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MONOGRAPH

The role of constructed wetlands in the conservation of biodiversity: a case study on birds diversity in Al-Hadba treatment plant, Tripoli, Libya

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ABSTRACT Urbanization as a result of human population increase has led to the depletion of natural resources and the destruction of natural wetlands. In contrast, the establishment of treatment and purification of plants has led to the creation of new wetlands (constructed wetlands). Although these new ecosystems established for the treatment of municipal wastewater, and subject to operational and maintenance disturbances, many studies have demonstrated that numbers of bird species using such sites are reasonably higher than expected. The present study has investigated the role of Al-Hadba treatment plant in the conservation of biodiversity and the diversity of birds in particular. This paper emphasizes that, this area is one of the stopover sites for migrating birds, especially aquatic birds, ducks and long-legged waders. A total of 74 species were recorded during the period of study. Moreover, this study observed the breeding of four species; Marbled Teal *Marmaronetta angustirostris*, Cattle egret *Bubulcus ibis*, Moorhen *Gallinula chloropus*, Black-winged stilt *Himantopus himantopus*. Some factors such as drought, predation and disturbance were affecting the abundance of individuals at the study area.

KEY WORDS Constructed wetlands; aquatic birds; breeding and stopover.

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INTRODUCTION

Wetlands are defined as an area that is permanently or seasonally wet, or during the year running or stagnant, fresh or saltwater, such as swamps, marshes, ponds, shallow water plains, dams, springs, rivers, lakes, valleys, industrial ponds, etc. (Moore, 2008). Wetlands are transitional habitats and the most productive ecosystems in the world compared to land-based rainforests and coral reefs in aquatic environments, occupying 6% of the world's land area, i.e. 5.3 to 8.6 million square kilometers (Ashkanani, 2013). The importance of wetlands is due to the fact that they are unique ecosystems in terms of their biological diversity and their renewable natural resources (many species of flora and fauna), as well as valuable and important habitat for the survival and nesting of many species of birds, especially endangered species (Sheldon et al., 2005; Duma, 2011). The importance of wetlands has long been disregarded because of the lack of knowledge of many features of this ecosystem. Moreover, they are used to express muddy marshes full of mosquitoes or unused land that need some improvements to be more beneficial to humans.

Natural wetlands are important ecosystems on our planet; they play a crucial role in conserving water and maintaining natural biodiversity at different levels (Zhao & Song, 2004). One of the most important and a major risk facing wetlands is urbanization, due to human population growth, which has exhausted these natural resources without proper management (Mackintosh & Davis, 2013).

Libyan wetlands are diverse from desert oases, fresh and salt water springs, salt marshes, coastal lagoons and man-made reservoirs and damps. In general, the majority of wetlands in Libya are shallow salt marshes, dry or semi-dry most of the year and sometimes connected to the sea (Sobkha) (Smart et al., 2006; EGA-RAC/SPA, 2012).

Wetlands are divided into two types: (i) natural wetlands including marshes, estuaries, swamps, lakes and oases, etc. (ii) Man-made wetlands (constructed, artificial or industrial wetlands) including dams, reservoirs and water treatment plants. However, researches and studies on the use of man-made wetlands began in the early 1970s in Germany and then expanded significantly to the other countries of the world. Wetlands vary in size and area from several meters to several kilometers. The countries are working to create artificial wetlands and join them in water treatment plants by digging ponds and small lakes filled with water. These ecosystems have benefits in storage and water conservation as well as became important sites to attract many species of aquatic and non-aquatic birds (Roger, 1998).

There are two basic types of artificial wetlands for treatment:

1. Underground systems do not have permanent visible water and are designed to flow sewage through gravel under vegetation.

2. Water flow systems on the surface are more suitable as treatment systems called Man-made wetlands (Jabbar, 2009).

Constructed wetlands are an important environment for aquatic and non-aquatic birds, providing shelter and food as well as a good habitat for nesting and stopovers during migration. Many of the studies conducted in these ecosystems have indicated that the number of bird species is increased more than expected (Paul, 2013). However, due to the im-

Figure 1. Study area: Al-Hadba station for sewage treatment.

portant role played by wastewater treatment plants (industrial wetlands) in conserving the components of biodiversity (plants and animals) and in particular water birds, therefore, this study was conducted at the Al-Hadba treatment plant in Tripoli to learn about its role in protecting the biodiversity, especially the birds, and also for the lack of studies on such environments in Libya.

MATERIAL AND METHODS

Study area

Al-Hadba station for sewage treatment is located in the city of Tripoli in Al-Hadba area, about 10 km south to the city center (Fig. 1) at latitude and longitude (N 32, 83'.55, E13, 16'.09). The station was established in 1968 and operated in 1970, the water capacity is about 110,000 square meters during the dry season and about 300,000 square meters during the rainy season. This plant is supplying the agricultural project of Al-Hadba with water after being processed, treated and recycled. There are seven full lagoons (basins) by water pumping machines between the ponds. The lagoons are surrounded by a variety of trees and grass, as well as many reed plants. The depth of each lagoon is about 4.5-6 meters. These lagoons are adjacent to each other, separated by small corridors. During the heavy rainfall, the basins become flooded. The site in general, has large areas surrounded by green and sandy hills. The station receives a large number of cars between 30 and 40 cars per day, sometimes more than this number; cars are loaded with sewage water from houses as well as the wastewater of some factories.

Methods

The study was conducted at the wastewater treatment plant in Al-Hadba during the period from May 2015 to April 2016. During this study, the following were used: Opticron and Optolyth telescops for bird observation and monitoring. Olympus binoculars with 10x50. Field Guide for Identification of Bird Species (Svensson, et al., 2009). Canon D700 digital camera and a 70-300 mm magnification lens. Varnish caliper to take measurements of eggs. Electronic balance (0.01 g).

The area was divided according to its topography to 6 basins (lagoons) and the counting of birds was carried out in each basin, with consideration of count repetition due to the movement of birds among the lagoons. Visits were twice a week to record and monitor the numbers of waterbirds species, and sometimes three visits per week to observe the nesting, from early morning to midday and sometimes to evening. Nests were numbered during the breeding season. Moreover, the eggs of breeding birds Black-winged stilt *Himantopus himantopus* were measured and compared with the eggs of the nearest colony at Al-Mallaha, Maitigha airport (Salina) (Eman et al., 2017).

Data analysis

Diversity indices were used to determine the differences between the seasons. The total numbers of species and individuals were considered.

The Shannon Index. It is one of the best tests used to measure the diversity of the ecological community and the distribution of the number of individuals among the species. It is zero when the sample is represented by one species (Ludwing & Reynolds, 1988).

$$H' = \Sigma \frac{ni}{N} \text{Ln} \frac{ni}{N}$$

The Simpson Index. It is one of the most widely used tests in ecological studies, and its values range from zero to one. The high probability indicates that the majority of the population belongs to one species, meaning that diversity is low or weak, and is expressed as follows:

$$D = \frac{1 - (\Sigma n (n - 1)}{N(N-1)}$$

where n is the number of species and N is the total number of species

Sorensen's coefficients of similarity (Ss). It is used to find the similarity between the two variables and the value is limited between 0 and 1 or expressed as a percentage, the closer value to one is the greater similarity. It is expressed as follows:

$$Ss = \frac{2a}{2a + b + c}$$

where: a = number of common species between sample A and sample B; b = number of specimens unique to sample B; c = number of species unique to sample A (Howege, 1998).

Egg size was calculated by using the following equation (Preston, 1974; Narushin, 2005):

$$V = Kv\ LB^2$$

where: V = size, B = width, L = length and Kv = 0.51.

A Correlation Test was used to find the relationship between egg size and egg weight.

General Linear Model (GLM) was used to find whether the brood size (the number of eggs in the nest) has an effect on the egg size.

T. Test was used to compare the egg size of Black winged stilt of this study and the nearest colony at Al-Mallaha area.

RESULTS

Depending on RAMSAR criteria, this study classified the site as number 8: water treatment areas (Sewage farms, settling ponds, oxidation basins).

During this study, a total of 8549 birds belonging to 74 species out of 29 families of aquatic and non-aquatic birds were counted (Table 1). The highest number of species was 52 species during February and the lowest was 17 in July (Fig. 2). The highest observed number of individuals was in December (4780) and the lowest was 336 during July (Fig. 3). The highest number of species was in winter (62 species) and the lowest number was 42 species during the summer (Fig. 4). The peak of individuals was in the winter season (2265) and the lowest recorded number was 531 during summer (Fig. 5).

By using Shannon index, it was found that the highest level of diversity in spring and lowest was in summer (Table 2). While the analysis of the dominance by using Simpson index showed that the highest level of dominance was in the autumn season and the lowest was in the spring season (Table 2).

Similarity index showed that the highest percentage of similarity was for autumn and winter, and the lowest level was for summer and spring (Table 3).

In this study, nesting of four species was recorded. Some of them were observed since egg-laying and others were recorded through monitoring and census of chicks.

Black-winged stilt (Himantopus himantopus)

The highest abundance of this species was 70, recorded in February, where 4 chicks were found at the end of May 2015, and during April 2016, 11 nests were recorded with different brood sizes in the drying pools (Fig. 6). The total number of eggs was 47. During the monitoring, parental defensive behavior

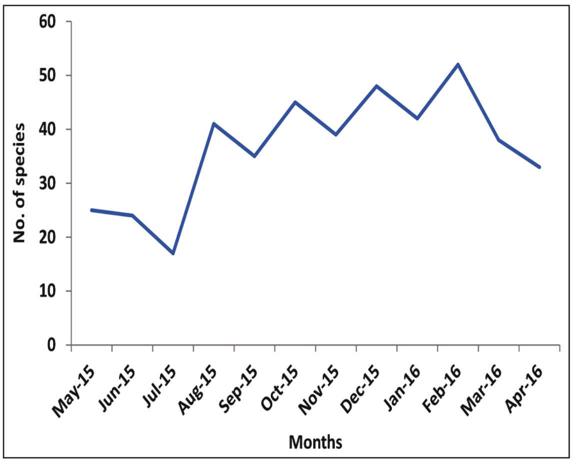

Figure 2. Number of species during the months of the study.

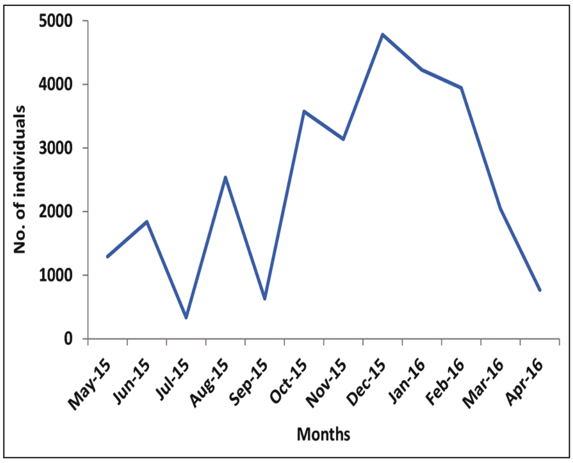

Figure 3. Number of bird individuals during the months of the study.

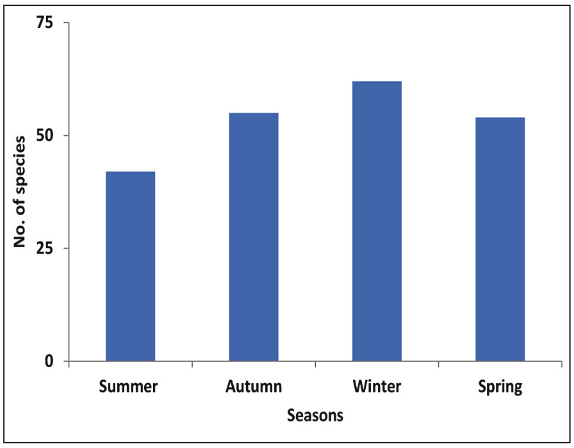

Figure 4. Number of species through the seasons of the study.

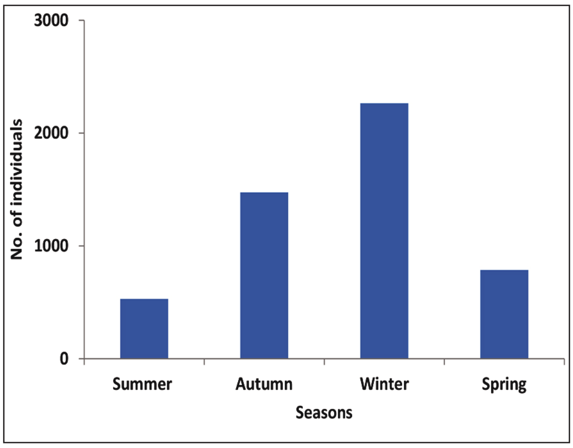

Figure 5. Number of bird individuals through the seasons of the study.

was observed (noisy sounds and broken-wing) to keep the different visitors away from the nests.

Measurements of egg were taken for 11 nests in different brood sizes, this included egg length, width and weight.

Correlation Test was used to find the relationship between egg size and weight. There was a significant relationship between them (Corr = 0.914). Therefore, it has been decided to exclude the egg weight and use only egg size to find the relationship between it and the brood size. By using the general linear model, the result shows that there was no effect of the brood size on the egg size ($r^2 = 0.038$, $df_{1,36}$, p = 0.24).

It was observed that the hatching rate was 0.13%, while nesting success was very low (0.07%). It was observed during this study that the egg size is somewhat small compared to the results of the study of Eman et al. (2017), which was conducted in Al-Mallaha at the Ma'aitiga base (Table 6). The results of this comparison showed that there was a significant difference, so, that the eggs in Al-Mallaha area were larger than those in Alhadba area (t = -7.84, df = 41, p = <0.001, Fig. 7).

***Marbled teal* (Angustirostris marmaronetta)**

The highest abundance of this species was recorded during the months from November to January (250 indiv.). A total of 28 chicks were recorded in May 2015, and in April 2016, 25 chicks were recorded (Fig. 8).

Little Grebe (*Tachybaptus ruficollis*)

The first record of four chicks of this species was in April 2015, and then the number reached 16 in June (Fig. 9).

Stone Curlew (*Burhinus oedicnemus*)

The highest abundance of this species was recorded in July 2015, with a total of 30 individuals. Only one egg of this species was observed in March 2016.

This study recorded six endangered species depend on the IUCN / Red list-2012. The study also recorded the Osprey, which is mentioned in Annex II of the Regional Activity Center for Specially Protected Areas (RAC/SPA) as an endangered species in the Mediterranean region (Table 5).

DISCUSSION

The results of this study found that Al-Hadaba wastewater treatment plant is classified according to the RAMSAR Convention for Wetlands as an artificial wetland (Manmade wetland), number 8: water treatment areas; sewage farms, settling ponds, oxidation basins. The convention has classified and identified all types of wetlands to be universal through the contracting parties and ratified countries, as well as, to avoid any misidentifications (www.ramsar.org).

No	*Species*	Common name	Sum	Status
1	ANATIDAE *Anas platyrhynchos* Linnaeus, 1758	Mallard	27	LC
2	*Anas strepera* Linnaeus, 1758	Gadwall	64	LC
3	*Anas acuta* Linnaeus, 1758	Northern Pintail	84	LC
4	*Anas clypeata* Linnaeus, 1758	Northern Shoveler	668	LC
5	*Anas Penelope* Linnaeus, 1758	Eurasian Wigeon	15	LC
6	*Marmaronetta angustirostris* Menetries, 1832	Marbled Teal	1227	VU
7	*Anas crecca* Linnaeus, 1758	Eurasian Teal	186	LC
8	*Anas querquedula* Linnaeus, 1758	Garganey	39	LC
9	*Aythya ferina* Linnaeus, 1758	Common Pochard	141	VU
10	*Aythya nyroca* Güldenstädt, 1770	Ferruginous Duck	558	NT
11	PHASIANIDAE *Alectoris Barbara* Bonnaterre, 1791	Barbary Partridge	138	LC
12	PODICIPEDIDAE *Podiceps nigricollis* Brehm, 1831	Black Necked Grebe	31	LC
13	*Tachybaptus ruficollis* Pallas, 1764	Little Grebe	74	LC
14	PHLACROCORACIDAE *Phalacrocorax carbo* Linnaeus, 1758	Cormorant	291	LC
15	ARDEIDAE *Botaurus stellaris* Linnaeus, 1758	Great Bittern	11	LC
16	*Ixobrychus minutes* Linnaeus, 1766	Little Bittern	2	LC
17	*Nycticorax nycticorax* Linnaeus, 1758	Night Heron	39	LC
18	*Bubulcus ibis* Linnaeus, 1758	Cattle Egret	267	LC
19	*Ardeola ralloides* Scopoli, 1769	Squacco Heron	76	LC
20	*Egretta garzetta* Linnaeus, 1766	Little Egret	250	LC
21	*Ardea cinerea* Linnaeus, 1758	Grey Heron	63	LC
22	*Ardea purpurea* Linnaeus, 1766	Purple Heron	12	LC
23	THRESKIORNITHIDAE *Plegadis falcinellus* Linnaeus, 1766	Glossy Ibis	9	LC
24	*Platalea leucorodia* Linnaeus, 1758	Eurasian Spoonbill	1	LC
25	PANDIONIDAE *Pandion haliaetus* Linnaeus, 1758	Osprey	3	LC
26	ACCIPITRIDAE *Circus aeruginosus* Linnaeus, 1758	Western Marsh-harrier	7	LC
27	*Buteo rufinus* Cretzschmar, 1829	Long-legged Buzzard	6	LC
28	*Pernis apivorus* Linnaeus, 1758	Honey-buzzard	4	LC
29	FALCONIDAE *Falco tinnunculus* Linnaeus, 1758	Common Kestrel	11	LC
30	*Falco peregrines* Tunstall, 1771	Peregrine Falcon	3	LC
31	RALLIDAE *Gallinula chloropus* Linnaeus, 1758	Common Moorhen	173	LC
32	*Fulica atra* Linnaeus, 1758	Common Coot	563	LC
33	RECURVIROSTRIDAE *Himantopus himantopus* Linnaeus, 1758	Black-winged Stilt	468	LC
34	*Burhinus oedicnemus* Linnaeus, 1758	Stone Curlew	35	LC
35	CHARADRIIDAE *Charadrius dubius* Scopoli, 1786	Little Ringed Plover	18	LC
36	*Charadrius hiaticula* Linnaeus, 1758	Ringed Plover	33	LC
37	*Charadrius alexandrinus* Linnaeus, 1758	Kentish Plover	5	LC

38	SCOLOPACIDAE *Calidris alpina* Linnaeus, 1758	Dunlin	434	LC
39	*Calidris minuta* Leisler, 1812	Little Stint	15	LC
40	*Calidris ferruginea* Pontoppidan, 1763	Curlew Sandpiper	2	NT
41	*Tringa glareola* Linnaeus, 1758	Wood Sandpiper	24	LC
42	*Tringa ochropus* Linnaeus, 1758	Green Sandpiper	48	LC
43	*Actitis hypoleucos* Linnaeus, 1758	Common Sandpiper	48	LC
44	*Tringa tetanus* Linnaeus, 1758	Common Redshank	73	LC
45	*Tringa erythropus* Pallas, 1764	Spotted Redshank	34	LC
46	*Tringa nebularia* Gunnerus, 1767	Common GreenShank	23	LC
47	*Tringa stagnatilis* Bechstein, 1803	Marsh Sandpiper	22	LC
48	*Numenius arquata* Linnaeus, 1758	Eurasian Curlew	5	NT
49	*Gallinago gallinago* Linnaeus, 1758	Common Snipe	18	LC
50	*Philomachus pugnax* Linnaeus, 1758	Ruff	99	LC
51	LARIDAE *Chroicocephalus ridibundus* Linnaeus, 1766	Black-Headed Gull	599	LC
52	*Sternula albifrons* Pallas, 1764	Little Tern	19	LC
53	*Chlidonias niger* Linnaeus, 1758	Black Tern	41	LC
54	*Chlidonias leucopterus* Temminck, 1815	White-winged Tern	8	LC
55	COLUMBIDAE *Streptopelia turtur* Linnaeus, 1758	European Turtle-dove	19	VU
56	*Streptopelia orientalis* Latham, 1790	Orintal Turtle-dove	11	LC
57	APODIDAE *Apus apus* Linnaeus, 1758	Common Swift	133	LC
58	*Apus melba* Linnaeus, 1758	Alpine Swift	35	LC
59	UPUPIDAE *Upupa epops* Linnaeus, 1758	Eurasian Hoopoe	131	LC
60	ALCEDINIDAE *Alcedo atthis* Linnaeus, 1758	Common Kingfisher	4	LC
61	MEROPIDAE *Merops apiaster* Linnaeus, 1758	European Bee-eater	105	LC
62	ALAUDIDAE *Galerida cristata* Linnaeus, 1758	Crested Lark	5	LC
63	HIRUNDINIDAE *Hirundo rustica* Linnaeus, 1758	Barn swallow	16	LC
64	MOTACILLIDAE *Anthus trivialis* Linnaeus, 1758	Tree Pipit	21	LC
65	*Motacilla flava* Linnaeus, 1758	Yellow Wagtail	25	LC
66	MUSCICAPIDAE *Saxicola rubetra* Linnaeus, 1758	Whinchat	4	LC
67	*Saxicola torquatus* Linnaeus, 1766	Common Stonechat	64	LC
68	*Ficedula albicollis* Temminck, 1815	Collared Flycatcher	2	LC
69	ACROCEPHALIDAE *Acrocephalus melanopogon* Temminck, 1823	Moustached Warbler	27	LC
70	PHYLLOSCOPIDAE *Phylloscopus collybita* Vieillot, 1817	Common Chiffchaff	32	LC
71	LANIIDAE *Lanius excubitor* Linnaeus, 1758	Great Grey Shrike	136	LC
72	LEIOTHRICHIDAE *Turdoides fulva* Desfontaines, 1789	Fulvous Babbler	95	LC
73	PASSERIDAE *Passer hispaniolensis* Temminck, 1820	Spanish Sparrow	518	LC
74	FRINGILLIDAE *Serinus serinus* Linnaeus, 1766	European Serin	52	LC

Table 1. Bird species recorded during this study and their numbers and status.

Season	Shannon index	Simpson index
Autumn	3.18	0.92
Spring	4.91	0.39
Winter	4.7	0.76
Summer	2.79	0.52

Table 2. Diversity indices between the seasons of the study.

Seasons	Autumn	Winter	Spring
Summer	74%	69%	68%
Autumn		87%	75%
Winter			81%

Table 3. Similarity index between the seasons of the study.

This area has shown a large diversity of birds. It is a roosting area for migratory and resident birds. They utilize the plant cover for nesting and eggs laying, and also as a shelter of many components of biodiversity in the area. Thus, these types of habitats are classified as wetlands of importance in the world, which recently attracted a great attention of researchers and specialists in term of protection and conservation of biodiversity (Duma, 2011; Mackintosh & Davis, 2013; www.ramsar.org).

This study shows the importance of the area to migratory birds, where there were large numbers of birds during the seasons of the study. The total number of birds was 8549; this large number indicates the importance of the site in terms of attracting migratory birds. Although the role of industrial wetlands is to treat and store the sewage water, it is also suitable places to attract many aquatic and non-aquatic birds (Roger, 1998). Moreover, they are used as recreational areas to enjoy the nature and observe the components of biodiversity, especially the birds attracted by these ecosystems (Jabbar, 2009), providing a suitable habitat for nesting and breeding of many species of birds, particularly the endangered ones (Sheldon et al., 2005).

In terms of the number of species, a total of 74 bird species were recorded. This diversity reflects the importance of the area and its ecosystem for many birds, where it is used as a ground for nesting and suitable shelter for many species. The number of repeated field-visits has provided a greater opportunity to record more species on the site. There was a difference in the numbers during the months from October 2015 until February 2016. This is due to the timing of migration and movement of birds where they stay for periods, and then they leave the area, leading to a shortage of numbers as well as post-nesting dispersal of some of them. This site is providing food and protection because there are many trees in the area which are suitable for egg-laying and protection from predators as well as the presence of many waders due to the suitable depths of the basins (lagoons) for these species. All of these characteristics make it a favorite habitat for many species of aquatic birds (Duma, 2011).

Diversity values (Shannon Index) indicated that the highest value was during the spring season. This indicates that the migration season has a significant impact on diversity in the site, and the lowest value was during the summer, when migratory species leave the area, so that only the resident species have remained. The values of dominant analysis (Simpson index) were almost similar between summer and spring with small values. This indicates that most of the species represented by several individuals are relatively identical, which means there were no large numbers of individuals belonging to certain species. The variation was significant in the autumn and winter, so that some species were represented by a large number of individuals. This was due to the increase in the number of waterbirds during migration and large numbers of certain species, for example: Anatidae (waterfowls).

During the seasons, the highest values were similar between winter and fall, due to the migration season, where winter in Europe is very cold, birds migrate to the southern Mediterranean searching of warm areas (Smart et al., 2006). Moreover, the study area provides a suitable habitat for roosting and food, which helps the birds to stay and nesting. The least similarity between the summer and spring is due to the change in climatic conditions and high temperature during the summer as well as the decrease of water level, therefore these led to a lack of food and decline of birds, resulting in a significant difference between the seasons.

	5 eggs			**4 eggs**			**3 eggs**			**2 eggs**			**1 egg**		
Alhadba 2016	n = 1			n = 7			n = 1			n = 0			n = 2		
	L. x̄	**W. x̄**	**V. x̄**	**L. x̄**	**W. x̄**	**V. x̄**	**L. x̄**	**W. x̄**	**V. x̄**	**L. x̄**	**W. x̄**	**V. x̄**	**L. x̄**	**W. x̄**	**V. x̄**
	41.4 ± 1.3	**29 ±07**	**17.7 ±1.3**	**42 ±1.6**	**29.03 ±0.7**	**18.07 ±1.17**	**37 ±1.41**	**27 ±0.82**	**13.8 ±1.30**	-	-	-	**41.5 ±0.71**	**29 ±0.0**	**17.80 ±0.30**
Al-Mallaha 2014	n =			n = 24			n = 3			n = 1			n = 0		
	L. x̄	**W. x̄**	**V. x̄**	**L. x̄**	**W. x̄**	**V. x̄**	**L. x̄**	**W. x̄**	**V. x̄**	**L. x̄**	**W. x̄**	**V. x̄**	**L. x̄**	**W. x̄**	**V. x̄**
	-	-	-	**43.90 ±1.26**	**30.9 ±0.66**	**21.4 ±1.32**	**43.40 ±1.76**	**31 ±0.21**	**21.27 ±0.82**	**43.12 ±2.96**	**29.5 ±1.4**	**19.20 ±3.12**	-	-	-

Table 4. Measurements of eggs of Black-winged stilt in Alhadba and Al-Mallaha.
n = number of nests, L = length of egg, W = width of egg and V = volume.

Figure 6. Clutch size of Black-winged stilt.

Al-Hadba sewage treatment plant is very important for the nesting of some bird species. This study recorded the nesting of Black-winged stilt, Marbled teal, Little grebe and Stone curlew; and this indicates that the site provides many suitable circumstances for the nesting of these species.

This study observed a nesting of Black-winged stilt, where a total of 11 nests were monitored in different clutch size. The nesting of this species was not completely observed due to the existence of some nests in small islets in the ponds, where it was difficult to reach. However, the nesting of this species has already been recorded in Tripoli region (Etayeb et al., 2013; Eman et al., 2017).

There was no relationship between egg size and egg weight and their effect on clutch size. Although some studies, such as Blackburn (1991), indicated a significant negative relationship between clutch size and egg size in Anatidae. However, the results of the present study were in accordance with the results of Eman et al. (2017), which was conducted in Al-Mallaha wetland in Tripoli.

The recorded rate of hatching in this study is weak compared to the number of eggs, maybe due to the fact that the rate of predation was high because of the presence of many dogs in the site.

	Scientific name	Common name	Total	Status	Source of Status
1.	*Marmaronetta angustirostris*	Duck Marbled	250	Vulnerable	IUCN Red List
2.	*Aythya ferina*	Pochard Common	60	Vulnerable	IUCN Red List
3.	*Aythya nyroca*	Duck Ferruginous	170	Near threatened	IUCN Red List
4.	*Calidris ferruginea*	Curlew Sandpiper	2	Near threatened	IUCN Red List
5.	*Numenius arquata*	Eurasian Curlew	4	Near threatened	IUCN Red List
6.	*Streptopelia turtur*	European Turtle-dove	5	Vulnerable	IUCN Red List
7.	*Pandion haliaetus*	Osprey	1	Threatened	SPA/RAC annex II

Table 5. Threatened species recorded in the study area.

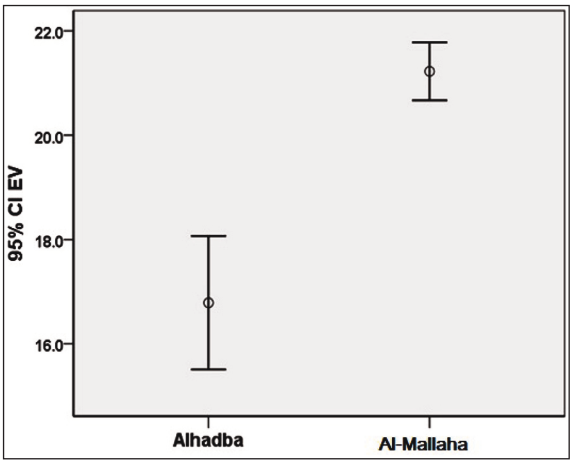

Figure 7. A comparison between the size of the eggs of Black-winged stilt in Ahadba and Al-Mallaha populations.

Black-winged stilt lay eggs in the ground nests, resulting in more exposure to predation than others, particularly, during the drought or water level decreasing (Picman, 1988; Adamou et al., 2009). Many studies have addressed the predation of either eggs or chicks and its negative impact on the overall rate of breeding success (Brown & Morris, 1994; Thorington & Bowman, 2003; Langston et al., 2007). Moreover, the most recent study in Al-Mallaha has confirmed the negative effect of disturbance and predation by dogs on the breeding success of Black-winged stilt and Little tern (*Sterna albifrons*) (Eman et al., 2017). Another reason is due to the immersing of many eggs as a result of the high water level, which also had a negative impact on the overall rate of breeding success, especially this site that receives varying amounts of sewage every day more than its capacity.

In term of comparing the size of the eggs of Black-winged stilt in the study area and Al-Mallaha site, the difference was significant as the eggs in Al-Mallaha were larger than those in Al-Hadba. This is maybe due to the difference to the nature of the two sites, and Al-Mallaha is a coastal Sabkha (salt marsh) adjacent to the sea and most of the bird species are fed on fish either from within the sabkha or from the sea, which provides more salt and minerals than its availability in Al-Hadba treatment plant, which depends on the sewage and its organic components. This study is in accordance with the study of Adamou et al. (2009) that the egg size decreases with the gradual dehydration of the wetland and decreased quality and productivity of habitats.

The first record of the breeding Marble teal in Libya was in 2012 in Al-Mallaha (Etayeb et al., 2014), where this species is previously reported as a winter visitor, with a small number records during the period from 2005 to 2011 in three sites namely, Al-Mallaha, Ain Tawergha and Wadi Kaam (Etayeb et al., 2007; Hamza et al., 2008; Bourass et al., 2013). This study supported the nesting information of Marbled teals in Libya, although it was difficult to find the nests to investigate more details on breeding parameters such as clutch size, rate of hatching and overall breeding success, however, the study recorded an important number of chicks of

Figure 8. Chicks of Marbled Duck.

Figure 9. Chicks and adult of Little grebe.

this species.

For the nesting of Little grebe, this study observed only chicks after hatching and did not record any nests in the site; this is also due to the difficulty of access to nesting sites. However, the evidence was an observation of 20 of not able to fly chicks swimming with one of the parents (Fig. 9). The first record of nesting of this species in Libya was in Ain Tawergha wetland in 1965 (Bundy, 1976). Records of nesting of the Little grebe have been reported in several other regions, such as Benghazi, Al-Marj and Waw al-Namous during the years 2005 to 2010 (Isenmann et al., 2016).

The results of this study reported some species are listed in the Red List (IUCN), as well as one species listed in Annex II of the Regional Activity Center for Specially Protected Areas (RAC/SPA) as endangered species in the Mediterranean region (UNEP, MAP, RAC/SPA, 2003). The listing of these species as endangered is due to the decline in numbers or because of the destruction of their natural habitats that led to the decrease of their numbers. The existence of these species reflects the importance of the area as a good shelter for birds, as it contains many characteristics that make it a vital area for biodiversity in general and endangered species in particular, and therefore, it is needed to designate this site as important bird's area (IBA).

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