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Diurnal Activity Patterns of the Greater Flamingo (*Phoenicopterus roseus*) in Two Algerian Sahara Wetlands: Case Study of Chott Oum Raneb (Ouargla) and Chott El-Goléa (Ghardaïa)

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ABSTRACT

This study on the greater flamingo (*Phoenicopterus roseus*) was conducted from September 2021 to August 2022 in two wetland areas of the central Algerian Sahara: Chott Oum Raneb (Ouargla) and Chott El-Goléa (Ghardaia). The findings indicate that this species is present year-round, classifying it as sedentary. The population was more abundant in Chott Oum Raneb than in Chott El-Goléa. The highest recorded number of individuals, 7.325, was observed in Chott El-Goléa during the coldest month (December 2021), while the lowest count, 212 individuals, was recorded in the hottest month (August 2022) at the same site. These waterbirds predominantly occupy the central areas of both wetlands, where they forage, suggesting that tranquility plays a crucial role in their distribution. Observations totaling 115 hours at each site revealed that feeding is the dominant diurnal activity, accounting for approximately 73% of the time at Chott Oum Raneb and 74% at Chott El-Goléa.

INTRODUCTION

Known as a symbol and flagship species of the Mediterranean coastline, the greater flamingo (*Phoenicopterus roseus*) is a large wading bird belonging to the family Phoenicopteridae. It feeds by filtering water for its nutrients (Johnson & Cezilly, 2007).

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This highly gregarious aquatic bird thrives in shallow waters, where it sifts through the "ground" in search for its favorite foods, which it filters with its beak: invertebrates, seeds, algae, and a shrimp species, *Artemia salina*, commonly found in salty waters. This shrimp contains carotene pigments that contribute to the greater flamingo's pink plumage coloration (Bechet, 2005; Matthiopoulos *et al.*, 2005). The bird is gregarious wader, breeding in colonies and forming metapopulations (Cramp & Simmons, 1977). In the southern Mediterranean shores, particularly in Algeria, there are two groups, a breeding and wintering population (Pradel *et al.*, 1997; Saheb *et al.*, 2006; Bensaci *et al.*, 2011; Boucheker *et al.*, 2011).

In the southern part of the Mediterranean basin, a remarkable biodiversity is observed, encompassing a complete mosaic of natural habitats. Among these ecological treasures, wetlands hold a predominant position, representing a natural heritage of extraordinary diversity (Houhamdi & Samraoui, 2001, 2002, 2003, 2008). These aquatic ecosystems are invaluable resources for our planet due to their contribution to biodiversity and their exceptional natural productivity. The scientific community now fully recognizes the fundamental role these environments play in maintaining essential ecological balances (Houhamdi *et al.*, 2008, 2009). Contemporary studies have highlighted the critical importance of wetlands in numerous vital ecological processes. These ecosystems regulate hydrological cycles, serve as refuges for diverse flora, and provide crucial habitats for many aquatic and avian species, notably as key stopover sites for migratory birds (Boulekhssaim *et al.*, 2006; Aberkane, 2014).

In Algeria, since the discovery of the first natural greater flamingo (*Phoenicopterus roseus*) colony in 2005 in Sebkhet Ezzemoul in the High Plateaus (Saheb *et al.*, 2006; Samraoui *et al.*, 2006; Seddik *et al.*, 2010, 2012; Baaziz *et al.*, 2011), many ornithologists have invested in studying this wader across various regions of the country. The greater flamingo has been regularly observed in large spread wetlands of the High Plateaus: Sebkha Bazer-Sakra, Sétif (Baaziz *et al.*, 2011; Laroug *et al.*, 2023). Moreover, they were observed in the Sahara, such as Lake El-Goléa (Samraoui *et al.*, 2006; Baaziz *et al.*, 2011), Sebkha de Safioune (Bouzid *et al.*, 2010; Mesbah *et al.*, 2011, 2014), and Chott Merouane (Bensaci *et al.*, 2011), as well as in the expansive water bodies in the western regions of the country (Beghadadi, 2016; Beghdadi *et al.*, 2016), where it regularly nests in large colonies. Unfortunately, the rapid drying of water bodies used to start from June often hinders colony establishment and is the main cause of nesting failures for this species.

In general, and based on previous studies, the largest concentrations of this species are consistently observed in the expansive water bodies of the High Plateaus and the Algerian Sahara (Saheb *et al.*, 2006; Samraoui *et al.*, 2006; Seddik *et al.*, 2010; Baaziz *et al.*, 2011; Mesbah *et al.*, 2011, 2014; Mesbah, 2014). Regular monitoring has been conducted in this central Saharan region of the country to monitor the phenology, spatiotemporal distribution patterns within major aquatic ecosystems, and gain insights into their diurnal behavior throughout an entire cycle at these sites by observing their daily activities.

MATERIALS AND METHODS

Study area

Chott Oum Raneb (32°01'47'' N, 5°23'10''E) (Figs. 1, 2) is a wetland covering an area of 7.155 hectares. It is located 4km north of the city of Ouargla. The wetland is primarily fed by untreated wastewater from the five municipalities in the Ouargla region, which are directly discharged without prior treatment. This permanent wetland, even in the summer season, is a large body of water surrounded by sand dunes. Its location in the middle of the desert allows it to host several migratory waterbird species (Mesbah, 2014). It serves as an important refuge for migratory and wintering waterbirds crossing the desert along the Africa-Eurasia migration route.

Chott El-Goléa ($30^{\circ} 35' 20''$ N, $2^{\circ} 52' 47''$ E) (Figs. 1, 3) is located 12km south of the El-Menia district, in the commune of Hassi El-Gara, and 280km from the city of Ghardaïa, the provincial capital (**Guergueb** *et al.*, **2018**). It is an endorheic depression covering 18.947 hectares, consisting of saline soils and comprising two water bodies. The first, located to the north (upper basin), exhibits moderate salinity, is highly biologically diverse, and resembles a pond, while the second is salty lake, devoid of vegetation. This area shelters many species of fish, crustaceans, birds, insects, and reptiles. The sector is rich in helophytes and also hosts large populations of birds, mainly ducks and coots. It serves as an ideal refuge for many migratory bird species such as the ferruginous duck (*Aythya nyroca*) and the northern shoveler (*Spatula clypeata*).



Fig. 1. Geographical situation of the two wetlands (Chott Oum Raneb and Chott El-Goléa), Algerian Sahara



Fig. 2. General view of Chott Oum Raneb, Ouargla (Ines Houhamdi 30/12/2021)



Fig. 3. General view of Chott Oum Raneb, Ouargla (Ines Houhamdi 07/2023)

Sampling method

In order to monitor the phenology and status of this large wader species in Algerian wetlands, specifically in two Saharan wetlands: Chott El-Goléa (Ghardaïa) and Chott Oum Raneb (Ouargla), regular field visits were conducted over an entire annual cycle, from September 2011 to August 2012. The total counts of the populations were carried out between 08:00 and 17:00 using a Kite SP 85HD 20x80 spotting scope. Individual counts were performed when the bird group was close (less than 200 meters) and contained no more than 200 individuals. In contrast, when the group was further away and/or contained a higher number of individuals, the group size was estimated visually (Lamotte & Bourrelière, 1969; Blondel, 1975; Houhamdi & Samraoui, 2002; Bara & Segura, **2019**). This method is commonly used during bird population counts, particularly in winter counts. However, it has a margin of error (5%), which varies based on the observer's experience and the quality of optical equipment used (Blondel, 1975). The diurnal budget time were also monitored throughout the study period, from September 2011 to August 2012, in both wetlands. The study of these diurnal time budgets was established through regular scans (Altmann, 1974), conducted every hour from 08:00 to 17:00 (Baldassare et al., 1988; Losito et al., 1989). The method based on observation of a group makes it possible to record the instantaneous activities of each

individual and then, thanks to mathematical transformations, to bring out the temporal percentage of each of them (Altmann, 1974). It has the advantage of being the only method applied at sites, where the numbers of waterbirds are very high (limit of focused sampling). Additionally, because it relies on instantaneous sampling, this method eliminates individual identification (Baldassare *et al.*, 1988), making it virtually impossible to determine the social status (e.g., paired or unpaired) of the birds observed (Losito *et al.*, 1989). Six activities were measured: feeding, resting, walking, preening, flying, and courtship activities.

RESULTS

Temporal variation of the greater flamingo abundance

The regular monitoring of the overall population dynamics of this Phoenicopteridae species at the two sites, Chott Oum Raneb (Ouargla) and Chott El- Goléa (Ghardaïa), throughout the study period clearly showed the presence of the greater flamingo in all our surveys. The population numbers ranged from 725 to 7325 individuals at Chott Oum Raneb and from 212 to 1280 individuals at Chott El-Goléa. This wader was recorded year-round at both water bodies, starting from the first week of September, with numbers gradually increasing until January, followed by a progressive decline until August. This pattern demonstrates a classic Gaussian trend, reflecting the presence of a sedentary population in the region alongside the massive arrival of wintering individuals, often in larger numbers. This further emphasizes the significant role these two wetlands (Chott Oum Raneb and Chott El-Goléa) play during the wintering season of this species. Despite its smaller size, Chott Oum Raneb was recorded to host a notable population compared to Chott El-Goléa. The former site, located along the less-trafficked road 18, is rich in food resources and shallow waters (Fig. 4). Consequently, this water body supports a highly diverse avian community, encompassing around 49 species (personal observation), notably including the marbled teal (Marmaronetta angustirostris), ruddy shelduck (Tadorna ferruginea), and the black-winged stilt (Himantopus himantopus).



Fig. 4. Monthly variation of flamingo abundance (2021-2022)

The second site, Chott El-Goléa, is much larger and consists of two distinct habitats from north to south. In the north, the wetland is fed by wastewater from the commune of Hassi El-Gara, offering various habitats that regularly host aquatic reptiles, amphibians, insects, and native fish. In this area, the emergence of small islets bordered by *Tamarix gallica, Typha angustifolia* and *Phragmites australis* were also observed. These islets, along with the reeds and tamarisk trees, form the preferred nesting habitat for avifauna. In the southern part, particularly the lower basin upstream, the vegetation is sparse and is limited to a few resistant phanerogam species, mainly a reduced number of grasses. This open, saltwater body, devoid of vegetation and shallow, is favorable for the greater flamingo populations, which exhibit their characteristic gregarious behavior. Other species, such as the ruddy shelduck (*Tadorna ferruginea*), marbled teal (*Marmaronetta angustirostris*), and the kentish plover (*Charadrius alexandrinus*), are also present. Overall, population numbers remained relatively stable throughout the annual cycle (Fig. 5).





In terms of abundance, the Wilcoxon test revealed a highly significant difference (P < 0.05) between the two water bodies and across the months (P < 0.05) (Fig. 6). The highest population numbers were recorded at the Chott Oum Raneb wetland compared to Chott El-Goléa, particularly during the main wintering season in January, February, and March. This highlights the critical role these two wetlands play in maintaining the populations of this wader species.

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Fig. 6. Monthly variation of greater flamingo abundance (2021-2022)

Spatial distribution of greater flamingo

Due to their gregarious nature, the greater flamingos often group together in areas far from disturbances. At Chott El-Goléa, this wader occupies the center of the water body, particularly the shallowest sections. During the wintering season, two populations with different and relatively distinct compositions can be observed, located next to each other (Fig. 5). These birds rarely frequent the southern region, which is rich in vegetation.

At Chott Oum Raneb, early in the morning, the greater flamingos are distributed across the entire water body, forming more or less distinct groups (Fig. 7). However, during the day, these waterbirds move closer to the road near the main sewage outlet that feeds this Saharan wetland. Alongside these species, other characteristics of the ecosystem can also be observed, associated with the marbled teal (*Marmaronetta angustirostris*), ruddy shelduck (*Tadorna ferruginea*), and the black-winged stilt (*Himantopus himantopus*).



Fig. 7. Spatial distribution of greater flamingo population at Chott El-Goléa and du Chott Oum Raneb

Global diurnal time budget

The regular monitoring of the daytime activity rhythms of this wader during the 2021/2022 cycle (115 hours of observation at each site) allowed us to conclude that feeding is the primary activity in the overall daytime balance in both wetlands. Feeding was recorded with a percentage of 73% at Chott Oum Raneb and 74% at Chott El-Goléa, accounting for three-quarters of the daytime activities. It is often followed by walking (17%), preening and plumage maintenance (5%), courtship displays and resting, both at 2%, and finally, flying (1%) at Chott Oum Raneb. At Chott El-Goléa, feeding is followed by flying (11%), walking (8%), courtship displays (4%), and preening or plumage maintenance (3%) (Figs. 8, 9). Sleeping was not observed at this site.



Fig. 8. General view of Greater Flamingo diurnal time budget in Chott Oum Raneb



Fig. 9. General view of Greater Flamingo diurnal time budget in Chott El-Goléa

Seasonal trend of diurnal time budget

The monitoring of the diurnal time budget of the greater flamingo (*Phænicopterus* roseus) during our study year shows that the bird spends more than half of the day

feeding. This activity was particularly observed at the beginning of the study, coinciding with the massive arrival of the greater flamingos in the Algerian Sahara. These birds engage in this activity to recover the energy expended during their migrations and/or movements.

In Chott Oum Raneb

At Chott Oum Raneb, the rates of the primary activity (feeding) fluctuate irregularly, showing peaks often recorded during the arrivals and passages of the greater flamingos at this site. The highest rate was observed at the beginning of the study. Walking comes in second place. It is often associated with feeding activity, as the birds' probe and filters the water, or it is caused by disturbances from human presence. Its progression also exhibits variations, often noted during October, November, and December. Preening or cleaning feathers occupies a minor share in this activity budget. It is often observed at the start of the day when the birds begin feeding. Sleeping and courtship displays hold equal shares in this activity budget. The greater flamingos, resting on one leg with their head placed on their back, were mainly observed during the early wintering period when the birds often need rest to recover energy. As for courtship displays, they were only observed during the period from December to July. These displays occurred exclusively in the water and among small groups of birds searching for food. Flying behavior was almost absent throughout our observations.

The multivariate analysis of the data collected over a full annual cycle using correspondence analysis (CA) (48 samples x 6 activities), as shown on the factorial plane 1x2, which accounts for 44 and 27% of the total inertia, respectively, or 73% of the total variance, reveals that, given the high proportion of feeding activity - representing more than three-quarters of the total activity - it is positioned at the center of the graph. Factor 1 (vertical axis), which accounts for 44% of the information, separates the other four measured activities from flying activity, which, due to its low proportion, is positioned alone on the left of this axis. Flying is thus a minimal activity for the greater flamingo. It is also observed that Factor 2 (horizontal axis), which accounts for 27% of the inertia, separates sleeping and preening activities from walking and courtship displays. This graph provides a clear temporal distribution of the six activities over the annual cycle. At the beginning of the study, during September, the greater flamingos primarily focused on feeding (center of the graph), accompanied by increased flying activity characteristic of this period. As the season progressed, from October to December, resting and plumage maintenance behaviors became more prominent. Subsequently, between January and April, courtship displays and walking-often linked to feeding-were frequently observed, suggesting the onset of pre-nuptial migration (Fig. 10).



Fig. 10. Monthly greater flamingo diurnal time budget variation in Chott Oum Raneb

In Chott El Goléa

The evolution of the diurnal activity rhythms of this wader at Lake El-Goléa reveals a variation that is somewhat similar to that observed at Chott Oum Raneb. Indeed, feeding is the primary activity recorded during the day. Its progression exhibits a slow evolution throughout the annual cycle, once again highlighting the fact that this site is a preferential foraging ground for the greater flamingo (*Phoenicopterus roseus*) and many other avian species. The maximum feeding rate was recorded in December, typically the coldest month of the year. The lowest feeding rate was noted in September 2021. It should be mentioned that during this month, the region experienced a heat wave. Flying, which is generally triggered by disturbances, either by humans or predators, occupied the second-largest share in this activity budget. It was recorded at relatively stable rates throughout the study period. Walking ranked third. This diurnal behavior is associated with foraging (Fig. 11), avoiding sources of noise pollution, or gathering after landing.



Fig. 11. Monthly greater flamingo diurnal time budget variation in Chott El-Goléa

This activity is essential in our wetlands (Houhamdi *et al.*, 2008, 2009). Courtship displays, as shown in the Fig. (11), began in January with a low rate that gradually increased to reach a peak during March and April, continuing until the end of the study in August. Preening, observed both in the water and on the lake's shores, was noted throughout almost the entire study period. This activity, often observed early in the day before these waders began feeding, showed consistently low and relatively stable rates. Diurnal sleeping was recorded only during the initial months of the study, from late September to the end of December (Fig. 12).



Fig. 12. Factorial design of correspondence factorial analysis 1x2 (Diurnal time budget of the greater flamingo *Phoenicopterus roseus* in Chott Oum Raneb (September 2021/August 2022). Axes of inertia: 0.44, 0.25, 0.17 & 0.09

This multivariate statistical treatment, conducted on the daytime activity budget data of the greater flamingos in Lake El-Goléa (2021/2022) using correspondence analysis (CA), which this time explains 78% of the inertia, shows almost identical results. Feeding, the main activity, is positioned at the center of the graph. Factor 1 (vertical axis,

54%) contrasts the activities of courtship and flying, which are often associated and primarily observed during the period from January to August, with the other activities: walking, preening, and sleeping. Factor 2 (horizontal axis, 24%) contrasts walking and preening activities, which are often associated with sleeping. Sleeping characterizes the end of November and all of December, while preening and sleeping are frequently recorded from September to November (Fig. 13).



Fig. 12. Factorial design of correspondence factorial analysis 1x2 (Diurnal time budget of the greater flamingo *Phoenicopterus roseus* in Lake El-Goléa (September 2021/August 2022). Axes of inertia: 0.54, 0.24, 0.09 & 0.06

DISCUSSION

Many studies on the greater flamingos have reported the dynamics, age structure, origin of populations, or breeding activity of this wader (Boucheker *et al.*, 2011). However, no data on their diurnal behavior in the Algerian Sahara are available. Balkiz *et al.* (2007) indicated that the origin of the greater flamingo population is from Turkey, which confirms the metapopulation dynamics. It is known that the presence of the greater flamingos in the Algerian Sahara is influenced by climatic constraints (Rendon *et al.*, 2001), where dry seasons may lead experienced individuals to avoid the region.

The feeding is untreated wastewater discharged directly from the city of Ouargla, a continuously expanding urban area (Mesbah, 2014). Consequently, these two water bodies, like most Algerian wetlands, serve as foraging grounds for this wader, which is considered a flagship species of our continental aquatic ecosystems (Ledant *et al.*, 1981; Isenmann & Moali, 2000; Samraoui *et al.*, 2006; Saheb *et al.*, 2006; Mesbah *et al.*, 2011, 2014; Mesbah, 2014). Moreover, the greater flamingo adapt itself as a response to a potential predator or to human presence, where birds need to fly (Tamisier & Dehorter, 1999; Ouldjaoui, 2010). Both two wetlands, the greater flamingos exhibit a rotational feeding activity, stirring the ground of these ecosystems with their feet while filtering the water for food.

The Saharan wetlands of Algeria play a crucial role in the maintenance of aquatic birdlife, especially for the greater flamingo *Phoenicopterus roseus*, which uses them yearround. These ecosystems are potential habitats and ideal sites for this wader. The greater flamingo was more abundant in Chott Oum Raneb compared to Chott El-Goléa. The largest numbers were observed during the wintering season, primarily in November, December, and January, showing that this species is composed of two populations: a sedentary one, which is sparsely represented, and a more significant wintering one. In these two water bodies, the greater flamingo showed high vigilance, occupying central areas away from disturbances and with abundant food availability.

The monitoring of the daily activity rhythms throughout the annual cycle showed that both wetlands function as feeding grounds, where the greater flamingo spends almost three-quarters of its time feeding in the water. This activity was recorded for both grouped birds and solitary individuals. The five other measured activities (sleeping, swimming, flying, preening, and courtship activities) were observed at low rates, not exceeding 10%.

Thus, these Saharan aquatic environments, serving as appreciated daytime feeding grounds, can also be considered potential nesting sites, highlighting the need for special monitoring to support and preserve the breeding of this species. It is therefore imperative to implement an action plan and a national and global strategy aimed at safeguarding this flagship wader species and its habitats.

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