ANURAN COMMUNITIES AS INDICATORS OF HABITAT TYPES OF A WEST AFRICAN RAINFOREST

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ABSTRACT

Ecological indicators are that are affected by, and indicate effects of, anthropogenic environmental stress or disturbance on ecosystems. Some anuran species constitute valuable biological indicators of certain types of habitat disruptions. This study aims to evaluate the level of disturbance or conservation of Banco National Park (BNP), a West African rain forest, using anuran assemblage. The standardized transects technique, based on acoustic and visual surveys, was used. We identified 28 species, 13 genera and 8 families in BNP. Typology based on environmental variables and anuran assemblage permit to identify four habitats groups according to disturbance and wetland gradients. IndVal index allowed isolation of 15 indicator species from the 28 species identified. Taxa indicators conserved closed canopy habitats types were, in order of relative importance, *Phrynobatrachus liberiensis*, *P. ghanensis*, *P. phyllophilus*, *Morerella cyanophthalma* and *Aubria subsigillata*. Disturbed open habitats were characterized by *Ptychadena mascareniensis*, *P. pumilio*, *Hyperolius guttulatus*, *Afrixalus dorsalis*, *Hoplobatrachus occipitalis*, *Phrynobatrachus latifrons*, *Amietophrynus maculatus*, *Hyperolius fusciventris*, *Amietophrynus regularis*, *Hylarana albolabris* in order of relative importance. These results showed that BNP was well preserved so far, except for the central clearing and the forest edges which were altered by human activities.

Keywords: Amphibians, Conservation, Indicator value, Rain forest, Upper Guinea.

INTRODUCTION

Bioindicators can be defined as a species or assemblage of species that is particularly well matched to specific features of the landscape and/or reacts to impacts and changes (Paoletti, 1999a, 1999b; Büchs, 2003). Identifying characteristic or indicator species is important for conservation or management purposes (Büchs, 2003). Appropriate indicators should then, return low variance for the mean number of individuals recorded per site and a high degree of habitat preference for the habitat considered (Perner and Malt, 2003). These requisites are met by the indicator Value Index (IndVal) proposed by Dufrêne and Legendre (1997) which quantifies the degree to which each species fulfills the criteria of specificity (uniqueness to a particular site) and fidelity (frequency within this habitat type) (McGeoch and Chown, 1998).
Several authors have demonstrated a close relationship between the composition of animal communities and habitat diversity. Indeed, it was shown that habitats degradation affect the dynamic and structure of biological communities and may e.g. cause local extinction of amphibians (Hillers *et al*., 2008). Amphibians represent a taxonomic group which is very sensitive to changes in environmental conditions (Pineda *et al*., 2005). Their species composition in a given ecosystem may thus reflect the degree of disturbance or habitat conservation (Rödel and Branch, 2002; Rödel and Ernst, 2003; Ernst and Rödel, 2005). They are closely related to certain microhabitats and/or micro-climates (Vallan, 2000; Guerry and

Hunter, 2002). Hence, amphibians can be regarded as are excellent indicators of the biotic integrity of various ecosystems (Büchs (2003; Ernst *et al*. 2006).

In the herein paper, we aim to use anuran communities as model to determine the conservation status of the Banco National Park, one of the rare remaining primary forests situated in the midst of Abidjan, a West African big city. Environmental variables and anuran assemblage are thus used to identify indicator species of disturbance or conservation within the park, which is still facing strong anthropogenic pressures.

METHODOLOGY

Site

This study focused on the Banco National Park (Figure 1) is located in Abidjan between 5° 21' to 5° 25' N and 4° 01' to 4° 05' W at an altitude between 0 and 113 m a.s.l. (De Koning, 1983). Its area is estimated to comprise 3474 ha (Lauginie, 2007). This park, created at 1953 is the oldest of the 11 national parks and natural reserves of Ivory Coast. It is the remnant of an evergreen forest. The BNP is crossed by the river "Banco" (9 km long with an average width of 3 m) which originates on the northern edge of the forest and flows south into the Ebrié lagoon. Inside the park, a forest school (founded in 1938), an accommodation (camp) and a fish farm, occupy an area of about 5 ha. The equatorial-type climate include (Eldin, 1971; Durand and Skubich, 1982) two rainy seasons (April to July; October and November) and two dry seasons (December to March; August and September). The average annual rainfall in the study area varies between 1650 to 2000 mm (De Koning, 1983; Da, 1992). Banco forest is part of the Guinean rainforest zone (Guillaumet and Adjanohoun, 1971), characterized by evergreen forest types. The vegetation is dominated by *Turraeanthus africanus* (Meliaceae) and *Heisteria parvifolia* (Olacaceae) trees.

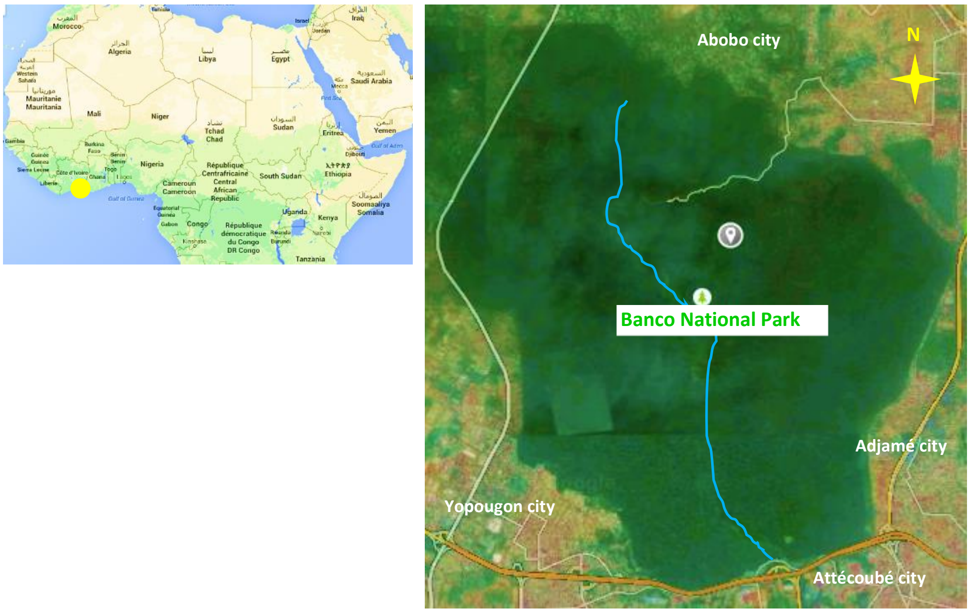

Figure 1: Location of the Banco National Park and Banco River (blue line) in Abidjan (modified satellite image of Google Maps 2015).

Data Collection

The sampling sites were selected taking into account all present types of habitats (Heyer *et al.*, 1994). These include primary and secondary forests, open and closed canopy areas, conserved and disturbed habitats. Wetlands, which generally offer breeding sites for amphibians had choice of sampling sites. Habitat parameters and amphibian data were collected in a standardized way along rectangular (200 x 100 m) transects (for exact transect and sampling design see Rödel and Ernst (2004)). The survey sampling was realized on 12 transects from BNP from March 2004 to February 2005.

Environmental Variables

Measurements of air temperature and relative humidity in each transect were conducted during day and night of each survey event. They were taken in different segments of each transect during the sampling. The proposed methodology by Rödel and Ernst (2004), Châtelain *et al.* (1996) and Pearman (1997) was used to estimate canopy cover, density of trees and shrubs, as well as the leaf-litter cover and density. Additional parameters were taken into account. This was the density of the grass cover, and the presence of water (ponds, streams) in different habitats.

Sampling

Amphibians were sampled opportunistically during visual surveys in different habitats. Sampling was carried out day and night applying standard techniques by Heyer *et al.* (1994) and Rödel and Ernst (2004). These study techniques included visual observations and investigation of potential shelters (i.e., rocks, dead wood or leaf litter). Anurans were also sampled using acoustic monitoring in all different habitat types. The collection of data on each transect always started in the southeast corner to ensure identical geographical orientation between the different sample events. During the transect walks, frogs were captured, determined and sexed, before releasing them at the same point. Representatives of each species were collected, anesthetized and killed in chlorobutanol solution and thereafter preserved in 70% ethanol. Specimen of all species were deposited in the collection of the Laboratoire d'Environnement et de Biologie Aquatique at the University Nangui Abrogoua (Ivory Coast). Vouchers are further housed in the Staatliches Museum für Naturkunde Stuttgart (SMNS) and the Museum für Naturkunde Berlin (ZMB), Germany. Tissue samples (toe tips) of recorded species were preserved in 95% ethanol. These samples are stored at the Museum für Naturkunde, Berlin (ZMB). The description of new species was realized in separate papers. These new taxa concern a tree frog of the family Hyperoliidae (Rödel *et al.*, 2009) and an arthroleptid frog (Rödel *et al.*, 2012).

Data Analysis
Species Richness Estimate

To evaluate the effectiveness of sampling techniques, two nonparametric estimators of species richness were used. Based on the assumption that the relative sampling effort was the same in each transect (always three people involved in searching), the theoretical number of amphibian species was calculated using the Jack-knife 1 (Burnham and Overton, 1978; 1979; Heltshe and Forrester, 1983) and Chao 2 estimators (Chao, 1987), based on presence / absence data. The estimation of species richness was performed with EstimateS (version 7) (Colwell, 2004).

Indicator Value (IndVal)

In order to identify indicator taxa, we used the method proposed by Dufrêne and Legendre (1997), the indicator value (IndVal). Sites were first gathered into groups (e.g. various levels of perturbation or different habitat types) using either a hierarchical classification. A given indicator species is defined as a species mostly present in a single group of sites and present in the majority of the sites belonging to that group. There are thus two components interfering in the computation of the IndVal index: one accounting for the specificity of the species, and the second accounting for the fidelity of that species to the groups of sites. The statistical significance of each index is evaluated using a standard permutation test.

The indicator values can be estimated for any given level of clustering, which constitutes a useful property of the approach. Species may have different indicator values according to the clustering level under consideration. Generalist (core) species have decreasing values of the indicator index from high level to lower levels of the typology. Specialised (satellite) species, on the contrary, display increasing indicator values from higher to lower levels of the typology. In addition, the method allows identification of species typical for intermediate levels of site hierarchy. Computation was realized using the software IndVal 2.

RESULTS

Typology of Sites

The analysis of environmental variables (Table 1) showed that the canopy, the thickness of leaf litter and density of trees and shrubs, values observed in transects were similar (ANOVA, $p>$ 0.05). Each transect was considered as a homogeneous ecological unit. However, canopy values were significantly lower in transect T10 than the other sites (Student t test, p <0.05). The density of trees was significantly larger (Student t test, $p<$ 0.05) from Upper stream and T9 than the other habitats. In transects T15, Fish Farm and Bay, habitats were characterized by grassland (open areas), no trees and shrubs were present. Regarding the air temperatures in T15 and Fish Farm values (31.8 – 33.1 °C) were significantly higher (Student t test, $p<$ 0.05) than those observed in the others transects (26.2 – 28.3 °C). However, the relative humidity values were significantly lower (Student t test, $p<$ 0.05) in T15 and Fish Farm (63.6 – 69.6 %) than in all other transect (78.7 – 87.3 %).

Table 1: Summary of environmental variables in the different transects, the values assigned the same letter (a or b) did not differ significantly (Student t test, $p>$ 0.05) from each other, different letter indicate significant differences, sample size of all transects (n) = 24 subunits, sd = standard deviation.

		US	T5a	T5b	T6	T7	T4	T9	T10	T15	FF	Bay
Canopy (%)	mean	65.6 ^{a}	55.2 ^{a}	51.0 ^{a}	54.2 ^{a}	58.3 ^{a}	62.5 ^{a}	63.5 ^{a}	47.9 ^{b}	0.0	0.0	0.0
	sd	12.4	14.7	17.3	17.5	15.9	14.7	12.7	16.3	0.0	0.0	0.0
Leaf litter thickness (cm)	mean	6.6 ^{a}	4.3 ^{b}	5.6 ^{a}	4.4 ^{b}	5.6 ^{a}	6.3 ^{a}	6.7 ^{a}	5.0 ^{b}	0.0	0.0	0.0
	sd	3.0	2.9	3.1	4.0	4.0	3.2	2.9	2.8	0.0	0.0	0.0
Shrubs density (ind./m^2)	mean	8.1 ^{a}	3.6 ^{b}	2.9 ^{b}	3.5 ^{b}	3.6 ^{b}	6.8 ^{a}	4.2 ^{b}	5.8 ^{a}	0.0	0.0	0.0
	sd	2.4	1.8	1.4	1.3	1.7	1.8	1.2	1.7	0.0	0.0	0.0
Density of trees (ind./m^2)	mean	3.7 ^{a}	2.0 ^{b}	1.7 ^{b}	2.0 ^{b}	1.8 ^{b}	1.4 ^{b}	2.3 ^{a}	1.4 ^{b}	0.0	0.0	0.0
	sd	1.4	0.7	0.6	0.9	0.7	0.6	0.9	0.9	0.0	0.0	0.0
Temperature (°C)	mean	27.3 ^{a}	27.8 ^{a}	26.7 ^{a}	26.8 ^{a}	26.9 ^{a}	27.4 ^{a}	26.3 ^{a}	26.2 ^{a}	33.1 ^{b}	31.8 ^{b}	28.3 ^{a}

	sd	1.9	2.3	2.3	2.4	1.9	1.8	2.2	1.8	4.7	5.5	1.9
Relative humidity of air (%)	mean	85.6ª	86.1 ª	86.2 ª	87.3 ª	85.5 ª	81.3 ª	86.8 ª	85.3 ª	63.8 ᵇ	69.6 ᵇ	78.7 ª
	sd	9.6	5.7	5.7	6.0	9.1	7.4	5.8	6.3	9.4	15.8	5.7

Transects were classified with respect of environmental variables (Figure 2). All transects (level 1) were grouped according to a disturbance gradient to closed or open canopy habitats types at the second level. At the third level of hierarchy, according to a wetland gradient, each closed or open canopy areas are classified to wet or dry habitat types.

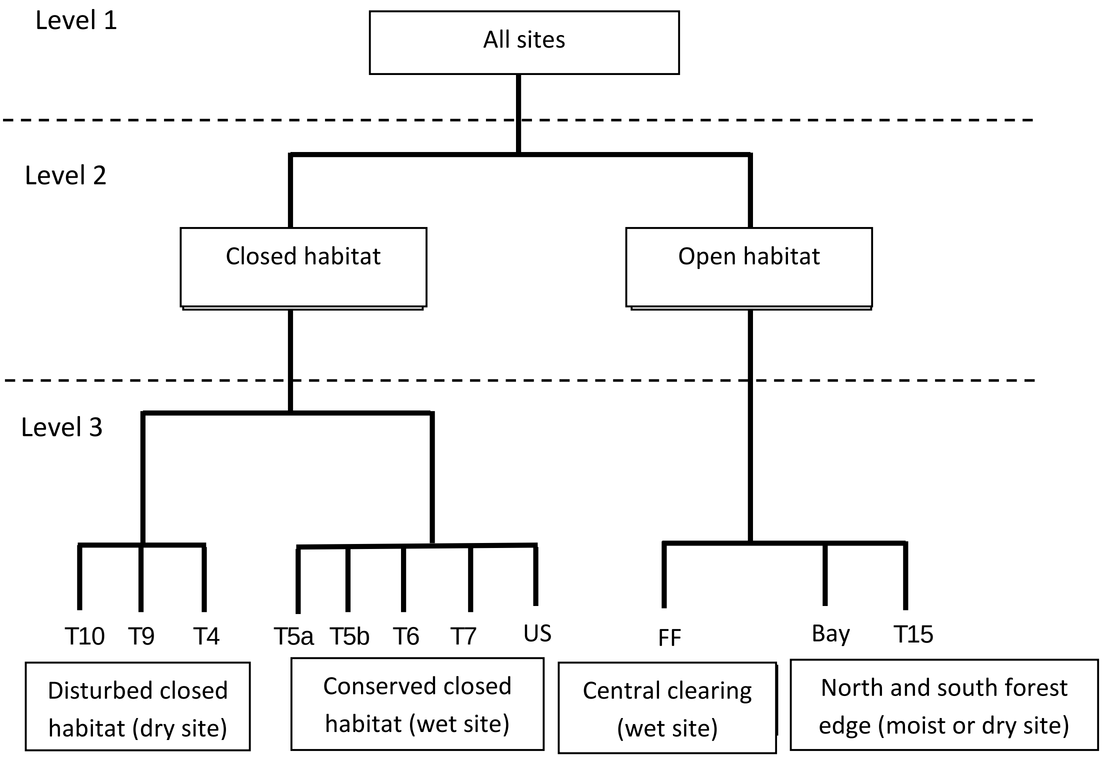

Figure 2: Dendrogram of sites indicating the type of habitat; transects were distributed into four groups according to disturbance gradient and the wetland status; transects Upper stream (US), T4, T5a, T5b, T6 , T7, T9, T10, T15, fish farm (FF) and Bay from the BNP.

Taxa Indicators of Different Habitats Types

A total of 28 species of anurans distributed in 13 genera and 8 families were identified in the different transects of the Banco National Park. The theoretical species richness obtained by Jack-knife and Chao indices was between 34 and 38 species, respectively. Thus we recorded 73.7 or 82.4 % of the estimated species richness, respectively. The classification of habitat types and indicator species associated are showed in figure 3. To determine indicator species, we first examined the significance of the IndVal index (values marked to **) and second retained index values greater than or equal to 25 %. This classification was carried out by removing the data abundances of rare species (of which the relative abundance of less than 5 %). At the first level of the hierarchy (all habitats combined), 9 taxa (or 32.14 %) of the entire population of amphibians were identified as Banco forest indicator. These were in order of

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decreasing index value: *Arthroleptis* sp.1 (57.58), *Hylarana albolabris* (42.42), *Phrynobatrachus liberiensis* (37.12), *Arthroleptis* sp.2 (32.58), *P. ghanensis* (28.79), *P. tokba* (27.27), *P. latifrons* (26.52), *Morerella cyanophthalma* (25.76) and *Hyperolius fusciventris* (25.00). At this level of classification, we have 22.22 % of taxa that are characteristic of primary forests, 66.22 % of secondary forests and 55.50 % of grasslands.

At the second level, 6 taxa (21.43 %) are indicative closed canopy forest and 13 taxa (46.43 %) of open canopy. In closed habitats, *Arthroleptis* sp.1 (76.77**) has the highest index value and *Phrynobatrachus phyllophilus* (24.24**) the lowest. All species in this habitat are specialised except *P. phyllophilus*. Thus, in closed canopy habitats (more or less preserved habitats), 33.33 % of the species are primary forests indicator and 66.66% secondary forests indicator. It is in the primary forest type: *Phrynobatrachus ghanensis*, *P. phyllophilus* and in the second forest: *P. liberiensis*, *P. tokba* and *Arthroleptis* complex. In open habitats, *Phrynobatrachus latifrons* (99.47**) and *Ptychadena pumilio* (81.82**) have the highest index values. In this area, *Hyperolius picturatus* (15.96**), *Afrixalus fulvovitatus* (15.15**) and *Hyperolius concolor* (12.12**) have the lowest values. Except these three species, all other are specialised species. At the third level of hierarchy, closed canopy forest contains only 8 indicator taxa (28.57 % of the total species richness). These taxa were concentrated in the conserved closed wet habitats. Five species from this anuran assemblage were specialised species. These indicator taxa were, in order of relative importance, *Phrynobatrachus liberiensis* (83.54**), *P. ghanensis* (63.73**), *P. phyllophilus* (43.91**), *Morerella cyanophthalma* (28.97**) and *Aubria subsigillata* (21.15**). Wetland habitats (transects Upper stream, T5a, T5b, T6 and T7) are representative of these closed areas.

Open canopy have the highest number of indicator species (14 taxa, 50 % of the total species richness). Thus, degraded open habitats are characterized by specialised species *Ptychadena mascareniensis* (93.19**), *P. pumilio* (92.78**), *Hyperolius guttulatus* (90.90**), *Afrixalus dorsalis* (88.35**), *Hoplobatrachus occipitalis* (87.66**), *Phrynobatrachus latifrons* (83.67**), *Amietophrynus maculatus* (73.48**), *Hyperolius fusciventris* (73.21**), *Amietophrynus regularis* (72.72**) and *Hylarana albolabris* (56.09**). Other indicator species have significant although relatively low index values. The fish farm (central clearing) represents better open disturbed habitats by its great species richness (14 taxa).

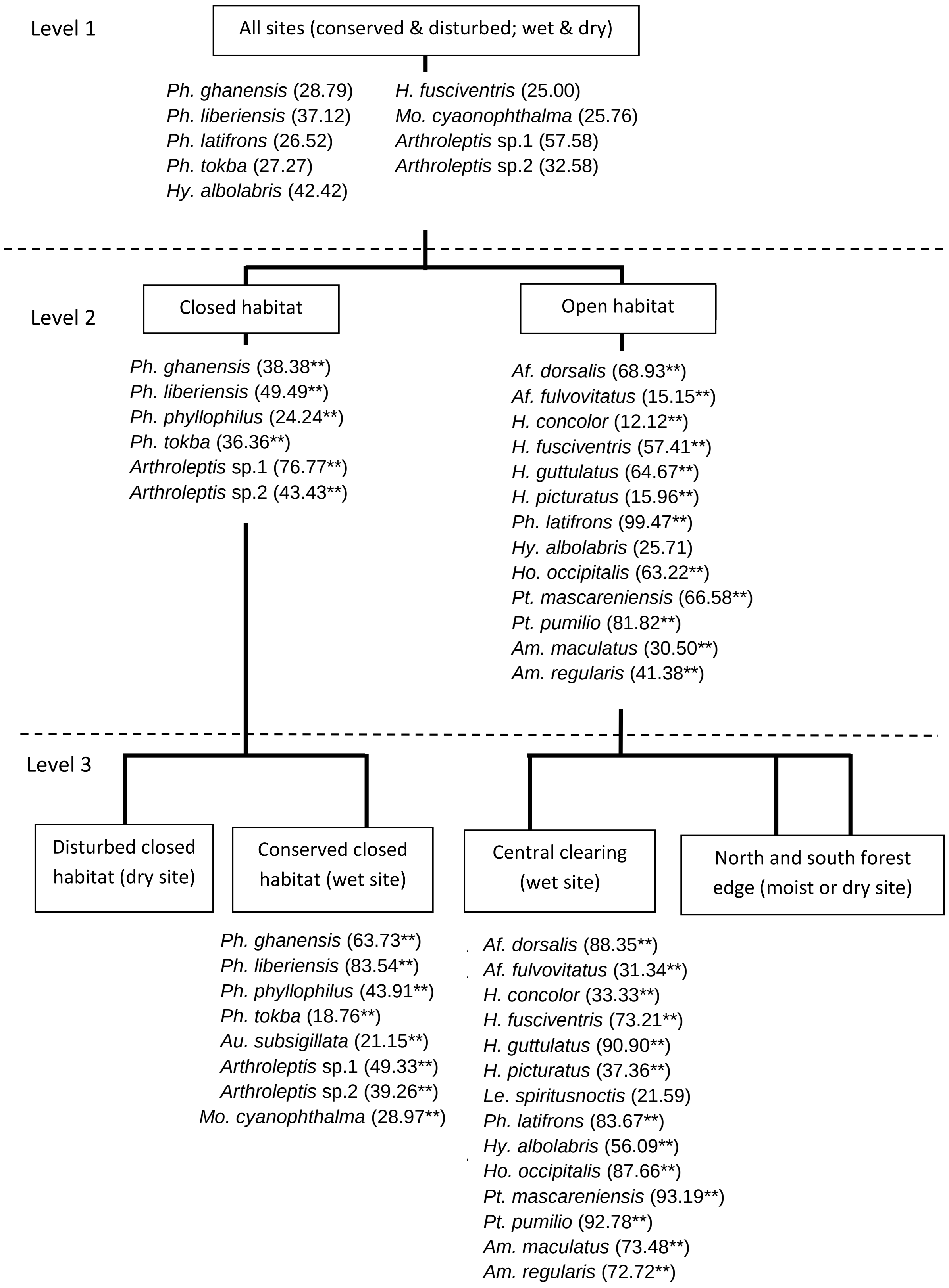

Figure 3: Indicator species associated with different nodes of the site dendrogram; the indicator value is given between parentheses; only maximum significant indicator values are presented; ** = p value of Student t test

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DISCUSSION

The habitat types of 28 anuran species were studied in the Banco National Park. The IndVal index (Dufrêne and Legendre, 1997) allows an evaluation of the indicator value of each species independently. We found 8 indicator species associated with closed canopy in wet habitat in primary or secondary forests, and 13 indicator species associated with open canopy (grassland) in wet areas. Among the 8 species, 5 species: *Phrynobatrachus liberiensis*, *P. ghanensis*, *P. phyllophilus*, *Morerella cyanophthalma* and *Aubria subsigillata* were confined with closed canopy in humid habitats. According to Rödel and Ernst (2002), Rödel (2003), Rödel *et al.* (2005) and Assemian *et al.* (2006), *Phrynobatrachus ghanensis*, *P. phyllophilus*, *P. liberiensis* and *Aubria subsigillata* were anuran often occurred in both primary and secondary forest swampy areas. The low increased value of *Morerella cyanophthalma* IndVal index from level 1 to level 3, indicate that this tree frog was not a good bioindicator species. This treefrog was mostly encountered in swampy forest and forest edges (Assemian *et al*. 2006; Rödel *et al*. 2009) while *P. tokba* and *Arthroleptis* complex which more widespread in the BNP could be considered as generalised species. These species occurred in both drier parts of disturbed forests and humid sites undisturbed forests with dense canopy. There, distribution seemed to be independent to water body. Indeed, due to their no aquatic larval phase, *P. tokba* and *Arthroleptis* complex neither need running water nor ponds to spawn (Lamotte and Perret, 1963; Rödel and Ernst, 2002).

However, specialist species associated with open canopy and grasses in wet habitats were *Ptychadena mascareniensis*, *P. pumilio*, *Hyperolius guttulatus*, *Afrixalus dorsalis*, *Hoplobatrachus occipitalis*, *Phrynobatrachus latifrons*, *Amietophrynus maculatus*, *Hyperolius fusciventris*, *Amietophrynus regularis* and *Hylarana albolabris*. In disturbed habitats, these anuran were either grassland or farmbush indicator species (Rödel, 2000; Rödel and Branch, 2002; Assemian *et al.* 2006).

While special microclimates present in closed canopy areas (i.e. low temperature and high humidity) is presumably the local environmental conditions affecting distribution of anurans (Vallan, 2000), the composition of the amphibian communities in the BNP was mostly influenced by the types of vegetation and canopy cover.. This is due to the fact that in dense forested areas, leaf-litters are an ideal environment for frogs' prey (Watling and Donnelly 2002; Menin *et al*. 2007). Also, it appears clear that the spatial variation in amphibian species richness were related to habitat diversity. Indeed, the presence of the river, brooks and ponds in moist habitats of BNP created favorable conditions for amphibian assemblages, thus corroborating Barbault (1972), Sinsch (1991) and Bastazini *et al*. (2007) who argued that permanent water bodies in a given habitat is essential for the majority of amphibian species and hence determine their spatial distribution. Choices of breeding sites and dispersal of these animal are largely influenced by the availability of canopy cover and water bodies (Werner and Glennemeier 1999).

CONCLUSION

The IndVal index has allowed to isolate 5 indicator species of primary or secondary swampy forests, and 10 indicator species of moist grassland or farmbush habitats. These results showed that some important areas of BNP were well preserved so far. However, other sites were altered due to anthropogenic activities. These sites were mainly situated in the central clearing and the rain forest edges. Conservation measures for this important rain forest located in the economical capital Abidjan should be improved.

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