

HABITAT USE AND BREEDING BIOLOGY OF HERONS IN THE RAMSAR WETLANDS OF NORTHERN TUNISIA

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ABSTRACT

We studied reproduction patterns and habitat use by Herons at Lebna, Chikli and Ichkeul wetlands in Northern Tunisia during 2009 and 2010. The largest number of herons was recorded at Ichkeul after completion of breeding. Cattle Egrets preferred farmlands but also inhabited marshes. However, all other species (Grey Herons, Great White Herons, Little Egrets and Squacco Herons) seemed to be much dependent on marshes and rivers. The distribution of heron species among habitats varied significantly with years and seasons. Variations of reproductive parameters were revealed between sites, biotopes and years. The most successful nesting points were recorded at Ichkeul for both Little and Cattle Egrets. At Chikli breeding parameters were catastrophic. Losses concerned mainly nests built on the ground; those arboreal had a significantly higher reproductive performance. The clutch size of Cattle Egrets varied positively with diameter of nest at Lebna. Also, at Chikli, the height of nest had a significant effect on both initial and final brood size of Little Egrets. Our results stress the need for further protection measures at study sites. For instance, suitable control of water regime through Tinja channel is absolutely necessary to improve the ornithological value of Ichkeul National Park. Also the accessibility to Lebna and Chikli sites should be highly controlled by managers of Tunisian wetlands, especially during the breeding season.

Key words: Herons, Habitat use, abundance, Reproductive performance, Ichkeul National Park, Lebna dam, Chikli islet, Conservation.

INTRODUCTION

Due to their bio-indicator capacity at wetlands (productivity, trophic structure, human disturbance, and contamination), herons and egrets are considered as wading birds of noticeable ecological importance (Custer and Osborn, 1977; Dister *et al.*, 1990; Kushlan, 1993; Briggs *et al.*, 1998; Osiejuk *et al.*, 1999; Guillemain *et al.*, 2000). Any environmental changes would induce variability in their distribution, habitat use and reproductive parameters, which is of considerable interest to wildlife and land managers (Temple and Wiens, 1989; Green, 1996). Their apportionment follows the distribution of few suitable wetlands where losses and deterioration of freshwater feeding and breeding habitat, resulting from changes in agricultural practices and urbanization, have been recorded (Tucker and Heath, 1994; Hafner and Didner, 1997; Kushlan and Hafner, 2000). Several studies have stressed the need for creation and preservation of habitat for wading birds in both Northern and Southern shores of Mediterranean basin (Fishpool and Evans, 2001; Tourenq *et al.*, 2001; Chauvelon *et al.*, 2003). Nevertheless, specific habitat requirements of most herons and egrets remain poorly understood (Kazantzidis and Goutner, 2008).

Nesting of herons in Tunisia has been reported by several authors (Whitaker, 1905; Cantoni and Castan,

1960; Castan, 1961; De Balsac and Mayaud, 1962; Etchecopar and Hue, 1964; Mayaud, 1982; Spiekman *et al.*, 1993; Isenmann *et al.*, 2005; Ouni *et al.*, 2009; Ouni *et al.*, 2011). In addition a few studies on wading birds' breeding success have been previously executed, such as for Glossy Ibises (*Plegadis falcinellus*) and Squacco Herons (*Ardeola ralloides*) (Ouni *et al.*, 2009; Nefla *et al.*, 2012; Nefla *et al.*, 2014). This pioneer work makes the first step to highlight the importance of Tunisian wetlands. The country is known to host particularly important North African wetlands (e.g., Ichkeul, Lebna Dam, Sejoumi, Lake of Tunis, Kelbia Lagoon, Thyna saline). In addition, it is a transition zone between the Palearctic and the Afro-tropical eco-zones. Investigations regarding eco-biology of heron species would contribute to increasing knowledge regarding the whole North African region (Si Bachir *et al.*, 2000; Belhadj *et al.*, 2007; Samraoui *et al.*, 2007; Si Bachir *et al.*, 2008; Qninba *et al.*, 2009; Hering and Fuchs, 2010). Such studies can certainly help in developing protection programs not only in Tunisian wetlands but also in the North African region.

In view of the above, we studied the eco-biology of herons in Northern Tunisia. Firstly, we determined habitat selection and environmental requirements of herons. Secondly, breeding parameters of the species were studied. Thirdly, we highlighted the relationship between nests characteristics of Little and Cattle Egrets

and their breeding success in three wetlands: 1) the Ichkeul National Park, 2) the Lebna Dam and 3) the Chikli Islet.

MATERIALS AND METHODS

Study area: The study was conducted in Ichkeul National Park, Lebna Dam and Chikli Islet (Fig. 1). The Ichkeul National Park, a natural site, is located in the extreme north of Tunisia (N 37.184992, E 9.633758) between northern Tell Mountains and lower valley of Mejerda river. The following four different habitat types were distinguished in the most suitable part of the park for the heron species (170 km²): 1) lake (79.4 Km², 46.68% of the total area), 2) marsh (28.3 Km², 16.64% of the total area), 3) river (0.16 Km², 0.1 % of the total area) and 4) farmland (62.2 Km², 36.58% of the total area). The Ichkeul colony hosted five ardeid species.

Lebna Dam (N 36.744161, E 10.916569) is formed of two major parts, a lagoon and Lebna Wadi. The latter feeds the lagoon with fresh water, which drains into the Mediterranean. The bank of the lagoon, the bank of the Wadi, and other shallow parts of both provide favorable habitat for the growth of (*Phragmites australis*) and (*Typha latifolia*), which extend for a surface of 40 ha. The flooded zone (20 ha) is covered by herbaceous aquatic plants and the surrounding plains are cultivated by vegetable and cereal crops.

Chikli Islet (N 36.816878, E 10.21815) is a natural reserve; it covers 3.5 ha and is located in the northern part of the lake of Tunis (mean depth 2 m) that opens to the Mediterranean through a rectilinear channel localized in its eastern part. It also contains an antic building "Fort Santiago Chikli, a former Cartago citadel". Within the site, *Egretta garzetta* nested alone in the Northern part of the islet. In the south of this region, Yellow- Legged Gulls (*Larus michahellis*) bred on the shore.

Data collection: Little Egret *Egretta garzetta* and Cattle Egret *Bubulcus ibis* formed three colonies within three localities with large variability in ecological features. During the study period from January 2009 to December 2010, regular monthly and bi-monthly census of Grey Heron *Ardea cinerea*, Great White Heron *Ardea alba*, Squacco Heron *Ardeola ralloides*, Little Egret and Cattle Egret were conducted. Herons were counted using telescopes from twelve observation stations fixed in advance along a predetermined route of 72.3 Km. This path included all available habitat types used by all species. Particular attention was paid to avoid the same subjects being counted twice if they moved from one locality to another. All visits lasted from two hours after sunrise to late afternoon. The size of each habitat type was calculated using satellite images and the Quantum GIS software. During each observation, we recorded the

date, Heron species found, number of individuals and habitat type.

Except Chikli that was not visited during 2010, several trips were made to the sites between late April and late July during the two breeding seasons (2009-2010). In order to recognize individually all sampled nests of Little Egret and Cattle Egret, we marked each one by a small numbered wooden label (placed below). We studied 21.2% ($n = 53$), 22.5% ($n = 9$) and 29.5% ($n = 59$) of all constructed nests of Little Egrets in Ichkeul, Lebna dam and Chikli islet, respectively and 16.3% ($n = 78$) and 30.5% ($n = 56$) of all constructed nests of Cattle Egrets in Ichkeul and Lebna. Total number of breeding pairs of all species was estimated by a direct count of constructed nests. All sites were weekly visited during which number of breeding pairs of each bird species was recorded, in addition to nest measurements and positions. Nests were observed from the beginning of the egg laying period with a pole-mounted mirror. We noted the clutch size (number of eggs), initial brood size (number of hatchlings) and final brood size (number of survivors per nest): chicks reached the age of 15 days (when chick scrambling made further visits impractical). That age is our operational criterion for fledging. When there was no changes on eggs number during two consecutive checks, the clutch was considered complete.

Data Analyses: The species abundance was expressed in percentage. The coefficient of variation ($CV = S/X \times 100$ (S: standard deviation; X: mean)) was used regarding comparing heron species' dispersion among the habitats. In fact, more the CV is low more the species is considered opportunistic. In order to evaluate the preferred habitats in relation to their extent, we used the selection index w_i (Krebs, 1999). Indeed, it was described as $w_i = o_i/p_i$, where o_i is the proportion of the mean number of a studied bird at the i habitat and p_i is the proportion of the habitat extent in the study area. (Values greater than 1 indicate preference).

As described in Nefla *et al.*, (2014), we evaluated seven reproductive parameters: 1) total mortality rate, 2) mortality rate of eggs, 3) mortality rate of young, 4) fledging success, 5) hatching success, 6) mean clutch size and 7) breeding success (Hafner, 1977, Nefla *et al.*, 2014). The chick/egg ratio was defined as the proportion of eggs hatched in nests where the whole nest did not fail (brood size/clutch size).

All statistical analyses were carried out using Statistica 7.0 software. Data were analyzed using parametric and non-parametric tests. Mean values are given \pm SD (standard deviation) and null hypotheses are rejected at $P = 0.05$. Firstly, descriptive results were provided as means and/or percentages in order to facilitate their comparison with the results of earlier studies. Secondly, the Student t -test was applied to measure the variation of the chicks/eggs ratio and the

height of nests between colonies. The Chi square (X^2) test was used to compare the reproductive parameters obtained at different sites and those recorded in 2009 and 2010 in each site. Likewise, temporal (annual and seasonal) variations of heron numbers were also calculated in the Ichkeul National Park. Finally, to analyze relationship between reproductive parameters (clutch size, initial brood size and final brood size) and nest characteristics (height of nest, diameter of nest and distance separating two neighboring nests) we used the Kruskal-Wallis test. This latter test was also conducted to evaluate the habitat selection by herons. To do so, we calculated, for each day (visit), the proportion of individuals of each species in each habitat and all counting days were used as replicas. Then, average proportions of each species were compared between habitats.

RESULTS

Seasonal fluctuation in Ardeids' population: The Little Egret occurred in the study area in low numbers during winter and early spring (January to mid-March) and at late autumn (late October to December). Population size increased from late March and reached its maximum in late July during both study years. Then, numbers decreased rapidly in the end of summer and autumn of each year. Low numbers of Grey Herons occurred in the study area all year long. They were more numerous in August and September (Fig. 2). Population levels of Cattle Egrets, sedentary species, were the highest among heron species. Great White Herons were observed from the beginning of October to late March-April with numbers peaking in February. However, Squacco Herons, breeding in the area, occurred from late March to the beginning of September.

Habitat use: The marshes have been used by the five studied species (Fig. 3). All of them showed a preference to this habitat ($w_i > 1$) (Table 1), in which, the Cattle Egret was the most abundant species. Both habitats (lake and rivers) have hosted three ardeid species each one. Grey Herons, Great White Herons and Little Egrets (most abundant species) occurred in the lake but no one showed a preference. By contrast, Grey Herons, Little Egrets and Squacco Herons particularly preferred rivers (Table 1). The farmland was greatly dominated by Cattle Egrets. It is the only species showing a significant preference towards this habitat.

Little Egrets were found in all habitat types. Most of them were recorded mainly in marshes, from January to early May, and lake banks (breeding period). However, much lower percentages occurred in other habitats ($H(3, n = 96) = 40.39, P < 0.001$) (Fig. 3). The mean number of Little Egrets per visit was greatest in the marshes (37.2), regarding the habitat extent, it was the

highest in the river (2.1 birds per visit / 10 ha) (indicating the importance of this habitat for the species) followed by the marshes (0.13), and was much lower in the lake and the farmland (Table 1).

Grey Herons were observed principally in marshes (all year long) and lake ($H(3, n = 96) = 44.82, P < 0.001$), which were most frequently visited during summer and autumn. The mean number of Grey Herons per visit was the highest in the marshes (10.16). However, their mean number per visit (in relation to the habitat extent) was the greatest in river (0.23 birds per visit /10 ha), being negligible in the other habitats. Like Little Egrets, Grey Herons used all habitat types. Both species were considered as the most opportunistic species, with lowest coefficient of variation (Table 1).

Cattle Egrets occurred in the study area all year long. They frequently used marshes and farmlands ($H(3, n = 96) = 75.43, P < 0.001$) (Fig. 3). The mean number of Cattle Egrets per visit was the greatest in the farmland (345). However, in relation to the habitat extent, this parameter was the highest in marshes (2.57 birds per visit /10 ha) followed by farmlands (1.56) indicating the importance of the marshes especially during juveniles rearing period (July).

Great White Herons were found mainly in marshes especially during their rally for prenuptial migration (from February to May) ($H(3, n = 64) = 18.16, P < 0.001$). The lake was also mostly used during the rest of period (Fig. 3). The highest mean number of Great White Herons per visit was recorded in marshes (2.29) followed by the lake (2.04). In relation to the habitat extent, this number was also the greatest in the marshes (0.008 birds per visit / 10 ha) (Table 1).

Numbers of Squacco Herons peaked in June and July due to postnuptial dispersion. In general, most Squacco Herons used greatly marshes ($H(3, n = 40) = 30.07, P < 0.001$). Their mean number per visit was the highest in marshes (10.45), while in the rivers it was 0.58. However, the mean number per visit (regarding the habitat extent) was 0.36 birds per visit/10 ha in the rivers and 0.02 in marshes (Table 1).

Temporal repartition: In general, herons populations occurred in the study area in 2009 were greater than those recorded in 2010. The distribution of all species among habitats varied significantly with years and seasons. The numbers of Grey Herons ($X^2 = 108.3, df = 3, p < 0.001$) and Great White Heron ($X^2 = 86.5, df = 2, p < 0.001$) increased in the lake and decreased in the marshes from 2009 to 2010. Inversely, Little Egrets used marshes more frequently ($X^2 = 21.1, df = 3, p < 0.001$). Likewise, Cattle Egrets showed a tendency to occupy the farmlands rather than the marshes ($X^2 = 1389.9, df = 1, p < 0.001$). Also, Squacco Herons varied significantly in their habitat exploitation between years ($X^2 = 117.1, df = 2, p < 0.001$). Grey Herons and Little Egrets occurred in all

habitat types during the non breeding season. Nevertheless, they only used lake and marshes during the breeding season. Great White Heron was not recorded in rivers, whereas, Squacco Heron did not use the lake.

Selection of nesting sites: At Ichkeul, Little Egrets and Cattle Egrets built their nests on *Tamarix africana* trees at a mean height of 203 ± 32.5 cm (range 100–280 cm, $n = 31$) and 200.5 ± 23.89 cm (range 172–263 cm, $n = 23$) from the ground, respectively. At Lebna, nests were built on *Acacia horrida* trees which had a mean height of 74 ± 30.25 cm (Little Egret) (range 37–122 cm, $n = 9$) and 101.4 ± 38.9 cm (Cattle Egret) (range 31–192 cm, $n = 80$) which was significantly lower than noted at Ichkeul ($t = 11.58$, $df = 101$, $P < 0.001$). At Chikli, the majority of nesting Little Egrets built their nests on the ground. However, 20 pairs were found nesting on arboreal stratum (5 small trees of *Casuarina sp.*). Nests were built on the main trunk just above the middle of the trees.

Reproductive performance: The overall mean clutch size of Little Egret (all sites) was 4.39 ± 1.01 eggs per

nest ($n = 124$), with clutches of four (33% of total clutches), five (32.3%), three (19.4%), six (12.9%), two (1.6%) and seven eggs (0.8%). The chick/egg ratio of Chikli colony (0.42) was significantly lower than those recorded at Ichkeul (0.84) and Lebna (0.75). However, the chick/egg ratio did not differ significantly between Ichkeul and Lebna. All other reproductive parameters recorded at Ichkeul were significantly greater than those calculated at Lebna and Chikli (Table 2). In addition, nesting point at Chikli was lower in height than at Lebna (Table 3). Little Egret lost 15.7%, 26.2% and 56.6% of their eggs during the first phase in Ichkeul, Lebna, and Chikli, respectively and 16.7%, 6.4% and 50.5% of their young in the second phase. All reproductive parameters varied between years within Ichkeul National Park and reached their maximum in 2009 (Table 4). We recorded the highest clutch size (seven eggs) at Chikli and the highest brood size (six chicks) at Ichkeul and Chikli (Table 5).

Table 1. Mean number of herons in each habitat per visit (MV) and in relation to their habitat extent (M10 h) (s.d : standard deviation ; w_i : selection index).

	<i>Ardea cinerea</i>				<i>Egretta alba</i>			
	MV	s.d	M10 h	w_i	MV	s.d	M10 h	w_i
Lake	4.91	5.14	0.006	0.66	2.04	3.6	0.002	0.94
Marshes	10.16	7.9	0.03	3.83	2.29	4.85	0.008	2.98
Rivers	0.37	0.76	0.23	25.7	-	-	-	-
Farmlands	0.5	0.93	0.0008	0.08	0.29	0.69	0.0004	0.17
Total	15.94	14.73	0.009		4.62	9.14	0.002	
CV (%)	92.4				197.8			
	<i>Bulbulcus ibis</i>				<i>Egretta garzetta</i>			
	MV	s.d	M10 h	w_i	MV	s.d	M10h	w_i
Lake	-	-	-	-	32.45	57.56	0.04	0.93
Marshes	258.33	573.95	0.91	2.57	37.2	50.67	0.13	3.01
Rivers	-	-	-	-	3.37	5.64	2.1	48.24
Farmlands	345	380.46	0.55	1.56	1.29	2.69	0.002	0.04
Total	603.33	954.41	0.66		74.31	116.56	0.04	
CV (%)	158.1				156.8			
	<i>Ardeola ralloides</i>							
	MV	s.d	M10 h	w_i				
Lake	-	-	-	-				
Marshes	10.45	22.57	0.03	5.5				
Rivers	0.58	2.16	0.36	53.9				
Farmlands	0.41	1.31	0.0006	0.09				
Total	11.44	26.04	0.01					
CV (%)	227.6							

The reproductive performance of Cattle Egrets was lower than that of Little Egrets. The overall mean clutch size of Cattle Egret (both sites) was 3.57 ± 1 eggs per nest ($n = 134$), with clutches of three (33% of total clutches), four (32.3%), two (19.4%), five (12.9%), six

and seven (1.6% each one), one (0.8%) and eight eggs (0.4%). The chick/egg ratio varied between colonies and was 0.59 at Lebna and 0.79 at Ichkeul. Likewise, other reproductive parameters recorded at Lebna were significantly lower than at Ichkeul (Table 2). In fact, the

total mortality measured at Lebna during both phases was significantly higher than that recorded at Ichkeul (Table 6). Cattle Egrets lost 19.2% and 37.45% of their eggs during the first phase and 17.1% and 9.5% of their young in the second phase in Ichkeul and Lebna, respectively. All reproductive parameters varied significantly between years in both sites (Table 4). At Lebna (2010), we recorded the highest clutch (eight eggs) and brood (six chicks) size, although the majority of nests (58.9%) contained no chick (Table 7).

Relationship between reproductive parameters and nest position: Excepting the significant rise of clutch size with the diameter increase of Cattle Egrets nest at Lebna, no relation found between reproductive parameters and nest characteristics in both sites (Table 8). Concerning Little Egrets, neither the height nor the diameter of nest significantly affected reproductive parameters at Ichkeul and Lebna. Contrariwise, at Chikli, both initial (number of hatchlings per nest) and final (number of survivals per nest) brood sizes increase with raising the height of nest (Table 8).

Table 2. Comparison between reproductive parameters of heron species at different sites.

		<i>Egretta garzetta</i>	<i>Bubulcus ibis</i>
Ichkeul Vs Lebna	Clutch size	$X^2 = 213.8^{***}; df = 1$	$X^2 = 22.1^{***}; df = 3$
	Initial brood size	$X^2 = 143.3^{***}; df = 1$	$X^2 = 33.1^{***}; df = 3$
	Final brood size	$X^2 = 185.8^{***}; df = 1$	$X^2 = 33.8^{***}; df = 3$
	Ratio chick/egg	$t = -0.97$ n.s; $df = 60$	$t = -4.75^{***}; df = 254$
Ichkeul Vs Chikli	Clutch size	$X^2 = 37.4^{***}; df = 3$	-
	Initial brood size	$X^2 = 65.2^{***}; df = 3$	-
	Final brood size	$X^2 = 145.6^{***}; df = 2$	-
	Ratio chick/egg	$t = -6.2^{***}; df = 110$	-
Lebna Vs Chikli	Clutch size	$X^2 = 348.8^{***}; df = 1$	-
	Initial brood size	$X^2 = 408.5^{***}; df = 1$	-
	Final brood size	$X^2 = 460.8^{***}; df = 1$	-
	Ratio chick/egg	$t = -2.22^*; df = 66$	-

Table 3. Breeding parameters of the Little Egret

Year	Ichkeul			Lebna	Chikli
	2009	2010	Combined years	2009	2009
Sampled nests	41	12	53	9	59
Average clutch size (egg laid / clutch)	5 ± 0.8	4.2 ± 0.8	4.8 ± 0.9	4.7 ± 0.7	4 ± 1
Percentage of hatching (%)	82.4	92	84.3	73.8	42.3
Hatching success (egg hatched / nest)	4.1 ± 1.6	3.8 ± 0.7	4.1 ± 1.4	3.4 ± 1.1	1.7 ± 1.8
Percentage of nests with nestlings (%)	92.7	100	94.3	100	61
Percentage of successful nest (containing at least 1 survivor) (%)	92.7	91.7	92.5	100	32.2
Mortality (%)	26.3	38	28.6	35.7	78.5
Fledging Success (survivor / nest)	3.7 ± 1.5	2.6 ± 1.2	3.4 ± 1.5	3 ± 1.3	0.8 ± 1.5
Breeding success (%)	73.7	62	71.4	64.3	21.5

Table 4. Variation of reproductive parameters between years (2009 and 2010).

		Clutch size	Hatching success	Fledging success
<i>Egretta garzetta</i>	Ichkeul	$X^2 = 21.1^{***}; df = 2$	$X^2 = 17.9^{***}; df = 2$	$X^2 = 22.2^{***}; df = 2$
	Lebna	-	-	-
<i>Bubulcus ibis</i>	Ichkeul	$X^2 = 127.2^{***}; df = 3$	$X^2 = 101.1^{***}; df = 3$	$X^2 = 93.4^{***}; df = 3$
	Lebna	$X^2 = 31.2^{***}; df = 3$	$X^2 = 106.8^{***}; df = 3$	$X^2 = 87.7^{***}; df = 3$

Table 5. Clutch and brood size of Little Egret at different sites

Sites	Year	Ichkeul				Lebna		Chikli	
		2009		2010		2009		2009	
	Number of clutch	41	%	12	%	9	%	62	%
Egg per nest	1	0	-	0	-	0	-	0	-
	2	0	-	0	-	0	-	2	3.2
	3	2	4.8	2	16.7	0	-	20	32.3
	4	7	17.1	7	58.3	4	44.5	23	37.1
	5	21	51.3	2	16.7	4	44.5	13	21
	6	11	26.8	1	8.3	1	11	3	4.8
	7	0	-	0	-	0	-	1	1.6
Young per nest	0	3	7.3	1	8.3	0	-	26	41.9
	1	0	-	0	-	1	11	6	9.7
	2	2	4.8	4	33.4	1	11	9	14.5
	3	3	7.3	6	50	0	-	9	14.5
	4	16	39.1	0	-	7	78	8	13
	5	10	24.4	1	8.3	0	-	3	4.8
	6	7	17.1	0	-	0	-	1	1.6

Table 6. Breeding parameters of Cattle Egret at different sites

Year	Ichkeul			Lebna		
	2009	2010	Combined years	2009	2010	Combined years
Sampled nests	36	86	122	78	56	134
Mean clutch size (egg laid / clutch)	3.44±0.96	3.34±0.68	3.37±0.77	3.88±0.88	3.55±1.42	3.49±1.04
Percentage of hatching (%)	75	83.3	80.8	76	42.2	61.8
Hatching success (egg hatched / nest)	2.58±1.38	2.79±0.88	2.72±1.05	2.94±1.16	1.5±1.89	2.17±1.54
Percentage of nests with nestlings (%)	83.3	97.7	93.4	97.4	57.1	81.1
Percentage of successful nest (containing at least 1 survivor) (%)	83.3	93	90.2	96.1	58.9	73.45
Mortality (%)	28.2	34.7	32.8	31	62.3	46.7
Fledging Success (survivor / nest)	3.68±1.5	2.58±1.16	2.27±1.06	2.67±1.12	1.33±1.74	1.86±1.46
Breeding success (%)	71	65	67	69	37	53

Table 7. Clutch and brood size of Cattle Egret at different sites.

Sites	Year	Number of clutch	Ichkeul				Lebna			
			2009		2010		2009		2010	
			36	%	86	%	78	%	56	%
Egg per nest	1	1	2.8	0	-	0	-	1	1.8	
	2	5	13.9	5	5.8	3	3.8	10	17.8	
	3	11	30.6	50	58.1	21	27	22	39.3	
	4	15	41.6	28	32.6	40	51.3	13	23.2	
	5	4	11.1	2	2.3	11	14.3	5	8.9	
	6	0	-	1	1.2	2	2.3	1	1.8	
	7	0	-	0	-	1	1.3	3	5.4	
	8	0	-	0	-	0	-	1	1.8	
Young per nest	0	6	16.7	6	7	3	3.8	33	58.9	
	1	0	-	9	10.5	6	7.7	1	1.8	
	2	9	25	36	41.9	24	30.9	3	5.4	
	3	14	38.9	33	38.3	29	37.3	11	19.6	
	4	6	16.7	2	2.3	13	16.7	5	8.9	
	5	1	2.7	0	-	2	2.3	3	5.4	
	6	0	-	0	-	1	1.3	0	-	

Table 8. Variation of reproductive parameters according to nest characteristics (height, diameter and distance between two neighboring nests cm) (Kruskal-Wallis H (ddl, n)).

		<i>Egretta garzetta</i>			<i>Bubulcus ibis</i>		
		Height	Diameter	Distance	Height	Diameter	Distance
Ichkeul	Clutch size	H (2, 31) = 0.23 n.s	H (2, 31) = 0.9 n.s	-	H (2, 23) = 0.64 n.s	H (2, 23) = 1.94 n.s	-
	Initial brood size	H (2, 31) = 1.16 n.s	H (2, 31) = 0.68 n.s	-	H (2, 23) = 0.39 n.s	H (2, 23) = 3.4 n.s	-
	Final brood size	H (2, 31) = 0.22 n.s	H (2, 31) = 0.41 n.s	-	H (2, 23) = 0.14 n.s	H (2, 23) = 3.54 n.s	-
Lebna	Clutch size	H (2, 9) = 1.54 n.s	H (2, 9) = 2.64 n.s	-	H (2, 84) = 0.57 n.s	H (2, 84) = 7.03*	-
	Initial brood size	H (2, 9) = 0.64 n.s	H (2, 9) = 1.83 n.s	-	H (2, 84) = 0.76 n.s	H (2, 84) = 3.59 n.s	-
	Final brood size	H (2, 9) = 0.18 n.s	H (2, 9) = 1.85 n.s	-	H (2, 84) = 0.09 n.s	H (2, 84) = 4.53 n.s	-
Chikli	Clutch size	H (2, 58) = 2.08 n.s	H (2, 58) = 1.03 n.s	H (2, 58) = 0.03 n.s	-	-	-
	Initial brood size	H (2, 58) = 8.11*	H (2, 58) = 3.11 n.s	H (2, 58) = 2.09 n.s	-	-	-
	Final brood size	H (2, 58) = 17.04***	H (2, 58) = 2.06 n.s	H (2, 58) = 3.81 n.s	-	-	-

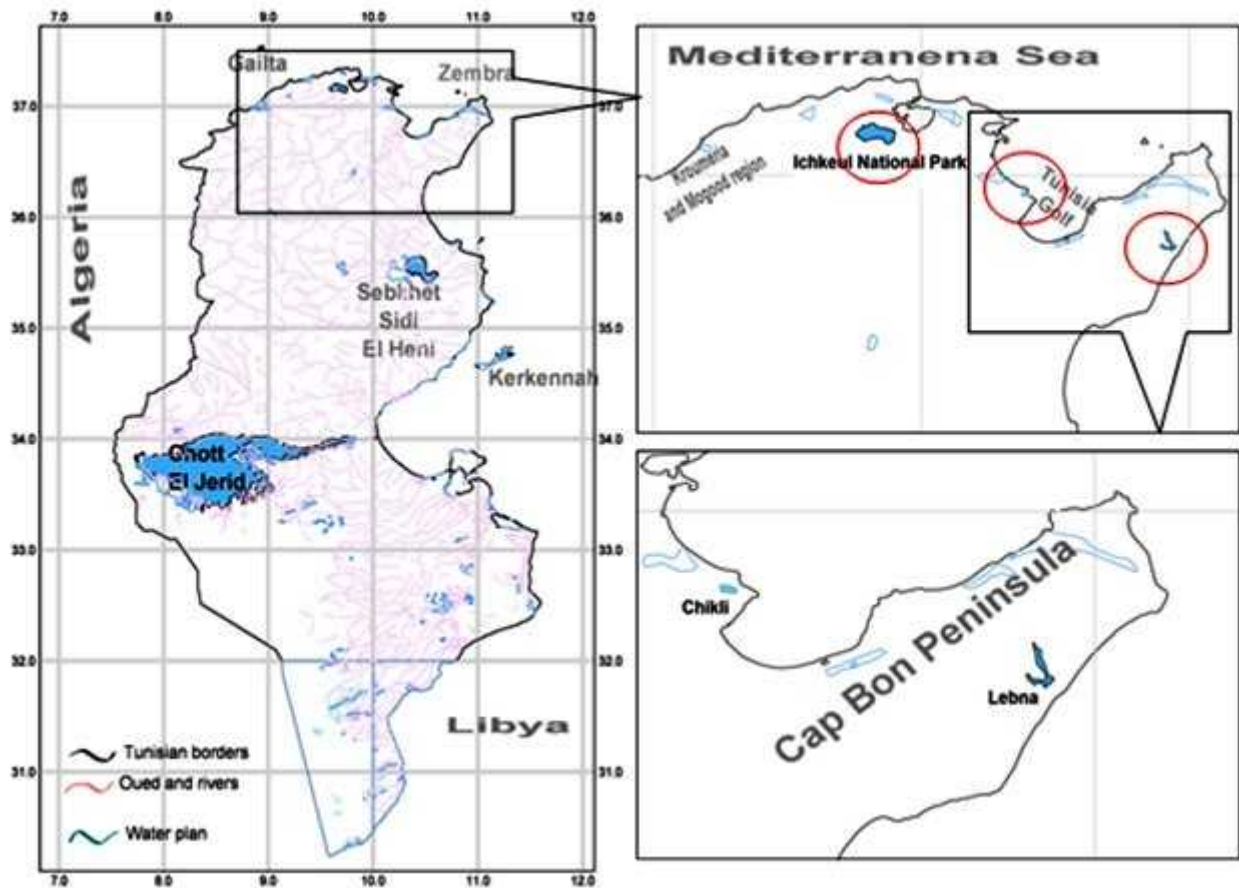


Fig. 1. Map showing the three study areas

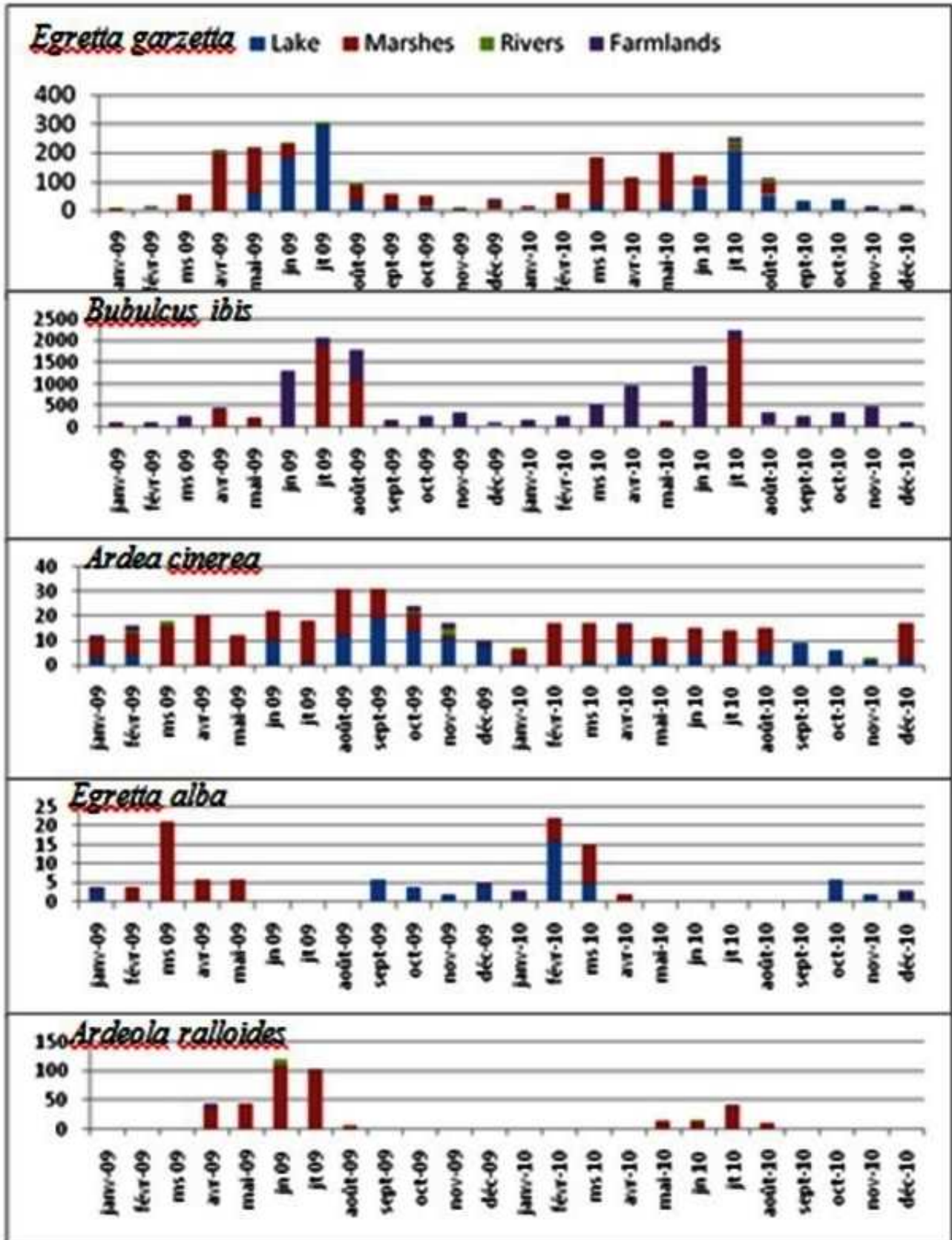


Fig. 2. Habitat use and seasonal fluctuation in numbers of various Heron species

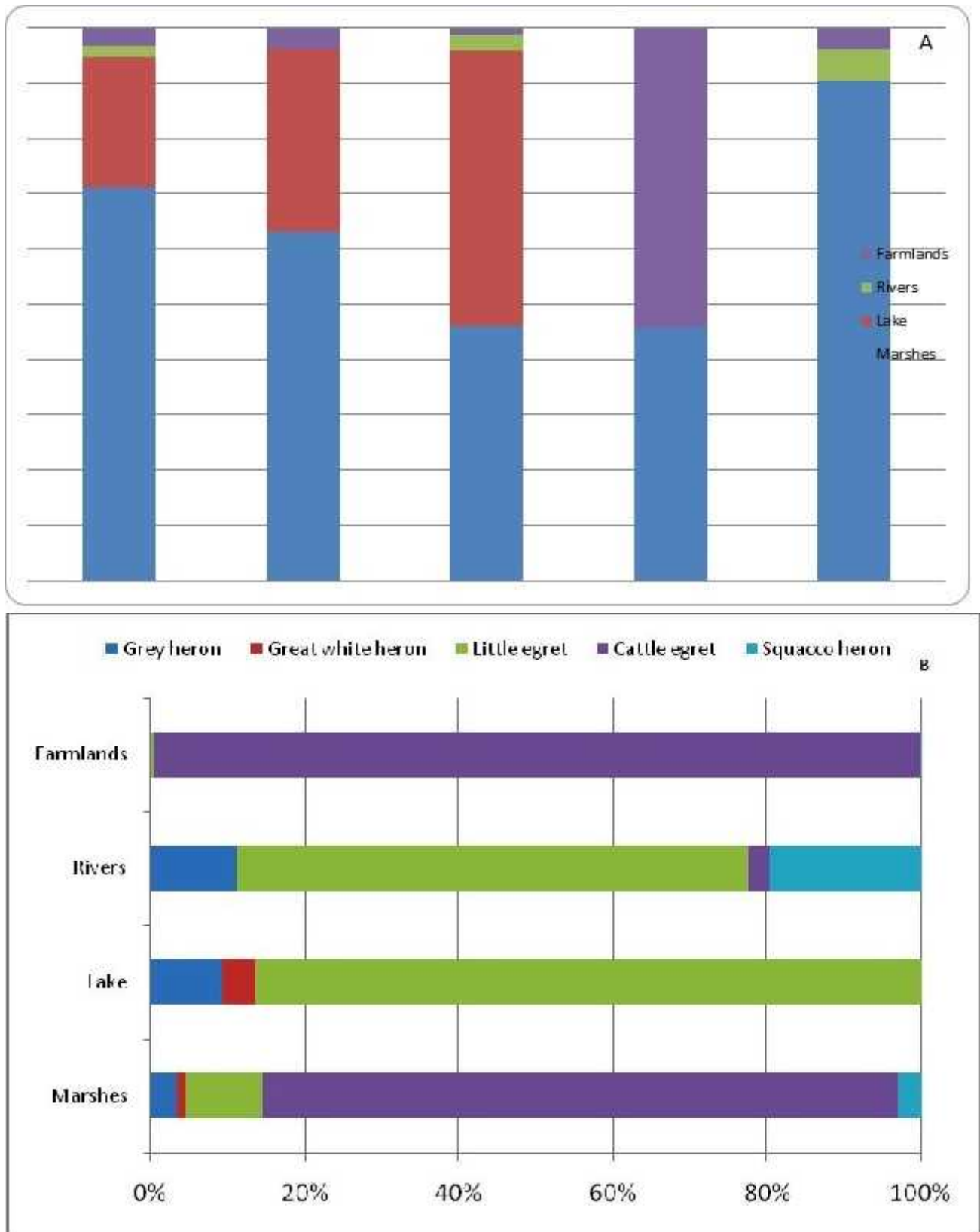


Fig. 3. Habitats occupation by heron species
 a) Habitats types used by each heron species
 b) Abundance of herons species in each habitat type

DISCUSSION

Cattle Egret was the most abundant species in the study area. The foraging number was considerably higher compared to other species. This is explained by the nature of the species which is recognized as expanding in North Africa as well as through its global range (Van Der Bosh *et al.*, 1992; Brochier *et al.*, 2010). Expansion in its distribution range and increase in number of populations and size have been reported over the last 50 years (Kushlan and Hafner, 2000).

All studied species may use several habitat types; however, some preferences were reported. Cattle Egret mainly occupied farmlands and marshes. Others waders were greatly associated with marshes and rivers. Those preferences are in accordance with previous results (Yamagishi, 1980; Hafner *et al.*, 1982; Hancock and Kushlan, 1989; Tojo, 1996; Kazantzidis and Goutner, 1996; Tourenq *et al.*, 2001; Kazantzidis and Goutner, 2008; Liordos, 2010).

Despite small extent, Ichkeul marshes (28.3 km²) (compared to the lake (79.4 km² and farmlands (62.2 km²)), harbor the most important number and density of herons (all species combined per visit (318.43 heron / visit; 1108 heron / 10 ha). This is consistent with the findings of Kazantzidis and Goutner (2008) who reported that herons are considerably subservient to freshwater habitats particularly freshwater marsh while sometimes some species show a preference for salty marshes such as Great White Herons, Grey Herons and Little Egrets at a specific period of the year. This phenomenon may cause an eventual overlapping in habitat use implying an inter-specific competition especially between Little Egret, Grey Heron, Great White Heron and Squacco Heron. However, variation of microhabitats (such as water depth and density of vegetation) and using time can reduce such conflict (Fasola, 1986).

It has been demonstrated that breeding parameters of birds varied significantly with space and/or time (Jarvinen, 1993; Saether *et al.*, 1999; Dreitz *et al.*, 2001). Tremblay and Ellison (1980) noted constant records between years. However, in accordance with findings of Custer *et al.*, (1983), our results showed significant variations of reproductive parameters of both Little and Cattle Egrets between areas and years. In fact, clutch size is often dependent on age of the parents, with younger laying smaller number of eggs (Klomp, 1970, Coulson and Porter, 1985), and territory quality (Hogstedt, 1980). Considering the Little Egret, the clutch size recorded at Ichkeul National Park was as high as in the northern shore of the Mediterranean basin (Hafner, 1980; Tsahalidis, 1990; Fasola and Pettiti, 1993; Prosper and Hafner, 1996; Kazantzidis *et al.*, 1997). Nevertheless, hatching and fledging success showed the same trend. Furthermore, all breeding parameters were more

important than those mentioned at the Tonga Lake (North African site) (Belhadj *et al.*, 2007). The clutch size of Little Egrets at Lebna was similar to recorded in the northern shore of the Mediterranean basin and higher than that showed at the Tonga Lake. Surprisingly at Chikli, we found a catastrophic weakness of hatching and fledging success of the species.

Cattle Egrets nesting at Ichkeul showed the highest breeding parameters across North and South Africa (Blaker, 1969; Siegfried, 1972; Franchimont, 1985; Si Bachir *et al.*, 2000; Si Bachir *et al.*, 2008). They were more also higher than those recorded at some American and Asian heronries (Weber, 1975; Maxwell and Kale, 1977; Ranglack *et al.*, 1991; Hilaluddin *et al.*, 2003; German Cupul-Maga a, 2004; Petry and Fonseca, 2005). Excepting clutch size, hatching success and fledging success were similar than those recorded on the northern shore of the Mediterranean basin (Hafner, 1977; Prosper and Hafner, 1996; Parejo *et al.*, 2001; Dragonetti and Giovacchini, 2009). On the contrary, Lebna showed lower reproductive parameters values compared with those sites. These values are in fact similar to those reported for the North African site.

To explain the observed spatial variation, we hypothesized that it may be related to the conservation statutes of each site. In fact, field observations made herein, but also on Squacco Herons (Nefla *et al.*, 2014), show that the heronry of Ichkeul National Park is naturally more protected against terrestrial predators than the other colonies. It is located at the mouth of Sejenen River which is the flooded zone. In the contrary, Lebna colony is accessible for terrestrial predators (both human (egg theft) and others) that cause loss of chicks and eggs. They manage to reach the heronry across a path created by the lowering of the water level, especially in periods of low precipitation (Nefla *et al.*, 2012). Likewise, at Chikli, a long way through the lagoon allows terrestrial predators (stray dogs, rats, humans) to reach the nesting area. This phenomenon seriously affects the reproductive performance of breeding birds and particularly reduces hatching and fledging success of Little Egrets, Cattle Egrets and other neighboring herons (Nefla *et al.*, 2014). In fact, protection programs in Chikli and Lebna do not go beyond being listed among African Important Bird Areas (Fishpool and Evans, 2001). It is worth mentioning that the same threats were also reported in southern heronries in Tunisia (Chokri and Selmi, 2011) where chick productivity was controlled by accessibility of breeding sites to terrestrial predators.

Aside from conservations statute of the site, nest characteristics are known to affect breeding success of birds (Hafner, 1977; Buckley and Buckley, 1980; Burger and Gochfeld, 1988; Bosch and Sol, 1998; Larison *et al.*, 2001). Our finding at Chikli showed that hatching and fledging success of Little Egrets were influenced by the height of nest. This criterion was considered as an

advantage when Burger (1982) signalized that it provides great visibility of predators, increases ability to make quick flight when predators approach and decreases losses to ground predators. Also, Fasola and Alieri (1992) reported that larger herons nest at higher levels, because movement is easier among the tall and open branches. However, other authors have discussed the absence of a relationship between nest characteristics and the reproductive parameters of Egrets (Ferguson, 1994; Kazantzidis *et al.*, 1997; Si Bachir *et al.*, 2000; Parejo *et al.*, 2001). This is in accordance with what was revealed at Ichkeul and Lebna.

Results presented herein confirm our earlier findings that highlight the need to conduct monitoring programs, aiming the conservation of biodiversity, including herons (especially at Lebna Dam and Chikli Islet). These programs should take into account diagnosis presented above and establish guidelines for the development of Action Plans. For example maintaining the water regime and productivity close to that recorded prior to dam building around the Ichkeul National Park which will provide more suitable foraging habitat especially marshes and limiting the accessibility to Lebna and Chikli sites.

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