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Effects of vegetation and water seasonal variation on habitat use of herons (Aves, Ardeidae) in Tonga Lake (North-East Algeria)

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Abstract. The present study was aimed to determine the effect of some environmental factors such as water features and vegetation cover on the distribution and habitat use of herons over different seasons of the bird's life (breeding, passage and wintering) in Tonga Lake (North East Algeria) from March 2017 to February 2018. We used remote sensing techniques to study the environmental factors variations, we adopted the normalized difference vegetation index (NDVI) to give an estimate of vegetation cover and we used the normalized difference water index (NDWI) to study the water features. In our study, we determine that the abundance and richness of herons species is largely influenced by the water features and vegetation cover. The seasonal variations in the amount of these environmental factors are known to affect the availability of various food items for herons. Eight species of herons were identified during the study period. Pearson's Correlation Coefficient was used to examine the effect of NDVI and NDWI on the distribution of herons. The results showed that the NDVI was significantly positively correlated with richness and abundance of herons respectively ($r=0.728$, $p<0.05$) ($r=0.651$, $p<0.05$), whereas the NDWI was significantly negatively correlated with the richness and abundance of herons ($r=-0.65$, $p<0.05$) ($r=-0.69$, $p<0.05$) respectively.

Keywords: habitats, herons, NDVI, NDWI, Ramsar site.

Introduction

The concept of habitats has been widely documented (Santilli and Bagliacca, 2010; Hull *et al*., 2016; Ashiagbor and Danquah, 2017), although several authors have recommended of habitat in the context of ornithology (Hayes and Fox, 1991; Jones, 2001; Tommy King and Michot, 2002; Litlefeld and Johnson, 2005; Bensaci *et al.,* 2015; Swathi and Antoney, 2018).

The conspicuous nature of birds has allowed ornithologists to assemble a vast amount of information relating to the distribution and the abundance of birds to the environment's aspects (Koskimies, 1989; Paracuellos and Telleria, 2004). The characteristics of the habitat reflect the waterbird diversity, whose relative importance varies on both spatial and temporal scales (Wu *et al*., 2014). Many other authors evaluated the influence of vegetation and water as determinants of habitat use by birds (Colwellando and Tafti, 2000; Bancroft *et al*., 2002; Rajpar and Zakaria, 2014). There are frequently assumed to be the primary proximate factors determining where and how species use resources. Temporal scale is also important because birds do different things to meet varying functional needs during different times of the year and they also exhibit habitat shifts between years (Saygili *et al*., 2011; González-Gajardo *et al*., 2009).

Wetlands provide habitats for many water bird communitiesand home for large number of migratory and resident species ofbirds (Vasudeva Rao *et al*., 2015) due to habitat diversity and productivity, they are also characterized by shallow water overlying waterlogged soil, interspersed submerged and emergent vegetation (Rajpar and Zakaria, 2014; Martins *et al*., 2017).

North-East Algeria holds a wide range of wetlands, many of them designated as Important Bird Areas (IBAs) and/or Ramsar sites (Samraoui and Samraoui, 2008). Tonga Lake within North east Algeria is classified among the North Africa's top biodiversity hotspots (Samraoui *et al*., 1998). This seasonal freshwater lake has an international importance under the Ramsar Convention in 1983. In turn, Family Ardeidae is one of the best represented in the North-Eeast Algeria (Chalabi-Belhadj, 2008). Herons are wading birds of considerable importance, because they constitute indicator species in wetlands. Additionally, some species of *Ardea* have been studied as bioindicators of mercury (Goutner *et al*., 2001) and organochlorines (Albanis *et al.,* 1996).

The main objective of our study is to determine the effect of vegetation and water seasonal variation on habitat use of herons during their annual cycle of occurrence in Tonga Lake.

Throughout this contribution we tried to analyzing the relationships between changes in waterbird communities and the environmental variables across the effect of seasonal variation of vegetation and water cover on the diversity, temporal and spatial distribution of herons in the Tonga lake in the ordre to used in further management and conservation implications of these wetlands and ensure the suitable habitat requirements of waterbirds.

Materials and methods

The Tonga lake (36°52′ N, 8°31′ E), where this study was carried out is situated in the extreme north east of Algeria near the Algerian-Tunisian border, within the protected natural reserve of El-Kala National Park (PNEK)(Fig. 1). This Lake is classified as an international importance site under the Ramsar Convention in 1983 and as an Important Bird Area (IBA), which is generally, recognized as one of the four major wetland complexes in the Western Mediterranean (Bensliman *et al.,* 2015; Boucheker *et al.,* 2009). This shallow freshwater lake covers an area of 2400 ha with a maximum depth of 2.5 m. It is fed by two tributaries: Oued El Hout from the southeast and Oued El Eurg from the east. On the north part of Tonga Lake the artifcial canal of the Messida represent the connection with the Mediterranean Sea. Almost 80% of its area is covered by helophytes (Lesser Bulrush *Typha angustifolia*, Common Club-rush *Scirpus lacustris* and Common Reed *Phragmites australis*) and hydrophytes (white lotus *Nymphaea alba* and Stuckenia pectinata*Potamogeton pectinatus*) (Aissaoui *et al*., 2011; Lazli *et al*., 2011; Kadid *et al*., 2007).

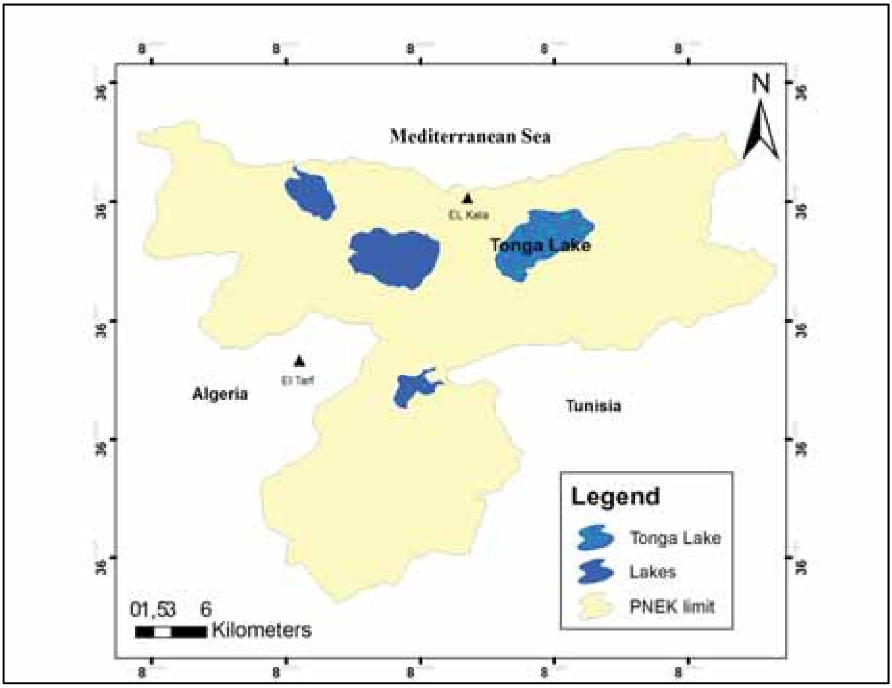

Figure 1. Location of Tonga Lake

Data collection

Heron surveys

Heron species surveys were conducted from March 2017 to February 2018, over different seasons of the bird's life (reproduction, passage and wintering). Heron censuses were conducted in breeding season(late April-late June), Passage season (late July-late November) and wintering season (late December-early March) (Yahner, 1986). Regular counts of richness and abundance of species in each habitat were undertaken by 2 observers by using a telescope 20 ×80 or 10 × 50 binoculars and birds guide of Heinzel (Heinzel *et al*., 1972). We carried out an individual count (absolute method), if thegroups of birds are less than 200 individuals and located at an inferior of 200 m, on the other hand we have made estimates of total numbers(relative method) for birds more than 200 m away, anda workforce of more than 200 individuals (Blondel, 1975). All observations and counts were made during the early hours of the day, between sunrise to 12:00 h and between 14:00 h to sunset.

Environnemental variables

In the aim to determine the effect of environment variables on the habitat use of herons over different season, two main parameters were taken in to count: spatio-temporal variation of vegetation and water cover.

To evaluate former parameters, two indexes were calculated relatively to all study period: NDVI and NDWI for vegetation and water cover respectively.

NDVI and NDWI analysis

The normalized difference vegetation index (NDVI) and the normalized difference Water index (NDWI) data were obtained from the Landsat TM images were obtained from United States Geological Survey (USGS).

The normalized difference vegetation index (NDVI) gives an estimate of the green vegetation abundance (Tucker, 1979).NDVI use band 4 (Red) come with band 5 (Near Infrared) for Landsat 8. NDVI is formulated as below:

NDVI= (NIR-RED) / (NIR+RED)

Where: NIR-near infrared radiation reflectance; RED-visible red radiation reflectance. The normalized difference water index (NDWI) is a method that has been developed to delineate open water features and enhance their presence in remotely-sensed digital imagery (Mcfeeters, 1996; Mcfeeters, 2013). NDVI use band 2 (Green) come with band 4(Red) for Landsat 8.The NDWI is expressed as follows:

NDWI= (GREEN -RED) / (GREEN+RED)

The results of NDVI and NDWI generate a value between -1 and +1.

Statistical analysis

All analyses were performed after verification of the normality test (test of Shapiro-Wilk) of the various dependent and independent variables. The one-way analysis of variance (ANOVA) and a Ttest. Those tests both are used when our data has a normal distribution. The one-way analysis of variance (ANOVA) was performed to search for a possible variation in the abundance, richness, NDVI and NDWI of herons during the deferent seasons. T test (Student's T-Test) was used to compare variation in abundance and richness between the two habitats (vegetation and water). In addition, the Pearson's correlation was used to search the relationship and association between species richness, abundance and habitat factors (NDVI and NDWI). The p-value<0.05 were *considered significant.* The species diversity in the different season was investigated by the biodiversity indices. All statistics were performed using the Software Package for Social Statistics (IBM SPSS Statistics Version 23).

Results and discussion

Heron species richness and relative abundance

During the study period, Tonga Lake recorded eight species of herons, out of which seven have breeding status. Thre especies of herons observed in Tonga Lake are threatened in Europe: the purple heron *Ardea purpurea*, little bittern *Ixobrychus minutus* (which are considered "declined") and squacco heron *Ardeola ralloides* which is considered "rare" (Leon *et al*., 2004).

The significant difference for richness of herons among the three seasons, was compared by applying the parametric test (normal distribution), the one-way ANOVA*.* The one –way ANOVA test indicated that the richness of herons in the three seasons was significantly different ($F = 3.85$, $p<0.05$). However,there was a significant difference in the mean richness of heron species between different vegetation's habitat and water habitat's($t(18) = -5.06$, $p<0.001$) (Tab. 1).

Table 1. Mean richness of herons in the three different seasons in Tonga Lake

	Richness			Abundance		
Season	Mean±*sd*	%	Range (*min-max*)	Mean±*sd*	%	Range (*min-max*)
Breeding	5.00±1.15	87.50	3-7	303.92±133.11	57.66	160–553
Passage	4.83±0.75	75.00	4-6	294.66±60.86	38.06	213-365
Wintering	3.50±0.57	43.75	3-4	34.25±9.06	4.27	21- 41

sd: Standard deviation

One–way ANOVA test revealed a significant difference of herons abundance between the three seasons (F= 10.17, p <0.001). Also, the variation in mean abundance between the vegetation habitat's and water habitat's was significantly different (t (18) = 2.37, p<0.05). The significant variation in species richness and abundance of herons throughout the diferent seasons could be due to seasonal movement patterns and habitat changes (Tab. 2). Yu-Seong *et al.,* 2007, recorded that the availability of feeding habitat is an important factor affecting the richness and abundance of herons species.

Table 2. Species variation of herons recorded in the three different seasons in Tonga Lake

Season	**Breeding**			**Passage**			**Wintering**		
Species name	Mean $\pm sd$	%	Range (*min-max*)	Mean $\pm sd$	%	Range (*min-max*)	Mean $\pm sd$	%	Range (*min-max*)
Little Egret	95.63 ±38.47	26.73	38-149	133.83 ±90.21	39.24	33-250	5.5 ± 3.69	18.36	1-9
Cattle Egret	104.9 ±79.79	39.46	6-223	5.66 ±1.63	1.25	4-8	4.66 ± 0.57	10.20	4-5
Squacco Heron	118.75 ±21.26	28.14	97-159	52.23 ±52.27	17.26	7-110	-	-	-
Grey Heron	2.1 ±0.69	0.53	1-3	48.16 ±52.54	19.15	4-122	10.16 ± 4.15	32.65	4-16
Purple Heron	10.87 ± 5.02	2.83	1-16	3.33 ±4.04	1.25	1- 8	-	-	-
Night Heron	8.25 ± 5.12	2.30	1-13	-	-	-	-	-	-
Little Bittern	1.66 ± 0.57	0.35	1- 2	-	-	-	-	-	-
Great Egret	-	-	-	90 ±52.12	21.82	24-139	10.71 ± 6.60	38.77	1-19

sd: Standard deviation

Diversity pattern

The diversity of heron species in the different study seasons shows that the passage season have the highest species diversity (Shannon's index H' = 1.40; Margalef's index R = 0.86) comparatively to breeding and wintering seasons (Tab. 3).

Waterbirds diversity distribution pattern has been often explained in terms of simple environmental factors. Vegetation cover and water features have been alternatively considered as key factors in the determination of the variable distribution of waterbird diversity (Rotenberry and Wiens, 1980; Wu *et al*., 2014; Dronova *et al*., 2016; Zhang *et al*., 2017).

Table 3. Comparison of herons species diversity of breeding, passage and wintering seasons in Tonga Lake

Diversity indices	Breeding	Passage	Wintering
Shannon_H	1.34	1.40	1.32
Margalef	1.03	0.86	0.89

Normalized Difference Vegetation Index (NDVI)

The ANOVA analysis for normalized difference vegetation index (NDVI) among the three study seasons indicated that the vegetation cover was significantly different (F = 8.7; p<0.01). The results of the normalized difference vegetation index (NDVI) show that the breeding season has the highest average (0.237 ± 0.019), and the wintering season has the lowest NDVI average (0,139 ± 0.05). One-way ANOVA analysis of surface vegetation cover indicated a significant difference between the three study seasons (F = 10. 97; p<0.001), where, the breeding season has the highest surface vegetation cover (58.95%). In contrast, wintering season has the lowest surface vegetation cover (10.44%) (Tab. 4).

The examination of the relationship between seasonal NDVI variations and herons population parameters in Tonga Lake revealed a positive correlation between NDVI and species richness (Pearson's correlation r = 0.728, p<0.01) and species abundance (Pearson's correlation r = 0.651, p<0.05).

Species richness and abundance increase positively with the NDVI. Higher NDVI may indicate the presence of better vegetative food resources (Figs. 2 and 3). Lower NDVI values may indicate lower vegetation coverage, and usually determine higher water levels (Fig. 4). The species richness and abundance of many waterbirds bird species are determined by the composition of the vegetation thatforms a major element of their habitats (Bancroft *et al*., 2002; Martins *et al.*, 2017). The breeding season has the higher NDVI average and vegetation cover; also this season has the higher abundance of herons. This might be due to the surface of vegetation cover which had created different microhabitats rich in food resources that offer suitable habitats and attracted a wide number of herons species (Cousin and Phillips, 2008; Hassen-Aboushiba, 2015). These habitats provide suitable foraging, roosting, and nesting area for the most heron's species. Additionally, vegetation may calm the water surface, thus increasing visibility and may have higher prey densities i.e. invertebrates (insects and gastropods) (Djamai *et al*., 2019), fishes (carps and cat fishes), amphibians (frogs and salamanders). Otherreason could be that, the heterogeneity of aquatic vegetation also provides shelterfrom weather and predators. This could be too the aquatic vegetation havingshallow water level.

Table 4. Values of NDVI, surface vegetation cover (ha) and percent of vegetation cover (%) in deferent season in Tonga Lake

	Breeding	**Passage**	**Wintering**
	Mean ± *sd*	Mean ±*sd*	Mean±*sd*
Mean NDVI	0.237 ±0.019	0.221 ±0.021	0.139 ±0.05
Mean surface vegetation cover (Ha)	1415 ±227.27	1164 ±474.59	282 ±257.25
Percent of vegetation cover (%)	58.95	43.11	10.44

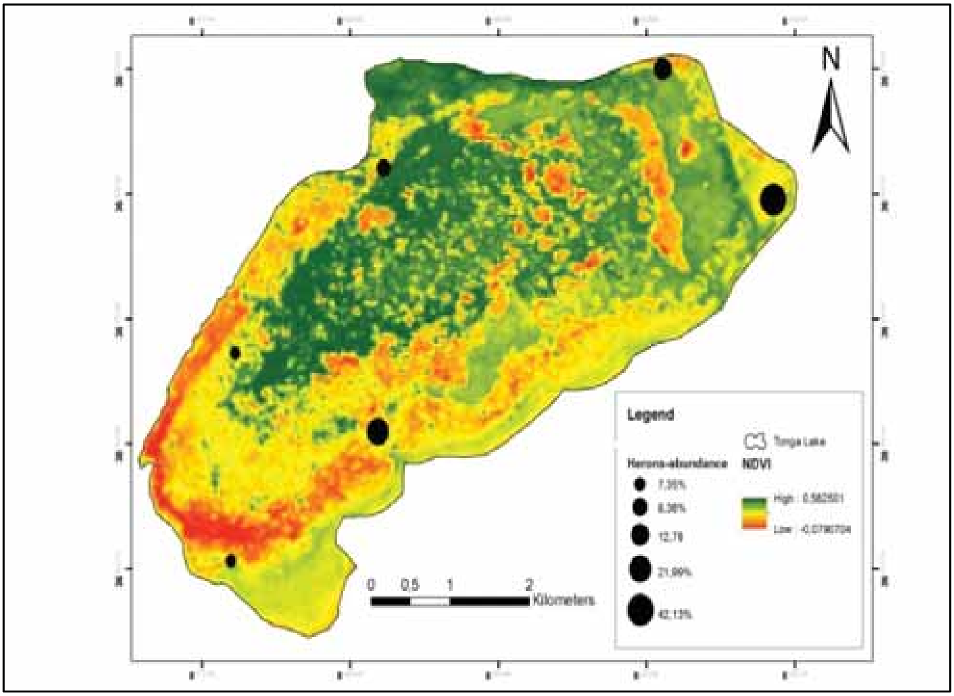

Figure 2. NDVI map of Tonga Lake in breeding season with the distribution of herons.

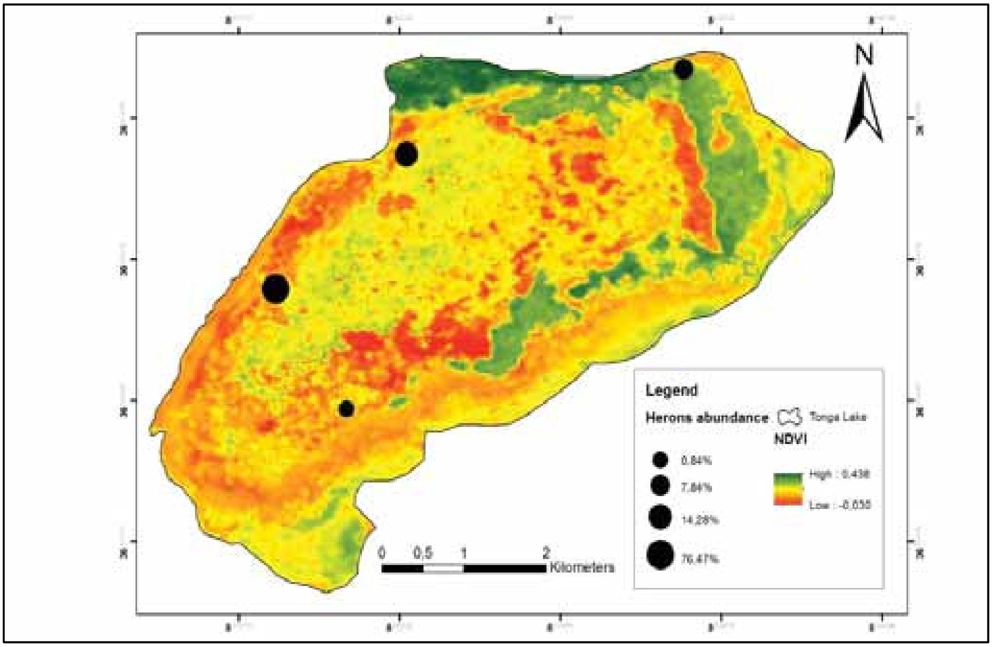

Figure 3. NDVI map of Tonga Lake in passage season with the distribution of herons.

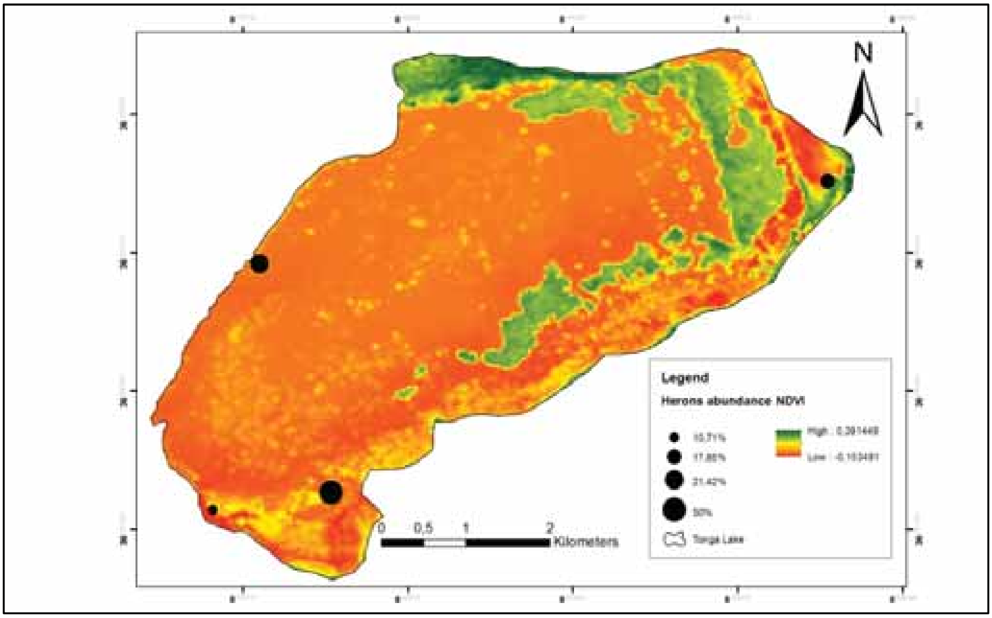

Figure 4. NDVI map of Tonga Lake in wintering season with the distribution of herons.

Normalized Difference water index (NDWI)

One-way ANOVA analysis of the normalized difference water index (NDVI) indicated that the water area of the three seasons was highly significantly different (F = 5.44, p<0.05). However, the wintering season has the higher NDWI average (0.081±0.021), while, the passage season has the lowest NDWI average (0.031±0.018). The one way ANOVA analysis showed that the water area of the three seasons was highly significantly different (F = 7.24, p<0.05).Although, the variation of water area during wintering season has the highest (41.95%), while the passage season has the lowest water area (3.79%) (Tab. 5).

The examination of relationship between seasonal variations NDWI and species abundance and richness variations revealed a negative correlation between species richness and NDWI (Pearson's correlation r = -0.65 ; p<0.05), and between species abundance and NDWI (Pearson's correlation r = -0.69 ; p<0.05).

Dubowy (1996), Colwel and Taft (2000) recorded that Herons showed a preference to shallow water because it provide suitable resources of food. Another study in Algeria of Nouidjem *et al*. (2019) recorded that herons usually seenon shallow shorelines.

Table 5. Comparison of Mean NDWI, Mean water area (Ha) and Percent of water surface (%) in deferent season of herons in Tonga Lake

	Breeding	**Passage**	**Wintering**
	Mean ± *sd*	Mean ± *sd*	Mean ± *sd*
Mean NDVI	0.047±0.016	0,031±0.018	0.081±0.021
Mean of water area (Ha)	475±264.75	91±47.07	1007±446.28
Percent of water area %	19.79	3.79	41.95

Our results showed a negative correlation between the species richness, abundance and the normalized difference water index (NDWI). While, the effect of water area on herons varied among seasons. The breeding season has an intermediate NDWI overage (Fig. 5), the passage season has a lowest NDWI average (Fig. 6) and the highest diversity index for herons species (H = 1.40). Generally, the presence of intermediate level of water decreases the species richness, abundance and diversity of herons. These results indicated that herons families showed a preference to shallow water. Dry season, recession in Tonga Lake may concentrate prey in shallow water.The water habitat includes shallow water harbored higher richness of aquatic invertebrates, fishes and amphibians which is major diet of herons species (Willard, 1977; Montesinos *et al*., 2008; Roshnath, 2015). Wintering season showed the lowest NDVI and the highest

NDWI overage. During winter period, due to severe rainfall precipitation, the water level increase and the cover of aquatic vegetation decrease (Fig. 7). In turn, the food availability will be severely impacted; in response to this the Herons are forced to migrate in other wetlands. These results confirmed that the habitats of herons related closely with prey and food availability. Clearly, prey availability plays a key role to avian life histories (Gawlik, 2002).

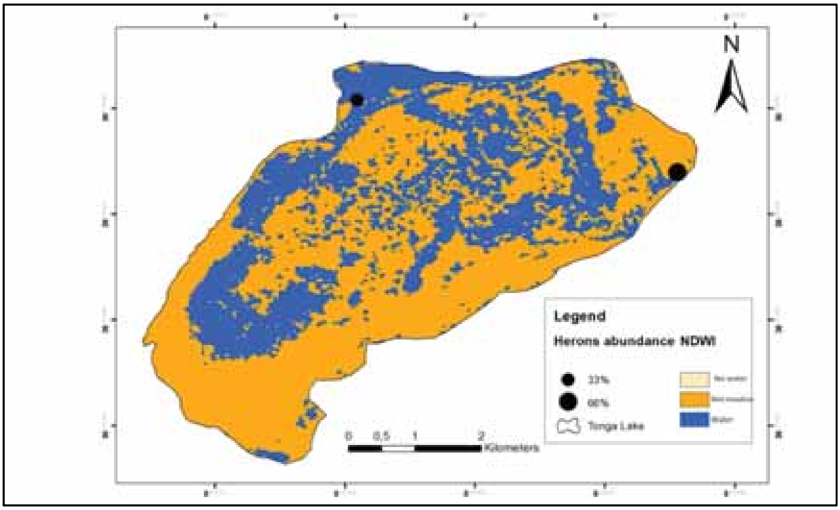

Figure 5. NDWI map of Tonga Lake in breeding season with the distribution of herons.

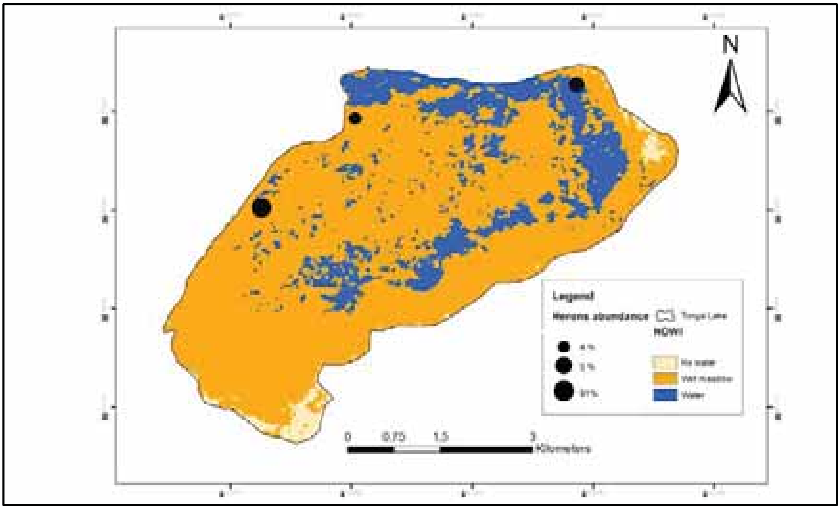

Figure 6. NDWI map of Tonga Lake in passage season with the distribution of herons.

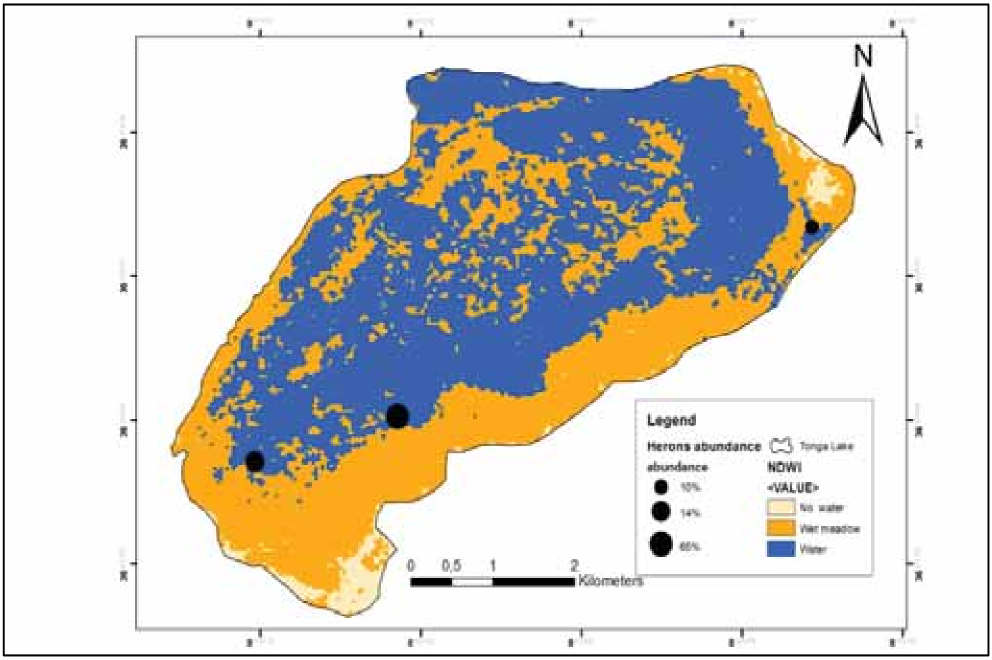

Figure 7. NDWI map of Tonga Lake in wintering season with the distribution of herons.

Conclusions

Our study concluded that herons species showed a preference for shallow waters and intermediate levels of vegetation cover. Herons family selected areas with shallow water and vegetation because these habitat features are often associated with high prey densities. Other variables, though not analysed in this study, might also influence the species richness, abundances, diversity and habitat use of herons.

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