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Effect of Air Temperature and Water Depth on Bird Abundance: A Case Study of Rallidae and Anatidae in the Northeastern Algerian Garaet Hadj Tahar

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Authors' Contribution
BM conceived the study, designed the methods, collected the data, edited the manuscript and performed statistical analysis. SNL conceived the study, edited the manuscript and helped in data analysis.

Key words
Climate change, Richness, African water birds, Guerbes-Sanhadja wetlands, Garaet Hadj Tahar.

ABSTRACT

Water birds have traditionally been used as ecological indicators to monitor natural habitats and wetland changes. Climate is widely recognized as a major predictor of bird abundance and richness along large-scale environmental gradients, but mechanisms by which climate influences the bird abundance are still unknown. We analyzed seasonal variations on the bird community structure of Rallidae and Anatidae families in the northeastern Algerian Garaet Hadj Tahar for three consecutive years (September 2012 to August 2015). We studied the effect of air temperature and water depth on bird abundance and two ecological diversity indices (Shannon and Shannon E). Significant inter-annual fluctuations in bird abundance were recorded. Maximum values were always recorded during autumn. Water depth correlated positively with bird abundance and Shannon index. Field samplings indicated that bird abundance was frequently higher than 1000 individuals, which suggests that this site is an important refuge of water birds in the Guerbes-Sanhadja wetlands complex. Two key conservation species were observed regularly in the Garaet: near threatened Ferruginous Duck (*Aythya nyroca*) and endangered White-headed Duck (*Oxyura leucocephala*). Our results highlight the importance of preserving the Garaet Hadj Tahar as a water bird refuge.

INTRODUCTION

Accelerated climate change and destruction of natural habitats through direct human activities are threats to all living ecosystems (Vesser and Both, 2005; Jetz *et al*., 2007). The change of climate could be a positive sign as species are apparently adapting to change their phenological conditions (Parmesan and Yohe, 2003). The birds have traditionally been used as ecological indicators to monitor natural habitats and wetland changes (Hamdi and Ismail-Hamdi, 2015). Bird distribution results from a global process and requires broad consensus that integrates macro-conservation perspectives (Ricklefs, 2004). Thus, changes in bird abundance and richness along large-scale environmental gradients, such as latitude and elevation, are among the longest known and most intensively studied patterns in ecology and biogeography (Gaston, 2000). In addition, land-use dynamics and climatic gradients have massive effects on many bird populations (Lumpkin and Pearson, 2013). Climate is widely recognized as a major predictor of bird abundance along large-scale environmental gradients, but mechanisms by which climate influences the bird abundance are still a matter of debate (Ferger *et al*., 2014).

To test the relationship between the bird community structure and abiotic conditions as air temperature and solar radiation, further research is required using approaches involving different functional groups of species and small geographical scales of known characteristics such as: habitat heterogeneity and direct measures of temperature (Lennon *et al*., 2000; Hurlbert, 2004; Evans *et al*., 2006; Carrascal *et al*., 2012). Newton (1998) and Clarke and Gaston (2006) argue that the air temperature is one of the most important climatic condition that affects the distribution and the dynamics of bird populations. The air temperature also directly affects the water depth in wetlands. In this study, we analyzed seasonal variations on the bird community structure of Rallidae and Anatidae families in the northeastern Algerian Garaet Hadj Tahar for three consecutive years. Specifically, we studied the effect of air temperature and water depth on: i) bird abundance, and ii) two traditional ecological diversity indices as

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Shannon (diversity) and evenness.

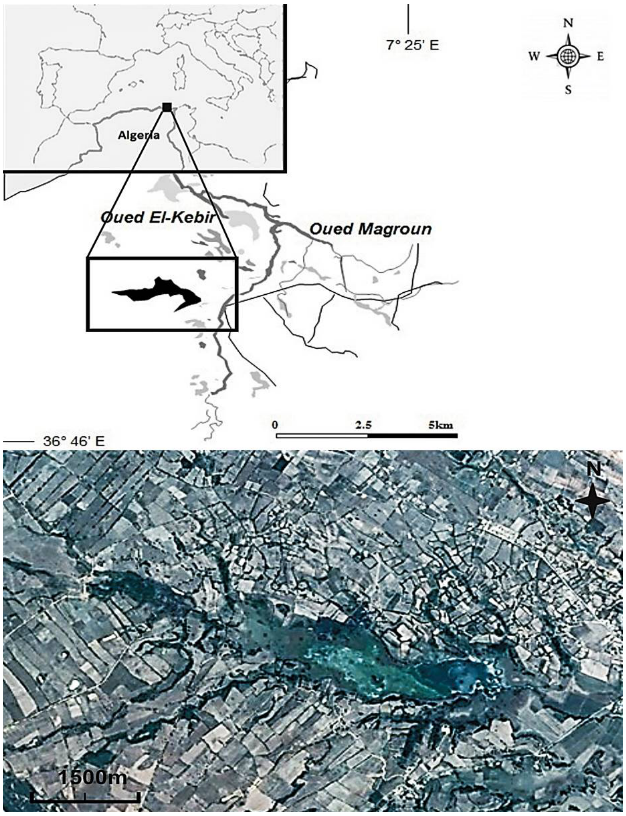

Fig. 1. Map showing the location of our study area in the Garaet Hadj Tahar, northeast Algeria (Western Numidia, Guerbes-Sanhadja wetlands complex).

MATERIALS AND METHODS

Study area

The Garaet Hadj Tahar (100 ha; 36°51′ N, 7°15′ E; hereafter 'Garaet', see Fig. 1) is a freshwater wetland located in Western Numidia (Guerbes-Sanhadja Wetlands Complex, northeast Algeria). This wetland is a Ramsar and IBA site (Samraoui and Samraoui, 2008) and regularly holds significant numbers of globally threatened water bird species (Evans and Fishpool, 2001). In particular, two threatened duck species regularly winter at this site: the white-headed duck (*Oxyura leucocephala*) and the Ferruginous duck (*Aythya nyroca*) (Bara *et al*., 2013; IUCN, 2018). Vegetation at the study site is mainly dominated by common reed *Phragmites australis*, lesser bulrush *Typha angustifolia* and seaside bulrush *Sciprus maritimus*, and secondarily by Nymphaeaceae (*Nymphea alba*), Araceae (*Lemna gibba*), and some species of Juncaceae (*Juncus maritimus*, *J. conglomeratus*, *J. acutus*) (Samraoui and De Belair, 1997). This Garaet is situated in a sub-humid bioclimatic stratum characterized by Mediterranean climate (see Bara *et al*., 2014). This climate is characterized by hot summers (mean maximum temperature: 34°C) and moderate winters (mean minimum temperature: 6°C), with most precipitation occurring between November–March. The National office of meteorology (Skikda station) from 2000–2010 reports historical annual rainfall of 679 mm and mean annual temperature as 18°C.

Data collection

During three consecutive years (September 2012 to August 2015), we surveyed the Rallidae and Anatidae population in the Garaet using a telescope Konus 60 x 40mm. The presence and abundance of these birds were recorded every 15 days using PIA method (punctual index abundance, Blondel, 1975) during the twilight period; every count took around 10 minutes (see Lumpkin and Pearson, 2013). We divided the Garaet into eastern and western sections, where two observers surveyed the birds from a fixed position in each section separately; and extrapolated the total number of birds in the area. The phenological status (*i.e.,* residents, winter migrants and summer breeder migrants) of all water birds recorded was determined according to previous scientific studies as Heim de Balsac and Mayaud (1962) and Isenmann and Moali (2000).

The matrix 12 x 2 of abundance data (which resumed two observations per month over a complete year) was assembled in order to calculate the bird abundance of mentioned families (Frelin, 1982). We calculated two ecological diversity indices: 1) Shannon index ($H' = -\sum p_i \ln p_i$; where H' is Shannon value, p_i is the relative abundance of each species and summation includes from species 1 to the total number of species encountered; Shannon, 1948) and 2) Shannon evenness index ($E = H'/\ln s$; where s is the total number of species encountered; Pielou, 1969) which measured equality of abundance in the stand (Lexerod and Eid, 2006). We recorded two environmental parameters in each visit: (i) mean daily air temperature of the day of the visit, obtained from a national office of meteorology (Skikda Station) and (ii) water depth, calculated from five randomly measures in both sections separately, from where we obtained an average per visit.

Statistical analyses

The statistical tests were performed using SPSS Inc. Software (2017) and the ecological indices (Shannon and Shannon *E*) were calculated by the package ADE-4 (Chessel and Doldec, 1992). Non-parametric Kruskal-Wallis test was performed to compare between the bird abundance by year. Levene's test was used to compare the equality of variance by years for the two ecological indices.

Table I.- Detail of abiotic factors (water depth and air temperature) by seasons at the Garaet Hadj Tahar (northeast Algeria) during three consecutive years (September 2012 to August 2015).

Year	Seasons	Water depth		Air temperature	
		Mean ± SD	Range	Mean ± SD	Range
2012/13	Autumn	3.18 ± 0.14	2.9 – 3.3	21.7 ± 2.57	18.5 – 24.81
	Winter	5.08 ± 1.01	3.4 – 6.3	11.78 ± 2.4	9.38 – 15.08
	Spring	4.83 ± 0.88	3.7 – 6	16 ± 2.02	13.51 – 18.4
	Summer	2.28 ± 0.79	1.3 – 3.7	26.53 ± 2.1	23.69 – 28.7
2013/14	Autumn	1.24 ±0.08	1.12 – 1.31	23.7 ± 2.57	20.5 – 26.81
	Winter	1.53 ± 0.27	1.25 – 1.91	13.78 ± 2.4	11 – 17.03
	Spring	1.56 ± 0.32	1.11 – 1.72	18 ± 2.02	15.5 – 20.4
	Summer	1.12 ± 0.09	1.04 – 1.26	28.53 ± 2.1	25.69 – 30
2014/15	Autumn	2.88 ± 0.14	2.6 – 3	24.7 ± 2.57	21.5 – 27.81
	Winter	4.78 ± 1.01	3.1 – 6	14.78 ± 2.4	12.3 – 18.08
	Spring	4.53 ± 0.88	3.4 – 5.7	19 ± 2.02	16 – 21.46
	Summer	1.98 ± 0.79	1 – 3.4	29.53 ± 2.1	26.7 – 31.73

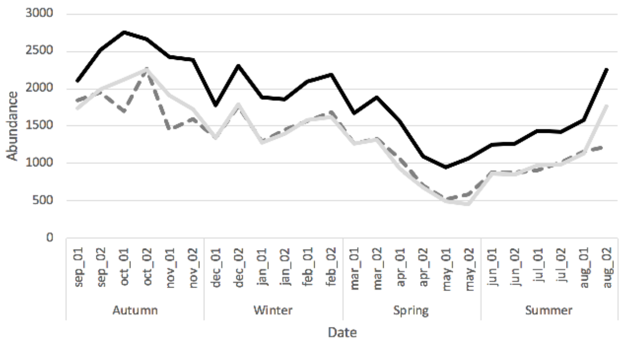

Fig. 2. Abundance by year and seasons of the Rallidae and Anatidae individuals at the Garaet Hadj Tahar, northeast Algeria. Black line, 2012/13; Dotted line, 2013/14; Grey line, 2014/15.

The effect of water depth and air temperature on the Shannon and Shannon *E* indices was tested using Spearman correlation. Relationship between air temperature/ water depth and the bird abundance were explored by a simple linear regression. Non-parametric tests were used because of the lack of normality in the data. Results were considered to be significant at level of 5%. Values are reported as mean ± SD. Study area map was performed using MapInfo 10.5 software.

RESULTS

Air temperature and water depth fluctuations during the four seasons of the year are shown in Table I. Figure 2 shows the seasonal changes in total number of birds during the study period; the maximum number of water birds was always recorded during autumn: 2746 in 2012/13 (late October), 2259 in 2013/14 (early November) and 2253 in 2014/15 (early November). The number of birds in the family Rallidae was always higher than the number of Anatidae (Fig. 3).

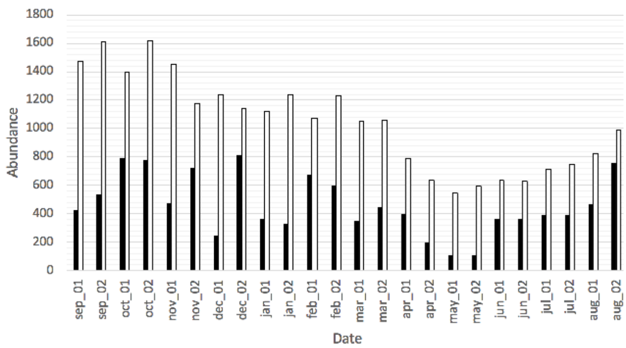

Fig. 3. Mean counts (all years combined) of water birds at Garaet Hadj Tahar, northeast Algeria. White bars, Rallidae; Black bars, Anatidae.

Bird abundance showed significant inter-annual fluctuation (Kruskal-Wallis test: H = 10.79, p-value = 0.005). The number of birds was significantly different between 2012/13 and 2014/15 (difference coefficient = 17.18, critical difference coefficient = 14.46) and between 2013/14 and 2014/15 (difference coefficient = 17.18, critical difference coefficient = 14.46), but not within 2012/13 and 2013/14 (difference coefficient = 0.00, critical difference coefficient = 14.46). As mean daily air temperature and water depth were strongly correlated (r = -0.58, p-value < 0.001), for analysis purpose we only used water depth. Bird abundance was positively influenced by water depth (R = 0.3, p-value = 0.009; see Fig. 4).

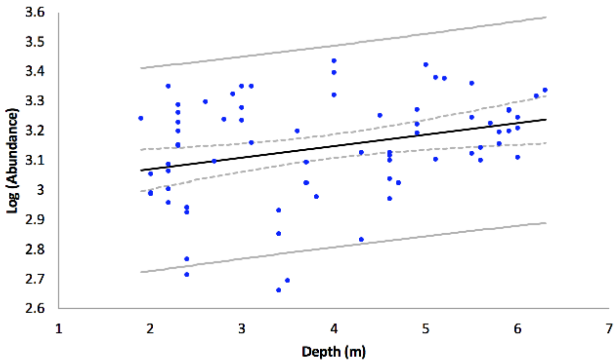

Fig. 4. Relationship between bird abundance (all years combined) and water depth.

A total of 14 species were inventoried during the study period: White-headed Duck, Garganey *Anas querquedula,* Eurasian Teal *Anas crecca*, Tufted Duck *Aythya fuligula,* Ferruginous Duck*,* Mallard *Anas platyrhyncos*, Northern Shoveler *Anas clypeata*, Gadwall *Anas strepera*, Eurasian Wigeon *Anas penelope*, Northern Pintail *Anas acuta*, and Common Pochard *Aythya ferina* (Anatidae); and Common Coot *Fulica atra*, Common Moorhen *Gallinula chloropus*, and Purple Swamphen *Porphyrio porphyrio* (Rallidae). Two of them are key conservation species observed regularly in the Garaet: the near threatened Ferruginous Duck and the endangered White-headed Duck. In addition, wintering migrant birds represented 50% of the total water birds observed in the Garaet, breeding migrant birds only 7% and the rest (43%) were the residents.

Table II shows the values of Shannon and Shannon *E* indices in relation to seasons of the year during the study period. Shannon and Shannon *E* indices were not correlated to each other (r = -0.02, p-value = 0.85). The mean value of Shannon index was 1.14 in 2012/13, 0.96 in 2013/14 and 0.87 in 2014/15, with maximum values usually recorded during autumn-winter. On the other hand, mean equitability in population distribution shown by Shannon *E* index was 0.28 in 2012/13, 0.35 in 2013/14 and 0.37 in 2014/15, with maximum values recorded typically during summer. Shannon index gradually decreased from autumn to summer, whereas Shannon *E* index increased in the same period. The variance of Shannon index values changed between years (Levene's test: F = 0.37, p-value = 0.69), but did not change for the Shannon *E* index (Levene's test: F= 4.48, p-value = 0.01). Water depth correlated positively with Shannon index (r = 0.31, p-value = 0.01), but negatively with Shannon *E* index (r = -0.37, p-value = 0.001).

DISCUSSION

In the Garaet Hadj Tahar 1) bird abundance showed inter-annual fluctuation, with the highest values always recorded during autumn and the minimum during spring, 2) bird abundance was positively influenced by water depth and, by default, negatively influenced by mean daily air temperature, 3) Shannon index showed inter-annual variation, and 4) water depth influenced negatively the Shannon index and positively the evenness index.

Bird abundance noted in field samplings at the Garaet was frequently higher than 1000 individuals, which indicates that this site is a very important refuge of water birds in the Guerbes-Sanhadja wetlands complex.

Table II.- Temporal fluctuation of the two ecological indices evaluated in this study (Shannon and Shannon E indices) at the Garaet Hadj Tahar (northeast Algeria) during three consecutive years (September 2012 to August 2015).

Year	Season	Shannon index		Shannon evenness index	
		Mean ± SD	Range	Mean ± SD	Range
2012/13	Autumn	1.12 ± 0.24	0.75 – 1.45	0.26 ± 0.03	0.23 – 032
	Winter	1.22 ± 0.21	0.91 – 1.48	0.27 ± 0.05	0.19 – 0.33
	Spring	1.18 ± 0.15	0.99 – 1.46	0.26 ± 0.04	0.2 – 0.33
	Summer	1.03 ± 0.05	0.95 – 1.12	0.31 ± 0.04	0.25 – 0.38
2013/14	Autumn	1.02 ± 0.29	0.62 – 1.38	0.37 ± 0.03	0.32 – 0.44
	Winter	1.07 ± 0.22	0.73 – 1.31	0.32 ± 0.07	0.2 – 0.45
	Spring	0.87 ± 0.14	0.62 – 1.06	0.31 ± 0.04	0.25 – 0.36
	Summer	0.88 ± 0.04	0.96 – 0.82	0.4 ± 0.01	0.38 – 0.43
2014/15	Autumn	0.93 ± 0.21	0.67 – 1.18	0.30 ± 0.02	0.29 – 0.32
	Winter	0.99 ± 0.19	0.76 – 1.3	0.33 ± 0.08	0.21 – 0.45
	Spring	0.79 ± 0.16	0.5 – 1.01	0.32 ± 0.05	0.25 – 0.41
	Summer	0.84 ± 0.04	0.89 – 0.78	0.52 ± 0.14	0.43 – 0.84

The abundance curve of birds had the same appearance in 2012/13 and 2013/14, but not in 2014/15. The increase in number of birds recorded in 2014/15 could be due to the occupation of the Garaet by water birds from other temporally not flooded areas in the surroundings, as the Guerbes-Sanhadja complex which was going through an intense drought. Our study area, however, maintained high flooding level despite the low level of precipitation in this year. This level of water in the Garaet may be affected in the near future due to strong warming noted in the region (see also Sokos *et al*., 2016), therefore many meteorological datasets predicted that mean air temperature values will increase in the Mediterranean (Lelieveld *et al*., 2012; Ozturk *et al*., 2015).

Fourteen species were recorded at the Garaet between 2012 and 2015, among them two key species: the ferruginous duck and the white-headed duck. These species regularly breed in the Garaet and commonly observed at this site (Bara *et al*., 2013; Metallaoui *et al*., 2009). Moreover, geographical position of this wetland between Mediterranean Sea and the Hauts Plateaux wetlands and Sahara wetlands suggests the advantage of this wetland as a stopover area for migratory birds (wintering birds and passage migrants), that is why understanding the consequences of this changing environmental conditions on the demographic parameters of these migratory species is key for addressing the widely reported decline of many of these species (Carneiro *et al*., 2016). For example, Houhamdi *et al*. (2008) and Samraoui *et al*. (2009) reported that, the North African wetlands (such as Garaet Hadj Tahar) play a key role in supporting the Mediterranean metapopulation of the Flamingo *Phoenicopterus roseus* during annual migratory cycle.

Two other important birds of the Anatidae family noted previously at this study site *viz*., Red-crested Pochard *Netta rufina* and Marbled Duck *Marmaronetta angustirostris* (Metallaoui and Merzoug, 2009; Metallaoui and Houhamdi, 2010) were not recorded during this study. These two ducks are usually very sensitive to environmental variation and change rapidly their behavior and status (Amat, 1984; Green, 1998).

Even though the richness reported in this study (14 species) is slightly lower than other studies (Samraoui and De Belair, 1997; Atoussi, 2008; Metallaoui and Houhamdi, 2010; Bara *et al*., 2013), geographical situation of the Garaet causes a high abundance of birds hence the site could be considered a hot spot for bird conservation, mainly for the winter period. We think that during spring and summer periods it is possible that due to the low precipitation levels in the area, birds are forced to move to other wetlands in northern Algeria, as 'El Kala' to the northeast or 'Jijel' to the northwest. Barbaro *et al*. (2007) also reported that bird richness and abundance structure can vary among seasons due to environmental parameters, and this motivates the birds to look for new and better sites in different times of the year (Sokos *et al*., 2016).

The Shannon index values varied between years due to direct changes of inter-annual water bird richness. Higher values during autumn and winter are due to the temporal presence of wintering migrant birds. A relatively stable number of all-year resident and breeding birds however remains in the Garaet. The evenness index did not vary between years and presented relatively low values between seasons (0.2 – 0.5).

Environmental factors such as temperature and precipitation usually limit or alter the phenology and distribution of migratory species (Hubálek, 2003; Hubálek, 2004; Vesser and Both, 2005; Hubálek and Čapek, 2008; Sokos *et al*., 2016); such negative effects however could be evident only in extreme and hard climatic conditions (Cook, 1969; Zuckerberg *et al*., 2011). Substantial water extraction recorded at several sites of the Guerbes-Sanhadja complex (mainly for agricultural purpose) could be acting as a negative factor that obliged the water birds to disperse to other wetlands in the area. However, during the study period, we did not register extreme or significantly high water extraction, hence richness and bird abundance values were relatively stable

Environmental factors other than water depth and daily air temperature such as the site productivity, food resources and/or habitat structure in our study area could also affect the abundance and richness of birds (Meehan *et al*., 2004; Carrascal *et al*., 2012; Ferger *et al*., 2014). For example, availability of nutricious Cyperaceae seeds (containing a large proportion of fiber and protein; Pirot *et al*., 1984) seems to attract breeding and wintering water birds in the area (Perrins, 1974).

Bird abundance reported in this study, in addition to the presence of two key species for conservation concerns, allow us to highlight the importance of preserving the Garaet Hadj Tahar as a water bird refuge. We strongly recommend to the government to finance more conservation projects in this complex in order to maintain this level of water bird abundance and diversity.

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Statement of conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES

Amat, J.A., 1984. Ecological segregation between red-crested pochard *Netta rufina* and pochard *Aythya ferina* in a fluctuating environment. *Ardea*, **72**: 229-233.

Atoussi, S., 2008. *Ecology of ducks in Garaet Hadj Tahar (Ben Azouz, Skikda).* Master thesis, university of Guelma, Algeria.

Bara, M., Merzoug, S.E., Bouslama, Z. and Houhamdi, M., 2013. Biodiversity and phenology of the Rallidae and the Anatidae in Garaet Hadj Tahar (Northeast of Algeria). *Annls. biol. Res*., **4**: 249-253.

Bara, M., Merzoug, S.E., Khelifa, R., Bouslama, Z. and Houhamdi, M., 2014. Aspects of breeding ecology of the purple swamphen *Porphyrio porphyrio* in the wetland complex of Guerbes-Sanhadja, northeast of Algeria. *Ostrich*, **85**: 185-191. https://doi.org/10.2989/00306525.2014.971901

Barbaro, L., Rossi, J.P., Vetillard, F., Nezan, J. and Jactel, H., 2007. The spatial distribution of birds and carabid beetles in pine plantation forests: The role of landscape composition and structure. *J. Biogeogr*., **34**: 652-664. https://doi.org/10.1111/j.1365-2699.2006.01656.x

Blondel, J., 1975. Analysis of water birds population: Ecological diagnosis element I. progressive frequency samples method. *Terre Vie*, **29**: 533-589.

Carneiro, C., Correia, E., Goncalves, D., Brito, R., Luis, A. and Alves, J.A., 2016. Weather mediate impact on the breeding output of an Afro-Palearctic migratory waterbird. *Avian Biol. Res*., **9**: 167-173. https://doi.org/10.3184/175815516X14628114851451

Carrascal, L.M., Seoane, J. and Villén-Pérez, S., 2012. Temperature and Food constraints in wintering birds an experimental approach in montane Mediterranean oakwoods. *Commun. Ecol*., **13**: 221-229. https://doi.org/10.1556/ComEc.13.2012.2.12

Chessel, D. and Doldec, S., 1992. *ADE software multivariate analysis and graphical display for environmental data,* Version 4. University of Lyon.

Clarke, A. and Gaston, K.J., 2006. Climate, energy and diversity. *Proc. R. Soc. London B*, **273**: 2257-2266. https://doi.org/10.1098/rspb.2006.3545

Cook, R.E., 1969. Variation in species density in North American birds. *System. Zool*., **18**: 63-84. https://doi.org/10.2307/2412411

Evans, M.I. and Fishpool, L.D.C., 2001. *Important bird area in Africa and associated islands: priority sites for conservation*. Birdlife International, Pisces Publications, Cambridge.

Evans, K.L., James, N.A. and Gaston, K.J., 2006. Abundance, species richness and energy availability in North American avifauna. *Glob. Ecol. Biogeogr*., **15**: 372-385. https://doi.org/10.1111/j.1466-822X.2006.00228.x

Ferger, S.W., Schleuning, M., Hemp, A., Howell, K.M. and Böhning-Gaese, K., 2014. Food resources and vegetation structure mediate climatic effects on species richness of birds. *Glob. Ecol. Biogeogr*., **23**: 541-549. https://doi.org/10.1111/geb.12151

Frelin, C., 1982. Relationship frequency-abundance, theoretical aspect; application on water birds population. *Terre Vie*, **36**: 435-464.

Gaston, K.J., 2000. Global patterns in biodiversity. *Nature*, **405**: 220-227. https://doi.org/10.1038/35012228

Green, A.J., 1998. Habitat selection by the marbled teal *Marmaronetta angustirostris*, ferruginous duck *Aythya nyroca* and other ducks in the Goksu delta, Turkey, in summer. *Rev. Ecol*., **53**: 225-2243.

Hamdi, N. and Ismail-Hamdi, S., 2015. Ecological index to monitoring wetlands based on aquatic avifauna: Case study of Tunisia.. *Terre Vie*, **70**: 328-341.

Heim De Balsac, H. and Mayaud, N., 1962. *Birds of northwestern Africa*. Paul Lechevalier, Paris.

Houhamdi, M., Bensaci, T., Nouidjem, Y., Bouzegag, A., Saheb, M. and Samraoui, B., 2008. Eco ethology of the greater flamingo *Phoenicopterus roseus* wintering in Oued Righ hill, oriental Sahara of Algeria. *Aves*, **45**: 15-27.

Hubálek, Z., 2003. Spring migration of birds in relation to North Atlantic Oscillation. *Folia Zool*., **52**: 287-298.

Hubálek, Z., 2004. Global weather variability affects avian phenology: A long-term analysis, 1881-2001. *Folia Zool*., **53**: 227-236.

Hubálek, Z. and Čapek, M., 2008. Migration distance and the effect of North Atlantic Oscillation on the spring arrival of birds in Central Europe. *Folia Zool*., **57**: 212-220.

Hurlbert, A.H., 2004. Species-energy relationships and habitat complexity in bird communities. *Ecol. Lett*., **7**: 714-720. https://doi.org/10.1111/j.1461-0248.2004.00630.x

Isenman, P. and Moali, A., 2000. *Birds of Algeria*. SEOFO, pp. 336.

IUCN, 2018. *The IUCN red list of threatened species*. International Union for Conservation of Nature.

Available at: http://www.iucnredlist.org/technical-documents/spatial (accessed 01 April 2018).

Jetz, W., Wilcove, D.S. and Dobson, A.P., 2007. Projected impacts of climate and land-use change on the global diversity of birds. *PLoS Biol*., **5**: 157. https://doi.org/10.1371/journal.pbio.0050157

Lelieveld, J., Hadjinicolaou, P., Kostopoulou, E., Chenoweth, J., El-Maayar, M., Giannakopoulos, C., Hannides, C., Lange, M.A., Tanarhte, M., Tyrlis, E. and Xoplaki, E., 2012. Climate change and impacts in the Eastern Mediterranean and the Middle East. *Clim. Change*, **114**: 667-687. https://doi.org/10.1007/s10584-012-0418-4

Lennon, J.J., Greenwood, J.J.D. and Turner, J.R.G., 2000. Bird's diversity and environmental gradients in Britain: a test of energy hypothesis. *J. Anim. Ecol*., **69**: 581-598. https://doi.org/10.1046/j.1365-2656.2000.00418.x

Lexerod, L.N. and Eid, T., 2006. An evaluation of different diameter diversity indiced based on criteria related to forest management planning. *Forest Ecol. Manage*., **222**: 17-28. https://doi.org/10.1016/j.foreco.2005.10.046

Lumpkin, H.A. and Pearson, S.M., 2013. Effects of exurban development and temperature on bird species in the southern Appalachian. *Conserv. Biol*., **27**: 1069-1078. https://doi.org/10.1111/cobi.12085

Meehan, T.D., Jetz, W. and Brown, J.H., 2004. Energetic determinants of abundance in winter land bird community. *Ecol. Lett*., **7**: 532-537. https://doi.org/10.1111/j.1461-0248.2004.00611.x

Metallaoui, S. and Merzoug, A.E., 2009. Wintering observation of red crested pochard *Netta rufina* beside Skikda (Algeria). *Alauda*, **77**: 57.

Metallaoui, S., Atoussi, S., Merzoug, A. and Houhamdi, M., 2009. Wintering of white headed duck (Oxyura leucocephala) in Garaet Hadj Tahar (Skikda, northeast of Algeria). *Aves*, **46**: 136-140.

Metallaoui, S. and Houhamdi, M., 2010. Biodiversity and ecology of aquatic avifauna wintering in Garaet Hadj Tahar (Skikda, northeast of Algeria). *Hydroecol. Appl*., **17**: 1-16. https://doi.org/10.1051/hydro/2010002

Newton, I., 1998. *Population limitation in birds*. Academic Press, London.

Ozturk, T., Ceber, Z.P., Türkeş, M. and Kurnaz, M.L., 2015. Projections of climate change in the Mediterranean Basin by using downscaled global climate model outputs. *Int. J. Climatol*., **35**: 4276-4292. https://doi.org/10.1002/joc.4285

Parmesan, C. and Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, **421**: 37-42. https://doi.org/10.1038/nature01286

Perrins, C., 1974. *Birds of Britain and Europe*. First university of Texas, Glasgon, pp. 360.

Pielou, E.C., 1969. *An introduction to mathematical ecology*. Wiley, New York.

Pirot, J.Y., Chessel, D. and Tamisier, A., 1984. Exploitation alimentaire des zones humides de Camargue par cinq espèces de canard de surface en hivernage et en transit: Modélisation spatiotemporelle. *Terre Vie*, **39**: 167-192.

Ricklefs, R.E.A., 2004. Comprehensive framework for global patterns in biodiversity. *Ecol. Lett*., **7**: 1-15. https://doi.org/10.1046/j.1461-0248.2003.00554.x

Samraoui, B. and De Belair, G., 1997. The Guerbes-Sanhadja wetlands (N.E. Algeria), Part I: Overview. *Ecologie*, **28**: 233-250.

Samraoui, B. and Samraoui, F., 2008. An ornithological surveys of Algerian wetlands: Important bird area, Ramsar sites and threatened species. *Wildfowl*, **58**: 71-96.

Samraoui, B., Boulkhssaim, M., Bouzid, A., Bensaci, E., Germain, C., Béchet, A. and Samraoui, F., 2009. Current research and conservation of the Greater Flamingo *Phoenicopterus roseus* in Algeria. *Flamingo Special Publication*, **1**: 20-26.

Shannon, C.E., 1948. The mathematical theory of communication. In: *The mathematical theory of communication* (ed. C.E Shannon and W. Weaver). University of Illinois Press, Urbana, pp. 29-125.

Sokos, C.K., Birtsas, P.K., Platis, P.C. and Papaspyropoulos, K.G., 2016. Wheather influence on the abundance of bird species wintering in three Mediterranean ecosystems. *Folia Zool*., **65**: 200-207. https://doi.org/10.25225/fozo.v65.i3.a4.2016

Vesser, M.E. and Both, C., 2000. Shifts in phenology due to global climate change: The need for yardstick. *Proc. R. Soc. B*, **272**: 2561-2569. https://doi.org/10.1098/rspb.2005.3356

Zuckerberg, B., Bonter, D.N., Hochachka, W.M., Koenig, W.D., De Gaetano, A.T. and Dickinson, J.L., 2011. Climatic constraints on wintering distribution are modified by urbanization and weather. *J. Anim. Ecol*., **80**: 403-413. https://doi.org/10.1111/j.1365-2656.2010.01780.x