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DIURNAL TIME BUDGET OF THE GREAT CORMORANT *PHALACROCORAX CARBO* WINTERING AT LAKE OUBEIRA (EL TARF PROVINCE, NORTH-EASTERN ALGERIA)

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Abstract. The present study investigates the diurnal behaviour of the Great Cormorant (*Phalacrocorax carbo* L.) at Lake Oubeira, a permanent freshwater ecosystem situated within the El Kala wetland complex in north-eastern Algeria, designated as a Ramsar wetland of international importance. The research focused on three main objectives: monitoring the temporal dynamics of the population frequenting the lake, analyzing spatial distribution patterns, and characterizing the species' diurnal activity budget. Observations were carried out from December to April over two successive wintering seasons (2015/2016 and 2016/2017). Results indicated that the highest numbers of individuals were recorded during the first week of February 2016 and the first half of March 2017. Spatially, the species was predominantly observed in the north-eastern and south-eastern zones of the lake. Analysis of diurnal activity revealed notable interannual variation. During the 2015/2016 wintering season, flight activity was predominant (38%), followed by resting (28%), preening (19%), swimming (12%), and feeding (3%). In contrast, during the 2016/2017 season, preening was the most frequent activity (33%), followed by resting (28%), flying (22%), swimming (14%), and feeding (3%). This study constitutes the first documented assessment of the diurnal behaviour of the Great Cormorant during its wintering period in Algeria, and it provides novel insights into the behavioural ecology of the species within North African wetland ecosystems.

INTRODUCTION

Cormorants represent a relatively homogenous group of aquatic birds, comprising between 26 and 40 species (Del Hoyo et al. 1992). They are predominantly piscivorous and exhibit gregarious behaviour throughout the annual cycle. These large birds inhabit both coastal and inland aquatic environments across Eurasia, Africa, and the North Atlantic region of North America (Klimaszyk and Rzymski 2016).

Two subspecies of the Great Cormorant (*Phalacrocorax carbo* L.) are commonly recognized: *P. c. carbo*, a coastal species that preferentially breeds on sea cliffs, and *P. c. sinensis*, a continental one that primarily nests inland, particularly in the Baltic region and the Netherlands, before migrating south to overwinter. The latter subspecies migrates from Northern Europe to North Africa, with substantial numbers wintering in the Maghreb, particularly in Algeria (Isenmann and Moali 2000). Recent observations estimate the Algerian wintering population at approximately 5,250 individuals, with around 70% concentrated at the Beni Haroun Dam in the north-eastern region of the country (Belfethi and Moulaï 2022).

On the European continent, where the largest populations are found (Marion 1995), the species is often regarded as problematic due to the substantial quantities of fish it consumes at the sites it frequents. Additionally, its droppings contribute to nutrient loading leading to soil and water pollution through inter-ecosystem nutrient transfer (Klimaszyk and Rzymski 2016).

Despite extensive research in Europe, the diurnal activity patterns of the Great Cormorant have not been

previously studied in its North African wintering grounds, particularly in Algeria. This study was therefore undertaken to estimate the wintering population size of *Phalacrocorax carbo sinensis*, assess its spatial distribution, and document its daily activity budget over two wintering seasons at Lake Oubeira, a wetland of international importance. This research is especially timely given the increasing concerns regarding the species' potential ecological impact on aquatic ecosystems when present in large numbers.

Despite the extensive body of research conducted across Europe on the Great Cormorant, the species' diurnal activity remains poorly documented within its North African wintering grounds, particularly in Algeria. Understanding these patterns is essential, as the behaviour and ecological requirements of migratory populations can vary significantly across biogeographical regions. This study was therefore undertaken to estimate the wintering population size of *Phalacrocorax carbo sinensis*, evaluate its spatial distribution, and quantify its daily activity budget over two successive wintering seasons at Lake Oubeira, one of the most important wetlands in the Western Mediterranean and a Ramsar-designated site of international significance.

By providing detailed observations of time allocation, habitat use, and spatial behaviour, this study fills a critical knowledge gap for North African populations and contributes to a broader ecological understanding of the species renowned for its behavioural flexibility, wide ecological tolerance, and capacity to exploit a variety of aquatic environments. Such insights are essential for informing future conservation strategies and for supporting evidence-based management decisions in sensitive wetland ecosystems.

MATERIALS AND METHODS

Study site

Lake Oubeira, a 2,200-hectare freshwater body in El Kala National Park, is both a Ramsar site and a UNESCO Biosphere Reserve. As one of the few remaining natural Mediterranean wetlands, it supports a rich diversity of avian species from various biogeographic origins (Le Feuvre 1989). The lake provides critical habitats for breeding, wintering, migration, and feeding and is particularly important as a wintering site for species such as the White-headed Duck, Eurasian Spoonbill, Greylag Goose, Great Cormorant, and several waders. It also hosts breeding populations of rare species like the Little Bittern, Purple Swamphen, and Eurasian Bittern (DGF 2002; Lazli et al. 2018).

Historically, Lake Oubeira has experienced major ecological disruptions, including two drainages (1975–1978 and 1990) and the 1986 introduction of Chinese carp, which devastated aquatic vegetation. Although partial recovery occurred after the 1990 drainage, carp remain present and are now exploited by local fisheries (Lazli et al. 2018).

Today, Lake Oubeira continues to be threatened by human activities, particularly the expansion of speculative agriculture, mainly peanut and watermelon farming, which poses serious risks to its ecological balance and long-term conservation.

Figure 1. Location of Lake Oubeira in El Tarf, north-eastern Algeria.

Methods

A weekly monitoring of the Great Cormorant population was conducted at Lake Oubeira over two consecutive wintering periods (2015/2016 and 2016/2017). Observations were carried out using a KONUS-SPOT spotting scope (20 × 60) and KERN binoculars (8 × 30). When bird numbers were low, individuals were counted directly. However, when numbers exceeded 200, visual estimates were employed (Lamotte and Bourrelière 1969; Blondel 1975; Bibby et al. 1998; Lazli et al. 2018; Beddiaf et al. 2020; Gherib et al. 2021; Aissaoui and Bara 2024): the field of view was divided into virtual bands containing approximately 50 to 200 birds, and the total number of bands was used to estimate overall abundance. Counts were performed from multiple fixed observation points selected to provide the maximal coverage of the lake and its most frequented areas (Figure 1).

The diurnal activity patterns of Great Cormorants were monitored weekly from December to April during both wintering periods. Observations were conducted using the scan sampling method (Altman 1974; Baldassare et al. 1988; Losito et al. 1989; Tamisier and Dehorter

1999). Each session began shortly after sunrise, once the birds had returned from nocturnal roosts. Observations were made from locations offering an unobstructed view of the roost while maintaining a sufficient distance to avoid disturbance.

Behavioural data were collected from 08:00 to 16:00 at 30-minute intervals, totalling 304 observation hours. The following behavioural categories were recorded: feeding, resting, flying, swimming, and preening. To investigate the structure and temporal dynamics of activity patterns, the behavioural data were analyzed by a Correspondence Factorial Analysis (CFA) using R3.6.1software (R Development Core Team, 2019) (Thioulouse et al. 1997; Houhamdi et al. 2025).

RESULTS

Population dynamics of the Great Cormorant at Lake Oubeira

The earliest arrivals of Great Cormorants were recorded as early as in December. The 2015/2016 wintering season exhibited the highest abundance, with a peak of 327 individuals observed in February 2016. Following this peak, the population began a steady decline, reaching a minimum of 24 individuals during the first half of April (Figure 2).

During the subsequent 2016/2017 wintering season, the population remained relatively small and stable, fluctuating between 22 and 23 individuals. A noticeable increase was observed from early January, culminating in a first peak of 152 individuals. This was followed by a decline to 17 individuals in the latter half of the month, prior to a second higher peak of 162 individuals recorded in the second half of February. After this peak, the number of individuals sharply decreased, stabilizing at 43 and then 6 individuals in last April (Figure 2).

Diurnal activity rhythms of the Great Cormorant during the wintering period

The activity patterns of Great Cormorant were quantified during the 2015/2016 and 2016/2017 wintering seasons and expressed as percentages of total observed behaviours.

During the 2015/2016 winter, flight was the predominant activity, accounting for 38% of total behaviour. This was followed by resting (28%), preening (19%), and swimming (12%). Feeding activity constituted only 3% of observed behaviour (Figure 3), while both intra- and interspecific interactions were rarely recorded.

In contrast, the 2016/2017 winter season exhibited a shift in activity patterns. Preening was the most frequent behaviour, representing 33% of activity, followed by resting (28%) and flight (22%). Swimming accounted for 14%, while feeding remained minimal at 3% (Figure 3). Intra- and interspecific competitive behaviours were not observed during this period.

Temporal change of Great Cormorant activity at Lake Oubeira during the 2015/2016 and 2016/2017 wintering seasons

During winter 2015/2016

Following their arrival at Lake Oubeira, Great Cormorants exhibited notable levels of flight activity, accounting for approximately 45% of behaviours during the second half of December 2015 and increasing slightly to 50% in the first half of January 2016. This activity gradually declined over the subsequent weeks, reach-

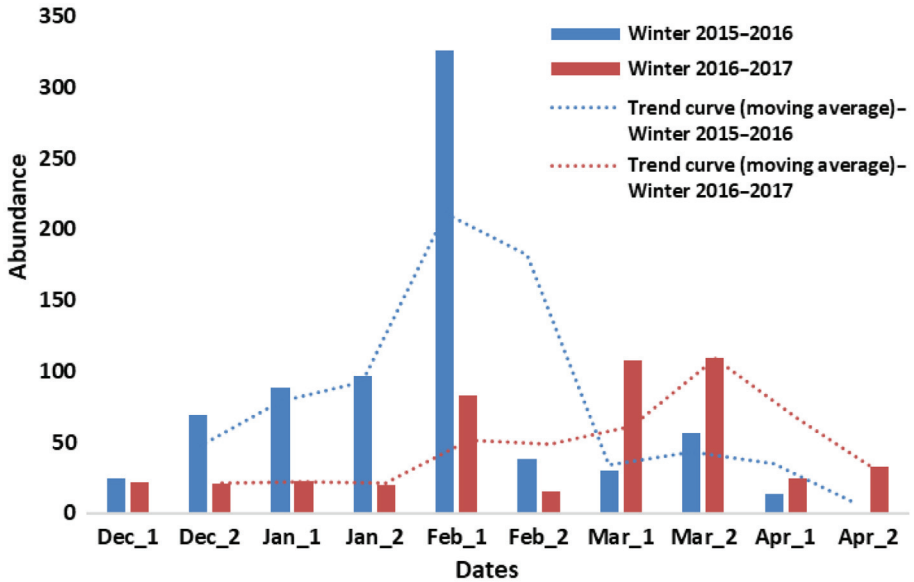

Figure 2. Population dynamic of Great Cormorant wintering at Lake Oubeira (El Tarf province) during the study period.

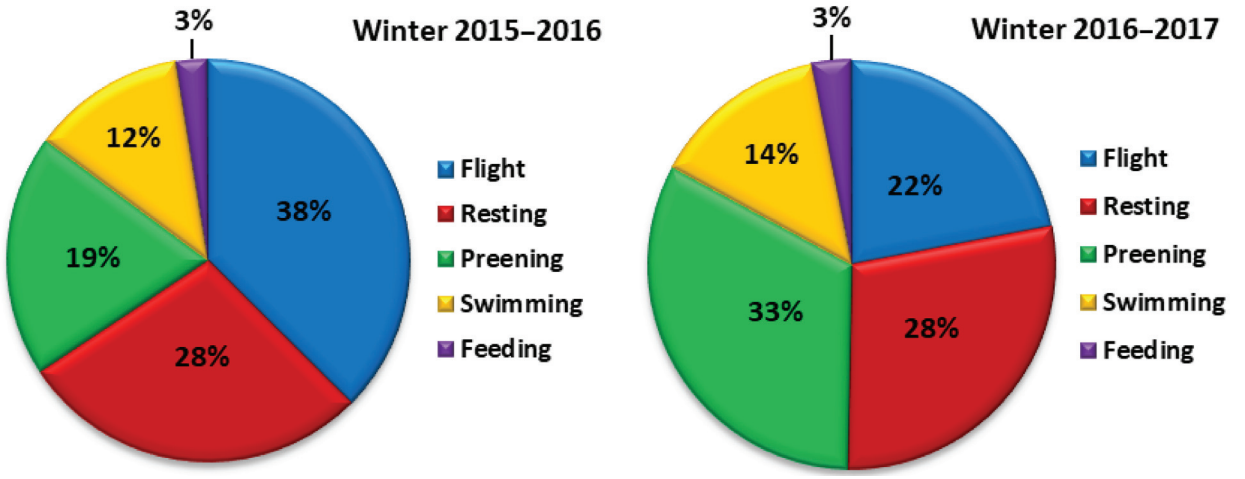

Figure 3. Diurnal time activity budget of Great Cormorant at Lake Oubeira (El Tarf province) during the two considered wintering seasons.

ing its lowest level (10%) in the second half of March, coinciding with the transition from the wintering phase to the onset of the breeding period.

Resting was the second most frequently recorded behaviour. It displayed relatively high levels at the beginning of the wintering season, ranging between 26% and 30% in December and early January, and remained relatively stable throughout much of this period. A notable increase was observed in the second half of February and towards the end of the rainy season, with peaks of 42% and 35%, respectively (Figure 4a). From mid-April onwards, resting activity was no longer recorded.

Preening constituted a significant part of the cormorants' daily activity budget, representing approximately 19% of total observations. This behaviour gradually increased from the second half of February, reaching a maximum of 42% during the second half of March (Figure 4a). Swimming was regularly observed throughout the study period, with activity levels fluctuating between 12% and 20%. In contrast, foraging activity remained consistently low, accounting for only 2% to 5% of behaviours recorded (Figure 4a). Inter- and intraspecific interactions were rare and made up only a minor portion of the behavioural repertoire.

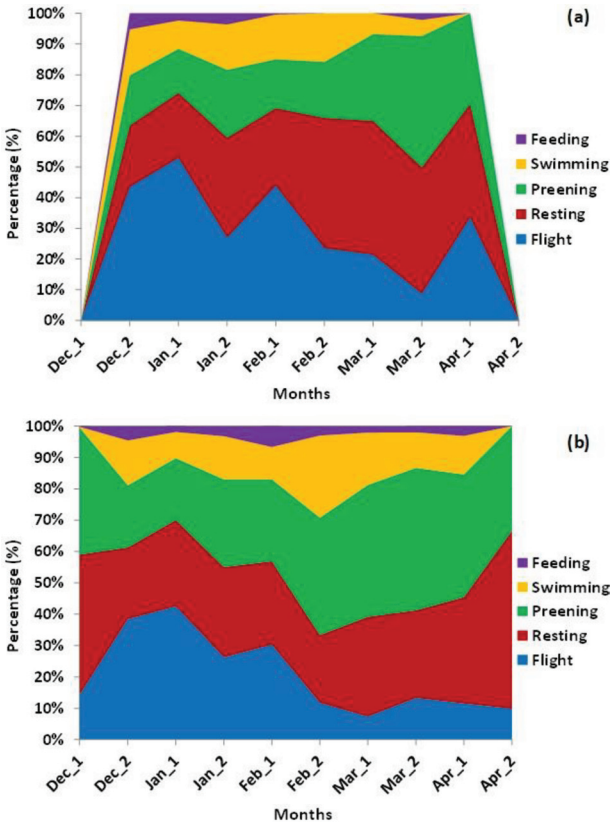

Figure 4. Temporal change of Great Cormorant activities at Lake Oubeira (El Tarf province): a) 2015/2016, b) 2016/2017.

During winter 2016/2017

Upon their arrival at Lake Oubeira in December, Great Cormorants exhibited a flight activity rate of approximately 15%. This behaviour increased progressively, reaching a peak of 41% during the first half of January (Figure 4b). A gradual decline was then observed from mid-January onwards, continuing until the end of the wintering period and the beginning of the breeding season. The lowest flight activity, 9%, was recorded in the first half of March.

Resting was the predominant activity among the first individuals to arrive, with an initial rate of 45%. High levels of resting behaviour were also recorded throughout December, January, and April, with values ranging between 35% and 53%. A marked decrease in resting was noted from the first half of January to the end of March, corresponding with the increase in other behaviours such as flight and swimming (Figure 4b).

Preening was particularly prominent during the early phase of the wintering period, especially in December, accounting for up to 40% of diurnal activity. This be-

haviour showed a steady decline from the second half of January to the second half of February, reaching its lowest recorded level at 13%. However, from March onwards, a resurgence in preening was observed, culminating in a peak of 42%.

Swimming was recorded at low levels (3%) during the early stages of the wintering period but showed a marked increase throughout January, reaching a maximum of 26% in February. Feeding activity remained consistently low across the entire study period, representing only 2% to 5% of the birds' daily activity budget.

Both inter- and intraspecific competition were rarely observed and consistently ranked lowest in the overall behavioural repertoire of the species during the wintering period (Figure 4b).

Daily variations in diurnal activities of Great Cormorant during 2015/2016 and 2016/2017 winter seasons

During winter 2015/2016

A detailed analysis of the daily time budget reveals distinct patterns in the distribution of behavioural activities among Great Cormorants during the 2015/2016 wintering season.

Flight activity dominated the daylight hours, particularly between 08:00 and 16:00, with noticeable declines around 10:00 and 16:00, likely due to disturbances caused by local fishing activity on the lake (Figure 5a). Peaks in flight behaviour were recorded at approximately 08:00 and between 11:00 and 12:00. These peaks correspond to movements between the birds' daytime roost (Lakes Oubeira and Mellah) and nighttime roost (Mexna Dam).

At around 08:00, approximately 40 individuals returned to the daytime roost, while a similar number departed for the nighttime roost between 13:00 and 14:00. Outside these peak hours, flight activity remained relatively stable, fluctuating between 20% and 50%. Birds observed flying during these periods were primarily individuals relocating in response to disturbances or wind conditions.

Resting, often associated with preening, occurred consistently from 08:00 to 16:00, with notable peaks at 08:30 and 10:00. Swimming activity displayed relatively stable levels during the early morning, with the lowest values observed around 10:00 and 12:30. This behaviour gradually increased towards midday, reaching maximum levels between 12:00 and 13:00 (Figure 5a).

During winter 2016/2017

Great Cormorant's diurnal activity patterns during winter 2016/2017 exhibited marked temporal variation

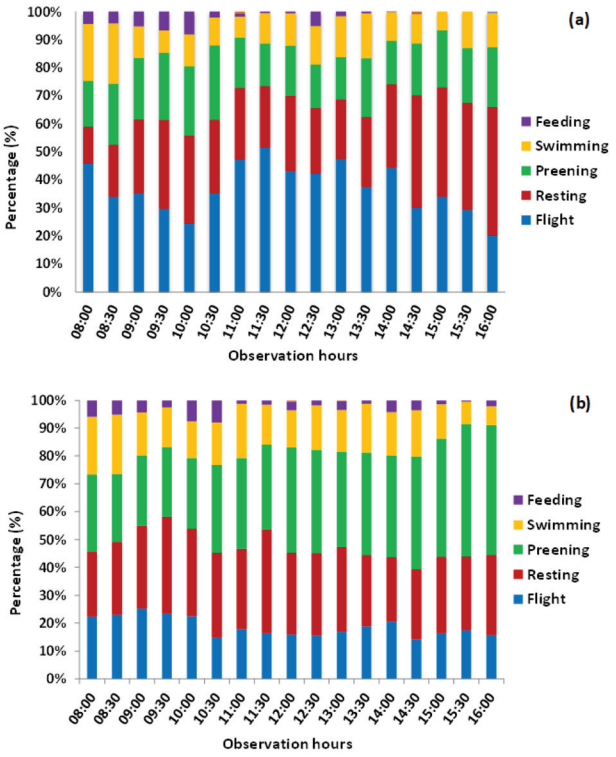

Figure 5. Daily variations in Great Cormorant activities at Lake Oubeira (El Tarf province): a) 2015/2016, b) 2016/2017.

throughout the day, with certain behaviours restricted to specific time intervals (Figure 5b).

Preening was consistently among the most dominant activities across the entire daylight period. Its frequency remained high throughout the day, culminating in a pronounced peak of 64% observed around 14:00 (Figure 5b).

Resting represented the second most frequent activity. Its occurrence remained relatively stable during most of the day but showed two distinct peaks, 53% and 61%, between 09:30 and 11:30.

Flight activity was most prominent during the early morning hours. A significant proportion of individuals were observed flying between 09:00 and 09:30, with a maximum of over 35%, after which flight frequency progressively declined to approximately 20% by 16:00.

Swimming and feeding were observed at generally low frequencies throughout the day, yet displayed distinct peaks. Swimming activity increased notably at two points: 08:30 and 13:30, with respective maxima of 30% and 28%. Feeding remained marginal across all time intervals, with the highest value recorded at 11% between 10:00 and 10:30 (Figure 5b).

Multivariate statistical analysis

The analysis of diurnal activity rhythms over the two wintering cycles, based on a 1 × 2 factorial design using

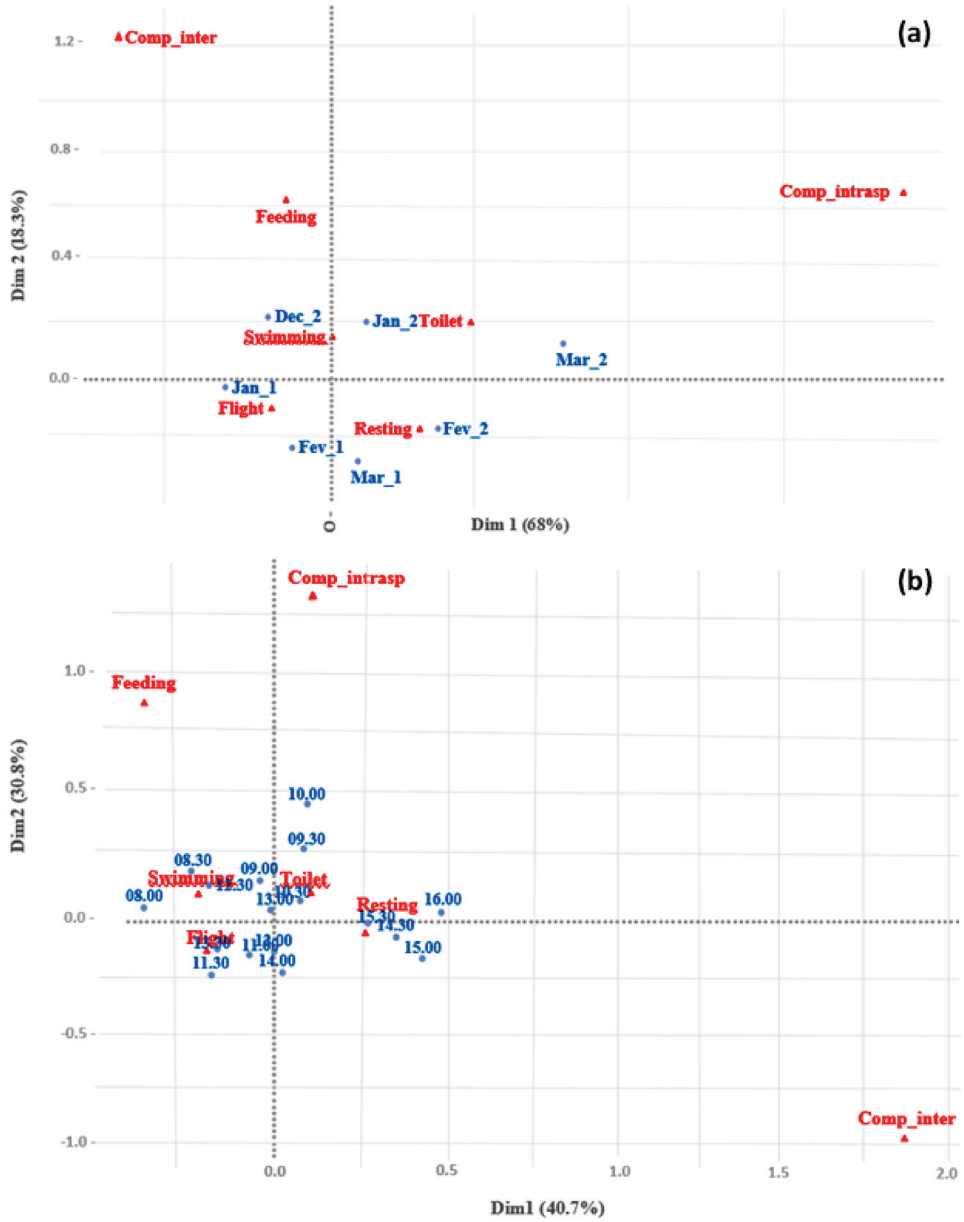

Figure 6. Factorial correspondence analysis of the Great Cormorant diurnal activity rhythms during the two wintering cycles: a) 2015/2016 and b) 2016/2017 at Lake Oubeira (El Tarf province).

Correspondence Factor Analysis (CFA), revealed that the first two axes accounted for 86% of the variability associated with monthly patterns and 72% of that related to the hourly distribution of behaviours.

The factorial projection indicates a close association between flight, swimming, and feeding activities, which were primarily observed during the second half of December, the first half of January, and the first half of February. These three behaviours showed a marked predominance during morning hours compared to the afternoon (Figure 6).

In contrast, resting and preening, two comfort behaviours characteristic of the wintering season, were frequently associated and formed a distinct behavioural cluster in the analysis. These activities were particularly prevalent in the morning and late afternoon. Their occurrence was most pronounced during the second half of December and January, as well as the first half of February, periods during which high frequencies of these behaviours were consistently recorded.

Social interactions, whether intra- or interspecific between species, were infrequently observed and accounted for only a minor component of the cormorants' behavioural repertoire during the study period. These rare activities were observed late in the morning (11:00 and 12:00) and in the early afternoon (13:00 and 14:30). Intraspecific competition occurred most frequently between January and March, whereas interspecific competition was consistently recorded in early December during both wintering seasons studied.

DISCUSSION

According to Tamisier and Dehorter (1999), any behavioural expression in birds, such as resting, flying, or foraging, is the result of an internal need. These needs are modulated by a combination of environmental factors (e.g., temperature, photoperiod, and food availability) and intrinsic biological requirements linked to the species' life cycle, including breeding and moulting periods, which vary significantly between the wintering and breeding seasons (Williams 2012).

The Great Cormorant depends on the availability of shallow aquatic habitats for effective foraging, as well as on suitable sites for resting and communal roosting. Roosts serve primarily as nocturnal resting places and are often used collectively. While some roosting sites remain occupied year-round, others are used exclusively during the wintering period. This is particularly true in the study region located in the eastern wetlands of Algeria, where the species is known to winter, especially in coastal zones.

Despite the species' regular seasonal presence, its activity patterns have not, to date, been the subject of systematic study in Algeria, nor specifically within the El-Kala region. Our observations during the monitoring period revealed notably low frequencies of swimming and feeding behaviours, suggesting a predominance of comfort and energy-conserving activities during the wintering phase at this site.

The analysis of the data collected over the two wintering seasons reveals that flight was the predominant diurnal activity exhibited by Great Cormorants (*Phalacrocorax carbo*), followed in decreasing order by resting, preening, swimming, and feeding. Both intra- and interspecific competition were rarely observed, with rates approaching zero across both seasons.

Upon arrival at Lake Oubeira, individuals exhibited high levels of resting behaviour, indicative of post-migratory recovery, a phase commonly observed in long-distance migratory species. Flight activity was distributed throughout the day, with a marked presence between 08:00 and 16:00. These patterns were influenced, in part, by anthropogenic disturbance, particularly the presence of artisanal fishermen operating along the lake's shores and within boats, which regularly disrupted the birds' behaviour. In addition to small-scale fishing, the lake has been leased for commercial exploitation of the European eel (*Anguilla anguilla*), further increasing human activity in the area (Lazli et al. 2018). Despite these disturbances, Lake Oubeira remains ecologically rich, supporting a diverse trophic web including insects, crustaceans, amphibians, and especially fish species such as common carp (*Cyprinus carpio*), a preferred prey item of the Great Cormorant (Santoul and Mastrorillo 2004; Carss and Ekins 2002; Gagliardi et al. 2007; Belfethi and Moulaï 2022).

Flight in this species is frequently associated with local displacement within the wetland, particularly under windy conditions or in response to disturbance. Distinct flight peaks were recorded in the early morning around 08:00 and again from midday (13:00) until late afternoon (15:30–16:00). These peaks coincide with observed commuting movements between the daytime resting site (Lake Oubeira) and the nocturnal roosting area located at the Mexna dam, suggesting a regular spatial structuring of activity between key habitat zones.

During winter, the Great Cormorant exhibits a spatially structured lifestyle centred around three main habitat types: nocturnal roosts, foraging sites, and daytime resting areas (Metaireau 2009). Each evening, individuals gather at communal roosts, which can host several hundred birds (Paquet 2002). These roosts are typically located in tall trees easily recognizable by branches whitened due to the accumulation of droppings. Cormorants display a high degree of site fidelity, often returning to the same roost and in many cases to the same tree or even the same branch for several consecutive years (Paquet et al. 2000, 2003; Grémillet et al. 1999).

At sunrise, individuals disperse from the roost to reach their respective foraging areas, which may be located over 25 kilometres away (Metaireau 2009). Foraging activity is predominantly concentrated in the early morning hours (Builles et al. 1986; Collas et al. 1999). Similar to roosting sites, Great Cormorants tend to exhibit fidelity to specific foraging locations (Grémillet et al. 1999), indicating spatial consistency in their use of feeding grounds.

Throughout the day, cormorants intersperse foraging with extended resting periods, which may account for up to 90% of their diurnal activity. Resting often occurs near the foraging areas (Géroudet 1991), although individuals may also return to the main roost during the day, depending on its proximity (Martucci and Consiglio 1991).

When perching, cormorants show a preference for the highest branches, occupying them near one another, often with several individuals sharing a single branch. This behaviour reflects both an efficient use of available space and a degree of social tolerance within the group. This spatial organization highlights a highly structured and energetically optimized daily pattern, combining site fidelity, social aggregation, and temporal partitioning of activities.

The results obtained in this study indicate that resting surpasses flight in terms of frequency and importance and is closely associated with preening, as individuals frequently alternate between these two behaviours. Combined, these diurnal activities constitute the dominant components of the Great Cormorant's behavioural repertoire during the wintering season.

According to Tamisier and Dehorter (1999), resting is a fundamental activity in birds and represents the most efficient strategy for conserving energy (Tamisier 1972a, b, c). Upon arrival at the wintering sites, cormorants allocate a significant portion of their time to resting, allowing them to recover from the energetic costs of migration. This pattern explains a high proportion of this activity observed at the beginning of the wintering period, supporting the hypothesis put forward by Gauthier-Clerc et al. (1998), which states that stationary individuals tend to increase the duration of comfort-related behaviours during cold spells.

During rest, cormorants often remain in a motionless posture, with only occasional, subtle head movements betraying their otherwise complete immobility.

The results of this study suggest that *resting* and *preening* are the predominant activities during the initial phase of the wintering period, coinciding with the arrival of migratory individuals. El Afri et al. (2016) report that the Great Cormorant dedicates between 70% and 90% of its daily time budget to preening emerging as the dominant activity at Lake Tonga, a wetland located not far from Lake Oubeira. This behaviour is particularly important during the early winter, likely serving both feather maintenance and ectoparasite removal following the breeding season, alongside a significant amount of time devoted to resting.

Swimming activity gradually increases throughout the day, peaking between 12:00 and 13:00. However, along with feeding, it remains one of the least time-consuming behaviours in the Great Cormorant's diurnal activity budget. Similar trends have been observed in other waterbird species; for instance, Amat and Sánchez (1982) reported a low feeding rate in the White-headed Duck during the wintering season in Spain, a pattern also documented by Chettibi (2014) at Lake Tonga for the same species.

Nevertheless, several studies have shown that in many bird species, feeding activity is typically higher in the morning and decreases during the afternoon and late afternoon (Paulus 1988; Michot et al. 1994). This pattern may be attributed to various ecological and physiological factors. Being essentially diurnal foragers, Great Cormorant's activity patterns reflect the need to foraging the day in order to satisfy energetic requirements. In addition, resting during the warmer midday period offers thermoregulatory benefits, while also reducing exposure to disturbance and diurnal predators and coinciding with periods of greater food availability (McNeil et al. 1992).

Although this behavioural strategy warrants further investigation, high feeding rates may also be influenced by allometric constraints related to body size and mass. Numerous studies have demonstrated that smaller bird species allocate more time to feeding than larger ones (Gibb 1954; Pearson 1968; King 1974), a trend explained by their higher surface-area-to-volume ratio. This ratio results in greater heat loss and, consequently, higher energy expenditure. As a result, the metabolic demands per unit of body mass are significantly higher in small birds, while larger species, such as the Great Cormorant, exhibit lower energy requirements relative to their mass (Calder and King 1974).

The few cases of interspecific competition were observed between Great Cormorants and Great Crested Grebes while swimming, likely as a means of defending their foraging area. Among individuals of the same species, aggressive behaviours were noted around certain preferred locations, particularly the trees surrounding the waterbody and the wooden stakes scattered across the lake, remnants of a former fish-farming operation on the site. On these stakes, the cormorants engaged in resting, with their heads tucked under one wing, preening, or drying their feathers, most likely after foraging.

CONCLUSION

Lake Oubeira serves as a vital wintering habitat for numerous waterbird species, especially the Great Cormorant, which is consistently abundant from autumn to late winter. Its presence is likely linked to the lake's coastal proximity and rich food supply, particularly carp, a key dietary component. Observations across two consecutive winters (2015/2016 and 2016/2017) reveal predictable daily patterns: birds roost overnight at Mexna Dam, return to the lake after sunrise, and spend most of the day resting or drying their plumage. Core behaviours include flight, resting, and preening, with increased flight activity often triggered by fishing disturbances or movements between roosts. Resting dominates early in the season, likely reflecting post-migration recovery needs. This study offers the first systematic insight into the wintering ecology of Great Cormorants in the El Kala wetlands and across Algeria. While the data are valuable, they highlight the need for long-term monitoring to better understand population trends, breeding potential, and migration routes. Further studies including bird tagging and genetic analyses are recommended to identify population origins and assess their ecological impact, particularly on local fisheries.

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Conflict of interests

The co-authors report no conflicts of interest.

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Data availability

The data used to support the findings of this study are included within the article.

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