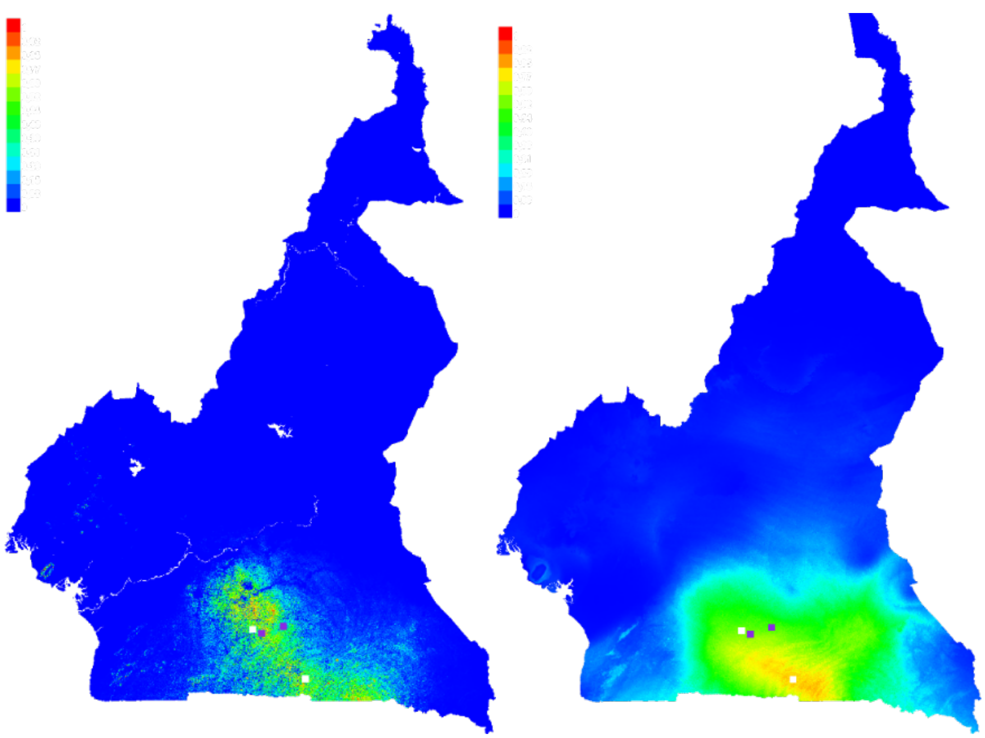

Figure 18: *present and future (2050) MaxEnt models of Neoromicia nana. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

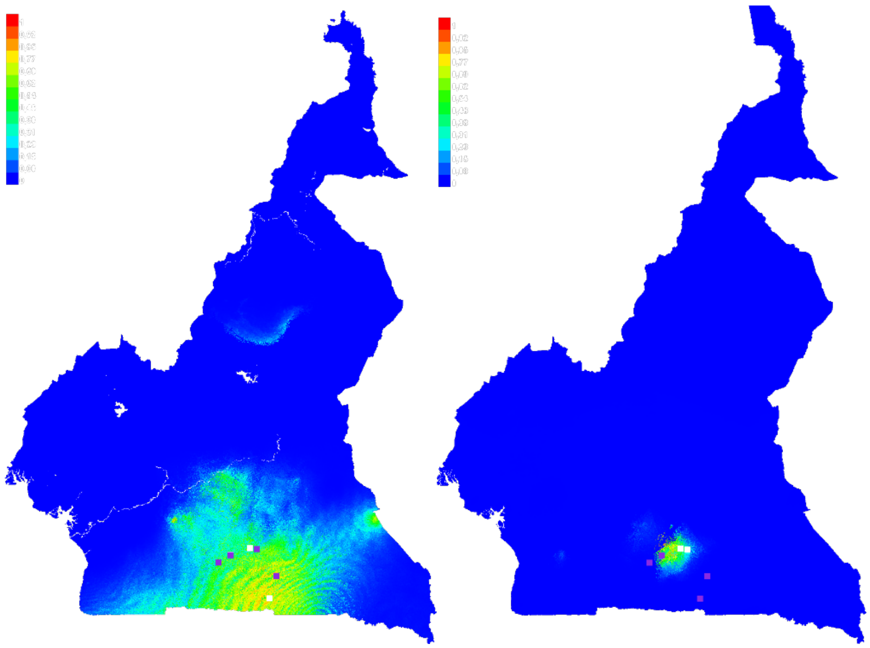

Figure 19: *present and future (2050) MaxEnt models of Pipistrellus nanulus. Areas in yellow indicate a high probability of occurrence, areas in blue indicate a low probability of occurrence.*

Awareness Campaign in Local Populations

Awareness campaigns were carried at 20 villages near sample sites. Campaigns consisted of explaining to local populations the morphology, physiology and ecological importance of bats using a living specimen. At the end of the explanation, populations were allowed to ask questions in order to be clarified on any doubts.

Future Plans as Follow-Up to this Project

1. Working with local populations of the Dja Biosphere Reserve and the authorities of forest and fauna department to spread the results of this project, and to control local threats.
2. Scientifics papers to be published in peer-reviewed journals.

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I sincerely thank the Rufford Small Grants Foundation, UK, Idea wild foundation and the Bat Conservation International (BCI) who funded this project that took me through a very important learning experience. I thank the Scientific Research and Innovation Ministry and the department of wildlife and protected areas of the Ministry of Forestry and Wildlife, for providing me research permits to study bats in the Dja Biosphere Reserve. I also thank the population and ecoguards of the Dja Biosphere Reserve for their constant help and support.

Figure 20. *Explaining to population of Mekas village, the anatomy of bat and their important role in an ecosystem.*

Figure 21: *Roosting cave containing Hipposideros* cf. *ruber in the forest (Somalomo)*

Figure 22: *Habitat degradation of bat in the Dja hBiosphere Reserve*. a: *tree containing Dorirhyna cyclops in 2018*; b: *same tree in 2020 burned by the villagers to hunt Dorirhyna cyclops*.

Figure 23: *Bat hunting in the Dja Biosphere Reserve*: a: *mosquito net used by villagers to hunt bats*; b: *Child going inside the cave to hunt bat in Mintom village*.

Figure 24: *Habitat perturbation*. a: *cave containing Hipposideros* cf. *caffer* in Schwam village; b: *fire index inside the same cave and it is empty*; c: *rifle cartridges index inside the same cave*.

Litterature Cited

Bakwo Fils Eric Moise, Alima Gibering Bol A. Anong, Donatien Badoana Tsala, Bernard Bernard Guieké,David Emery Tsala & Appolin Kuate Fotso.2014. Diversity of bats of the Far North Region of Cameroon–with two first records for the country, *Biodiversity*. 15(1). 16-22. DOI: 10.1080/14888386.2014.889578.

Bakwo Fils. E.M. 2010. Bats of Cameroon: proving the benefits of the forgotten fruit bats. *Bats*. (13): 13-15.

Bakwo Fils. E.M., Bol A Anong., Tchuenguem Fohouo fernand Nestor 2012. The first record of *Scotophilus dinganii* in Cameroon. *Biodiversity journal*. 3(1) :55-58p

Bonaccorso, F.J., Smythe, N., 1972. Punch-marking bats: an alternative to banding. *J. Mammal*. 389-390

Colwell, R., 2009. Estimates: Statistical Estimation of Species Richness and Shared Species from Samples. Version 8.2. http://viceroy.eeb.uconn.edu/estimates.

Cosson, J. F., J. M. Pons, and D. Masson. 1999. Effects of forestfragmentation on frugivorous and nectarivorous bats in French Guiana. *Journal of Tropical Ecology* 15:515–534.

Echeverria, C., A. C. Newton, A. Lara, J.M. Reybenayas, and D. A. Coomes. 2007. Impacts of forest fragmentation on species composition and forest structure in the temperate landscape of southern Chile. *Global Ecology and Biogeography* 16:426–439.

Gotelli, N. J., and G. L. Entsminger. 2001. EcoSim: null models' software for ecology. Version 6.0. Acquired Intelligence Inc. & Kesey-Bear.

Gotelli, N. J., and R. K. Colwell. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecology Letters* 4:379–391.

Hayman R. W. and Hill J. E., 1971. Order Chiroptera. In: The Mammals of Africa. An identification manual. Part 2 (Meester, J. and Setzer, H. W. [Eds.]). Smithsonian Institution Press. Washington, D.C., 1 - 73.

IUCN (International Union for Conservation of Nature). 1987. The IUCN directory of Afro tropical protected areas. International Union for Conservation of Nature, Gland, Switzerland

Laurance, W. F., ET AL. 2002. Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conservation Biology* 16: 605–618.

Letouzey, R., 1968.Etudes phyto-géographiques au Cameroun. Paul Le Chevalier, Paris.

Loayza, A. P., and B. A. Loiselle. 2008. Preliminary information on the home range and movement patterns of *Sturnira lilium* (Phyllostomidae) in a naturally fragmented landscape in Bolivia. *Biotropica* 40:630–635.

Matthew Lebreton, Eric Moise Bakwo Fils, Jean Michel Takuo and Joseph Le Doux Diffo .2014. The first record of the african sheath-tailed bat *Coleura afra* (peters, 1852) (Mammalia, Chiroptera) in cameroon with information on its ecology. *African Bats Conservation News*. 36.2-4

McCune, B., Grace, J.B., Urban, D.L., 2002. Analysis of Ecological Communities. MjM Software Design, Gleneden Beach, Oregon.

Medellin, R. A., M. Equihua, and M. A. Amin. 2000. Bat diversity and abundance as indicators of disturbance in neotropical rainforests. *Conservation Biology* 14:1666–1675

Meyer, C.F., Aguiar, L., Aguirre, L.F., Baumgarten, J., Clarke, F.M., Cosson, J.-F., Villegas, S.E., Fahr, J., Faria, D., Furey, N., 2010. Long-term monitoring of tropical bats for anthropogenic impact assessment: gauging the statistical power to detect population change. *Biol. Conserv*. 143, 2797-2807

Patterson, B. D. and P. W. Webala. 2012. Keys to the Bats (Mammalia: Chiroptera) of East Africa. *Fieldiana: Life and Earth Sciences* 6: 1 - 60.

Pianka, E. R., 1973.The structure of lizard communities. Annual Revue. Ecology. Syst.4, 53e74.

Pierce, M.W. and Keith, M. 2011. Healing rates of wing membranes in two species of Vespertilionid bats. *African Bat Conservation News*, 25: 3 - 5.

Rosevear, D. R. 1965. The Bats of West Africa. Trustees of the British Museum (Natural History), London, i - xvii, 1 - 418.

Sedláček O., D. Hořák, J. Riegert, J. Reif and I. Horáček. 2006. Comments on Welwitsch's mouse-eared bat (*Myotis welwitschii*) with the first record from Cameroon. *Mammalian Biology* 71 (2): 120 - 123. DOI: 10.1016/*j.mambio*.2005.11.004.

Simmons, N. B. 2005. Order Chiroptera. Pp. 313 - 529. In: WILSON, D. E. and D. M. Reeder [Eds]: Mammal species of the World: a taxonomic and geographic reference. Third Edition. Smithsonian Institution Press, Washington, D.C.

Stoner K.E., 2005. Phyllostomid bat community structure and abundance in two contrasting tropical dry forests. *Biotropica* 37, 591e599.

Turner, I. M. 1996. Species loss in fragments of tropical rain forest: a review of the evidence. *Journal of Applied Ecology* 33:200–209.