International Journal of Research in Biosciences
Vol. 5 Issue 4, pp. (27-35), October 2016
Available online at http://www.ijrbs.in
ISSN 2319-2844

Research Paper

Distribution of Pygmy hippopotamus (*Choeropsis liberiensis*) in Taï National Park, Ivory Coast: Influences of natural and anthropogenic factors

[*]Elie Bandama Bogui[1,2], André Djaha Koffi[2,3], Inza Koné[1,2], Karim Ouattara[1,2], Célestin Yao Kouakou[2,3], Anthelme Gnagbo[1,2]
[1]Unité de Formation et de Recherche Biosciences, Laboratoire de Zoologie et de Biologie Animale Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Abidjan, Lagune, Côte d'Ivoire
[2]Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS), Km 17 route de Dabou, Adiapodoumé - Yopougon - 01 BP 1303 Abidjan 01 Abidjan - Côte d'Ivoire
[3]Unité de Formation et de Recherche Environnement, Université Jean Lorougnon Guédé 12 BP V 25 DALOA 12 Côte d'Ivoire

(Received September 02, 2016, Accepted September 22, 2016)

Abstract

The pygmy hippopotamus is an endangered species which receives little attention from the scientific community, especially wild populations. The highest density of wild pygmy hippopotamus is found in the Taï National Park in Ivory Coast which is inscribed on United Nations Educational, Scientific and Cultural Organization's World Heritage list. Tai National Park experiences significant anthropogenic pressure from agricultural expansion, threatening pygmy hippopotamus due to habitat loss. To date, we have little information on the distribution of pygmy hippopotamus in the park. Therefore, the present study aims to determine the distribution of the species, emphasize the influence of the most dominant environmental factors and to present a model to predict areas of the Tai National Park supporting a pygmy hippopotamus population. We used a line transect method to make indirect observations through presence indices because of cryptic behavior of the pygmy hippopotamus. All indirect observations were combined with geographic information system and maximum entropy approach to species distribution modeling. Establishing the distribution of pygmy hippopotamus in the park has been established. Anthropogenic factors related to poaching and natural factors related to the river system and high altitudes were identified as the main factors influencing hippopotamus distribution. This work will help develop appropriate methods of monitoring this species, which requires further scientific studies to build a strategy for its protection.

Keywords: pygmy hippopotamus, spatial distribution, modeling, Tai National Park.

Introduction

In tropical areas, the continued increase in human population densities and anthropogenic activities lead to habitat changes or loss for many animals [1]. In Ivory Coast, over 75% of the forest area has disappeared in 30 years largely because of agricultural development[1]. Numerous species experience reduction in their distribution and are often endangered. This is the case of the pygmy hippopotamus (*Choeropsis liberiensis*) whose habitat declined dramatically due to human pressures [2]. In 1968, it was named a protected species by the African Convention on Nature and Natural Resources, classified as vulnerable by the IUCN in 1996, and listed as endangered by the IUCN in 2005 [3,4]. The population has greatly reduced over the past decades, and its habitat is largely reduced to forest fragments due to deforestation [5].

Pygmy hippopotamus has been the subject of significant study on aspects of biology, morphology, ecology, and taxonomy e.g.[6-14]**.** Other authors have focused their works on the description of habitats and geographical areas of distribution of the species. The pygmy hippopotamus is endemic to four countries in West Africa: Liberia, Guinea, Sierra Leone and Ivory Coast [15,16]. Roth et al. (2004) reported that in Ivory Coast, the Tai National Park (TNP) is the last refuge where there is a large viable population of this species. However, data on its spatial distribution in the TNP is still limited. A prediction model of distribution is useful for developing appropriate monitoring strategies both because of pygmy hippopotamus' cryptic behavior, and the difficulty of implementing specific ecological monitoring programs in protected areas [10,17,18]. The present study aims to establish the distribution of the pygmy hippopotamus, to test the influence of anthropogenic and natural factors on hippopotamus distribution, and present a model to predict areas of TNP favorable to the presence of the species.

Materials and Methods

Study site

The study was conducted from October 2014 to June 2015 over the whole of the TNP, in south-western Ivory Coast, between latitudes 5 ° 10'N, 6 ° 20'N and between longitudes 4 ° 20'W and 6 ° 20'W (Figure 1). The TNP extends over an area of 536 000 ha of rainforest and is the largest tropical rainforest protected in West Africa [19]. It offers a variety of flora and rare fauna, including many endemic species. These include the forest elephant, West African chimpanzee, zebra duiker, Jentink duiker, pygmy hippopotamus concerning fauna and *Chrysophyllum taiense*, *Diospyros sp* and *Mapania ivorensis* for flora. Thanks to its biological richness this park was declared a biosphere reserve and UNESCO World Heritage site (United Nations Educational, Scientific and Cultural Organization).

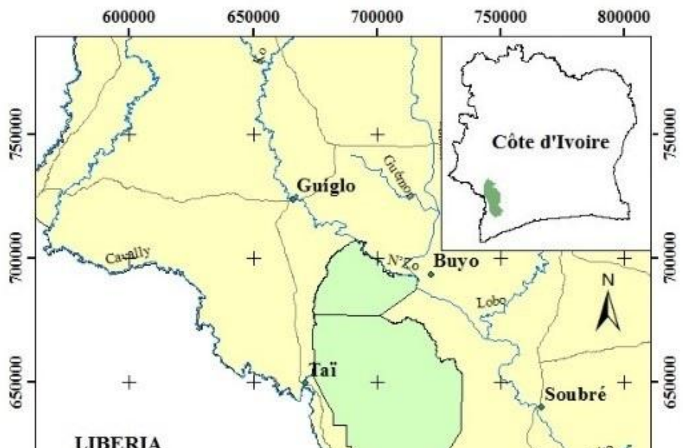

Figure 1: Location of the Tai National Park, in the southwest of Ivory Coast

Material and data collection design

We conducted surveys along a transect network, distributed in five sectors (Tai, Djouroutou, Djapadji, Soubré and the V6 sector) defined by the Ivorian Office of Parks and Reserves (OIPR) as part of an ecological monitoring program. The pygmy hippopotamus is a difficult species to observe because of its cryptic habits and poor visibility in dense rainforest. Therefore, observations on transects focused on presence indexes such as droppings, footprints and leftover food. The transect network included 184 transects arranged in a systematic manner throughout the TNP. Each transect measured 2 kilometers long and consisted of four 500 meters sections (Figure 2). This area layout reduces the walking effort while maximizing the walking time. In addition, ecologically it allows to explore a large area. A space is left between the sections to reduce replicates. Data collected from a total of 368 km of transects were supplemented. The sampling device used is recognized as an effective method to study the distribution of animals [20-23]. Five teams (one team per sector), composed of six investigators, were formed to collect data. All investigators were trained to recognize signs of pygmy hippopotamus signs of presence in the wild. When signs were recognized, investigators recorded the presence of a sign, geographical coordinates, and habitat type. In addition, investigators recorded environmental factors that could influence pygmy hippopotamus distribution, including all signs of clearing activities, agricultural and forestry product harvesting, clandestine gold mining, poaching, and tracks of poachers. Finally, natural factors such as altitude and the presence of rivers were recorded.

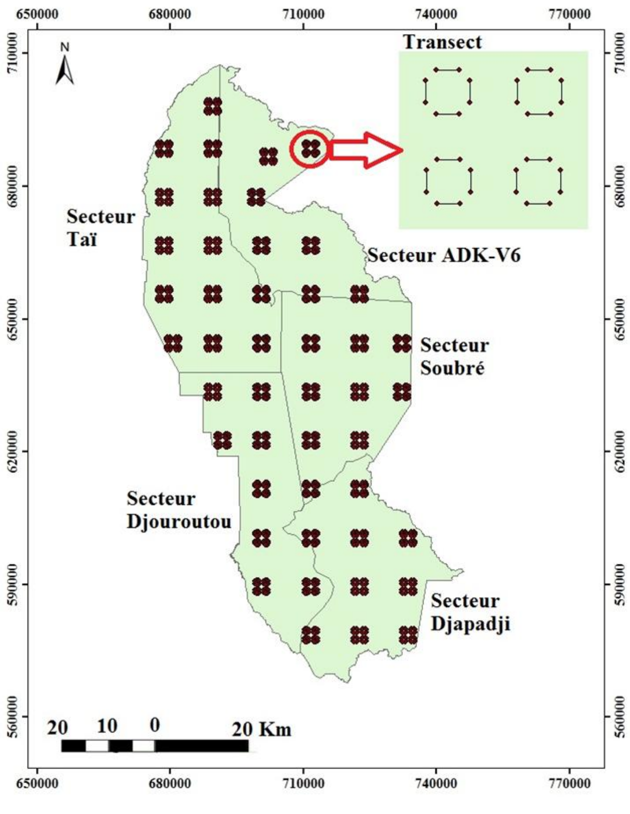

Figure 2: Data Collection Device

Spatial analysis

We converted georeferenced points of all recorded pygmy hippopotamus signs and indicators of human presence, and polylines represented streams and paths, to raster layers. We used the Kernel Density Estimation, a non-parametric test of dispersion based on Monte Carlo tests, to analyze these data[24]. We identified areas with the highest concentration of pygmy hippopotamus signs by determining the density of point features around a point. We used a digital surface model of Côte d'Ivoire to build a raster layer with altitudes in the TNP. The next step was to make a grid of polygons from the mask of the TNP. This is a uniform grid of pixels (the basic unit for measuring the definition of a digital image matrix), with a 1 square kilometer resolution. All raster layers were standardized using this grid of polygons to get files of the same spatial resolution with the same geographical coverage. Arcgis 10.3 software was used as a tool for these spatial analysis, but we converted the raster files in ASCII format used for modeling with maximum entropy (Maxent) approach.

Maxent software

Spatial autocorrelation is the dependence of variables in geographic space, such that the disparity among variable values is strongly influenced by the distances among the points of landmarks where there was a species [25-28]. Because spatial autocorrelation can affect the estimated parameters in the model selection, we deleted georeferenced indices of presence data with strong autocorrelation [29]. A grid of 1 km² was defined to implement the maximum entropy model. Following [30], we deleted all observation points of the pygmy hippopotamus within a kilometer, which allows the Maxent program to be more effective. 169 points of presence indexes through the TNP were selected for analysis in the Maxent software. This transformation was conducted with ETGeowizard used as extension in the Arcgis software. Implementation of the model requires consideration of the following variables: (i) the position of the paths (ii) the position of rivers, (iii) poaching indices, (iv)altitude and (v) agricultural indices and other types picking activities. Independence between these variables were verified through Pearson correlation tests. To perform this test and improve the spatial analysis of environmental variables used in Maxent, we used a Python script to build the Species distribution models (SDMs) [31].

Analysis in Maxent program was performed using 75% of presence data for model calibration and 25% for testing [32-35] . To allow comparison of a larger number of models, 5000 iterations were performed. The robustness of the model is evaluated using "Area Under the Curve" (AUC) determined by the receiver's analysis (receiver operating characteristic curve - [ROC]) [33]. A random prediction (AUC = 0.5) would predict 50% of the potential distribution area of pygmy hippopotamus using 50% of data of species presence. At each iteration of the model, the algorithm randomly selects 25% points of presence to test the model. Subsampling was used for to select of test points, enabling the random re-selection of a new set of points test for each iteration.

Results and Discussion

Spatial distribution of the pygmy hippopotamus in Tai National Park

The positioning of 1092 georeferenced points of pygmy hippopotamus presence indices on the TNP mask (Figure 3) shows that this species does not occupy space homogeneously but is concentrated in certain areas of the park.

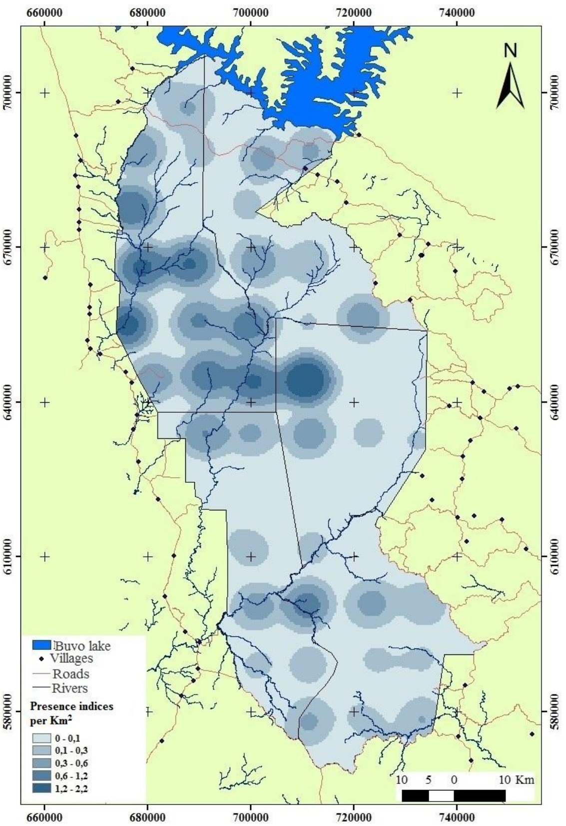

Figure 3: Core density pygmy hippopotamus presence indices in the Taï National Park

The central and western areas of the park have the highest densities of indices of hippopotamus presence, ranging from 0.6 - 2.2 per Km^2. In the eastern area, density is much lower and fluctuates between 0-0.1. The north and south areas also have relatively high densities of pygmy hippopotamus, ranging from 0.1 - 0.6 presence indices per Km^2.

Factors and distribution model for predicting the presence of pygmy hippopotamus in the TNP

We considered environmental variables which may influence the distribution of the pygmy hippopotamus (Table 1). Because there is a low correlation between these variables, they are considered independent of each other.

Table 1: Correlation matrix of continuous variables selected for modeling

	Agricultural and other activities	Altitude	Poaching Indices	River position	Roads position
Agricultural and other activities	1	- 0,14	0,17	-0,13	0,24
Altitude		1	0,2	-0,32	-0,04
Poaching Indices			1	-0,08	0,4
River position				1	0,15
Roads position					1

The Maxent model produced for the distribution data of pygmy hippopotamus gives an AUC of 0.622 with a standard deviation of 0.02. The variables that contribute the most are poaching indices (35.4%), proximity to roads (20.8%), proximity to rivers (18.6%) agricultural and other activities (13%) and altitude (12.2%). Figure 4 shows the result of Jackknife test of variables that are important in predicting the distribution of the pygmy hippopotamus. The variable with the highest gain when used alone is indicative of poaching, which seems to have the most useful information in the model building. The variable that reduces the most when it is omitted gain is still the index of poaching. This variable seems to provide more information than the other variables.

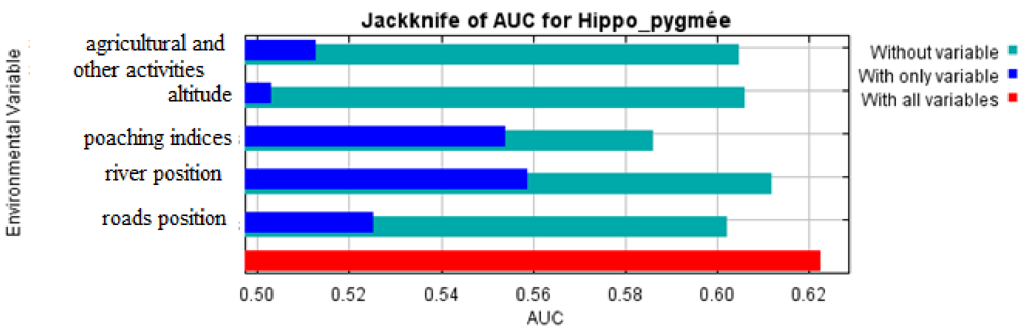

Figure 4: Contribution of environmental variables to Jackknife test

Figure 5 summarizes ASCII files generated by the model of Maxent. This synthesis constitutes a representation of probability of the presence of pigmy hippopotamus through the park based on the presence indexes. Pygmy hippopotamus's viable habitat is located in islands distributed throughout the park, particularly in the northern, western, central and southern parts of the park. Habitat is most viable in the wettest parts of the park center, near rivers (above 50% probability of finding hippopotamus traces). However, the eastern borders of the park have fairly low probabilities.

Table 2 shows the influences of each of the environmental variables in predicting the probability of presence of the pygmy hippopotamus in the Tai National Park. Agricultural and other activities variable include geo referenced points of cocoa planting, new clearings, plant crops and clandestine gold mining sites. These activities are minimal and localized to the periphery of the park. Areas with low anthropogenic influence have higher probabilities of containing indicators of pygmy hippopotamus. Pygmy hippopotamus signs were also more likely to be found in higher altitude areas. Areas with more poaching indices, including empty shotgun cartridges collected, gunshots, and traps for animals throughout the park, were associated with a lower probability of pygmy hippopotamus. When there are fewer signs, the presence of pygmy hippopotamus is more likely. River position favours the presence of pygmy hippopotamus. Roads are generally located towards the edge of the park. The possibility of observing the pygmy hippopotamus is not influenced by the proximity of the road.

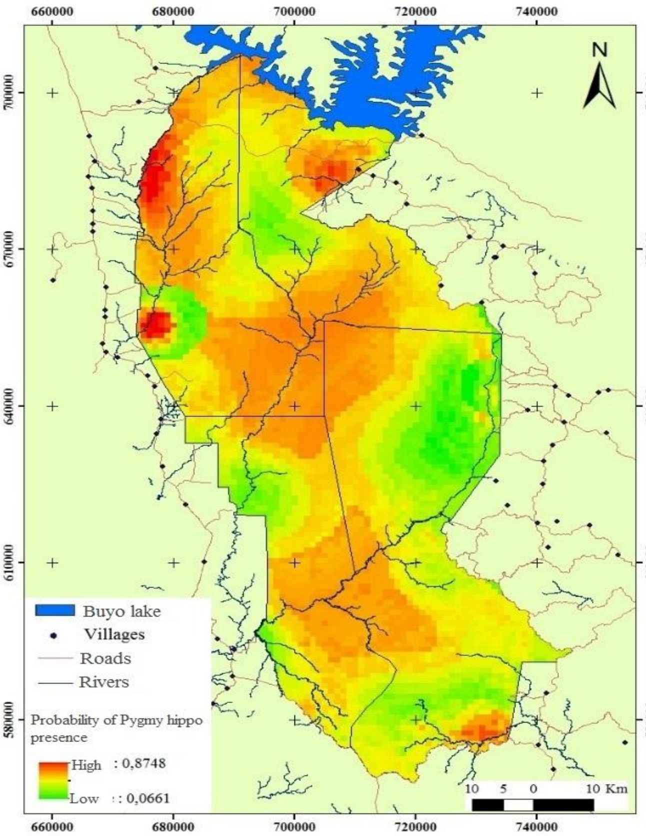

Figure 5: Probability of pygmy hippopotamus presence through the Tai National Park

Table 2: Effect and contribution of the variables to the model used in MaxEnt

Variables	Effect	Contribution in percentage
Poaching indices	Limiting	34.1
Agricultural and other activities	Limiting	20.9
Paths position	No effect	21.2
Rivers position	Encouraging	13.6
altitude	Encouraging	10.2

The analysis methods used to describe and to model the spatial distribution of the pygmy hippopotamus are complementary. Indeed, statistical analysis shows some general trends and shows the influence of environmental factors on the distribution. To conserve the pygmy hippopotamus in the Taï National Park, we must understand its spatial distribution in this park. Kernel density method shows that the species has an aggregated distribution and in this case we can consider that different environmental factors have different effects on pygmy hippopotamus distribution [36]. Our MaxEnt model showed that pygmy hippopotamus is distributed mainly in four major parts of the park: the northern, central, western and southern parts of the park. The probability of species presence is low in the eastern part.

These results corroborate those obtained with kernel density method and those of the OIPR biomonitoring program [37]. The low probability of observed signs of pygmy hippopotamus in the east of the park is due to the historically higher frequency of illegal human activities (gold-washing) and poaching [38]. Pygmy hippopotamus took refuge in the central part of the park that remains free from human disturbance. Their presence in the north and the south of the park could be explained by the abundance of rivers in these areas. Indeed, as signified by [39] pygmy hippopotamus spends 10 to 150 minutes of his time per day resting in the shallows filled vase near rivers. Thus, these water points are preferred places for pygmy hippopotamus, and pygmy hippopotamus may maintain territories with rivers for these resting areas.

We attempted to determine whether certain variables influence the distribution of the pygmy hippopotamus in the park but data on their distribution and these variables are not homogeneous. By calculating the probability of pygmy hippopotamus presence according to environmental variables in the park, we then seek to predict the distribution of the species in TNP by determining environmental conditions favorable to the presence of the species, i.e. as an ecological niche model [40]. Our analyses in MaxEnt minimized bias in observations from differential access within the park, and differences in the probability of detecting indices.

According to results of the model used in MaxEnt, altitude is a factor that promotes observation of pygmy hippopotamus. The higher the altitude, the higher the probability of detecting hippopotamus signs [11] showed that pygmy hippopotamus of TNP used an average of six hours of their time looking for food, moving away from the resting sites and climbing hills (85-230 m) that correspond to preferred feeding areas for possessing favorite food plant species such as *Geophila sp*. This may account for the higher probability of detecting signs at higher altitudes.

One of the main threats to the pygmy hippopotamus is deforestation resulting in habitat fragmentation[5]. Our study showed that agricultural activities and clandestine gold washing taking place in the park significantly, though minimally, influence the distribution of the species. However, the position of the paths has no significant effect on the distribution of the pygmy hippopotamus, which corroborated previous findings showing that species abundance increases with the presence of research tracks in TNP [41].

Conclusion

Various natural and anthropogenic factors influence the distribution of the pygmy hippopotamus. This is based on natural elements that support the presence of species such as altitude and rivers position in the central part and on the contrary unfavorable anthropogenic factors such as the presence of agricultural activity and illegal gold mining found in the park. Pygmy hippopotamus does not systematically avoid areas with human presence, such as roads or areas with researches. However, human activities and disturbance affect the distribution of the species, which avoids the eastern PNT where human presence is stronger.

Because feeding occupies 80% of activity budget of the pygmy hippopotamus, data on its should be combined with botanical surveys to understand whether food resources' temporal availability, diversity, and distribution on their home ranges are additional factors that influence the distribution of the pygmy hippopotamus in the TNP.

Acknowledgements

We thank the Southwest Zone Management (Dzso) of the Ivorian Office of Parks and Reserves (OIPR) for the financial and logistical support that he has kindly granted us during this study. We are grateful to the Centre Suisse de Recherches Scientifiques (CSRS) in Ivory Coast and the Wild Chimpanzee Foundation (WCF) for their technical input. We express our gratitude to Institute for Breeding Rare and Endangered African Mammals (IBREAM), especially to Professor Robert Millar, to Dr. Monique Paris and Dr. Karim Ouattara, for their financial support. Our gratitude also goes to University Félix Houphouët-Boigny, precisely to the Training and Research Unit (UFR) Biosciences, for administrative and academic support for the realization of this work.

References

1. Levêque C., Environnement et diversité du vivant, PARIS: ORSTOM, POKET, glossaire. (EXPLORA). ISBN 2-266- 06302-2, 127, **(1994)**

2. Lewison R., Oliver W., *Choeropsis liberiensis*, In: IUCN 2010. IUCN Red List of Threatened Species, Version 2010.2.**(2008)**

3. Lyster S., International Wildlife Law. Cambridge : Grotius Publications Limited **(1985)**

4. Baillie J. & Groombridge B., IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland, and Cambridge, U.K. **(1996)**

5. Mallon D., Wightman C., De Ornellas, P. & Ransom C., Conservation Strategy for the Pygmy Hippopotamus, IUCN Species Survival Commission, Gland, Switzerland and Cambridge, UK, 48 **(2011)**

6. Schomburgk H., On the trail of the pygmy hippo, an account of the Hagenbeck expeditionto Liberia, Zoological Society Bulletin 16, 880-884 **(1912)**

7. Oliver R. C. D., Aspects of skin physiology in the pygmy hippopotamus *Choeropsis liberiensis*, Journal of Zoology, 176, 211-213 **(1975)**

8. Galat-Luong, A., Quelques observations sur un hippopotamus pygmée nouveau-né (*Choeropsis liberiensis*) en Forêt de Tai, Côte d'Ivoire, Mammalia, 45, 39-41 **(1981)**

9. Bülow, W. Untersuchung am Zwergflusspferd im Azagny-National park, Elfenbeinküste, Diplomarbeit **(1987)**

10. Hentschel K., Untersuchung zu Status, Ökologie und Erhaltung des Zwergflusspferdes (*Choeropsis liberiensis*) in der Elfenbeinküste, Dr. rer nat, thesis, University of Braunschweig **(1990)**

11. Eltringham S. K.,The hippopotamus, T. & A. D. Poyser : London **(1999)**

12. Boisserie J.R., Lihoreau F., Brunet M., The position of Hippopotamidae within Cetartiodactyla, PNAS, 102(5), 1537-1541 **(2005)**

13. Hashimoto K., Saikawa Y., Nakata M., Studies on the red sweat of the *Hippopotamus amphibius,* Pure and Applied Chemistry, 79, 507-517 **(2007)**

14. Fisher R.E., Scott K.M., Naples V.L., Forelimb myology of the pygmy hippopotamus (*Choeropsis liberiensis*). The Anatomical Record, 290, 673-693 **(2007)**

15. Eltringham S. K., The pygmy hippopotamus (*Hexaprotodon liberiensis*), In : Pigs, Peccaries and Hippopotamus. *Ed.* W.R.L. Oliver, IUCN, Gland, 55 - 60 **(1993)**

16. Roth H., Hoppe-Dominik B., Muhlenberg M., Steinhauer-Burkart B. & Fischer F., Distribution and status of the hippopotamuspotamids in theIvory Coast, African Zoology, 39, 211-22 **(2004)**

17. Possingham H. P., Franklin J., Wilson K. & Regan T. J.,.The roles of spatial heterogeneity and ecological processes in conservation planning. Ecosystem function in heterogeneous landscapes : Springer **(2005)**

18. Comte L. & Grenouillet G.,. Do stream fish track climate change? Assessing distribution shifts in recent decades, Ecography, 36, 001-011 **(2013)**

19. Lauginie, F., Conservation de la nature et aires protégées en Côte d'Ivoire. NEI/Hachette et Afrique Nature, Abidjan, 668 **(2007)**

20. Bouché P.H., Méthodologie et techniques de recensement des grands mammifères en Afrique. 182, **(2001)**

21. Kouakou, Y., C., Boesch C., Kuehl H.,Estimating chimpanzee population size with nest counts: validating methods in Taï national Park: American journal of Primatology 71: 447-457 **(2009)**

22. Hoppe-Dominik B., Kühl H., S., Radl, G., Fischer F.,.Long-term monitoring of large rainforest mammals in the Biosphere Reserve of Taï national Park, Côte d'Ivoire: African Journal of Ecology, 49, 450-458 **(2011)**

23. N'goran K.P., Suivi écologique intégré pour une gestion durable des aires protégées de Côte d'Ivoire : cas des parcs nationaux de Taï (Sud-Ouest) et de la Marahoué (Centre). Thèse de Doctorat. Université Nangui Abrogoua, Côte d'Ivoire, 228 **(2015)**

24. Botev Z. I., Grotowski J. F. & Kroese D. P., Kernel density estimation via diffusion. The Annals of Statistics, **38(5)**, 2916-2957 **(2010)**

25. Cressie N., Statistics for spatial data, John Wiley and Sons. New York, 920, **(1991)**

26. Legendre P., Spatial autocorrelation: problem or new paradigm. Ecology, 74: 1659-1673 **(1993)**

27. Anselin L., Bongiovanni R. G. & Lowenberg-Deboer J., A spatial econometric approach to the economics of site Specific nitrogen management in corn production. American Journal of Agricultural Economics, 86, 675-687 **(2004)**

28. Segurado P., Araújo M. B. & Kunin W. E,Consequences of spatial autocorrelation for niche-based models. Journal of Applied Ecology, 43, 433-444 **(2006)**

29. Lennon J.J., Red shifts and red herrings in geographical ecology. Ecography, 23, 101-113 **(2002)**

30. Luque S., Prédiction de la distribution d'alliances de végétation des milieux ouverts d'altitude à l'aide de l'approche dite du maximum d'entropie. Programme CarHAB–Volet modélisation Milieux ouverts d'altitude, 77, **(2012)**

31. Brown J.L., SDM toolbox: a python-based GIS toolkit for landscape genetic, biogeographic and species distribution model analyses, Methods in Ecology and Evolution, 5(7), 694-700 **(2014)**

32. Phillips S.J., Avenue P. & Park F., A Maximum Entropy Approach to Species Distribution, Modeling, 655-662 **(2004)**
33. Phillips S.J., Anderson R. P. & Schapire R. E.,.Maximum entropy modeling of species geographic distributions, Ecological Modelling, 190: 231-259 **(2006)**

34. Phillips S.J. & Dudik M., Modeling of species distributions with Maxent: new extensions and a comperhensive evaluation. Ecography, 31: 161-175 **(2008)**

35. Phillips S., A brief tutorial on Maxent. Lessons in Conservation, 3, 107-135 **(2012)**

36. Rabeil. T., Distribution potentielle des grands mammifères dans le Parc du W au Niger. Ecology, environment. Universit_e Paris-Diderot - Paris VII. French. <tel-00006931> **(2003)**

37. Tiédoué M. R. Normand E., Diarrassouba A., Tondossama A.et Boesch C., - Etat de conservation du Parc National de Taï : Rapport de suivi-écologique - phase 10 (novembre 2014- mai 2015)-, Rapport OIPR/WCF, Soubré, Côte d'Ivoire, 38 **(2015)**

38. Hoppe-Dominik B., Analyse du système de biomonitoring pour l'évaluation des activités du projet au Parc National de Taï. Rapport d'Office Allemand pour la Coopération Technique (GTZ), Eschborn, Germany. **(1999)**

39. Lang E.M., Hentschel K. & Bülow W., Zwergflusspferde (Gattung Choeropsis). In Grzimeks Enzykopädie: Säugetiere. B and V., Kindler Verlag, Munich, 62-64 **(1988)**

40. Grinnell J., Field tests of theories concerning distributional control. American Naturalist, 51, 115–128. **(1917)**

41. Campbell G., Kuehl H., Diarrassouba A., N'goran P., K., & Boesch, C., Long-term research sites as refugia for threatened and over-harvested species. Biology Letters 7(5), 723–726 **(2011)**.