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Spatio-temporal distribution and interannual variability of waterbirds of the lower valley of Ouémé in the south of Benin

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1 ABSTRACT

Located in the East of the complex of wetlands in southern Benin, the Lower Valley of Ouémé includes water bodies (Lake Nokoué, Lagoon of Porto-Novo, Sô and Ouémé rivers), relics of forest, mangroves, flooded savannas, grasslands, plantations, fields and fallows. Annual counts of waterbirds were conducted over a period of ten years. Eighty-seven species of waterbirds belonging to 48 genera, 19 families and 9 orders were recorded during the period 1998 to 2004 and 2008 to 2010. Correspondence analysis and discriminant analysis applied to matrices species / sites x years allowed determining two groups of waterbirds A and B established along a salt gradient.

2 INTRODUCTION

Few studies have dealt with waterbirds in southern Benin; most of the information concerning Benin is those of birds of protected areas (Berlioz, 1956; Green and Sayer, 1979; Claffey, 1995; Anciaux, 1996; Anciaux, 2000; Anciaux, 2002; van den Akker, 2003). Indeed, the wetlands in southern Benin have been little studied and it is only recently that they have started to be object of general research (Brunel, 1958; Holyak and Seddon, 1990; Dowsett and Forbes-Wastson, 1993; Adjakpa *et al.* 1996; Adjakpa 1999; Adjakpa, 2000; Hagemeiger *et al.*, 2000 a and b; Adjakpa, 2001 a and b, Adjakpa *et al.*, 2002). All the scientific reports were developed for main objectives to establish an exhaustive list of waterbirds species present in each surveyed wetland, to identify the sites hosting the Western Palearctic species and to assess the international importance of these Beninese wetlands for waterbirds populations. Several species of waterbirds counted between 1998 to 2004 and 2008 to 2010 in Benin by then "Ornithological and Environmental Research Center (CEROE)" as *Dendrocygna viduata*, *Chlidonias niger, Glareola pratincola, Chlidonias hybridus, Egretta ardesiac*a have responded to the selection criteria of 1% of the Ramsar Convention (Dodman *et al.*, 1998; Dodman and Diagana, 2003; Diagana and Dodman, 2006). These studies also show that the water bodies of

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the Lower Valley of Ouémé and Mono are the largest wetland in Benin for migratory and resident birds. However, little attention has been given to the spatio-temporal distribution and interannual variability of water birds in this area. The purpose of this work is to analyze the mode of distribution of waterbirds and to study the characteristics of this avifauna.

2.1 Study Area: The study environment is located between latitude 6° 26' and 6° 40' North and longitude 2° 22' and 2° 40' East. Soils are hydromorphic and halomorphic and are based on alluvial material, clayey and sandy clay, clayey sediments of the continental terminal (Volkoff, 1976; Wolkoff and Willaine, 1976). Two parallel watercourses form the hydrographic network: Ouémé river in the East and Sô river in the West. The two rivers, interconnected by arms, sometimes play the role of tributary; sometimes play the role of distributary depending on time (of flooding or flood recession). They are bordered by vast floodplains. Between rivers Ouémé and Sô, the vast plain usually receives water during flood periods. The climate of the study area is type of guinea or subequatorial characterized by two rainy seasons from march to July and September to October and two dry seasons from November to February and August. The annual average of rainfall patterns are of 1250.5 mm for Cotonou, of 1295.5 mm for Porto-Novo and of 1123.5 mm at Adjohoun. The minima and maxima average temperatures are 24.4° and 30.2°C (Adjakpa, 2012). The vegetation is composed of a mosaic of swamps, some islands of planted mangrove, low meadows and aquatic vegetation. Agriculture is the major activity and occupies nearly 70% (INSAE, 2002).

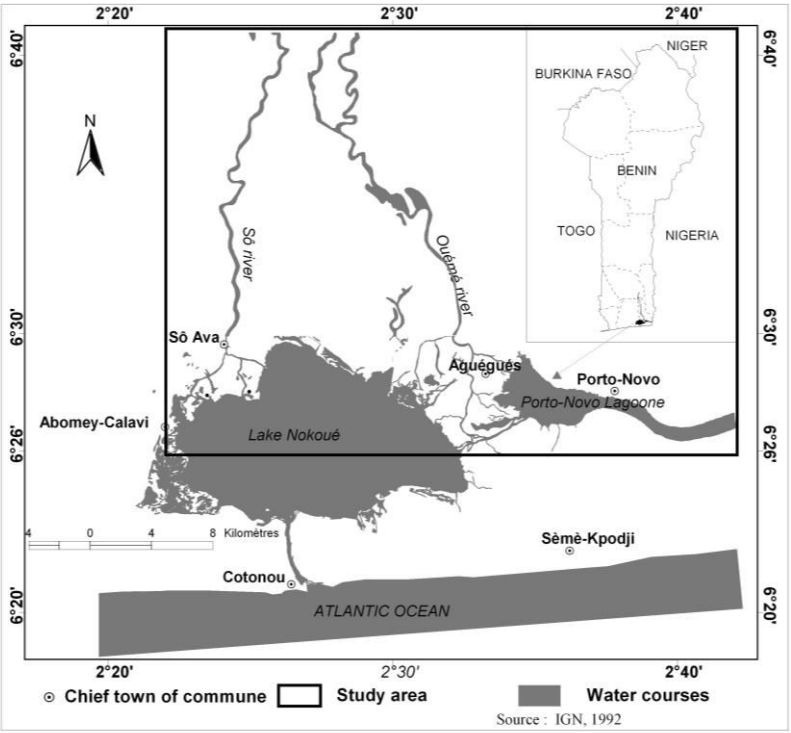

Figure 1: Location of the study area

3 MATERIAL AND METHODS

The ornithological data comes from waterbirds census carried out in wetlands of the Lower Valley of Ouémé by Ornithologists of the "Environmental and Ornithological Research Center (CEROE)" from 1998 to 2004 and from 2008 to 2010 (10 years) in Bénin. These water bodies were selected due to their specific position, richness and abundance of waterbirds.

The water bodies studied were the Lake Nokoué, the Lagoon of Porto-Novo, the rivers Sô and Ouémé. Pairs of binoculars (Zeiss 10 x 40, Minolta 7 x 50) and a telescope (Opthoyth 30-60) were used. Birds were identified by comparison with the literature data of Serle and Morel (1993) and Borrow and Demey (2001). The nomenclature and biogeographic status according to Borrow and Demey (2001) were adopted. Birdlife (2004) threat status of species was used. The observations were carried out particularly where the disturbance caused by users of water bodies is of lesser magnitude. Censuses have been carried out mainly in morning (7 am to 11 pm) in favorable weather conditions. The displacements were by canoe and on foot. The inventory was conducted using two techniques: 1) by counting all individuals when the group of waterbirds is close to the observation point and counts less than 200 individuals 2) or by visual estimation if the size of the group is very high and the birds are at a considerable distance. This method of counting is the most used (Blondel, 1975; Girard, 1998; Seddik *et al.*, 2010; Yakokoré-Beibro *et al.*, 2010).

5 DATA ANALYSIS

5.1 Spatio-temporal variability: The data was analysed using the softwares Minitab 14 and XLSTAT 2011. A correspondence analysis and discriminant analysis were performed. The matrix species (87) / Sites (4) x Years (10) has been subjected to correspondence analysis (Benzeckri, 1966). The sites were lake Nokoué, Lagoon of Porto-Novo, rivers Sô and Ouémé. The surveys covered the years 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2008, 2009 and 2010. Temporal variability was studied from 1998 to 2004 and from 2008 to 2010. The matrix species / Years was subjected to correspondence analysis.

5.2 Characteristics of the population of waterbirds: The study was addressed by measuring some ecological indices directly related to the balance of avian populations: total abundance, species richness, diversity index of Shannon- Wiener and index of evenness:

- species richness is a measure of the biodiversity of all or part of an ecosystem, it means in the context of the study, the number of bird species present in the Lower Valley of Ouémé;
- abundance (n_i) is the number of individuals of each species in each season;
- the relative abundance (pi) is the ratio of the number of individuals of each species in the area;

$$P_i = \frac{n_i}{N} \; avec \; N = \sum n_i$$

Pi= ni/N with N= ∑ni

The diversity index (H ') of Shannon-Wiener expresses the relative importance of the number of abundant species in a given environment. Its value is an estimate of the uncertainty with which we can accurately predict the species for which belongs to the next individual collected. The index is minimum when all individuals belong to the same species. It is maximal when each individual represents a distinct species (Legendre and Legendre, 1984). Its formula is:

$$H' = -\sum P_i \; Log_2 \, P_i \quad bits$$

Pi = relative abundance of each species. Logarithms are calculated in base 2.

The evenness index of Pielou provides information on the distribution of abundances of species in the area. Evenness index of Pielou or regularity appears as a more rigorous term of comparison. It is between 0 and 1. It tends to 0 when all individuals correspond to a single species. It tends to 1 when each species is represented by the same number of individuals (Ramade, 1975).

Its formula is:

$$J' = \frac{H'}{H'_{max}} = \frac{H'}{Log_2 \, r}$$

(H ': Shannon index, r: number of species).

6 RESULTS

The fluctuations of the avian composition of the avian population of the Lower Valley of Ouémé are studied as a function of the spatial and temporal variability.

6.1 Spatial variability: The four axes of the correspondence analysis reflect that 69.13% of the total variability of which 27.55% are carried by the first axis, 16.54% by the second, 14.54% by the third and 10.48% by the fourth.The first two axes account for 44.09% of the total information (Figure 2). The average contribution is 1.14% of bird species and 2.50% for Sites (Lake Nokoué, Porto-Novo lagoon, rivers Ouémé and Sô) x Years (10).

Regarding species of waterbirds in relation to the F1 axis, we note:

- *Chlidonias niger* which has a strong contribution (3.61% above the average) in the positive abscissa with a square cosine (r) of 68%, reflecting a good performance with respect to this axis;
- In the negative abscissa, waterbirds species greatly contributing to the formation of this axis are: *Bubulcus ibis* (19.91%), *Nycticorax nycticorax* (11.9%), *Glareola pratincola* (8.9%), *Amaurornis flavrostris* (2%), *Vanellus spinosus* (1.6%). These species are relatively well correlated with this factor with squared cosines of 0.66, 0.28, 0.18, 0.31 and 0.31 respectively. As for the position of sites x years on the F1 axis, we have:
- in positive abscissa, the following points columns with strong contributions are: Lake Nokoué_1998 (9.56%), lake Nokoué_1999 (6.95%), lake Nokoué_2010 (3.72%), Lake Nokoué_2002 (3.57 %), river Sô_2002 (3.50%), lake Nokoué_2000 (2.53%), the points columns more strongly correlated with this factor are: Lake Nokoué_1998 (r = 0.48), Lake Nokoué_1999 (r = 0.48), Lake Nokoué_2000 (r = 0.26), Lake Nokoué_2002 (r = 0.57), river Sô_2002 (r = 0, 33), Lake Nokoué_2010 (r = 0.29).
- In negative abscissa, the points following column with a strong contribution are: river Ouémé_2000 (3.02%), river Ouémé_2001 (5.77%), river Ouémé_2003 (3.86%), river Ouémé_2008 (4.32 %), river Ouémé_2009 (3.63%), river Ouémé_2010 (2.82%), river Sô_2001 (2.28%), Lake Nokoué_2009 (3.64%) = Novo_2009, Lagoon of Porto (4.74%) river Sô_2009 (3.63%). The points columns more strongly correlated with this factor are: river Ouémé_2000 (r = 0.50), river Ouémé _2001 (r = 0.35), river Ouémé _2003 (r = 0.55), river Ouémé _2008 (r = 50), river Ouémé _2009 (r = 0.39), river Ouémé _2010 (0.10), river Sô_2001 (r = 0.20), Lake Nokoué_2009 (r = 0.43), Lagoon of Porto-Novo_2009 = (r = 0.56), river Sô_2009 (r = 0.52), river Ouémé_2009 (r = 0.40), river Ouémé_2010 (0.09).

The axis F1 opposes records of birds of Lake Nokoué and the Lagoon of Porto-Novo in positive abscissa to those of birds of the rivers Sô and Ouémé in negative abscissa. This distribution of birds led to interpret this axis as representing the salinity gradient. This axis separates all the population of waterbirds of freshwater environments that are generally observed in 2000, 2001, 2002, 2008, 2009 and 2010 to those observed in saline environments 1998, 1999, 2002 and 2010. The F1 axis allows identifying two groups of waterbirds: group A consists of waterbirds of the river Sô and Ouémé and group B of those of Nokoué Lake and the Lagoon of Porto Novo.

Group A consists of herons, storks, ducks, rails and shorebirds especially resident species, both afrotropical and palaearctic species. Group B includes grebes, cormorants, shorebirds, gulls, terns and birds of prey mainly dominated by palearctic species (Table 1).

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Table 1: List of surveyed species

Orders/Families/Species	Biogeographical Origins	Identified groups A	B1	B2
PODICIPEDIFORMES				
Podicipedidae				
Tachybaptus ruficollis (Pallas, 1964)	R	0	X	0
PELECANIFORMES				
Phalacrocoracidae				
Phalacrocorax africanus (Gmelin, 1789)	R	0	X	0
CICONIIFORMES				
Ardeidae				
Ixobrychus minutus (Linné, 1766)	R/P	X	0	0
Trigriornis leucolophus (Jardine, 1846)	R	X	0	0
Nycticorax nytcticorax (Linné, 1758)	R/P	X	0	0
Ardeola ralloides (Scopoli, 1769)	R/P	X	0	0
Bubulcus ibis (Linné, 1758)	R/M	X	0	0
Butorides striatus (Linné, 1758)	R	X	0	X
Egretta ardesiaca (Wagler, 1827)	R/M	0	X	0
Egretta gularis (Bosc, 1792)	R/M	0	0	X
Egretta garzetta (Linné, 1766)	R/M/P	X	0	0
Egretta intermedia (Wagler, 1829)	R/M	X	0	0
Egretta alba (Linné, 1758)	R/M/P	X	0	0
Ardea purpurea (Linné, 1768)	R/P	X	0	0
Ardea cinerea (Linné, 1758)	R/P	X	0	0
Ardea malanocephala Vigors & Children, 1826	R/M	X	0	0
Ardea goliath Cretzchmar, 1827	R	X	0	0
Ciconiidae				
Anastomus lamelligerus Termmink, 1823	M/R	X	0	0
Ciconia abdimii Lichtenstein, 1823	M/R	X	0	0
Threskiornithidae				
Plegadis falcinellus (Linné, 1766)	R/P/V	X	0	0
ANSERIFORMES				
Anatidae				
Dendrocygna viduata (Linné , 1766)	R/M	0	0	X
Sarkidiornis melanotos (Pennant, 1769)	M	X	0	X
Nettapus auritus (Boddaert, 1783)	R	X	0	0
Anas querquedula (Linné, 1758)	P	0	X	0
FALCONIFORMES				
Pandioniae				
Pandion haliaetus (Linné, 1758)	P/R	0	X	0
Accipitridae				
Circus macrourus (Gmelin, 1770)	P	0	X	0
Circus pygargus (Linné, 1758)	P	0	0	X
Circus aeruginosus (Linné, 1758)	P	X	0	X
GRUIFORMES				

Orders/Families/Species	Biogeographical Origins	Identified groups A	B1	B2
Rallidae				
Crex egregia (Peters, 1854)	M/R	0	X	0
Amaurostris flavirostris (Swainson , 1837)	R	X	0	0
Porphyrio alleni Thomson, 1842	M/R	X	0	0
Porphyrio porphyrio (Linné, 1758)	R	X	0	0
Gallinula chloropus (Linné, 1758)	R/P	X	0	0
Gallinula angulata Sundevall, 1850	R/M	X	0	0
CHARADRIIFORMES				
Heliornithidae				
Podica senegalensis (Vieillot, 1837)	R	X	0	0
Jacanidae				
Actophilormis africana (Gmelin, 1789)	R	X	0	0
Microparra capensis (Smith, 1839)	R	X	0	0
Rostratulidae				
Rostratula benghalensis (Linné, 1758)	R/M	X	0	0
Recurvirostridae				
Himantopus himantopus (Linné, 1758)	R/P	X	0	X
Burhinidae				
Burhinus senegalensis (Swainson, 1837)	R/M	0	0	0
Glareolidae				
Pluvianus aegyptius (Linné, 1758)	R/M	X	0	0
Glareola pratincola (Linné, 1766)	R/M/P	0	0	X
Charadriidae				
Charadrius dubius Scopoli, 1786	P	0	0	X
Charadrius hiaticula Linné, 1758	P	0	0	X
Charadrius pecuaris Temminck, 1823	R/M	X	0	0
Charadrius forbesi (Schelley, 1883)	R/M	X	0	0
Charadrius alexandrinus Linné, 1758	R/P	X	0	0
Charadrius maginatus Vieillot, 1818	R	0	0	X
Pluvialis squatarola (Linné, 1758)	P	0	0	X
Vanellus spinosus (Linné, 1758)	R	X	0	0
Vanellus superciliosus (Reichenow, 1886)	M	0	X	0
Scolopacidae				
Calidris alba (Pallas, 1764)	P	0	X	0
Calidris minuta (Leisler, 1812)	P	0	0	X
Calidris temminckii (Leisler, 1812)	P	0	0	X
Calidris ferruginea (Pontopidan, 1763)	P	0	0	X
Philomachus pugnax (Linné, 1758)	P	0	X	0
Lymnocryptes minimus (Brünnich, 1764)	P/V	X	0	0
Gallinago gallinago (Linné, 1758)	P	X	0	0
Gallinago media (Latham, 1787)	P	X	0	0
Limosa limmosa (Linné, 1758)	P	X	0	0
Limosa lapponica (Linné, 1758)	P	0	0	X
Numenius phaeopus (Linné, 1758)	P	0	0	X

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Orders/Families/Species	Biogeographical Origins	Identified groups A	B1	B2
Numenius arquata (Linné, 1758)	P	0	0	X
Tringa erythropus (Pallas, 1764)	P	0	X	0
Tringa totanus (Linné, 1758)	P	0	X	0
Tringa stagnatilis (Bechstein, 1803)	P	X	0	0
Tringa nebularia (Gunnerus, 1767)	P	0	X	0
Tringa ochropus (Linné, 1758)	P	X	0	0
Tringa glareola (Linné, 1758)	P	X	0	0
Actitis hypoleucos (Linné, 1758)	P	X	0	0
Arenaria interpres (Linné, 1758)	P/V	X	0	0
LARIFORMES				
Laridae				
Larus genei Brème, 1840	P/M/V	0	X	0
Larus cirrhocephalus Vieillot, 1818	R	0	X	0
Larus fuscus Linné, 1758	P	0	X	0
Sternidae				
Gelochelidon nilotica (Gmelin, 1789)	R/P	0	0	X
Sterna caspia Pallas, 1770	R/P	0	0	X
Sterna maxima Boddaert, 1783	R/M	0	0	X
Sterna bengalensis Lesson, 1831	P	0	X	X
Sterna sandvicensis Latham, 1787	P	0	X	X
Sterna dougallii Montagu, 1813	P	0	0	X
Sterna hirundo Linné, 1758	P	0	0	X
Sterna paradisaea Pontoppidan, 1763	P	0	0	X
Sterna albifrons (Pallas, 1764)	R/M/P	0	0	X
Chlidonias hybridus Pallas, 1811	P	0	X	0
Chlidonias niger (Linné, 1758)	P	0	X	0
Chlidonias leucopterus (Temminck, 1815)	R/P	X	0	0
STRIGIFORMES				
Strigidae				
Asio capensis (Smith, 1834)	R/M	0	X	0

Group A: Sô river, Sub-group B1: Lake Nokoué, B2: Porto-Novo Lagoon, Presence: X, Absence: 0; Resident: R; Migrant: M, Resident/Migratory: R/M, Palearctic Migratory: P, Vagrant: V.

Regarding bird species relative to the axis F2, we note:

- In positive ordinate, only the species *Dendrocygna viduata* with contributes strongly to the formation of this axis (45.93%) with a good r = 0.76;
- In negative ordinates, species with contribution above the average are: *Anastomus lamelligerus* (6.06%), *Egretta garzetta* (4.64%), *Actophilornis africana* (4.20%), *Himantopus himantopus* (1.93%), *Tringa glareola* (1.67%), with correlations of 0, 18, 0.18, 0.18, 0.14 and 0.38 respectively.

As for sites x years position on F2 axis, we have:

- In positive ordinates sites x years that have a strong contribution are: Lake Nokoué_2004 (4.50%) and Lake Nokoué_2008 (37.60%). The points columns more strongly correlated with this factor are: Lake Nokoué_2004 (r = 0.093) and Lake Nokoué_2008 (r = 0.78).
- In negative ordinates sites x years that have a strong contribution are: river Sô_1998 (5.39%), Lake Nokoué_2001 (8.39%), Lake Nokoué_2003 (6.40%). The points columns more strongly

correlated with this factor are: river Sô_1998 (r = 0.33), Lake Nokoué_2001 (r = 0.55%), Lake Nokoué_2003 (r = 0.28). The F2 axis enables to divide the group into two subgroups of waterbirds B1 and B2. Subgroup B1 is distributed in the upper left quadrant of the positive abscissa and ordinate while the B2 subgroup includes waterbirds species of the lower right quadrant of the positive abscissa and negative ordinate. Birds in groups B1 and B2 are opposed by the diet. The representative species on F2 are *Dendrocygna viduata* (45.93%) with a good correlation (r= 0.76) and *Anastomus lamelligerus* (6.06%) with a correlation (r= 0.18). The overall analysis has therefore easily identify two groups (A and B), B subdivided into B1 and B2 (Figure 2).

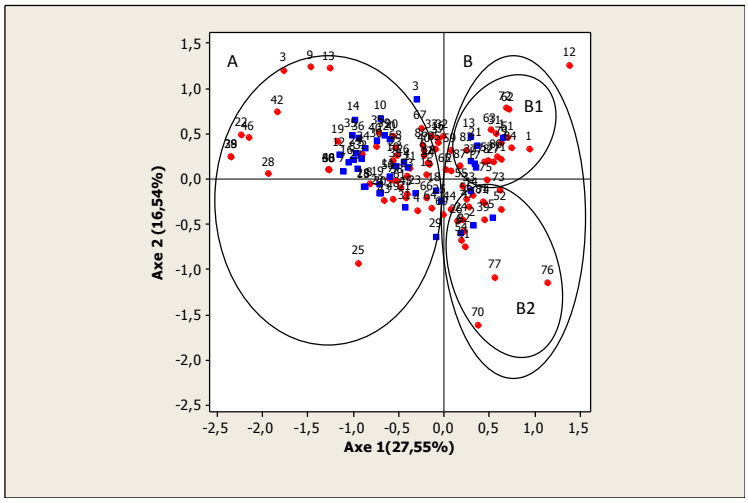

Figure 2: First two dimensions of the correspondence analysis on the matrix species (87) / Sites (4) x Years (10)

The groups of birds were subjected to discriminant analysis to assess their stability. The analyse has been carried out on four numeric variables (factorial coordinates on F1, F2, F3 and F4) using the software XLSTAT. The axis F1 accounts for of 70% of the total inertia, which deemed enough to separate groups (Figure 3).

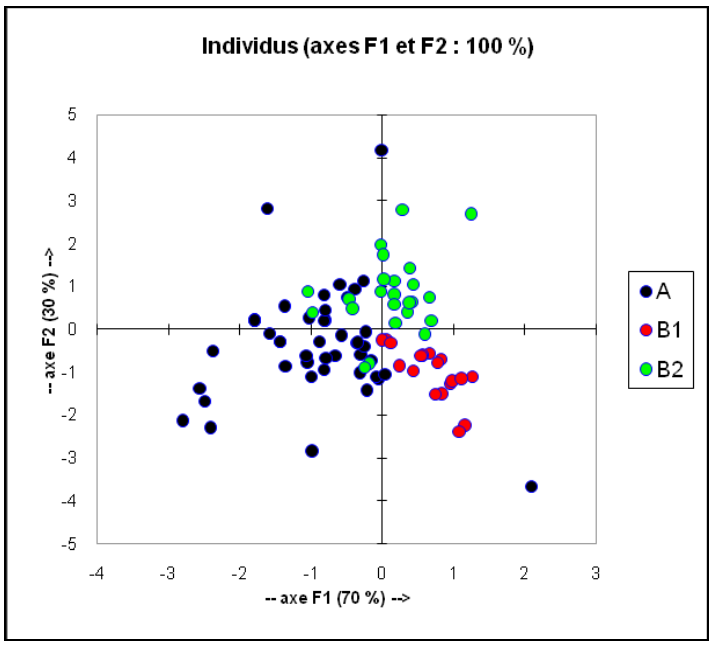

Figure 3: Discriminant analysis in the first two dimensions F1 and F2 on the matrix Species / Sites x Years

The analysis of the table 2 shows that 87 species belonging waterbirds are well classified with an error of 14.94%. Group A shares with the subgroup B1 four species (*Phalacrocorax africanus*, *Ardea goliath*, *Tringa nebularia* and *Larus fuscus*) and nine with the group B2 (*Arenaria interpres*, *Circus pygargus*, *Circus aeruginosus*, *Glareola pratincola, Charadrius hiaticula*, *Pluvialis squatarola*, *Calidris ferruginea*, *Tringa stagnatilis*). The highest percentage of misclassified species (6.90%) occurs in B2 group. This analysis thus indicates two groups of waterbirds A, B, mainly comprising the waterbird populations of the river Sô, the stream Ouémé, and those of Lake Nokoué and Lagoon of Porto Novo.

Table 2: Confusion matrix of the discriminant analysis

	To A	To B1	To B2	Sum
From A	41 (47.13%)	1 (1.15%)	3 (3.45%)	45 (51.72%)
From B1	3 (3.45%)	15 (17.24%)	0 (0.00%)	18 (20.69%)
From B2	6 (6.90%)	0 (0.00%)	18 (20.69%)	24 (27.59%)
Sum	50 (57.47%)	16 (18.39%)	21 (24.14%)	87 (100.00%)

6.2 Temporal variability: The diachronic analysis that characterizes different avian population fluctuations over the past ten years (1998 to 2004 and 2008 to 2010) is performed on each of the three birds groups. Figure 3 shows the diagram of the ten years of observations (1998 to 2004 and 2008 to 2010). The path is defined as the line that connects the different years. It reflects the population dynamics of birds and it embodies the mutual relations between species group.The first four axes defined by the correspondence analysis of the two groups A and B account for over 84% of the total variability (Table 3). The case of group A is selected to illustrate this temporal variability.

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Table 3: Variance explained by the axes of the correspondence analysis on Bird Species / Years matrix of the different groups

Axes	% Inertia Axe 1	% Inertia Axe 2	% Inertia Axe 3	% Inertia Axe 4	% Inertia Axe (1-4)
Group A	31.85	26.20	16.38	10.36	84.73
Group B	57.23	28.08	05.78	03.52	94.60

The diachronic study of group A is performed on the matrix species (46) / years (10). Figure 4 shows the results of species dynamic. The first two axes (F1 and F2) explain 84.73% of the total variability. The evolution is marked by strong oscillations reflecting a high temporal variability. The oscillations in the plane of axes 1 and 2 of the representative points of bird populations are similar. The F1 axis opposes two sets of years: Group 1 carried by the four years that has a strong contribution in the formation of the F1 axis with a correlation of 0.75 and group 2 carried by the year 10 with a contribution of 19.2% and a correlation of 0.38. The F1 axis opposes years with rainfall deficit to rainy ones. Associated species in this group are composed of a mixture of wading birds, ducks, rails and shorebirds.

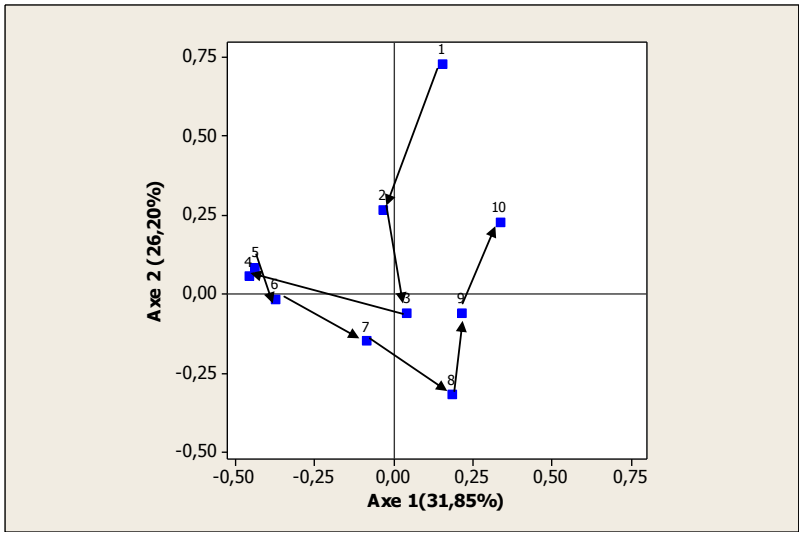

Figure 4: Interannual variability (1998 to 2004 and 2004 to 2010): Diagram sites x years in the first two dimensions of the correspondence analysis map for group A.

7 CHARACTERISTICS OF WATERBIRD STANDS

7.1 Avian diversity: In total, 87 species belonging to 48 genera and 20 families were recorded during the period 1998 to 2004 and 2008 to 2010 (Table 1). The most representative families in genera (9 %) are Scolopacidae (9 genera), Ardeidae (7 genera), Anatidae (4 genera) and Rallidae (4 genera) and Charadriidae (3 genera) and Sternidae (3 genera) representing 42.86%. Three families (Ciconiidae. Jacanidae and Glareolidae) have more than two genera, representing 12.24%. Eleven families, Podicipedidae, Phalacrocoracidae, Scopidae, Threskiornithidae, Pandioniae, Accipitridae, Rostratulidae, Recurvirostridae, Burhinidae, Laridae and Strigidae are represented by a single genus accounting for 24.49%.The relationship between total species richness (87) and the total number of genera (48) is equal to 1.7. That is to say almost as many genera as species that actually denotes a variety. Indeed, the most important families in species are: Scolopacidae with 21 species (24.70%), Ardeidae with 15 (17.65%), Sternidae with 10 (11.76%), Charadriidae with 9 (10. 58%) and Rallidae with 6 species (7.05%). These five families represent 71.76% of the species. The families Anatidae, Accipitidae,

Ciconiidae, Jacanidae and Glareolidae with more than 2 species account for 15. 30%. All other families (11) Podicipedidae, Phalacrocoracidae, Scopidae, Threskiornithidae. Pandioniae, Rostratulidae, Recurvirostridae, Burhinidae, Laridae and Strigidae are only represented by a single species (12.94%).Species of waterbirds are divided into three groups according to their origin: the exclusive resident species (15.12%), the inter-Afrotropical migratory species (4.65%), Palaearctic migratory species (37.21 %) and species both Palaearctic and afrotropical (43.02%).

7.2 Ecological indices: Biodiversity and richness show a significant variation from an avian group to another but also from one year to another as shown by the values of ecological indices (Figure 5).

7.2.1 Abundance: The actual population of birds fluctuates between 1512 individuals in 1999 (group A) to 8210 individuals in 2008 (subgroup B2). The numbers of birds varied slightly except in 2004 and 2008 the number of individuals in subgroup B2 is significantly higher than that of A (Figure 5a). This is the case for *Bubulcus ibis* in the subgroup B2, *Anastomus lamelligerus* for group A, *Chlidonias niger* in the subgroup B1. There is a variation between the numbers of different species of waterbirds counted. In addition during this period, some unusual species in the study area were observed. This is the case of *Ciconia abdimii* with a single individual observed respectively in 1999, 2002, 2003 and 2004 on the floodplain of the river Sô, *Ardea goliath* with a single individual in 1998 on the River Ouémé, *Charadrius forbesi* in 2000 and 2004, *Charadrius pecuarius* in 2000 on the floodplain Sô, *Sterna bengalensis* on tle lake Nokoué in 1999.

7.2.2 Specific richness: Avian richness of waterbird population of Sô and Ouémé (group A) (46 species, 52.87% of total richness) is much higher than the waterbirds stand Lake Nokoué and the Lagoon of Porto-Novo (Group B) (41 or 47.23%) including Lake Nokoué (subgroup B1) with 18 species (20.69%) and the Lagoon of Porto-Novo (subgroup B2) with 23 species (24.44%) (Figure 5b). Avian richness in group A is slightly higher than that of subgroups B1 and B2 in 2001, 2008, 2009 and 2010. The richness of B2 is greater than B1 over the inventory period except in 2001 and 2003 and even equal to B1 in 2004.

7.2.3 Shannon-Wiener index : Diversity indices provide information on stand structure and how individuals are distributed among various species. They are used to define the phenomena of dominance between particular species. Indices of Shannon-Wiener are weak for the B1 group (from 0.3 to 1.03 bits) and group B2 (0.45 to 1.51 bits). In contrast, they are higher in group A (2.80 to 3.88 bits). These higher indices indicate not only specific dominance in the distribution of different species in the site but also greater stability compared to the other two sites. The avifauna of the rivers Ouémé and Sô however appears more balanced (Figure 5c).

The evenness index tends to 0. It is less than 0.50 for Lake Nokoué (B1) and the Lagoon of Porto-Novo (subgroup B2). These values range between 0.13 and 0.30 respectively for Lake Nokoué and between 0.12 and 0.31 for the Lagoon of Porto-Novo (subgroup B2). These indices are very low for subgroups B1 and B2. Conversely, the evenness indices of group A are between 0.52 and 0.70. These values are higher than 0.5 demonstrating a good level of organization. The indices are very low for both subgroups and reflect an environment with scarce diversified resources. Lake Nokoué and Lagoon of Porto-Novo contains few species but each has significant numbers. This could be explained by the presence of one or two species with high numbers of rare species with very low numbers observed only one time. In contrast, the shape of the graph of the group A (Sô river and Lagoon of Porto-Novo) reveals that Shannon indices are high which corresponds to favorable environmental conditions for the installation of many species.

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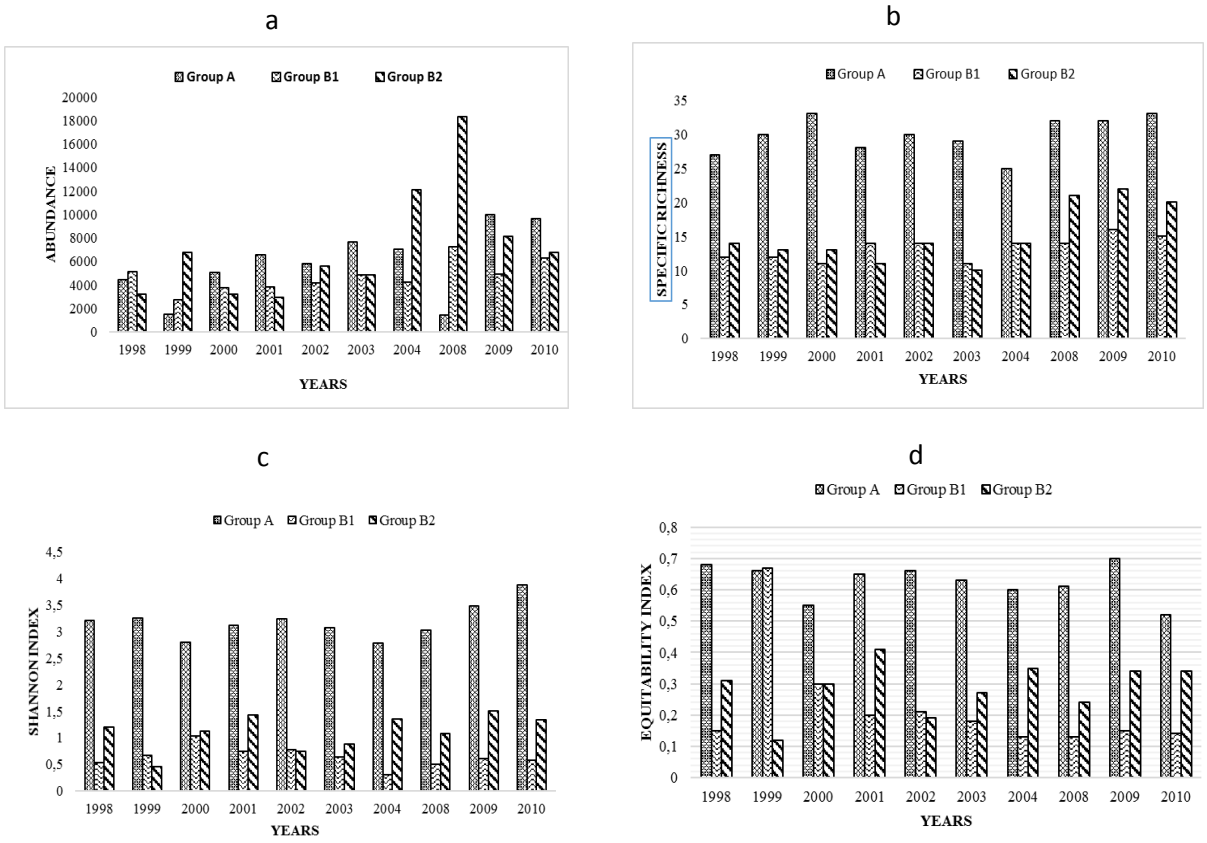

Figure 5: Evolution of ecological indices (abundance, species richness, Shannon-Wiener index) of bird populations in the Lower Valley Ouémé (1998 to 2004 and 2008 to 2010).

8 DISCUSSION

The study aims to analyze the evolution of the population of waterbirds and diversity, the spatio-temporal variability and environmental factors that determine the dynamics of the birds of the Lower Valley Ouémé. The correspondence analysis has identified two groups of waterbirds including the entire rivers Sô and Ouémé (Group A) on the one hand and the Lake Nokoué and Lagoon of Porto-Novo (Group B) on the other hand. This second group of birds is divided into two subgroups B1 (Lake Nokoué) and B2 (Porto-Novo Lagoon). This analysis helped to highlight the different populations of waterbirds, indicator species, rare species and accidental ones in the Lower Valley Ouémé. The diachronic analysis of the avifauna showed an increase in the number of birds in the population between 2008 and 2010. The size and avian species diversity show interest in wetlands of the Lower Valley Ouémé for water birds. These 87 species represent more than half the number of waterbirds in wetlands in the countries of West Africa (Dodman and Diagana, 2006). Lower Valley of Ouémé is one of the most important wetlands in southern Benin for its diversity and bird abundance, mainly herons, storks, rails, ducks, waders, shorebirds and terns. This medium is on the one hand a host site for many species of the western palearctic such as *Anas querquela*, *Pandion haliaetus, Charadrius dubius, Charadrius hiaticula, Calidris ferruginea, Gallinago media, Arenia interpres, Sterna paradisisaea, Chlidonias niger , Larus fuscus etc* and on the other hand a nesting site for resident species such as *Egretta ardesiaca, Butorides striatu, Dendrocygna viduata, Gallinula angulate, Amaurostris flavirostris and Actophilornis Africana* .The abundance and diversity of bird fauna are not uniformly distributed across all identified groups. For

example in 2000, 5034 individuals of birds were recorded for the sites of the rivers Sô and Ouémé (group A) and 3739 individuals on site Lake Nokoué (subgroup B1) in the same year. Species diversity is higher in group A (25 to 33 species) than for group B1 (5-15 species) during the ten years period. Some bird species also show a significant variation in the spatial and temporal distribution of the study area. For example, *Ardea goliath* and *Microparra capensis* identified once they were no longer observed during the remaining years of follow-up. The number of *Chlidonias niger*, *Bubulcus ibis*, *Dendrocygna viduata* are larger respectively in groups B1, B2 and A. These differences may be explained by the availability of food and the capacity of host sites. The birds then enjoy the abundance of food and remain on the sites as long as possible (Weesie, 1996). Anthropogenic pressures can also explain them. In the lake villages bordering the study area where there is a high concentration of human populations living in the middle of the wetland, the human impact is very important (Bonou and Gnonlonfin, 1999; Adjakpa *et al.*, 2009). Much of the floodplain land is cultivated because of its fertility due to organic matter inputs by water during floods (Le Barbe *et al.*, 1993). On most sites hosting migratory and resident birds, lean period crops maize, cassava, sweet potato, cowpea, groundnut and vegetables are the main agricultural activities of local populations. These factors can be a source of disturbance for birds that need places foraging, resting and safety. In addition, in all the studied sites we found poaching of waterbirds, which is organized by local hunters and expatriate residents of the cities of Cotonou, Abomey and Porto-Novo. This form of illegal hunting is a serious threat to the birds in the area including whistling widowers, jacanas, moorhens, egrets and shorebirds. Despite these variations, the Lower Valley of Ouémé seems to play a crucial role in the conservation of waterbirds.

9 CONCLUSION

The study of waterbirds has allowed an inventory of 87 species belonging to 48 genera and 20 families. Lower Valley of Ouémé occupies a prominent place in the wetlands of south-eastern Benin as a habitat of great value to waterbirds, as well as a wintering area for migratory birds. Large spatial and temporal variability in the abundance, richness and diversity reflects the unstable nature of the bird populations. This requires regular monthly monitoring of the avifauna to better understand the mechanisms and causality of their dynamics.

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