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# Thesis

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## *Title*

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# Signing sessions

*To my family…*

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# Summary

**Abstract**

The eco-ethological study of five regular breeding avian species in Algerian wetlands belonging to the Phœnicopteridae (the Greater Flamingo *Phoenicopterus roseus*) and breeding Anatidae families (the Mallard *Anas platyrhynchos*, the Ferruginous Duck *Aythya nyroca*, the White-headed Duck *Oxyura leucocephala* and the Marbled Teal *Marmaronetta angustirostris*) in their favorable environments.

The study of the diurnal behavior of these five species showed that our wetlands play a dual role for this aquatic avifauna: a feeding ground for the Greater Flamingo and the Marbled Teal, and a staging ground for the Mallard, the Ferruginous Duck and the White-headed Duck.

During the 2021/2022 season, the Greater Flamingo was very abundant in two Saharan wetlands (Lac El-Goléa: Ghardaia and Chott Oum Raneb: Ouargla). The maximum number of individuals recorded was 7500. This wader's diurnal balance was dominated by feeding (73% in Chott Oum Raneb and 74% in Lac El-Goléa). Other activities (swimming, grooming, courtship, sleeping and flying) were observed at low rates. For the Marbled Teal, during three monitoring seasons (2020/2021, 2021/2022 and 2022/2023) at Chott Oum Raneb, the total number of this species, considered rare, exceeded 200 individuals. Its diurnal behavior is dominated by increased feeding activity, which accounts for between 43 and 46% of the total count.

In Lake Tonga and during three monitoring seasons (2020/2021, 2021/2022 and 2022/2023), the maximum Mallard population recorded was 1306 individuals. Total diurnal activity is dominated by feeding activity, which accounts for over 40% of the total. In five wetlands along the country's eastern coast (Lake Tonga, Lac des Oiseaux, Marais de la Mékhada marsh, Lake Fezzara and Garaet Hadj-Tahar) and during two study seasons (2021/2022 and 2022/2023), the Ferruginous Duck was also very abundant. Its numbers reached 790 individuals in these hydrosystems. Its diurnal behavior is dominated by sleeping, which varies from 46.17% at Garaet Hadj-Tahar to 50.17% at Lac Fezzara. While during two study seasons (2020/2021 and 2021/2022) at five High Plateau wetlands (Garaet Timerganine, Garaet Ouled Amara, Chott El-Hodana, Barrage de Bouguezoul and Barrage de Bougara), the White-headed ducks were observed in very large numbers, often fluctuating between 50 and 200 individuals. The balance of their diurnal time budget is dominated by sleeping, which accounts for between 39 and 53%, except at the Bougara dam, where the diurnal balance is dominated by feeding, often at a rate of 40%.

It should also be noted that the quality and nature of the water, as well as the depth of these aquatic ecosystems, exert considerable effects on the hosting and monitoring potential of these avian populations.

**Key words**: Abundance, Effectives, Diurnal behavior, Time budget, Eco-ethology, Spatial occupation, Greater Flamingo, Mallard, Ferruginous Duck, White-headed Duck, Marbled Teal.

**Résumé**

L'étude éco-éthologique de cinq espèces aviennes nicheuses régulières des zones humides algériennes appartenant aux familles des Phœnicoptéridés (le Flamant rose *Phœnicopterus roseus*) et des Anatidés nicheurs (le Canard Colvert *Anasplatyrhynchos*, le Fuligule nyroca *Aythya nyroca*, l'Erismature à tête blanche *Oxyura leucocephala* et la Sarcelle marbrée *Marmaronetta angustirostris*) dans leurs milieux favorables a été réalisée.

L'étude du comportement diurne de ces cinq espèces a montré que nos zones humides jouent un rôle double pour cette avifaune aquatique : un terrain gagnage pour le Flamant rose et pour la Sarcelle marbrée et un terrain de remise pour le Canard Colvert, le Fuligule nyroca et pour l'Erismature à tête blanche.

Ainsi, pendant la saison 2021/2022, le Flamant rose s'est montré très abondant dans deux zones humides sahariennes (le Lac El-Goléa : Ghardaïa et le Chott Oum Raneb : Ouargla). L'effectif maximal enregistré est de 7500 individus. Cet échassier a montré un bilan diurne dominé par l'alimentation (73% au niveau de Chott Oum Raneb et de 74% au niveau de Lac El-Goléa). Les autres activités (la marche, le toilettage, la parade, le sommeil et le vol) ont été observées avec des taux faibles. Pour la Sarcelle marbrée et pendant trois saisons de suivi (2020/2021, 2021/2022 et 2022/2023) au niveau du Chott Oum Raneb, l'effectif total de cette espèce considérée comme rare a dépassé les 200 individus. Son comportement diurne est dominé par une activité alimentaire accrue qui détient entre 43 et 46% du bilan total.

Dans le Lac Tonga et pendant trois saisons de suivi (2020/2021, 2021/2022 et 2022/2023), l'effectif maximal du Canard Colvert enregistré est de 1306 individus. Le bilan total des activités diurnes est dominé par l'activité alimentaire qui détient plus de 40% du bilan total. Au niveau de cinq zones humides du littoral oriental du pays (le Lac Tonga, le Lac des Oiseaux, le Marais de la Mékhada, le Lac Fezzara et la Garaet Hadj-Tahar) et durant deux saisons d'étude (2021/2022 et 2022/2023), le Fuligule nyroca s'est aussi montré aussi très abondant. Ses effectifs ont atteint 790 individus dans ces hydrosystèmes. Son comportement diurne est dominé par le sommeil qui varie entre 46,17% au niveau de Garaet Hadj-Tahar et 50,17% au niveau du Lac Fezzara. Alors que pendant deux saisons d'étude (2020/2021 et 2021/2022) au niveau de cinq zones humides des Hauts plateaux (Garaet Timerganine, Garaet Ouled Amara, Chott El-Hodna, Barrage de Boughezoul et Barrage de Bougara), l'Erismature à tête blanche a été observée avec des effectifs très importants, fluctuant souvent entre 50 et 200 individus. Le bilan de leur budget temps diurne est dominé par le sommeil qui détient entre 39 et 53% sauf qu'au niveau du Barrage de Bougara le bilan diurne est dominé par l'alimentation observée souvent avec un taux de 40%.

A noter aussi que la qualité et la nature de l'eau ainsi que la profondeur de ces écosystèmes aquatiques exercent des effets considérables sur le potentiel d'accueil et le monitoring de ces populations aviennes.

**Mots clés :** Abondance, Effectif, Comportement diurne, Budget temps, Eco-éthologie, Occupation spatiale, Flamant rose, Canard Colvert, Fuligule nyroca, Erismature à tête blanche, Sarcelle marbrée.

**الملخــص**

أجريت دراسة سلوكية بيئية لخمسة أنواع من الطيور تعشش بشكل منتظم في بيئاتها الملائمة بالأراضي الرطبة الجزائرية والتي تنتمي إلى عائلات: النحاميات (النحام الكبير) والبطيات (البط الخضاري) (الحمراوي ابيض العين) (البط أبيض الرأس) (البط الرخامي).

أظهرت دراسة السلوك النهاري للأنواع الخمسة أن هذه الأراضي الرطبة تلعب دورًا مزدوجًا بالنسبة لهذه الطيور المائية، فهي أرض ملائمة لتغذية بعضها وفي نفس الوقت هي أرض ملائمة للراحة.

خلال موسم 2022/2021، تواجد طائر النحام الكبير بوفرة كبيرة في منطقتين رطبتين في الصحراء الكبرى (سبخة المالح بغرداية وشط أم الرانب بورقلة). العدد الأقصى المسجل هو 7500 فرد، وهيمن على نشاطه النهاري عملية التغذية (73% في شط أم الرانب و74% في سبخة المالح). كما لوحظت أنشطة أخرى وهي: المشي، والتنظيف، والمغازلة، والنوم، والطيران، لكن بمعدلات منخفضة. بالنسبة لطائر البط الرخامي فقد تجاوز عدده في شط ام الرانب 200 فردا، وخلال ثلاثة مواسم (2021/2020 و 2022/2021 و 2023/2022) فقد سيطر على سلوكه اليومي نشاط التغذية بنسبة (43 إلى 46%) من الرصيد الإجمالي.

أظهرت دراسة السلوك النهاري لهذه الأنواع الخمسة أن الأراضي الرطبة الشمالية تلعب دورًا مزدوجًا بالنسبة لهذه الطيور المائية: فهي أرض ملائمة للراحة بالنسبة لطائر النحام الكبير والبط الرخامي، وأرض ملائمة للتغذية بالنسبة للبط الخضاري والحمراوي أبيض العين والبط أبيض الرأس. في بحيرة طونقا وخلال مواسم المراقبة الثلاثة (2021/2020، 2022/2021 و2023/2022)، بلغ الحد الأقصى لعدد البط الخضاري 1306 فردًا. يسيطر النشاط الغذائي على إجمالي رصيد الأنشطة النهارية، حيث يشكل أكثر من 40% من إجمالي الرصيد. على مستوى الأراضي الرطبة: بحيرة طونقا، وبحيرة الطيور، ومستنقع المخدة، وبحيرة فتزارة، وبحيرة الحاج الطاهر، خلال موسمي الدراسة (2022/2021 و2023/2022)، لوحظ تواجد البط أحمر العين بوفيرة كبيرة. ووصلت أعدادها إلى 790 فردًا في هذه الأنظمة البيئية المائية. ويسيطر النوم على سلوكها النهاري، حيث تتراوح نسبته بين 46.17% في غارة الحاج طاهر و50.17% في بحيرة فزارة. بينما خلال موسمي الدراسة (2021/2020 و2022/2021) على مستوى خمسة مناطق رطبة في الهضاب العليا (قرة تيمرقانين، قرعة أولاد عمارة، شط الحضنة، سد بوغزول وسد بوقرة)، تم رصد البط ذو الرأس الأبيض بأعداد كبيرة جدًا، تراوح بين 50 و200 فرد. وقد هيمن نشط النوم خلال النهار بنسبة تتراوح بين 39 و53%، باستثناء مستوى سد بوغارة حيث هيمن نشاط الغذاء بنسبة 40% في كثير من الأحيان.

تجدر الإشارة أيضًا إلى أن جودة المياه وعمق الماء في هذه النظم البيئية المائية كان لها تأثيرات كبيرة على إمكانية استضافة هذه الطيور وبالتالي السماح بمراقبتها.

**الكلمات المفتاحية:** الوفرة، العدد، السلوك النهاري، التوزيع الزمني للنشاطات، السلوك البيئي، الانتشار المكاني، طائر النحام الكبير، البط الخضاري، البط أحمر العينين، البط أبيض الرأس، البط الرخامي.

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# Introduction

## Introduction

Wetlands are ecosystems of crucial importance on a global scale. They provide numerous ecosystem services essential to sustaining life on Earth. They encompass a wide range of habitats, from marshes and peatlands to mangroves and coral reefs, and play a key role in maintaining the global ecological balance (Mitsch & Gosselink 2015). Defined by the Ramsar Convention as " areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt" (Ramsar 2016), wetlands cover around 6% of the world's land surface (Davidson 2014). Despite their relatively limited extent, these ecosystems are home to exceptional biodiversity, hosting over 40% of the world's species and 12% of all animal species (Keddy 2010). The importance of wetlands extends far beyond their role as reservoirs of biodiversity. They provide essential ecosystem services, including regulating the hydrological cycle, alleviating flooding and recharging aquifers (Bullock & Acreman 2003), improving water quality by filtering pollutants and sediments (Joshi *et al.,* 2006), sequestering carbon, playing a crucial role in climate change mitigation (Moomaw *et al.,* 2018) and supporting the livelihoods of millions of people through fishing, agriculture and tourism (Russi *et al.,* 2013).

In the global wetlands landscape, the Mediterranean region stands out as a unique crossroads where exceptional biodiversity, millennia-old cultural heritage and intense anthropogenic pressures converge. While wetlands globally represent crucial ecosystems for the planet, those in the Mediterranean basin are of particular importance in several respects (MedECC 2020).

The wetlands of the Mediterranean basin are ecosystems of key ecological importance, encompassing a remarkable diversity of habitats such as coastal lagoons, deltas, salt marshes and temporary lakes. These unique environments are distinguished by their crucial role in maintaining regional and global biodiversity (Geijzendorffer *et al.,* 2019). Recognized as one of the world's 36 biodiversity hotspots, the Mediterranean basin is home to a multitude of endemic species, including emblematic ones such as the GreaterFlamingo *Phœnicopterus roseus* and the Glossy ibis *Plegadis falcinellus* (Médail & Quézel 1999). These wetlands are not just sanctuaries of biodiversity; they also serve as vital migratory corridors on the African-Eurasian axis, providing vital stopovers for millions of migratory birds (Ramsar 2018).

The Mediterranean basin is recognized as one of the world's major "hot spots" for its high biological diversity, with a variety of plants representing 4.3% of all plants on earth, as well as amphibians and fish (Myers *et al.,* 2001), including a mosaic of wetlands representing

1.5% of the world's wetlands (Perennou *et al.*, 2012). The importance of these ecosystems extends far beyond their role as refuges for flora and fauna. They provide invaluable ecosystem services, acting as natural hydrological regulators, pollutant filters and effective carbon sinks in the fight against climate change (Mediterranean Wetlands Observatory 2018). Their exceptional biological productivity makes them natural nurseries for many aquatic species, supporting complex food webs essential to marine and terrestrial life (UNEP/MAP 2012).

The wetlands of North Africa, including those in Algeria, are of vital importance because of the diversity of flora and fauna they contain, as well as their crucial role as stopover sites for waterfowl migrating from the Palearctic to sub-Saharan Africa. These areas are important wintering, staging and breeding grounds (Van Dijk & Ledant 1980 Stevenson *et al.*, 1988, Britton & Crivelli 1993, Samraoui *et al.*, 2011). North Africa is home to a wide variety of wetlands that serve as wintering and resting sites for migratory Palearctic birds (Stevenson *et al.*, 1988; Evans & Fishpool 2001, Boulkhessaim *et al.*, 2006). These areas are among the most valuable resources in terms of biodiversity and natural productivity.

Despite their undeniable ecological importance, these wetlands are facing increasing threats. Rapid urbanization, pollution and the effects of climate change are exerting considerable pressure on these fragile ecosystems. The Ramsar Convention reports an alarming loss of more than half of Mediterranean wetlands over the last century, underlining the urgency of conservation efforts (Blondel *et al.*, 2010, Gardner *et al.*, 2015). Faced with these challenges, initiatives such as the Mediterranean Wetlands Initiative (MedWet) are coordinating cross-border actions to protect and restore these precious ecosystems. These conservation efforts are crucial not only to preserve the region's unique biodiversity, but also to maintain the vital ecosystem services these wetlands provide to human communities and the environment as a whole (MedWet 2021).

The biodiversity of the western Mediterranean in general, and Algeria in particular, is highly varied due to its geographical location, its potential for wetlands of great ecological, cultural and economic value, and the wide variety of these habitats (Quezel & Médail 2003, Ouldjaoui 2010).

In Algeria, these areas are of particular importance due to the arid and semi-arid climate that characterizes much of the country. They are havens of biodiversity and play a vital role in regulating the water cycle, preventing flooding and combating desertification. Most wetlands in Algeria are subject to numerous anthropogenic disturbances that impact their functioning and make the biodiversity they host particularly vulnerable (Bouldjedri *et*

*al.*, 2011, Demnati *et al.*, 2017). Major disturbances are attributed to factors such as habitat fragmentation, water pollution, the introduction of exotic species and urbanization (Samraoui *et al.*, 1992, de Belair & Samraoui 1994, Dudgeon *et al.*, 2006;). Algeria, Africa's largest country, is crossed by the two major migration routes of the international East-Atlantic Fly-Way and the North-Algerian Fly-Way (Isenmann & Moali 2000). As Isenmann and Moali (2000) point out, the Sahara represents a considerable link between the Mediterranean region and Sahelian Africa, and displays a series of climatic contrasts that vary along a latitudinal gradient. Five bioclimatic stages are distinguished from north to south (humid, subhumid, semi-arid, arid and Saharan) (Daget 1977, Isenmann & Moali, 2000). Due to its geographical location, our country is home to a wide variety of wetlands, distributed not only along the coast (Samraoui & de Bélair 1997, 1998) but also in the high plateaux and Sahara (Samraoui *et al.*, 2006, Saheb 2003, Houhamdi *et al.*, 2008), which are sites of ornithological importance (Stevenson *et al.*, 1988, Houhamdi & Samraoui 2008). Onone hand, it occupies a pivotal position in the migration systems of the Western Palearctic, and on the other, it constitutes a vast wintering area for many Eurasian-breeding species, for which the Mediterranean zone is the main wintering ground (Isenmann & Moali 2000). The multifunctional role (ecological, biological, feeding, breeding, shelter, refuge and climatic) of these areas has led to them being given the status of natural infrastructure (Samraoui & de Bélair, 1997, 1998).

Knowledge of these wetlands can only be envisaged after studying their overall functioning and their use by waterbirds (Anatidae and Phœnicopteridae), which are true descriptors of the functioning of an environment. Algeria now has 2,375 wetlands, including 50 Ramsar sites of international importance, of which 2,056 are natural wetlands and 319 man-made (Medwet 2021). Its participation in the Ramsar Convention enhances the implementation of the Migratory Birds Conservation Act, the Endangered Species Act and the Wildlife Act. As a result, Algeria has drawn up a national wetlands management strategy 2015-2030 with the support of WWF (ministerial decree of March 20, 2012 JO No47), in response to conservation commitments such as the Ramsar Convention, biological diversity and climate change, in line with the target of the MEDWET 2016-2030 action framework.

Waterbirds, the emblem of these ecosystems, are the biological model most studied by researchers throughout history, and their biology, reproduction and migration have been the subject of many studies. Less well known, however, are their wintering ecology, the first studies of which began in the 1970s in the Camargue region of France (Tamisier *et al.*, 1971, 1972a, 1995, Allouche *et al.*, 1989). These studies revealed the crucial importance of winter quarters in maintaining migratory bird populations, by conditioning the breeding season. In

Algeria, the situation is less well known, the most studied site to date being Lake Tonga in the El- Kala wetland complex. These studies have shown the major importance of the wetlands of northeastern Algeria for a large number of species classified as endangered by the IUCN (Boumezbeur 1993).

This convention has made it possible to classify a large area of wetlands and save them relatively from degradation. However, despite these international actions in favor of wetlands, small aquatic ecosystems, of great interest for the diversity of flora and fauna, are still in danger of disappearing in the face of increasing anthropization in certain regions (Hull 1997, Wood *et al.,* 2003, Angélibert *et al.,* 2004, Della Bella *et al.,* 2005).

In Algeria, 41 wetlands have been designated as Important Bird Areas (IBAs), the majority of which have been grouped into three regions: Numidie (Annaba and El-Tarf), the Eastern High Plateaux (which includes the Oum El-Bouaghi complex), and the Oran wetland complex (Samraoui & Samraoui 2008).

- **Study sites**

At present, thanks to considerable efforts and growing interest, Algeria has been able to have a total of 50 sites included on the Ramsar list of international importance. Our study focuses on 15 sites, 11 of which are classified as Ramsar sites of international importance (fig.2). The four sites not classified as Ramsar sites are Sabkhet Ouled Amara, the Bougara dam, Chott Gadaine and Boussedra marsh (fig.1).

- **Sabkhat Ouled Amara**

The Ouled Amara Sabkha is located in the high plateaux of the Khenchela wilaya and forms part of the wetlands complex of the High Plateaux of North-East Algeria (often referred to as the "Constantinois" or Oum El-Bouaghi wetlands complex) is an eco-complex of some twenty wetlands of undoubted ecological importance (fig.1). It is fed mainly by rainwater and plays an important role in bird migration (Bouakkaz 2017). (Tab.1).

- **Chott Gadaine**

Chott Gadaine is located in the northern part of the wilaya of Batna, is part of the structural ensemble of the Constantine high plains (fig.1). The Chott wetland has retained its water, unlike other areas affected by drought. From west to east, Chott Gadaïne is a series of marshes with brackish waters which communicate with each other and flow through the narrow channel of the Oued Saboun into Chott Tinslit (in the wilaya of Oum El Bouaghi) (Athamena 2018). (Tab.1)

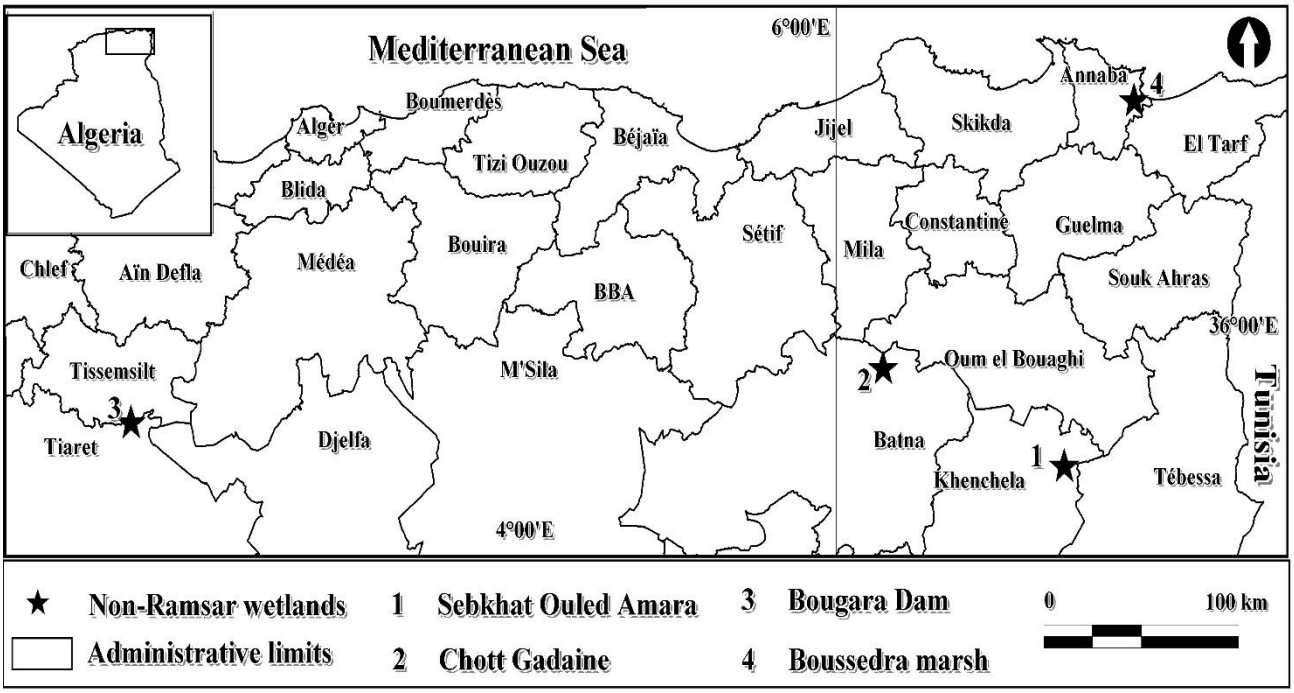
- **Bougara Dam**

The Bougara dam is located downstream of the Dahmouni dam on the same Nahr El-Ouassel watercourse, between the wilayas of Tissemsilt and Tiaret on three communes Bougara and Hamadia in the wilaya of Tiaret and Tissemsilt in the wilaya of Tissemsilt (fig.1). In addition to Nahr El-Ouassel, the dam is fed by rainwater and treated wastewater from the Tissemsilt wastewater treatment plant (STEP) (Oudihat 2011). (Tab.1).

- **Boussedra marsh**

Boussedra is a peri-urban freshwater marsh located in northeastern Algeria (Fig.1). Despite its small size, it is a site of great ornithological importance, representing a wintering and breeding ground for several species, some of which are on the IUCN red list, such as: Little Bittern *Ixobrychus minutus*, White-headed Duck *Oxyura leucocephala* and Ferruginous Duck *Aythya n*yroca (Aberkane 2014) (Tab.1).

**Fig.1: Non- Ramsar wetlands studied.**




**Tab. 1: List of non-Ramsar wetlands studied**

| Site | Wilaya | Geographical coordinates | Size (Ha) | Altitude (m) |
|---|---|---|---|---|
| Sebkhet Ouled Amara | Khenchela | 5°49'25"N, 39°25'33"E | 1,290 | 1070 |
| Chott Gadaine | Batna | 35°45'N 06°15'E | 140000 | 803 |
| Bougara Dam | Tissemsilet | 35°33'41"N, 1°51'39"E | 500 | 472 |
| Boussedra Marsh | Annaba | 36°50'N 07°43'E | 55 | 5 |

- **Lake Tonga**

Northeastern Algeria, and the El-Kala region in particular, boasts a wetland complex that is unique in the Maghreb for its size and diversity: lakes, ponds, wadis, etc. form a mosaic of remarkable biotopes and are home to more than half of the country's aquatic fauna and flora. The rich fauna and flora of these areas attract large numbers of ducks in winter (Boumezbeur 1993). Along with Lac Obéira (wilaya of El-Tarf), Lac Tonga was one of the first sites to benefit from this international nomenclature (fig.2). It is undoubtedly one of the country's and North Africa's most prestigious wetlands, both in terms of flora and birds. This hydro system has the particularity of being both an excellent wintering area for migratory waterbirds from the Black Sea and the Mediterranean, serving as a resting ground on the one hand, and as an important nesting site for sedentary and breeding species on the other, offering in both eventualities the trophic, climatic and safety requirements (Aissaoui 2012) (Tab.2).

- **Lac des Oiseaux**

Lac des Oiseaux (Bird Lake), located in the same wilaya as Lac Tonga, is part of the El-Kala National Park (fig.2). The lake has a more or less oval shape, stretched to the northeast by a characteristic pond tail (Houhamdi, 1998). Despite its small size, Lac des Oiseaux harbors an abundance of remarkable avifauna. The lake is a refuge for many wintering and transiting waterbirds and birds of prey (Houhamdi 2002, Houhamdi & Samraoui 2002, Loucif *et al.,* 2021) (Tab.2).

- **Mékhada Marsh**

The Mékhada is a temporary Mediterranean marsh forming part of the El-Kala wetland complex. It is located on the Ben M'hidi sublittoral plain, some twenty kilometers east of the town of Annaba (fig.2). In summer, the low bathymetry of the marsh, combined with the absence of rain and intense evaporation, cause it to dry up from May to October. It is then massively exploited by various species of breeding birds, as well as by numerous mammals (wild boar, jackal, fox, mongoose, etc.). During the winter months, livestock only graze in areas with little or no flooding on the marsh banks. Bird disturbance is therefore negligible during this period (Bendjeddou *et al.,* 2022) (Tab.2).

- **Garaet Hadj-Tahar**

The avian situation is less well known at Garaet-Hadj Tahar, part of the Guerbes-Sanhadja wetland complex, a freshwater lake that is often flooded, except in exceptional cases, and irrigated by tributaries of Oued El-Kébir (Fig.2). Located some twenty kilometers from the Mediterranean, it has a very elongated oval shape, surrounded to the northwest by a

clay hill and degrees, to the east by 15 dunes and to the southeast by the alluvial plain of Oued El-Kébir. The depression occupied by this lake is oriented northwest-southeast (Metallaoui & Houhamdi 2008, 2010, Atoussi *et al.*, 2013) (Tab.2).

- **Lake Fetzara**

The lake is represented by a wide depression bounded to the north by the Edough mountain range and to the south by the Nechmaya hills in the Wilaya of Guelma, by the west, theclear natural boundary is the 25m slope which corresponds to a hill (fig.2). By the east, the lake is separated fromthe Annaba plain by the El Gantra dune belt. From an ornithological point of view, this wetland was the most important nesting and wintering site in the east of north-east of Algeria (Djemai 2018) (Tab.2).

- **Sabkhet Bazer-Sekhra**

Sebkha of Bazer-Sakra is located in the southern part of the Setifien high plains, whichare part of the Tellien high plains (fig.2). The site, of natural originis a natural depression and whose altitude is the highest in thein the Sétif region. It is located 9 km south of the town of El-Eulma and 3 km south of the village of El-Mellah. (Boumezbeur 2004) (Tab.2)

- **Lake Boughezoul**

Lac de Boughezoul (or Bou Ghizoum) is an artificial lake built in 1936, around 175 km south of Algiers, at the southern edge of the first foothills of the Tellian Atlas (François 1975), just north of the town of Boughezoul beside the national road N°1 linking Algiers and Djelfa (fig.2) (Cherbi 1986). This brackish water area is selected as an important site for IBA bird conservation (Coulthard 2001, Bounab *et al.*, 2018) (Tab.2).

- **Chott El-Hodna**

The Chott El-Hodna is one of a series of chotts that have developed where water from the Saharan Atlas in the south and the Tellian Atlas in the north converge. The Chott straddles two departments (wilaya), M'sila (1000 $Km^2$) and Batna (100 $Km^2$) in southeastern Algeria (fig.2). Its flooded surface area, though variable, never exceeds 80,000 ha. It is fed by at least 22 main rivers, plus freshwater springs. It only becomes wet in winter, dry and salty in summer, with salt crusts covering its entire extent (DGF 2002) (Tab.2).

- **Garaet Timerganine**

Garaet Timerganine is located 26 km south of the town of Oum El-Bouaghi, and is bounded to the north by the road linking the commune of Ain Zitoune to that of Chemora (Wilaya of Batna), to the south by the Remila plain, to the west by the commune of Ain Zitoune and to the east by the road linking the Wilaya of Oum El-Bouaghi to Khenchela

(fig.2). The Timerganine region is essentially characterized by endoreism, reflected in the existence of a multitude of basins, either settling basins occasionally flooded, or flood basins frequently inundated during floods of the Oued Boulafraiss (Benazzouz 1986). This complex of wetlands has always been underestimated, despite the fact that it is known to be a wintering area for waterfowl and plays an important role in the transit of migratory birds (Maazi *et al.,* 2011) (Tab.2).

- **Chott Oum Raneb**

Chott Oum Raneb supplies most of the sewage water for the Ouargla region (5 communes), which is discharged into this site that constitutes the main water inlet in addition to water from the chott's underground aquifer (fig.2). This wetland is permanent, even in summer. This site is a vast body of water surrounded by sand dunes, and its location in the middle of the desert means it is home to several migratory waterbird species (Bouzegag 2015). It is an important refuge for migratory and wintering waterbirds crossing the desert on the African-Eurasian flyways. The pink flamingo *Phœnicopterus roseus* and the white stilt *Himantopus himantopus* breed here; the wigeon, the shelduck, the coot macroule, the sickle ibis, the elegant avocet, the grey heron and the red-necked gravelot are also present in the site (Ramsar 2018) (Tab.2).

- **Lac El-Goléa**

Lac El-Goléa or Sebkhet El-Maleh is an endoreic depression made up of saline soils and 2 bodies of water, the first located to the north (upper basin), with moderate salinity, very rich in biological diversity and similar to a pond; the second is the Sebkha, or saline lake, bare with salt-covered banks (fig.2) (DGF 2004). Located 12 km south of the Daïra of El-Menia, in the commune of Hassi El-Gara and 280 km from the town of Ghardaïa, the wilaya capital (DGF 2005) (Tab.2).

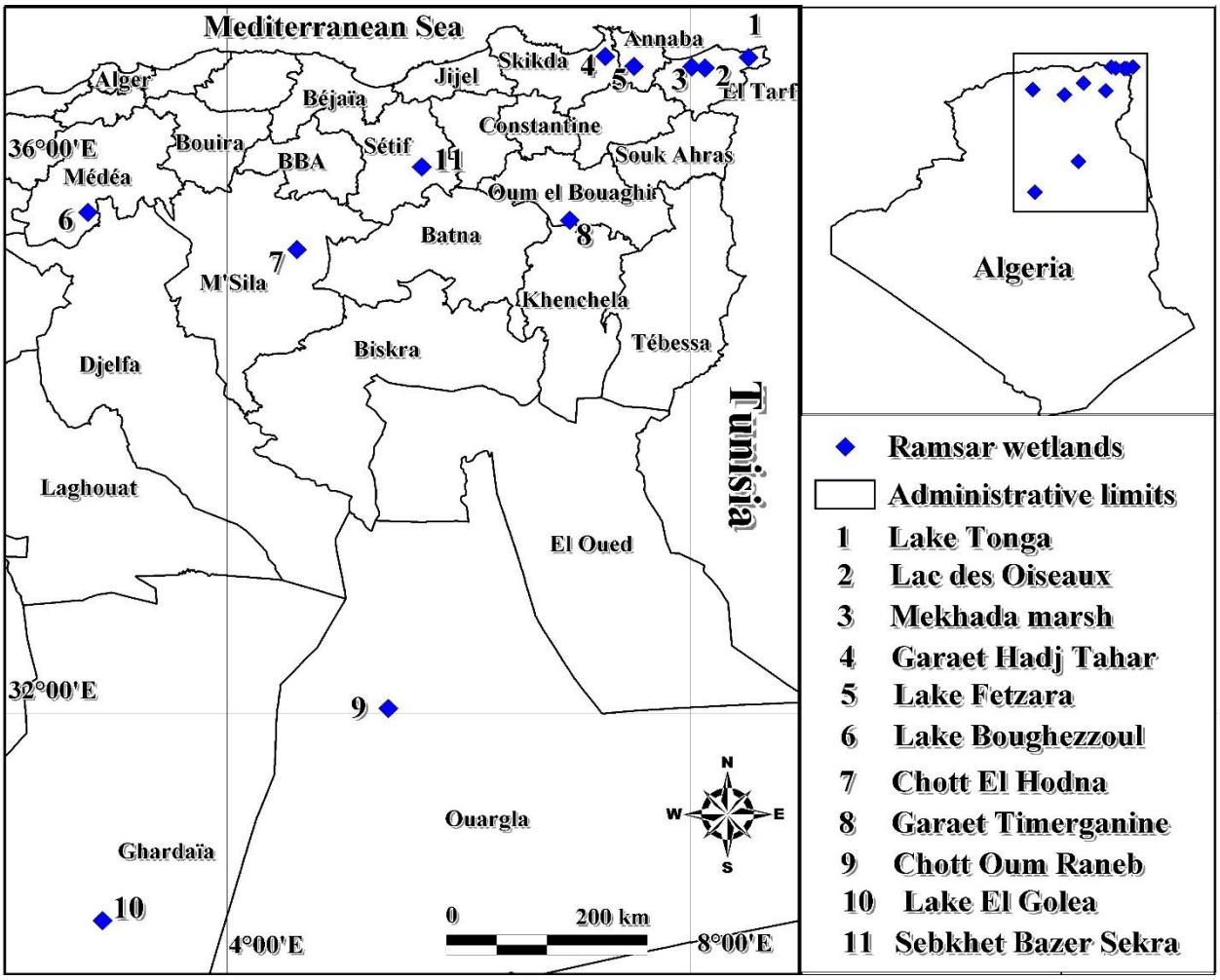
In the heart of the Western Palearctic region, in the southern part of the Mediterranean basin, lies a territory remarkable for its exceptional ecosystem wealth. Our country boasts remarkable biodiversity at the biological, ecological and genetic levels, encompassing a complete mosaic of natural habitats. Among these ecological treasures, wetlands occupy a prominent place, constituting a natural heritage of extraordinary diversity.

These aquatic ecosystems represent invaluable resources for our planet, both in terms of their contribution to biological diversity and their exceptional natural productivity. The scientific community now fully recognizes the fundamental role played by these environments in maintaining essential ecological balances.

Contemporary studies have highlighted the crucial importance of wetlands in many vital ecological processes. These ecosystems regulate hydrological cycles, provide refuge for a diverse flora, and are crucial habitats for many aquatic and avian species, not least as favored stopover sites for migratory birds (Aberkane 2014).

Wetlands represent sites of considerable importance for scientific research programs and biodiversity conservation (Ramsar 2018). Nevertheless, despite their inestimable value, the protection and management of these ecosystems continue to suffer from profound shortcomings. These shortcomings manifest themselves both at the level of strategies and planning and in concrete applications on the ground, making these environments particularly vulnerable to a variety of threats (Mediterranean Wetlands Observatory, 2018). These fragile ecosystems face numerous challenges. Long-lasting hydrological disturbances and changes, caused mainly by increased drilling and illicit pumping, are a major threat (García-Ruiz *et al.,* 2011). The situation is exacerbated by the destruction of ecotones, sacrificed to aggressive "slash and burn" agriculture (Samraoui & Samraoui 2008). Pollution, whether organic or chemical, particularly from fertilizers, also degrades the quality of these environments (Kahoul & Touhami 2014). Deforestation of watersheds represents another significant threat, causing the progressive filling in of water bodies (Touati *et al.,* 2010). In addition, the over-exploitation of natural resources, whether through excessive fishing, unregulated hunting or acts of vandalism, jeopardizes the balance of these ecosystems. The introduction of exotic species is disrupting native communities (Samraoui *et al.,* 2011), while uncontrolled urbanization and habitat fragmentation are gradually reducing the extent and connectivity of these essential areas (Saber & Mostefa 2011). Faced with these multiple pressures, it is becoming urgent to strengthen protection measures and improve the management of these precious natural spaces. An integrated approach, taking into account all these challenges, is needed to ensure the sustainability of these vital ecosystems (Geijzendorffer *et al.,* 2019).

**Fig.2: Ramsar wetlands studied.**




**Tab. 2: List of Ramsar wetlands studied**

| Site | Wilaya | Geographical coordinates | Date | Size (Ha) | Altitude (m) |
|---|---|---|---|---|---|
| Lake Tonga | El Tarf | 36° 51′ 22″ N, 8° 30′ 04″ E | 11/04/1983 | 2700 | 2-4 |
| Lac des Oiseaux | El Tarf | 36° 46′ 55″ N, 8° 07′ 26″ E | 22/03/1999 | 120 | 10 |
| Mékhada marsh | El Tarf | 36° 47′ 06″ N, 8° 00′ 29″ E | 06/04/2003 | 8900 | 0-1 |
| Guerbez-Sanhadja complex | Skikda | 36° 52′ 48″ N, 7° 18′ 04″ E | 02/02/2001 | 421000 | 0-90 |
| Lake Fetzara | Annaba | 36° 47′ 17″ N, 7° 30′ 32″ E | 04/06/2003 | 12000 | 10-40 |
| Sabkhat Bazr-Sekhra | Sétif | 36°02'N, 05°41'E | 12/12/2004 | 4379 | 972 |
| Lake Boughezzoul | Médea | 35° 41′ 56″ N, | 05/06/2011 | 9058 | 630-650 |

| | | | | | |
|---|---|---|---|---|---|
| | | 2° 47′ 35″ E | | | |
| Chott El-Hodna | M'sila-Batna | 35° 26′ 06″ N, 4° 41′ 53″ E | 02/02/2001 | 3620 | 390-400 |
| Garaet Timerganine | Oum El Bouaghi | 35° 39′ 58″ N, 6° 57′ 07″ E | 18/12/2004 | 1460 | 843 |
| Chott Oum Raneb | Ouragla | 32° 02′ 20″ N, 5° 23′ 31″ E | 12/12/2004 | 7155 | 126 |
| Lac El-Goléa (Sebkhat el Melah) | El Meniaa | 30° 30′ 22″ N, 2° 55′ 34″ E | 12/12/2004 | 18947 | 367-478 |

Among the avifauna frequenting coastal ecosystems and high plains, Anatidae represent a group of major interest to both the hunting community and ornithologists (Elmberg *et al.,* 2006). Although their main habitat is not located directly on the foreshore, a coastal zone regularly used by a limited number of species (Matellaoui *et al*., 2010), these birds make temporary use of these areas during their migratory movements or foraging activities (Guillemain *et al.,* 2005, Houhamdi *et al.,* 2008). The spatio-temporal distribution of waterbirds has been the subject of numerous scientific studies. Research has shown that this distribution is structured according to precise patterns in time and space (Raveling 1979, Gullestrad *et al.,* 1984, Allouche *et al.,* 1990). It has also been established that the reproductive success of migratory Anatidae is closely linked to their wintering strategies and the quality of resources available in their wintering quarters and staging areas (Tamisier *et al.,* 1995).

Rare species that come to no attention, the Marbled Teal *Marmaronetta angustirostris* is classified as "vulnerable", the White-headed Duck *Oxyura leucocephala* is classified as "endangered" and the Ferruginous *Duck Aythya nyroca* is classified as "near-threatened" on the IUCN red list (BirdLife international 2004, IUCN 2006).

The Marbled Teal has this status in Algeria and throughout the Western Palearctic. Its global numbers have been declining rapidly over the years, estimated at 55,000 individuals in 2010 (BirdLife international 2012). According to Rose and Scott (1994), there are four distinct regional populations of the species. The two largest are in Asia: one in the southwest with around 25,000 individuals, and one in the south with just 5,000 individuals. The other two populations are located in the Mediterranean region: in the east (Turkey, Egypt, Palestine) with less than 1,000 individuals, and in the west (Spain, Morocco, Algeria, Tunisia) with around 2,000 individuals. There are an estimated 450 breeding pairs, 200 in Spain, 150 in Tunisia, and 50 in Morocco and Algeria. The total world population is estimated at 33,000 individuals, which has led to the species being classified as globally threatened according to

Collar *et al.* (1994), and even vulnerable according to the IUCN. At national level, although Isenmann and Moali reported the presence of only 40 individuals in 2000, the total numbers of Marbled Teal are considered significant. Scott and Rose (1996) mention a regional wintering population of around 3,000 individuals.

The White-headed Duck is a globally threatened duck and one of the top three rarest Anatidae in Europe. Native to the Palearctic, with a sedentary to erratic Mediterranean population and a migratory Eastern population. It is both a sedentary breeder and a winterer in Algeria (Isenmann & Moali 2000, Metallaoui *et al.,* 2009, Chettibi *et al.,* 2013, Meziane *et al.,* 2014, Halassi *et al.,* 2016). Its global population declined sharply during the 20th century. The species is now classified as "vulnerable" in the European Union EU 27 and "endangered" at European and global level (BirdLife international 2015) is also protected by Algerian legislation as an endangered species (Bergier *et al.,* 2003; Lazli *et al.*2011 a, b). The causes of the decline are multiple. Habitat degradation or loss remains the main threat (Bonnet *et al.,* 2005), along with heavy hunting pressure, given that Anatidae constitute the bulk of the world's waterfowl (El Agbani 1997).

The range of the Ferruginous Duck *Aythya nyroca* spans three continents: Europe, Asia and Africa (BirdLife International 2018). In recent decades, however, this species has experienced significant population fluctuations and alterations in its geographical distribution (Vinicombe 2000). Robinson and Hughes (2006) attribute this decline mainly to two anthropogenic factors: habitat deterioration and loss, and hunting pressure driven by local consumption. Despite its "little threatened" status according to the criteria of BirdLife International and the African-Eurasian Migratory Waterbird Agreement (AEWA) (Nagy *et al.,* 2014), the Ferruginous Duck shows notable sedentary behavior in certain areas, notably Lake Tonga. This site provides it with favorable conditions in terms of trophic resources, safety and quietude (Lazli *et al.,* 2011). It is interesting to note that, contrary to trends observed in Europe and Asia (Petkov *et al.,* 2003), Algerian Ferruginous Duck populations appear to be undergoing a phase of expansion. This positive trend is evident in both the northern and southern regions of the country. Observations and studies carried out by the scientific and ornithological community corroborate this trend, attesting to the presence of the species at various times of the year throughout the national territory (Samraoui *et al.,* 2006, Aissaoui *et al.,* 2012, Merzoug 2014). This particular situation in Algeria highlights the importance of local conservation efforts and suggests the need for in-depth studies to understand the factors underlying this divergence from the species' global trends (Isenmann & Moali, 2000).

The Mallard *Anas platyrhynchos* is a sedentary breeder and overwinterer in Algeria (Isenmann & Moali 2000), but despite its status as a species of "minor concern", it is little studied on a national scale. The description, egg-laying phenology, wintering population structure, copulation, effect of environmental change, effect of predation, reproductive investment and habitat selection have been successively mentioned in studies by Potiez (2002), Pawlina *et al,* (1993), Cunningham (2003), Guillemain *et al,* (2010), Legagneux *et al,* (2009), Giraudeau *et al,* (2010), Pöysä *et al,* (1998) and Doherty *et al,* (2002). In Algeria, the study by Fouzari (2016) provided new data on breeding biology at Lake Tonga (PNEK), where 57 nests were recorded. The present study is the only one of its kind in northeast Algeria.

Phœnicopteridae are an important component both in terms of their specific richness and their very high numbers (Halassi *et al.,* 2016). These waterbird families have been the subject of numerous studies carried out in most of the country's wetlands, including those by Boulekhsaim *et al,* (2006), Saheb *et al,* (2009), Bensaci *et al,* (2010), and Mesbah (2014). The Greater Flamingo*, Phœnicopterus roseus*, an emblematic wetland species, is widely cosmopolitan, but there are fewer than 15 breeding sites for the entire Mediterranean basin (Johnson *et al.,* 2007). This species, considered emblematic of Mediterranean wetland ecosystems (Cramp & Simmons 1977, Johnson & Cézilly 2007), favors shallow, brackish or saline water bodies, characteristic of the Maghreb landscape (Balkız *et al.,* 2010). These birds, known for their fearful nature and sensitivity to human disturbance, have been the subject of numerous scientific studies in the North African region. Research has been particularly concentrated in Tunisia, with pioneering work dating back to the 19th century (Johnston 1881) followed by in-depth studies in the 20th century (Domergue, 1951-1952, Castan 1960; Kahl 1955). Recent research has continued to enrich our knowledge of the species in this region (Johnson 1997, Smart *et al.,* 2009). In Morocco, the study of Greater Flamingos has also generated a significant scientific literature, with major contributions by Panouse (1958) and Robin (1966, 1968). More recently, the work of Qninba and Dakki (2009) has provided new insights into the ecology of the species in Moroccan wetlands. In Algeria, apart from sightings (Dupuy 1969, Johnson 1979, Johnson and Hafner 1972, Le Berre and Rostan 1976, Metzmacher 1979, Burnier 1979, Jacob and Jacob 1980, Ledant and Van Dijk 1977, Ledant *et al.,* 1981, Isenmann and Moali 2000), no ecological studies were carried out until the 2000s. Since 2003, several studies have been carried out on this species, particularly in the eastern high plains and Sahara of Algeria (Boulkhssaim *et al.,* 2006, Saheb *et al.,* 2006, Samraoui *et*

*al.*, 2006, 2008,2009, Houhamdi *et al.*, 2008, Bouzid *et al.*, 2009, Bensaci *et al.*, 2011, Baghdadi *et al.*, 2016).

More recent studies have highlighted the crucial importance of staging areas for the conservation of these species (Arzel *et al.*, 2006). The availability and quality of food resources at these sites significantly influence the birds' body condition and, consequently, their ability to successfully migrate and reproduce (Drent *et al.*, 2007).

Changes in water status are the main factor affecting them (Guillemain *et al.*, 2010), and they react quickly to any environmental change (Carignan & Villard, 2002), so they can be reliable tools for analyzing the functioning of the ecosystem to which they belong (Moali 2009). The status of many bird species is deteriorating, and a worldwide decline in bird populations is well documented (Kirby *et al.*, 2008).

Wetlands in the High Plateaux of northeastern Algeria have been the subject of numerous studies, the most recent of which have focused on vegetation (Aib & Boutouil 2020), waterbirds (Saifouni 2007, Ouldjaoui 2010, Guellati *et al.*, 2014, Bouakkaz 2017, Oudihat 2018, Bounab 2018, Sahbi *et al.*, 2022) and macro-invertebrates (Zarouel 2014). However, little is known about the physico-chemical and bacteriological properties of the water in these ecosystems, bearing in mind that eutrophication in particular, accelerated by human activities, can lead to their disappearance (Guergueb *et al.*, 2014).

To our knowledge, there is very limited data on the physico-chemical and bacteriological properties of the four sites (Sabkhet Bazer Sakra, Chott Gadaine, Boussedra marsh and Garaet Hadj Tahar), which considered complex and vulnerable ecosystems.

- **Background and objectives of this thesis**

The thesis is in line with the research themes of the Biology, Water and Environment Laboratory (LBEE), University of 8 Mai 1945 Guelma.

Firstly, it seems crucial to deepen our understanding of the ecological and behavioral characteristics of the five avian species studied: Marbled Teal *Marmaronetta angustirostris*, White-headed Duck *Oxyura leucocephala*, Ferruginous Duck *Aythya nyroca*, Mallard duck *Anas platyrhynchos* (Anatidae) and Greater Flamingo *Phœnicopterus roseus* (Phœnicopteridae). The aim is to fill the gaps in our knowledge of the specific features of their respective habitats. Then, we will follow the phenology of these species, helping to determine their spatio-temporal distribution during their presence in these aquatic environments. Acquiring this information is a prerequisite for developing effective conservation strategies and optimizing management practices for these species. Such an integrated approach, combining the study of eco-ethology and habitat analysis, would enable

more targeted protection measures to be put in place, adapted to the specific needs of each of these species in their natural environment.

Secondly, we set out to study and determine the current state of water quality, through its physico-chemical and microbiological characterization, and then to study the effect of these parameters on the biology of the five species studied. Determining water quality and understanding its spatiotemporal changes is the key to taking the necessary measures to preserve this ecosystem of international importance.

- **Thesis structure**

Accordingly, this thesis is structured into seven chapters. After a general introduction outlining the state of knowledge of the five species studied in the fifteen wetlands concerned by the study, the following chapters describe the equipment and methodology used to carry out the study, listing the different techniques used to count waterbirds, their spatio-temporal distribution and occupation, the study of diurnal activity rhythms and, finally, the analysis of the physico-chemical and bacteriological parameters of the water. Next comes the results and discussion section, with six chapters covering the results obtained for each of the five species studied and the effect of abiotic factors on their ecology. Finally, a general conclusion closes this thesis.

# Chapter I: Materials and methods

The present study is based on three parts: a study of the phenology and population counts of the Phœnicopteridae: Greater Flamingo *Phœnicopterus roseus* and Anatidae breeding in Algeria, including Mallard Duck *Anas platyrhynchos,* Ferruginous Duck *Aythya nyroca*, White-headed Duck *Oxyura leucocephala* and Marbled Teal *Marmaronetta angustirostris*. The second part concerns the spatio-temporal distributions and use of different water bodies with different bioclimatic levels by waterbirds. We localized these waterbirds on specific preliminary maps using certain landmarks within our study sites. We then transferred them to other maps, enabling a better and clearer graphic representation of spatial occupation without taking into account the numerical importance of the birds. Finally, we studied the diurnal activities rhythms of each species. By studying the main activities and behavior of birds during winter, we can determine the identity and intensity of their needs and ecological requirements. Observing the behavior of wintering fauna is one method of understanding the needs that waterbirds must meet during the months they spend on a wintering area (Tamisier & Dehorter 1999, Houhamdi 2002).

## 1. Bird population structure and dynamics

There are several reasons for counting waterbirds, such as obtaining information on the monitoring and dynamics of species at different levels, whether at local level, to estimate the numbers occupying a site, their fluctuations and the carrying capacity of the ecosystem, or at national level, to learn about the importance and role of wetlands, and to recommend ways of developing action and conservation plans for these ecosystems, at national level, to understand the importance and role of wetlands, and to recommend ways of developing action and conservation plans for these ecosystems. Finally, bird counts are of great importance at international level in estimating regional populations of several species and their trends (Bensaci *et al.*, 2011, Charchar 2017).

### 1.1. Waterfowl counting techniques

There are many different methods of bird observation, depending on the species studied and the goal sought. Two methods are commonly used for this purpose: ground counts and aerial counts. What they have in common is the numerical evaluation of groups (Blondel, 1975).

In a body of water, several thousand birds may congregate. Counting them one by one is certainly out of the question, so we have to estimate their numbers (Tamisier & Dehorter, 1999). It should be remembered, therefore, that waterfowl counting is much more a matter of absolute counting. There are different variants, and the choice of one or the other depends on

the size of the site, the size of the bird population to be counted and the homogeneity of the population observed (Houhamdi 2002, Houhamdi & Samraoui, 2002).

For all the methods used, counts are based on an individual count, itself based on the principle of estimation. This is the principle adopted in our counts, when the group of birds does not exceed two hundred individuals in size and is close to our observation point, i.e., less than two hundred meters away. In the opposite case, i.e., when the size of the bird population exceeds two hundred individuals and/or the group is at a greater distance, we make a visual estimate. To do this, we divide the field into several strips, count the number of birds in an average strip and report as many times as there are strips (Houhamdi & Samraoui, 2002). This widely-used method, however, has a margin of error ranging from 5% to 10% among professionals (Tamisier & Dehorter, 1999).

### 1.2. Sampling frequency

For the purposes of our work, we have chosen to carry out fortnightly counts from the beginning of September to August, thus covering almost the entire wintering period for three consecutive years, 2020/2021, 2021/2022 and 2022/2023.

### 1.3. Species concerned by our work

Our study focuses on five species belonging to the Phœnicopteridae and Anatidae families.

- Greater Flamingo *Phœnicopterus roseus* (Phœnicopteridae)
- Mallard duck *Anas platyrhynchos* (Anatidae)
- Ferruginous Duck *Aythya nyroca* (Anatidae)
- White-headed duck *Oxyura leucocephala* (Anatidae)
- Marbled teal *Marmaronetta angustirostris* (Anatidae)

## 2. Distribution and spacio-temporal occupancy

Birds are distributed in the lake environment in ways that are unique to them. Rarely random, this distribution responds to biological and ecological criteria that characterize both the species and the environmental conditions (Houhamdi *et al.,* 2008b, 2009). Quietness and the sharing of food resources apparently condition the distribution of bird groups in a site (Houhamdi *et al.,* 2008a, 2009, Elafri *et al.,* 2016a, 2017).

During our outings and after systematically counting these waterbirds (Anatidae and Phœnicopteridae), we tried to locate them on maps using constant landmarks in our study regions. These specific and provisional maps were then transferred to other definitive maps,

which will enable us to monitor the use of water bodies. The graphical representations of spatial occupancy presented in this thesis do not take into account the numerical importance of waterbirds.

### 3. Study of Anatidae and Phoenicopteridae activities rhythms

The time budget or activity rhythm is defined as the proportion of time spent by individuals in each type of behavior, during a given period and in a given area (Tamisier & Dehorter, 1999). Two methods are known for studying the diurnal behavior of waterbirds, the *Scan* or Instantanious scan sampling method and the *Focus* or focal Animal sampling method (Althman 1974).

#### 3.1. *Scan* method

The activity budget is simply measured using the *Scan* method, so that the observer scans the landscape from one point to another, noting the behavior of each visible individual. Then, using mathematical transformations, the temporal percentage of each activity is calculated. This method has the advantage of being the only one applied in densely vegetated sites, where waterbirds (particularly Anatidae) are still not observed for long periods (the limit of focused sampling). On the other hand, it eliminates the need to select individuals (Baldassare *et al.,* 1988). As a result, since sampling is instantaneous, it is virtually impossible to determine the social status (paired or separated) of the birds observed (Houhamdi 2002).

#### 3.2 *Focus* method

Focused sampling involves observing an individual for a pre-determined period, not to exceed 10-15 minutes, during which the activities displayed are continuously recorded. The results obtained are then proportioned to determine the percentage of time spent on each behavior (Althman, 1974, Baldassare *et al.,* 1988). This method makes it possible to study the behavior of small groups of birds over small areas. It allows better monitoring. It also defines and valorizes behaviors that are not always frequent, such as aggression and parasitism. It should be noted that the Focal-Switch Sampling or Switch method (Losito *et al.,* 1989) is used to compensate for the occasional loss of sight and observer fatigue. Each loss of sight must be compensated for by another individual from the same group displaying the same activity.

To study the diurnal behavior of the above-mentioned waterfowl at various study sites, we opted to use the *Scan* method, in which every hour (from 8 a.m. to 4 p.m.) we carried out a series of scans at the water surface, across the group of birds on which the long ornithological

view (*Kite SP 82 ED* 20x80) was aimed, in order to count the various activities displayed by these ducks in the field of view. Five activities were measured: sleeping and feeding (primary activities), swimming, grooming and flying (comfort activities). Antagonism was observed in Ferruginous Duck only. Instantaneous sampling of the activity rhythms of species enables us to obtain the percentage of time allocated to each activity, using a conversion method to determine the role of study regions (Tamisier and Dehorter, 1999).

**4. Multivariate statistical processing**

Multivariate statistical exploration using Correspondence Factorial Analysis (CFA) is one way of interpreting these observations. Its main aim is to calculate a set of saturations to explain the correlations observed between tests by highlighting a number of fundamental skills, and to identify these skills as far as possible (Dagnelie 1975). Using ADE-4 software (Chessel & Doledec 1992), we performed CFAs on the diurnal activity rhythm data of the five species studied over the entire study period.

**5. Analysis of physico-chemical parameters**

Physico-chemical analysis of the water was carried out monthly during our period. We measured temperature (°C), pH, Turbidity, Dissolved Oxygen (DO) and Electrical Conductivity (EC) in situ with a multi-parameter (Multi-parameter HANNA HI98194 PH/EC/OD waterproof with probes). Nitrite ($NO_2^-$), nitrate ($NO_3^-$), ammonium ($NO_4^+$ ), chloride ($Cl^-$), sulfate ($SO4^{2-}$), potassium ($K^+$ ), calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), dry residue (DR) and suspended solids (SS) were measured in the laboratory using the method of Rodier *et al,* (1996). All measurements and sample collection were carried out at two different stations in each wetland.

The bacteriological examination of the water focused on the evaluation of microbial indicators of fecal pollution, in particular Total Coliforms (TC), Fecal or thermotolerant Coliforms (FC) and Fecal Streptococci (FS). We followed established methodologies provided by the American Public Health Association (Rice *et al.,* 2017) and FUNASA-National Health Foundation (2013). To identify Fecal Coliforms, a subgroup of coliform bacteria, *Escherichia coli* serves as the main representative bacterium of this category and is exclusively of fecal origin. Detection and quantification of these thermotolerant bacteria were carried out using the Most Probable Number (MPN) method on Bromocresol Purple Lactose Broth (BCPL) medium. Inoculated tubes were then incubated at 44°C for 24 to 48 hours, in accordance with the guidelines set out in AFNOR T 90-413 (1985).

**6. Effect of abiotic factors on aquatic avifauna**

The aim of this study was to reveal similarities and differences in waterbird composition and water physico-chemical parameters between four important wetlands in northeastern Algeria. Firstly, the coastal sites showed distinct avian communities from those in the Highlands, with the former characterized by greater abundance of the endangered White-headed Duck, while the latter were characterized by greater abundance of the Greater Flamingo and Marbled Teal. *Secondly*, our physico-chemical analysis showed that one site in the High Plains (Sabkhet Bazer-Sakra) was markedly different from the other three sites in many parameters, but had some similarities with a coastal site (Garaet Hadj-Tahar). *Thirdly*, we performed a PCA based on avian community composition and physico-chemical parameters, which showed that, although the two coastal sites and the two High Plateau sites were relatively isolated ecologically, there was also a notable overlap between one High Plateau site and the two coastal sites.

During 2022, we carried out a systematic search for nests of each species studied twice a month per wetland throughout the breeding season, using a kayak. The Greater Flamingo was not included, as it breeds in Salt Lake islets (Sebkhas) and not in the wetlands studied. We minimized the impact of monitoring on habitat and species by using the same path throughout the study. We counted the number of active nests (nests containing at least one egg) and labelled them to avoid repeated counts.

We compare differences in waterbird abundance between sites, seasons, categories of human activity (urban vs rural) and regions (Litoral vs. Highlands) using the Kruskal-Wallis test and the Wilcoxon rank test. To avoid collinearity between physicochemical and bacteriological water parameters, we used Spearman correlations. Parameters with pairwise correlation coefficients > 0.7 were excluded from pairwise variables of lesser biological significance (supplementary material, Figure S1). After selecting parameters that were only weakly correlated (rho < 0.4), we retained seven parameters (fecal streptococcal abundance, $NO_3$, $NO_2$, $NH^{4+}$, MO and CE). We then performed principal components analysis (PCA) based on seven water physicochemical parameters and the abundance of five waterbirds in four wetlands to determine the overlap of waterbird composition and abundance between study sites. All analyses were performed using R 4.3.1. (www.r-project.com) and alpha = 0.05

# Chapter II: Results and discussion

# Chapter 1: Ecoethology of the Greater Flamingo *Phœnicopterus roseus*

## 1. Trends in Greater Flamingo numbers in the northern Sahara

Long considered a symbol and flagship species of the Mediterranean coastline, the Greater Flamingo *Phœnicopterus roseus* is a large wading bird belonging to the Phœnicopteridae family that feeds by filtering compounds from the water (Johnson & Cézilly 2007). It is an extremely gregarious aquatic bird that enjoys shallow waters where it is busy foraging in search of its favorite foods, which it filters with its beak: invertebrates, seeds, algae and a shrimp, *Artemia salina*, found in over-salted waters and containing carotene pigments that contribute to the pink color of its plumage (Johnson & Cézilly, 2007). The Greater flamingo is one of the few species to raise its chicks in nurseries, and breeds in colonies, forming metapopulations. This leads us to believe that there are two types: a breeding population and a wintering population in the wetlands on the southern shores of the Mediterranean basin, mainly in Algeria (Pradel *et al.*, 1997, Balkiz *et al.*, 2007b, 2010, Bensaci *et al.*, 2011, Boucheker 2012).

Regular monitoring of the overall numbers of this Phœnicopteridae at two sites: Chott Oum Raneb (Ouragla) and Lac El-Goléa (Ghardaia) during the 2021/2022 wintering season clearly shows the presence of the Greater Flamingo in all our surveys, with numbers varying between 725 and 7500 individuals for Chott Oum Raneb and between 212 and 1280 individuals for Lac El-Goléa (Fig. 1).

Thus, this wader has been recorded throughout the year in both wetlands, from the first week of September onwards, when numbers gradually increase until January, followed by a gradual decline until August, thus displaying a classic Gaussian evolution, expressed by the presence of a sedentary population in the region and massive arrivals of individuals and wintering populations that are often more substantial (Fig. 1). This shows once again that the two wetlands (Chott Oum Raneb and Chott El-Goléa) play a very important role in the wintering of this species. Despite its small surface area, Chott Oum Raneb is home to a significant number of birds compared with Chott El-Goléa. The first site, on the little-used N18 road, is rich in food and shallow (Fig. 2). It is fed by a network of wastewater discharged directly and without prior treatment from the entire city of Ouargla, an agglomeration in continuous expansion, and as a result, the water body exhibits a highly diversified avian presence approaching 49 species (personal observation), characterized mainly by the presence of the Marbled Teal *Marmaronetta angustirostris* and the Ruddy Shelduck *Tadorna ferruginea* (Photo 1).

In the north, the wetland is fed by wastewater from the Hassi El-Garra commune, providing several habitats that regularly host aquatic reptiles (*Natrix natrix* water snake),

amphibians, insects and native fish. This area is a habitat for numerous species of fish, crustaceans, birds, insects and reptiles. The mounds and dunes of the Erg Occidental are home to reptiles, mammals (*Gerbillus sp., Psammomis sp. and Canis sp.*) and insects. This area is also rich in helophytic vegetation, and is home to large numbers of birds, mainly Anatidae, Coots and numerous waders (Guergueb *et al.*, 2018). We have also observed the immersion of small islets lined with *Tamarix gallica*, *Typha angustifolia* and *Phragmites australis*. The islets, phragmites and tamarisk are the preferred nesting habitat of the avifauna. To the south, the lower basin, particularly in its southern upstream section, is sparsely vegetated (Photo 2), with only a few hardy phanerogam species, notably grasses. The shallow, open, saline water, free of vegetation, favors populations of Greater Flamingos with their characteristic gregarious behavior, as well as other species such as Ruddy Shelduck *Tadorna ferruginea* and Marbled Teal *Marmaronetta angustirostris*. In general, we observed a certain degree of stability in numbers throughout annual cycle (Fig. 1).

In terms of abundance, the Wilcoxon test revealed a highly significant difference ($p<0.05$) between the two bodies of water and between months ($p<0.05$) (Figs. 2 and 3). The highest numbers were recorded in the Lac El-Goléa wetland compared with the Chott Oum Raneb, mainly during the wintering season in January, February and March, demonstrating the role played by these two wetlands in maintaining populations of this wader.

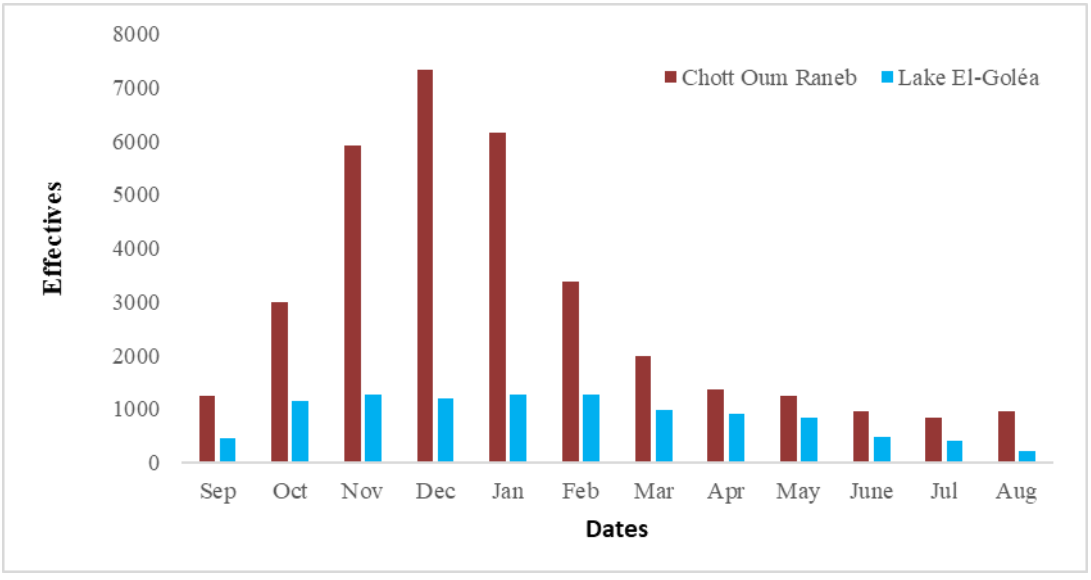



**Fig. 3: Population trends for the Greater Flamingo *Phœnicopterus roseus* (2021-2022).**

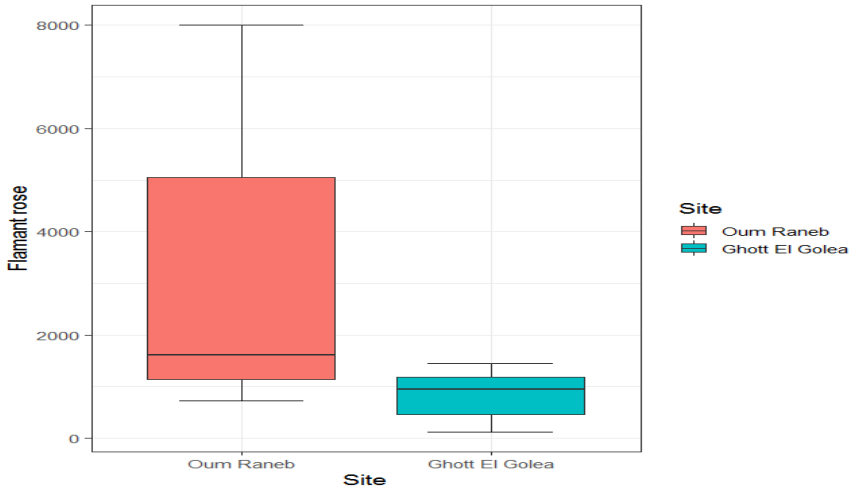



**Fig. 4. Box-plot: Average number of Greater Flamingos in the two wetlands**

**We used the following abreaviation: Greater flamingo= flamant rose**

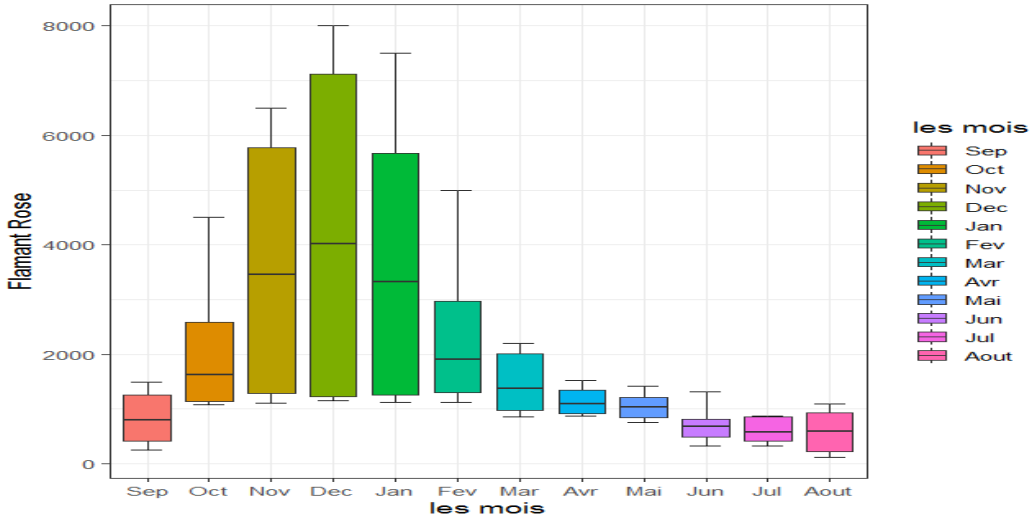



**Fig. 5. Evolution of Greater Flamingo numbers**

**We used the following abreaviations: Greater Flamingo= flamant rose, month= mois.**

## 2. Spatial occupation of the two wetlands by the Greater Flamingo

Due to their gregarious nature, Greater Flamingos often congregate in areas away from disturbance. At Lac El-Goléa, this wader occupies the center of the lake, especially in shallow areas. During the wintering season, we can observe two more or less distinct populations, of different compositions, located close together (Fig. 4). These water birds do not frequent the vegetation-rich southern region.

At the Chott Oum Raneb, early in the morning, Greater Flamingos spread out over the entire stretch of water, forming more or less distinct groups (Fig. 4). However, during the day, these waterbirds move closer to the road near the main sewer that feeds this Saharan wetland.

Alongside them, we can observe species characteristic of these ecosystems: Marbled Teal *Marmaronetta angustirostris*, Ruddy Shelduck *Tadorna ferruginea* and numerous Redshanks and Scolopacids.

At the two lakes, these flamingos rotate around in search of food, grazing the ground with their feet and filtering the water.

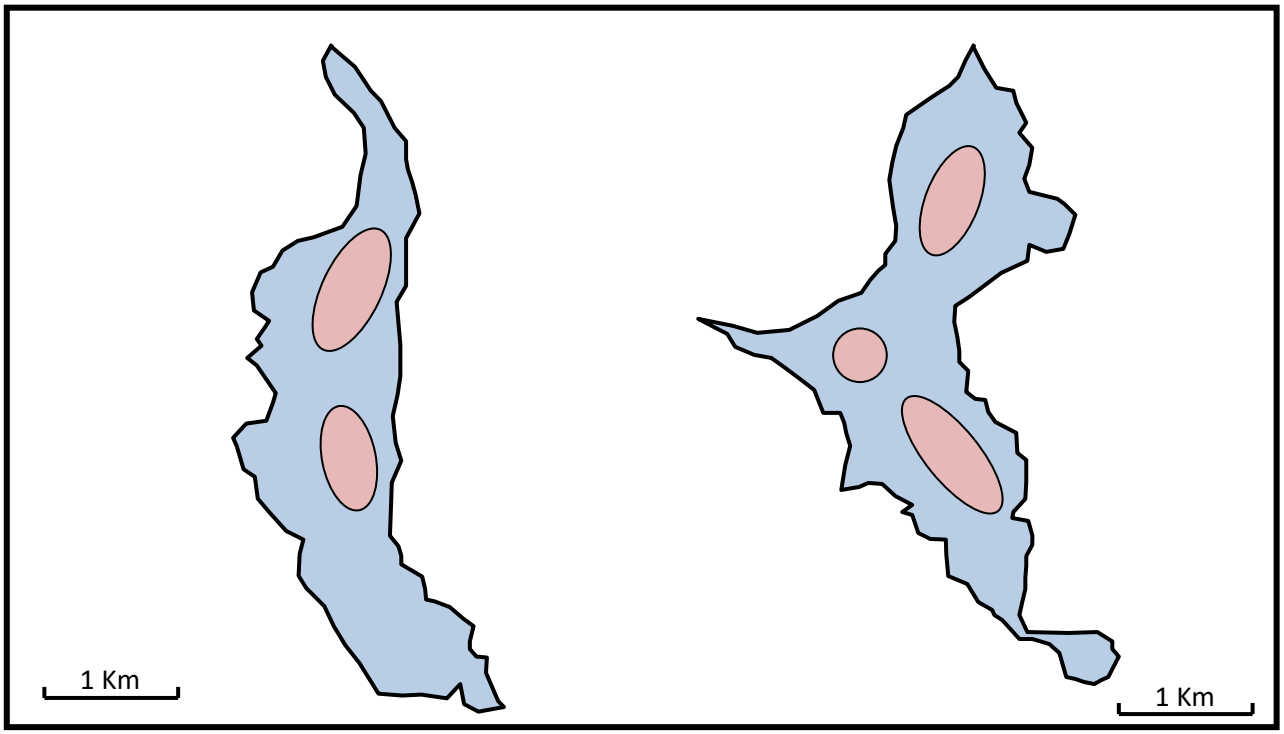



**Fig. 6. Spatio-temporal occupation of Lake El-Goléa and Chott Oum Raneb by Greater Flamingos *Phœnicopterus roseus***

**Photo 1: General view of Chott Oum Raneb, Ouargla (Taken by Ines Houhamdi on December 30, 2021)**

**Photo 2. General view of Chott Oum Raneb, Ouargla (Taken by Ines Houhamdi on March 07, 2023)**

### 3. Follow-up on daytime activity patterns

Regular monitoring of the diurnal activities rhythms of the Greater Flamingo during the 2021/2022 cycle (115 hours of observations at each site) has enabled us to conclude that feeding is the main activity in the total balances at both wetlands. Feeding is recorded with a percentage of 73% at Chott Oum Raneb and 74% at Lac El-Goléa, i.e. it accounts for three quarters of diurnal balances for this wader (Fig. 5). It is often followed by marching with

17%, grooming and plumage maintenance with 5%, courtship and sleep with equal rates of 2% and finally flight with 1% (Fig.4). At Chott Oum Raneb and Lac El-Goléa, it is followed by flying with 11%, walking with 8%, courtship with 4% and grooming with 3% (Fig.5). Sleep was not observed at this site.

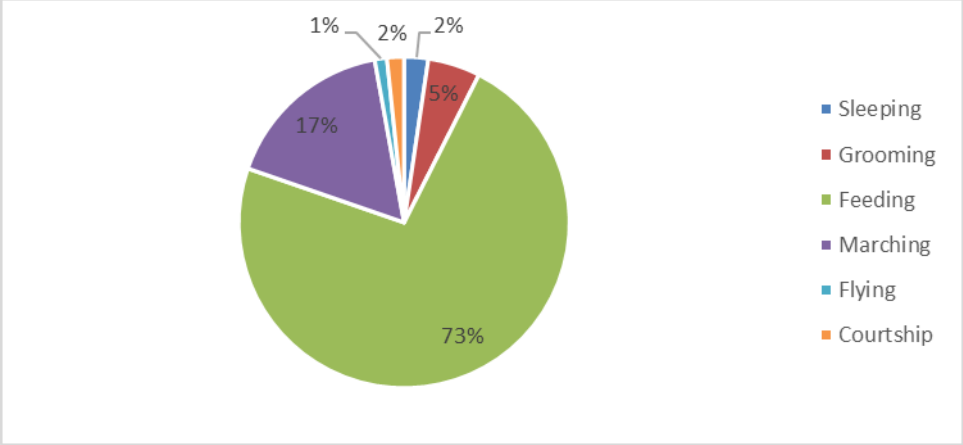



**Fig. 7: assessment of diurnal activities rhythms at Chott Oum Raneb.**

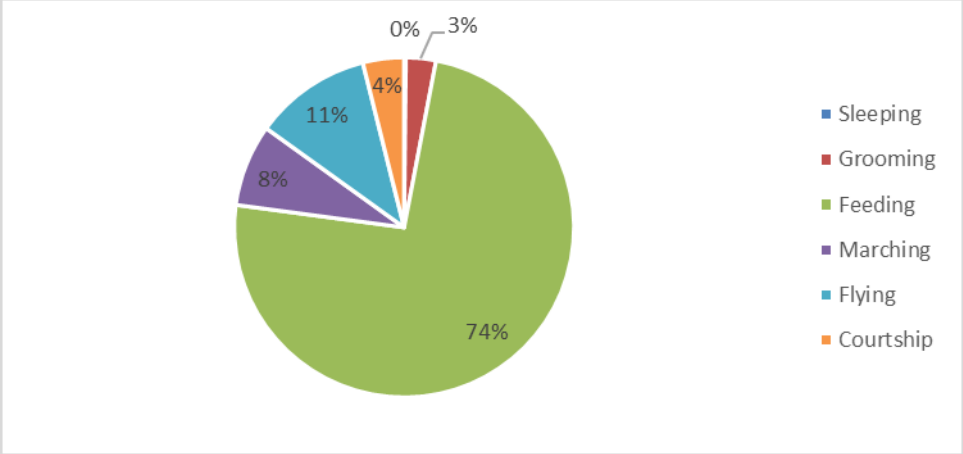



**Fig.8: assessment of diurnal activities rhythms at Lake El-Goléa.**

**4. Evolution of daytime activities over the annual cycle**

Monitoring the diurnal time budget of the Greater Flamingo *Phœnicopterus roseus* during our study year shows that the bird spends more than half the day feeding. This activity is particularly noticeable at the start of the study, with the massive arrival of flamingos in the Algerian Sahara. The latter engage in this activity to recover the energy used during their migrations and/or displacements (Fig. 5). As a result, these two bodies of water, like most Algerian wetlands, act as feeding grounds for this wader, considered a flagship species of our continental aquatic ecosystems (Samraoui *et al.*, 2006, Saheb *et al.*, 2006, Ouldjaoui 2010, Mesbah *et al.*, 2014).

It should be noted that positive correlations were noted between these measured diurnal activities, where feeding is often associated with walking ad grooming activities (Fig. 8).


**Fig. 9. Correlation between the different activities of the Greater Flamingo**

### 4.1 Chott Oum Raneb

At Chott Oum Raneb, rates for the main activity (feeding) fluctuate up and down, with peaks often recorded during flamingo arrivals and transits at this site (Figs. 9 and 10). The maximum rate was recorded at the start of the study.

Walking comes second. It is often associated with feeding activity, foraging and filtering water compounds, or is due human disturbance (hunting). Its evolution also exhibits variations often noted during the months of October, November and December (Figs. 9 and 10).

Plumage maintenance and grooming plays a minimal role in this assessment. It is often observed at the start of the day when the birds are beginning to feed (Figs. 9 and 10).

Sleeping and courtship play an equal part in this assessment. Birds sleeping on one foot and with their heads resting on their backs was particularly noticeable in the early winter months, when they often need time to recover.

Courtship is only observed from December to July (Figs. 9 and 10). It is only observed in the water and in small groups of foraging birds.

Flying behavior was almost non-existent during all our surveys. It generally corresponds to four needs for the bird: - movement between two diurnal discounts - systematic movement

between resting and feeding sites - movement as part of a courtship display - flight reaction to a potential predator (Tamisier and Dehorter, 1999, Ouldjaoui, 2010) (Figs. 9 and 10).

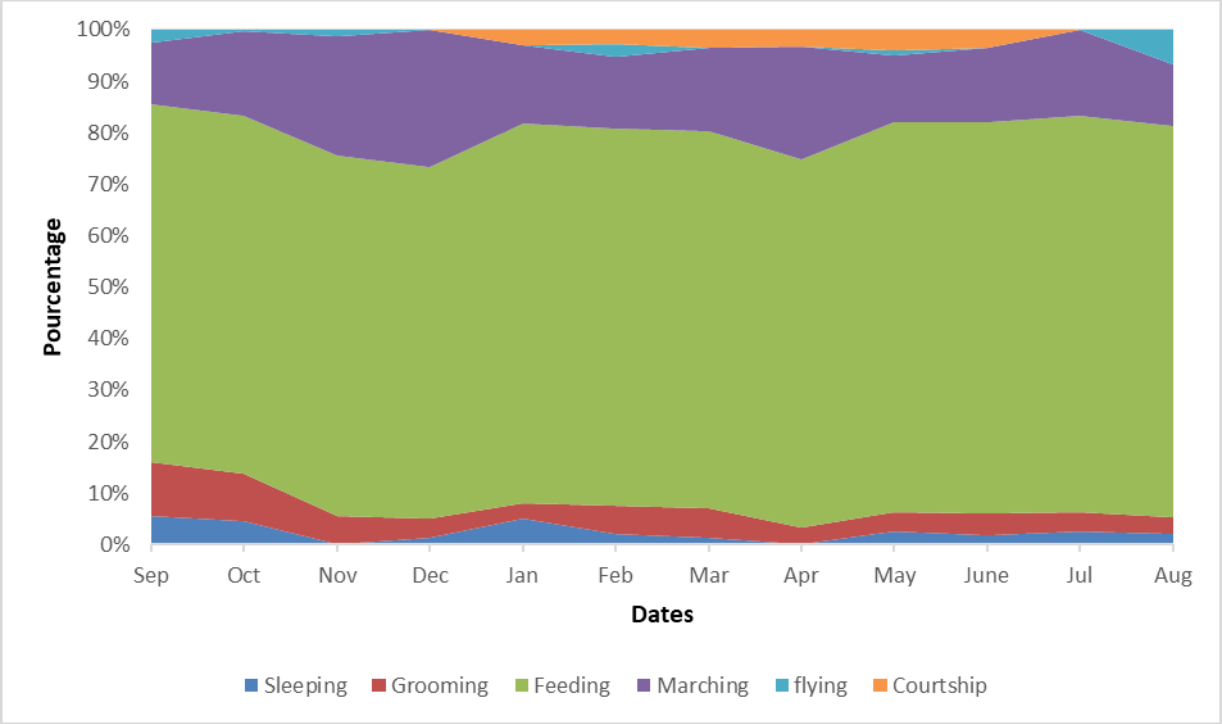



**Fig. 10. Diurnal activity of the Greater Flamingo in the Chott Oum Raneb.**

### 4.1. Lac El-Goléa

The diurnal activity patterns of this wader in Lac El-Goléa show a variation more or less similar to that observed in Chott Oum Raneb. In fact, feeding is the main activity recorded during the day. Its pattern shows a slow evolution throughout the annual cycle, demonstrating again the primacy of this site as a preferential feeding ground for the Greater Flamingo *Phœnicopterus roseus* and many other avian species. The maximum was recorded in December, generally the coldest month of the year (Fig. 9). The lowest feeding rate during the entire study period was recorded in September 2021. It should be noted that the region experienced a heat wave during this month.

Flying, which is generally caused by disturbance, whether by humans or predators, took the second largest share of the total (Fig. 9). It was recorded with more or less stable rates throughout the study period (Fig. 9).

Marching comes third. This diurnal behavior is triggered by the search for food, distance from sources of noise pollution or, above all, to enable birds to gather after landing. This activity is essential in our wetlands (Fig. 9).

Courtship appears, as the figures show, from January onwards, with a low rate that gradually increases to reach peaks in March and April, and lasts until the end of the study, in August (Fig.9).

Grooming, both in the water and on the lake shore, was observed throughout most of the study period. This activity, observed mainly at the start of the day before the flamingos feed, often occurs at low but more or less stable rates (Fig. 9).

Daytime sleep was only recorded during the first months of the study, from late September to late December (Fig. 9). They are often observed in the water.

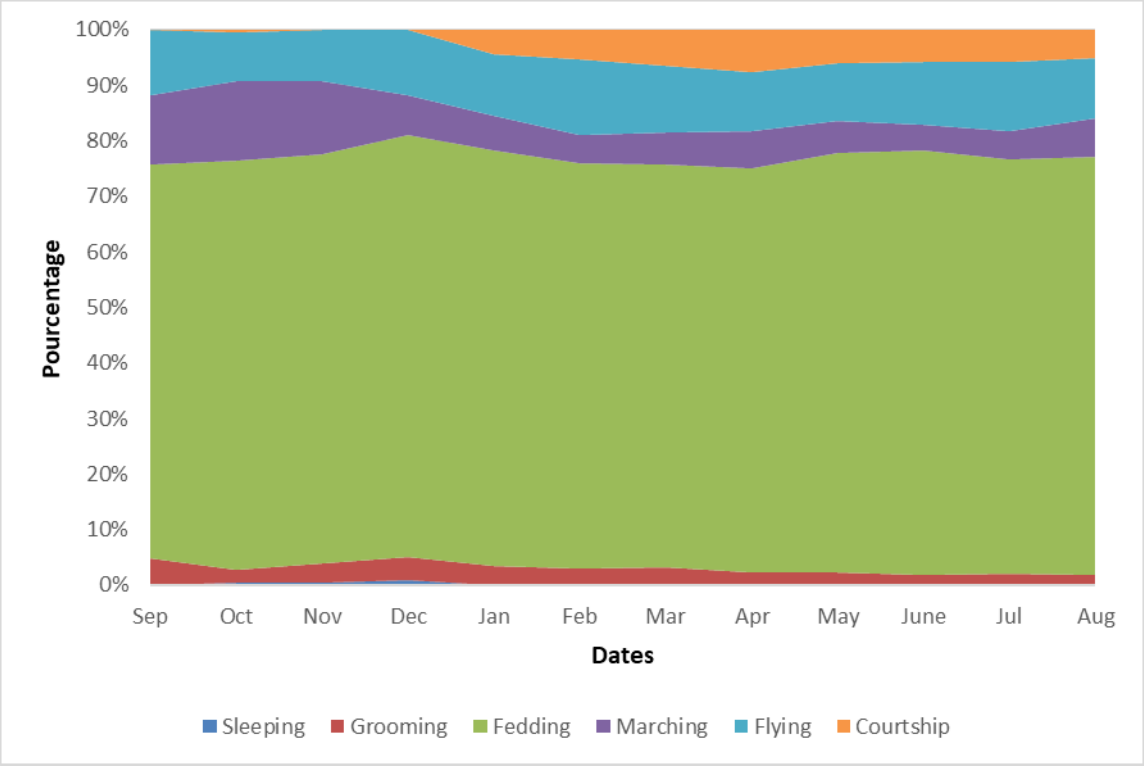



**Fig. 11. Diurnal activity of the Greater Flamingo in Lac El-Goléa**

## 5. Multivariate statistical processing

### 5.1. Chott Oum Raneb

The multivariate analysis of these data, collected over an entire annual cycle by CFA (48 records x 06 activities) and displayed on the 1x2 factorial plane, which accounts for 44% and 27% respectively; i.e. 73% of the inertia (Fig. 11), shows us that, given the high proportion of the food activity, which accounts for over three-quarters of the total balance, it is positioned at the center of the graph. Thus, the ordinate factor, which holds 44% of the information, separates the other four activities measured from the activity of flying, which, given the small proportion allocated to this activity, is located alone to the left of this factor. Flight is thus a minimal activity for the Greater Flamingo. We also observe that factor 2 (27%

of inertia) separates the activities of sleeping and grooming from those of walking and parading (Fig. 11).

From another angle, this graph shows us a true temporal distribution of the six activities over the course of the annual cycle (Fig. 11). Thus, at the beginning of the study and during the month of September, the flamingos are feeding (in the center of the graph) and we observe the flight activity characteristic of this period. Then, as we move forward in time, we record the sleep and plumage maintenance activities observed mainly during the months of October through December. Then, from January to April, we can observe courtship and walking activity, which is often associated with feeding, indicating preparation for an imminent pre-breeding migration.

### 5.2. Lac El-Goléa

This multivariate statistical treatment of the diurnal time budget data of Lac El-Goléa's Greater Flamingos, using the CFA method, this time gathering 78% of the inertia (2021/2022), reveals more or less the same results. Feeding, the main activity, is positioned at the center of the graph (Fig. 12). Y-axis factor 1 (54%) contrasts the activities of courtship and flight, which are often associated and observed mainly during the period from January to August, with the other activities: walking and grooming, and sleep. Factor 2 (24%) contrasts the activities of walking and grooming, often associated with sleep. The latter characterizes late November and the whole of December, while sleep and feather maintenance are often noted in the period from September to November (Fig. 12).

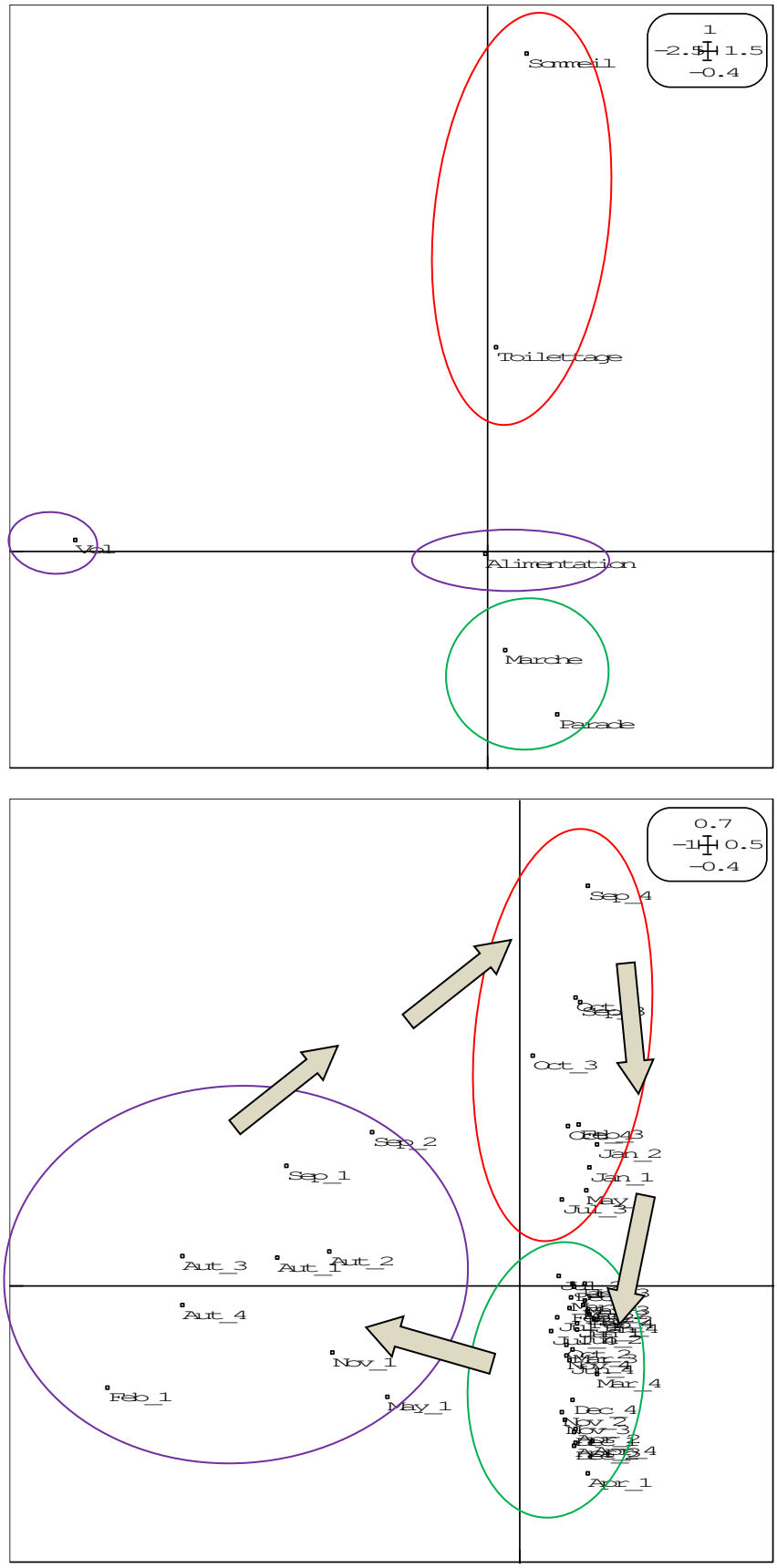



**Fig. 12. Biplot Correspondence Analysis (Rhythms of diurnal activities of the Greater Flamingo *Phœnicopterus roseus* in the Chott Oum Raneb (September 2021/August 2022). Axes of inertia: 0.44, 0.25, 0.17 & 0.09**

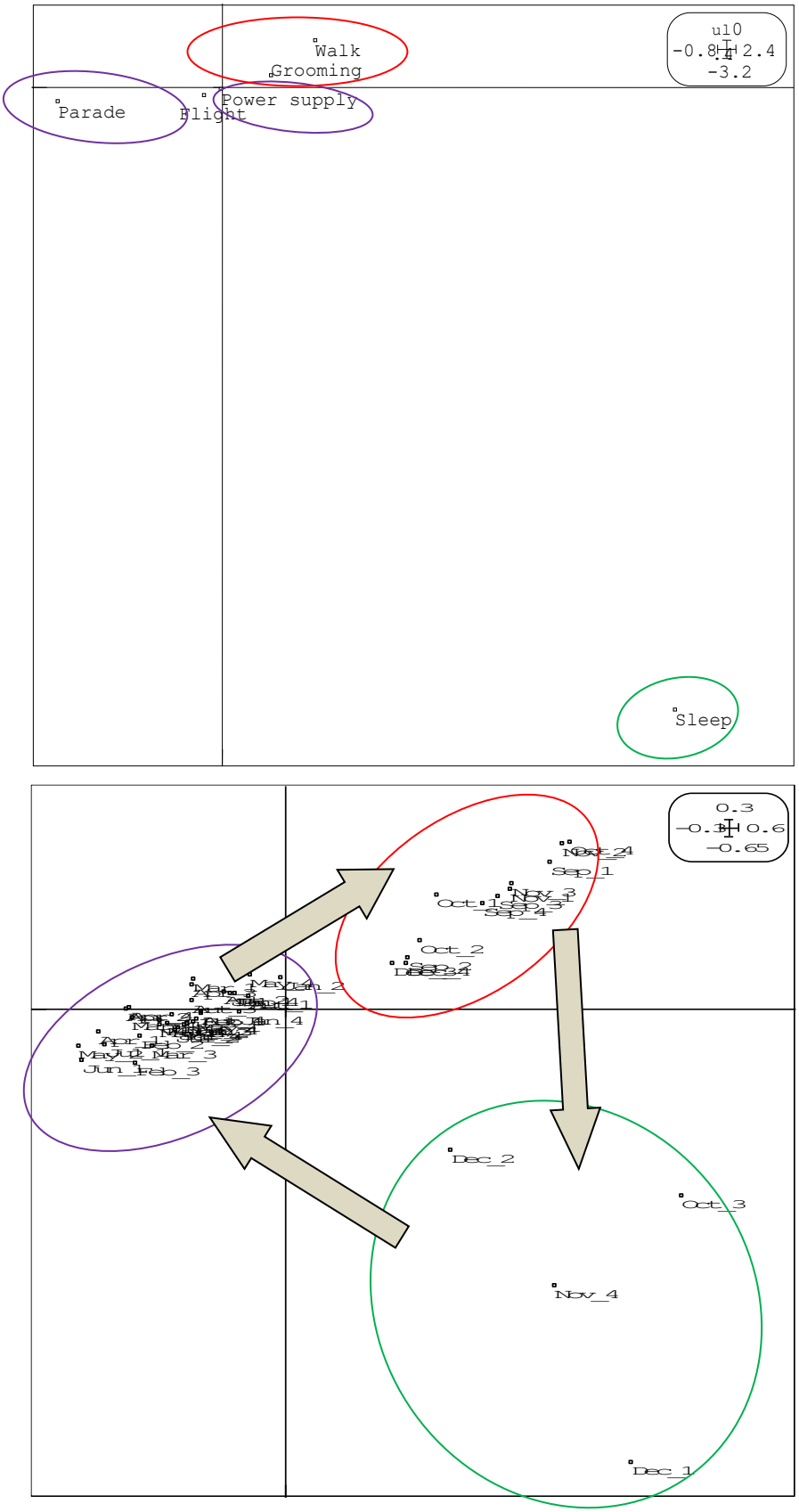
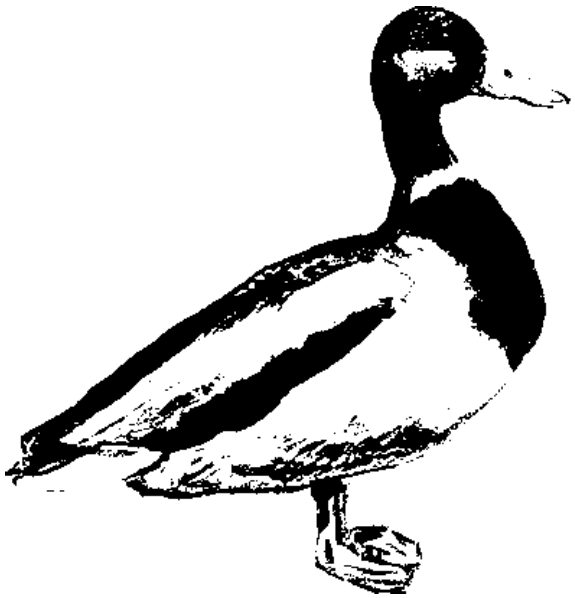



**Fig. 13. 1x2 factorial design of the Correspondence Analysis (Rhythms of diurnal activities of the Greater Flamingo *Phœnicopterus roseus* in Lac El-Goléa (September 2021/ August 2022). Axes of inertia:0.54, 0.24, 0.09 & 0.06.**

# Chapter 2: Ecoethology of the Mallard Duck *Anas platyrhynchos*



## 1. Mallard population trends in Lake Tonga

Surface ducks are so called because they essentially frequent shallow waters, mud and palustrine plant formations, as is the case with the Mallard *Anas platyrhynchos*, a very common breeder widely distributed in the Western Palearctic (Yesou *et al.*, 1983, Houhamdi, 1998, 2002, Dubois *et al.*, 2008). It frequents all types of wetlands: streams, marshes, ponds (Dziri 2014, Dziri *et al.*, 2014, Labbaci 2017).

They are often the only waterfowl we come into contact with from childhood, and for this reason are catalogued as "common ducks". With its metallic green head, white collar and black tail feathers, this bird is one of our country's most beautiful waterfowl, as are the more subtle, black-striped brown females. Both feature blue mirrors with white edges on the wings (Dziri 2014).

During our study period, which ran from 2020 to 2023, i.e. three consecutive years of observation 2020/2021, 2021/2022 and 2022/2023 at Lake Tonga, In the first year, maximum numbers were recorded in December (1,354 individuals) and minimum numbers in June (77 individuals), followed by a total absence over the three years of observation in July and August, due to the lake's drought conditions (Fig. 13). The second year, 2021/2022, was the most fruitful, with a maximum of 2,306 individuals observed in December and a minimum of 13 in June. The third year, 2022/2023, saw a maximum of 1979 individuals in November and a minimum of 16 in June (Fig. 13).

The peaks are probably due to migratory individuals wintering in other wetlands and using this wintering area as resting sites (Houhamdi 2002). From January to June, the lowest numbers are due to the cumulative effects of migration, hunting mortality and the dispersal of birds to Algerian breeding grounds, leaving only the breeding population.

Contrary to popular belief, the peak of winter numbers is not always in January (Deceuninck & Fouque 2010). Monthly counts provide an insight into the phenology of wintering, and indicate that January is not always the time of year when duck numbers are highest. They highlight the fact that certain sites, which do not host numbers of international importance in January (Ramsar criteria), may well exceed these thresholds in December or February, and merit appropriate protection or management measures. The December and February counts therefore complete the list of sites to be considered of international importance for ducks in winter (Deceuninck & Fouque, 2010).

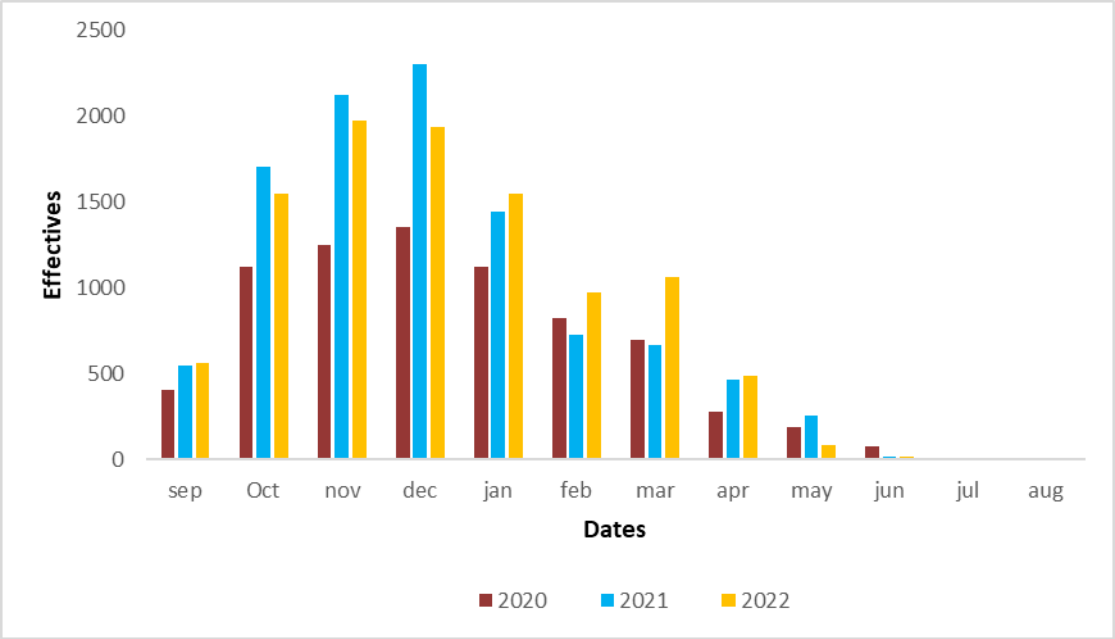



**Fig.14. Changes in Mallard numbers during the 2020/2021, 2021/2022 and 2022/2023 wintering seasons at Lake Tonga.**

In terms of abundance, the Wilcoxon test revealed a highly significant difference ($p<0.05$) between the three years and between the months with $p<0.05$ (Figs. 14 and 15). In this lake of international importance, the highest numbers were recorded during the wintering season, mainly in the months of October, November, December and January, confirming once again the role that this ecosystem plays in maintaining Mallards and all avian biodiversity.

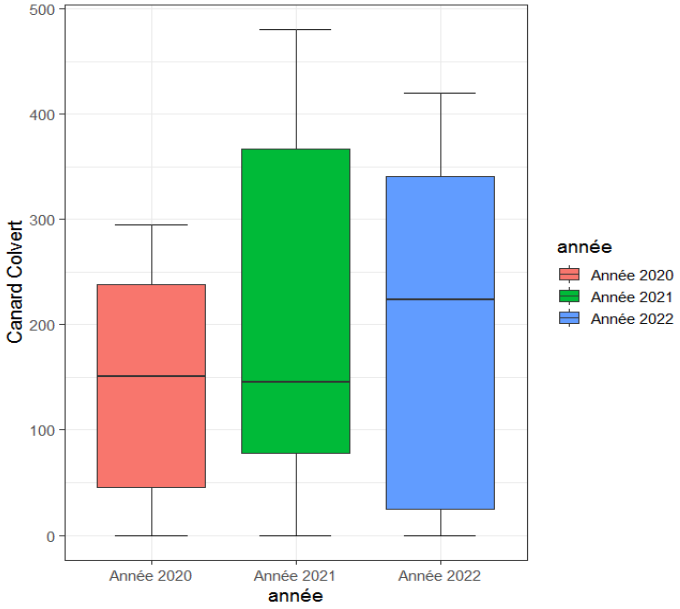



**Fig. 15. Box plots: Average number of Mallard Duck 2020, 2021 et 2022**

**We used following abreaviations: Mallard duck= canard colvert, year= année.**

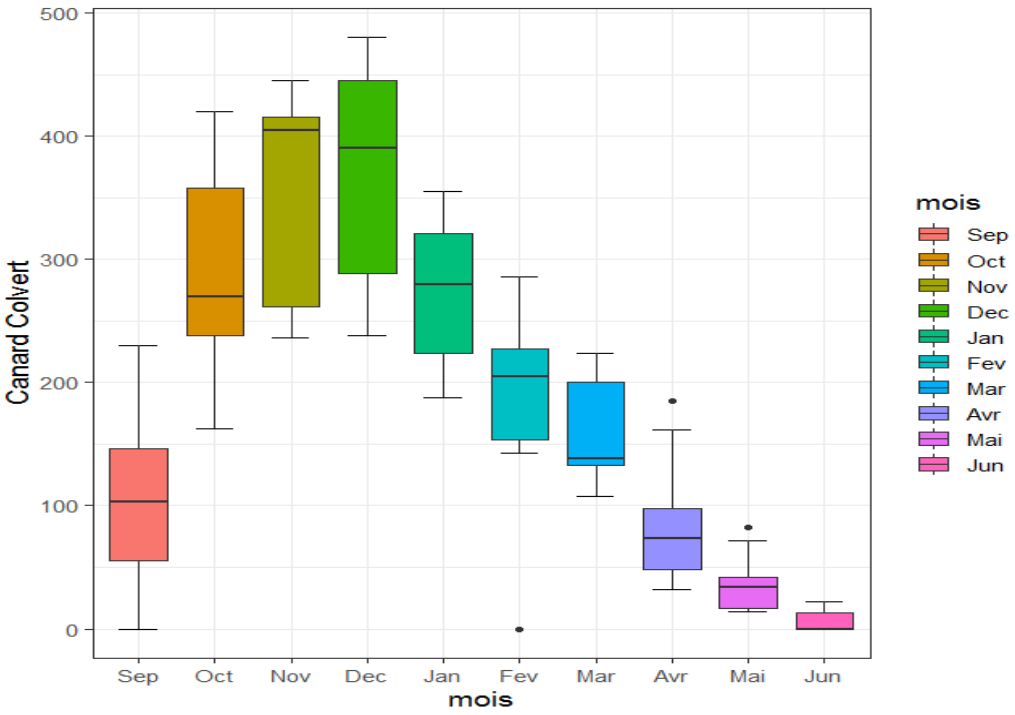



**Fig. 16. Evolution of Mallards Duck numbers**

**We used the following abreaviations: Mallard duck= canard colvert, month= mois.**

## 2. Spatial occupation of Lake Tonga by Mallards

Mallards have been recorded in virtually all areas of Lake Tonga (Fig. 16), where they are distributed in small groups from September to December. In most cases, we then observed pairs crisscrossingthe entire lake. However, they prefer areas rich in helophytes, mainly clumps *of Phragmites australis*, *Scirpus maritimus* and *Typha angustifolia* in the northern and central parts of the lake (Fig. 16).

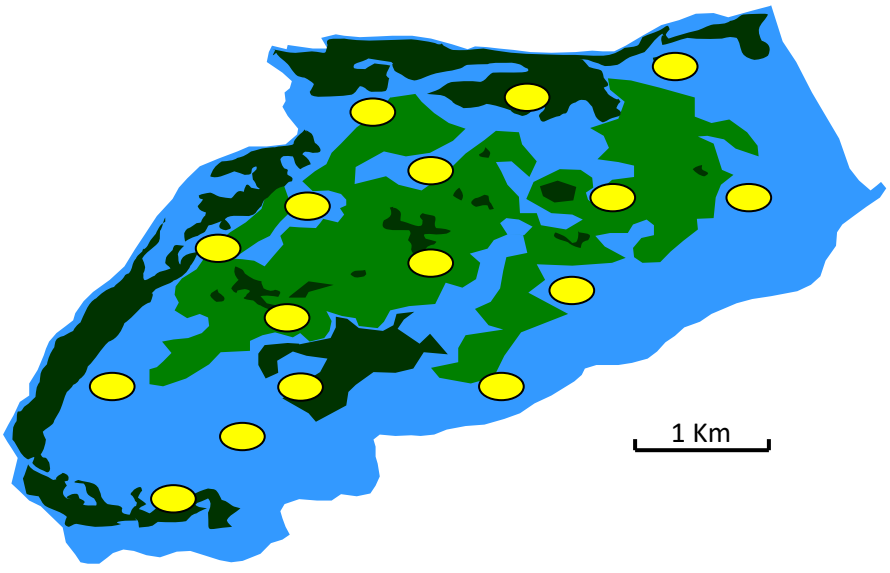



**Fig. 17. Spatial and temporal occupation of Lake Tonga by Mallards *Anas platyrhynchos***

**Photo 3. General view of Lake Tonga (Taken by Ines Houhamdi on March 2022)**

### 3. Study to assess the diurnal activity rhythm of the Mallard duck

Monitoring of the diurnal activities rhythms of Mallards in Lake Tonga during the three years of the study (2020/2021, 2021/2022 and 2022/2023) showed that feeding was the main activity of this species, with a percentage approaching 41% during the last two years of monitoring and 40% during the first year (Fig. 17). This is followed by sleeping and swimming activity, with more or less similar rates for the 2020/2021 and 2022/2023 seasons (27% and 25%) and a rate of 27% sleeping and 23% swimming for the 2021/2022 season (Fig. 18). Plumage maintenance and grooming account for 7% in the 2020/2021 season, 9% in the 2021/2022 season and 8% in the 2022/2023 season (Fig. 19). Finally, flying activity is rarely observed. It plays a minimal role in this diurnal assessment. From this, we can deduce that Lake Tonga acts as a diurnal feeding ground for mallard duck*Anas platyrhynchos.*

Our results corroborate those observed in Lac des Oiseaux (Houhamdi 2002) and in the Guerbes-Sanhadja wetlands (Dziri 2014, Dziri *et al.*, 2014) and differ from those obtained by Meziane (2015) at the Boussedra urban marsh (Annaba), who cited sleep with 46% as the activity that dominated the balance of diurnal time budgets during the 2011/2012 wintering season. This was followed by swimming (22%), feeding (12%), flying (8%), resting and grooming (6% each).

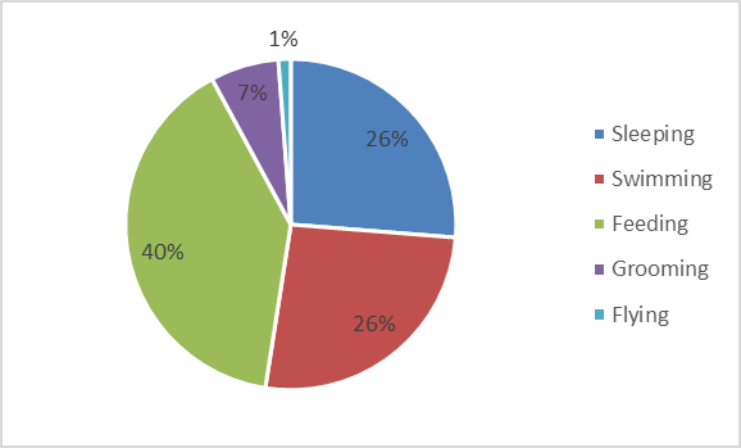



**Fig. 18. Overview of diurnal activities rhythms of the Mallard Duck (Year 2020/2021).**

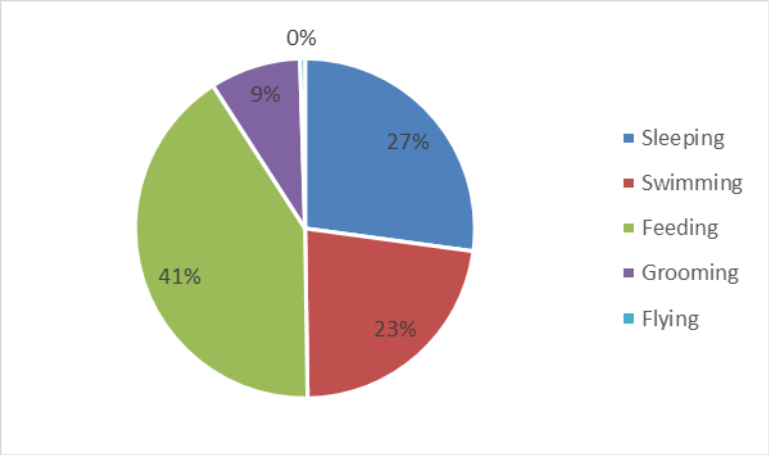



**Fig.19. Summary of diurnal activities rhythms of the Mallard Duck (Year 2021/2022).**

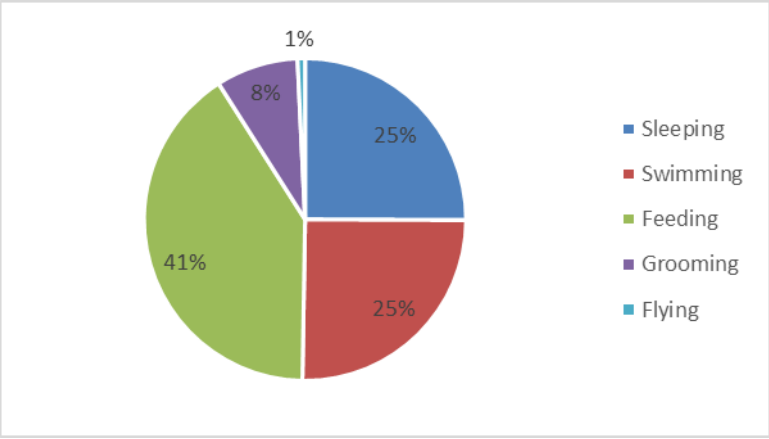



**Fig.20. Overview of diurnal activities rhythms of the Mallard Duck (Year 2022/2023).**

**4. Evolution of diurnal activities over the annual cycle**

A study of the temporal variation in the various activities of the Mallard duck during the 2021/2022 season shows that the waterfowl spends half the day feeding. This was true throughout the study period, with the percentage recorded exceeding 40%. This activity is

mainly observed from November onwards. Mallards occupying Lake Tonga are less active during September and October, when they are much more occupied with feather maintenance and swimming (Fig. 20). These early occupants of the site are obliged to maintain their damaged plumage following post-nuptial migration. Swimming is often observed in birds seeking to group together. The heat wave and the regular passage of boats, or disturbance by hunters and poachers, also play a part.

During the other two seasons, 2020/2021 and 2022/2023, the same pattern of temporal evolution is observed as in 2021/2022, and the Mallard spends more than half its time feeding. (Fig. 23). As a result, the diurnal activities observed in Mallard's frequenting Lake Tonga evolve in much the same way. We observed very high feeding rates throughout the study period, except in very specific cases, often due to extrinsic environmental factors (disturbance, hunting, poaching, heat waves… etc.).

Sleep ranks second in this assessment of the activity rhythms of this species, with an annual average fluctuating between 25.1% and 27.2%. The highest rates were recorded in April (29.5%), May (29.2%) and September (30.1%) for the years 2020/2021, 2021/2022 and 2022/2023 respectively (Fig. 24).

Swimming is the activity that remains more or less stable throughout the study period and for all three years of monitoring, with annual averages of 26.2%, 22.6% and 25.2% in years 2020/2021, 2021/2022 and 2022/2023 respectively. The highest values were recorded in September (30% and 28.2%) and October (29.4%) for years 2020/2021, 2021/2022 and 2022/2023 respectively (Fig. 25).

Grooming, which takes fourth place in this assessment with annual averages varying between 6.7% and 8.66%, is an activity observed during all our outings. It changes little and is recorded mainly among the lake's first occupants (Fig. 26).

Flying is an induced activity, often provoked by grazing animals or people passing through. It accounts for a very small proportion of the total. It varies between 1.21%, 0.47% and 0.75% for the three years of monitoring (Fig. 27).

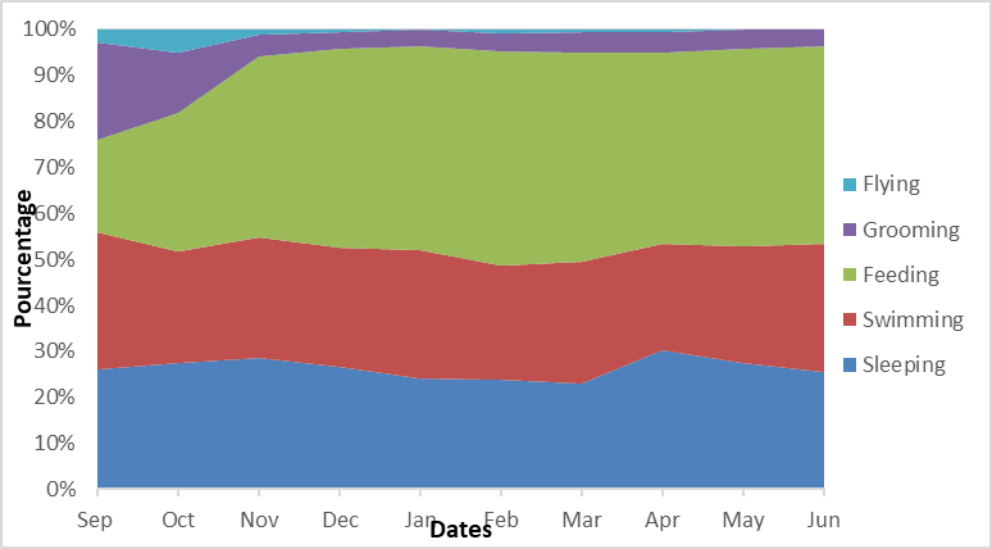



**Fig. 21. Total diurnal activities for the year 2020/2021**

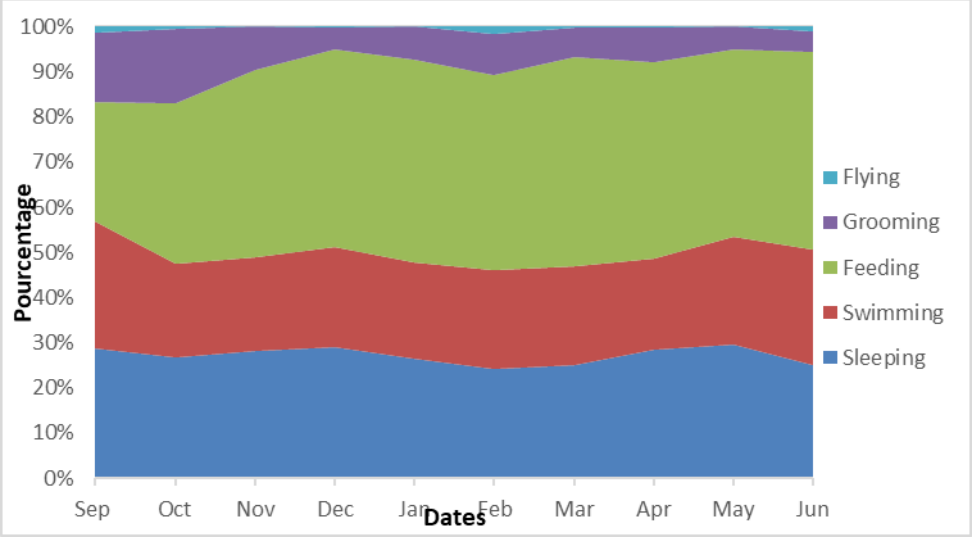



**Fig. 22. Total diurnal activities for the year 2021/2022**

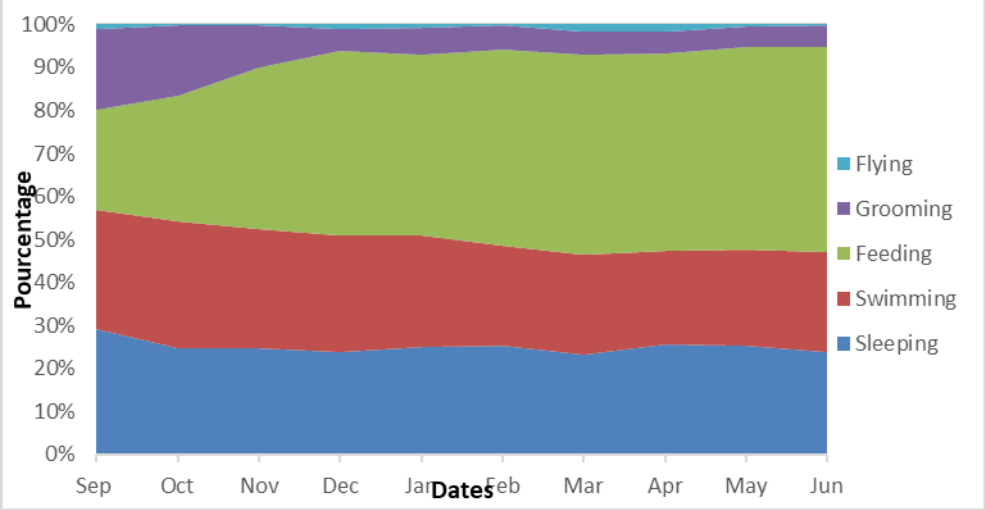


**Fig. 23. Total diurnal activities for the year 2022/2023.**

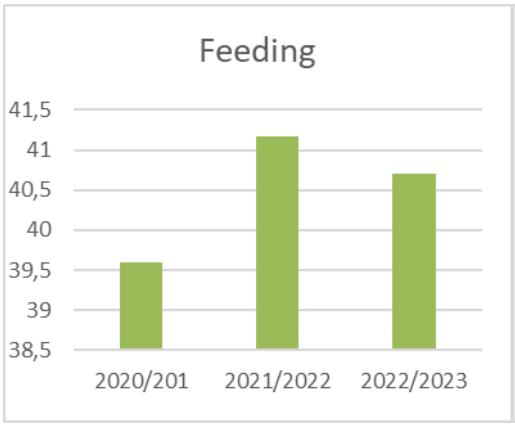



**Fig. 24. Annual feeding trends.**

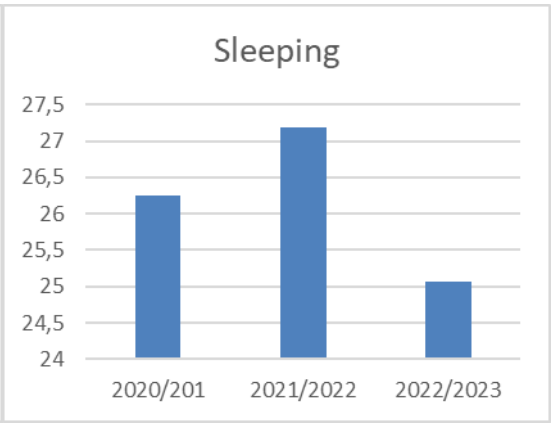



**Fig. 25. Annual sleeping trends.**

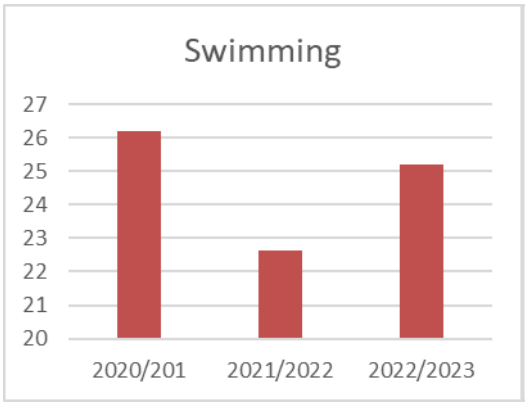



**Fig. 26. Annual swimming trends.**

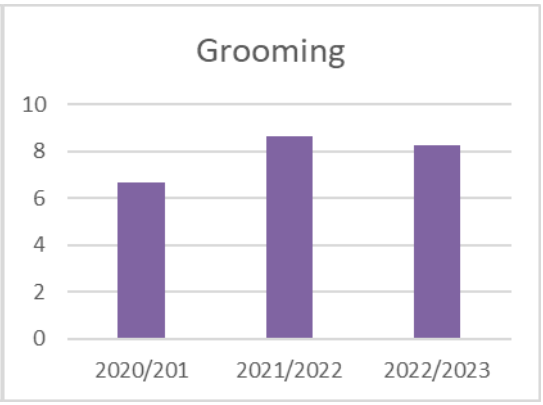



**Fig. 27. Annual grooming trends.**

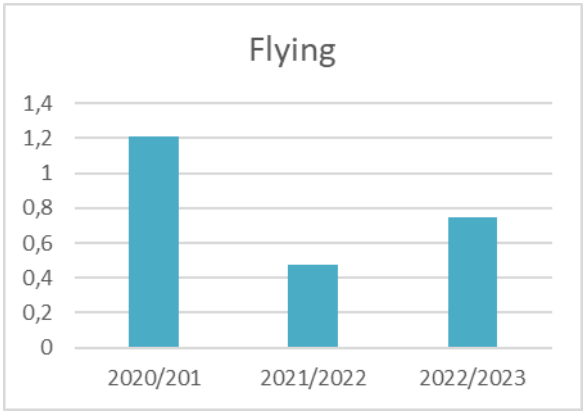



**Fig. 28. Annual flying trends.**

## 5. Multivariate statistical processing

The multivariate analysis carried out on the diurnal activities rhythms of Mallard ducks visiting Lake Tonga during the three monitoring periods, using FCA (Correspondence Factorial Analysis) and expressed on the 1x2 factorial plane (Fig. 28), which gathers the maximum inertia (87%), shows us that the ordinate axis (74% of inertia) separates the start of

wintering (September and October) from the other months of the year, and exposes structured information in the form of a temporal evolution of the five activities measured in Lake Tonga by groups of Mallards. The abscissa factor 2 (14%) separates the months of September and October. In fact, three periods stand out

- ✓ At the start of the study, in September, the first Mallards *Anas platyrhynchos* occupying Lake Tonga showed very intense swimming activity, especially early in the morning. Indeed, these birds seek to gather and form groups in the water, verifying the data in the scientific literature (Street 1975, Owen & Black 1990, Prevost *et al.* 1978, Titman 1982, Jorde *et al.* 1983, Dzus & Clark 1997, Guillemain *et al.*, 1999).
- ✓ The second period characterizes the month of October, when the birds give themselves over to plumage maintenance and flying. In fact, after occupying the water for a month, the Mallards are intensively maintaining their plumage and replacing damaged feathers following an often-lengthypost-nuptial migration. Flights are often very short. They allow the birds to regroup and form small groups, often swimming together (Street 1975, Titman 1982, Jorde *et al.*, 1983).
- ✓ Finally, the third period covers the remaining months (November to June), when we observe the two most important activities of wintering and breeding Mallards in Lake Tonga: feeding and sleeping (Titman 1982, Baldassare *et al.*, 1988, Losito *et al.*, 1989, Tamissier et Dehorter 1999, Houhamdi 2002). Diurnal feeding and. This activity is intense during this period, showing that the site acts as a feeding ground for this Anatidae species.

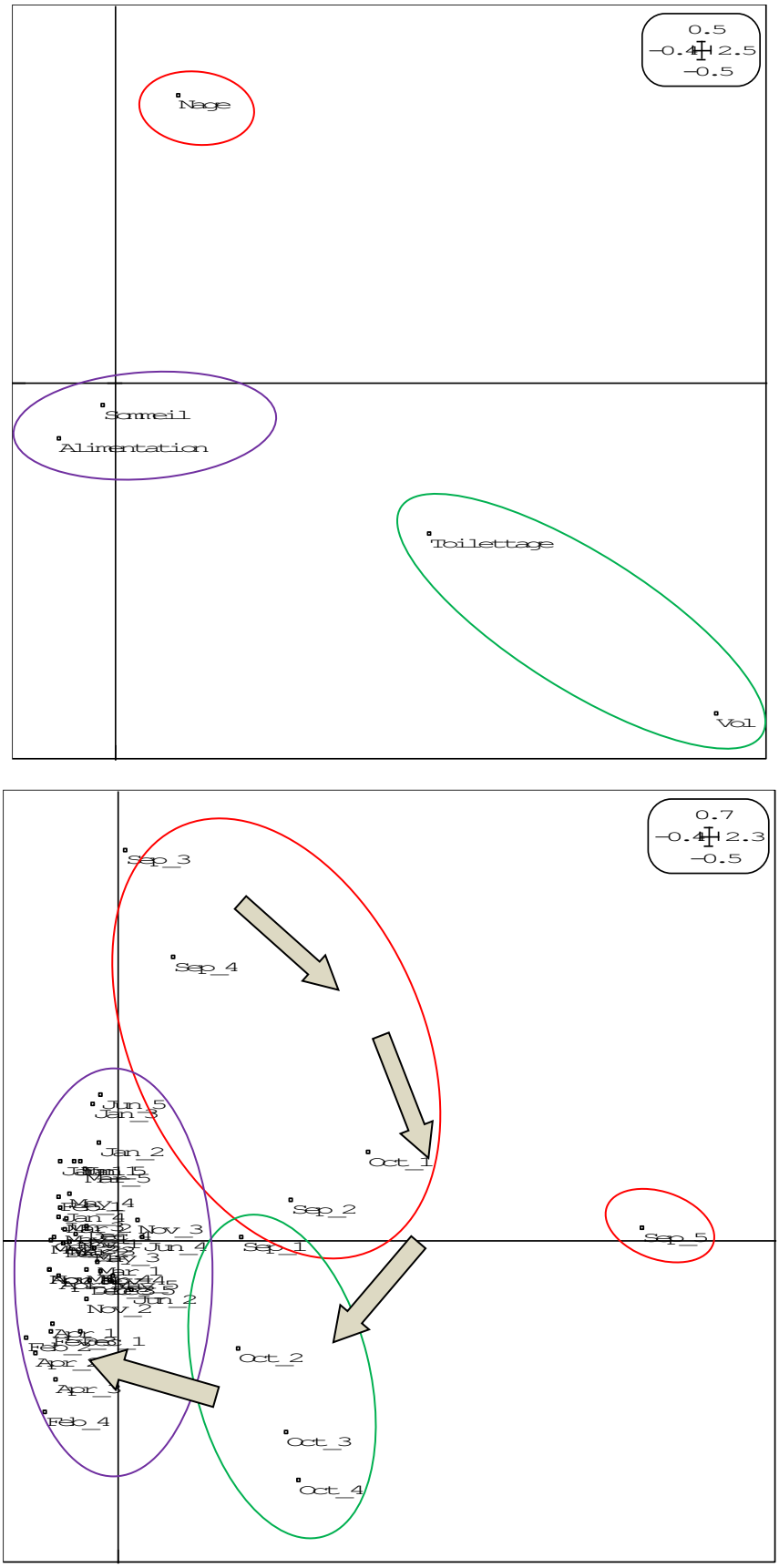
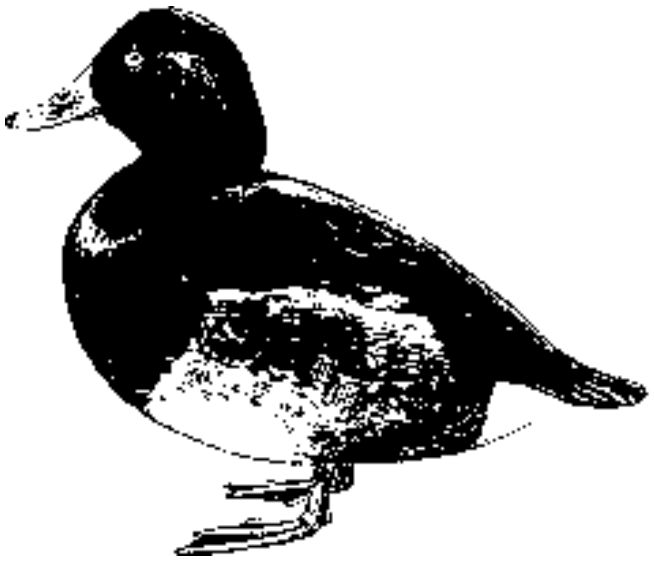



**Fig. 29. 1x2 factorial design of Correspondence Analysis (Rhythms of diurnalactivitiesof Mallard duck *Anas plathyrhynchos* in Lake Tonga (2020/2023). Axes of inertia: 0.73, 0.14, 0.07 & 0.04**

# Chapter 3: Eco ethologyof the Ferruginous Duck *Aythya nyroca*



**1. Ferruginous Duck population trends**

A member of the Anatidae family, the Ferruginous Duck *Aythya nyroca* is a small diving duck that frequently inhabits freshwater plains and marshes with abundant paludal vegetation and aquatic plants, which play an important role in its diet (Boumezbeur 1993, Houhamdi & Samraoui 2008). Compared with other duck species, the Ferruginous Duck is a late breeder. Pairs are not formed until January, and the male begins courtship in March (Aissaoui *et al.,* 2009, 2011). Nests can be built on floating vegetation or well-covered banks with immediate access to water (Lazli *et al.,* 2012).

Population monitoring of the Ferruginous Duck *Aythya nyroca* over two consecutive years in Lac des Oiseaux, Mékhada marsh, Lake Tonga, Lake Fezzara and Garaet Hadj-Tahar reveal its regular presence in most of our surveys, with populations arriving from September onwards in numbers ranging from 63 to 225 individuals at the five sites during the 2021/2022 observation year, and from 88 to 246 individuals at the same sites during the 2022/2023 observation year. From September 2021 to August 2022, monthly trends in numbers showed that the greatest number of individuals arrived between October and February. Peak abundance was generally in December, with 380 individuals at Lac des Oiseaux (LDO), 720 at Mékhada marsh, 650 at Lake Tonga, 760 at Lake Fezzara and 730 at Garaet Hadj Tahar (GHT). The same was true for 2022/2023, with peaks in December of 410 individuals at Lac des Oiseaux, 690 at Mékhada marsh, 560 at Lake Tonga, 750 at Lake Fezzara and 790 at Garaet Hadj-Tahar. These values only reflect the passage populations that use the sites of northeastern Algeria as shedding and feeding grounds during their obligatory stopover (Houhamdi 1998, Tamisier & Dehorter 1999, Houhamdi & Samraoui 2008, Lazli *et al.*, 2012, Bara 2014).

Additional unobserved populations may exist in the wetlands of the Mekhada marsh, Lake Tonga and Lake Fezzara. This is due not only to the impressive size of the sites, but also to the danger and difficulty of access. Vegetation is also important, as the Ferruginous Duck is a diving duck that prefers areas away from disturbance and human activity (Boumezbeur 1993, Lazli *et al.,* 2012).

The evolution of the total number of Ferruginous Duck individuals wintering in the wetlands of the El-Kala eco-complex (north-east Algeria), during the wintering season from September 2002 to March 2009, shows that average winter numbers fluctuate between 1,500 and 3,500 individuals, with a maximum of 3,642 birds recorded in January 2008 (Fig. 29) (Aissaoui *et al.,* 2011). Monitoring of the species' numbers in the field (between 2006 and 2008) at Lake Tonga has shown that these birds are generally observed throughout the year.

However, low or even near-absent numbers were recorded during occasional winter visits (Lazli *et al.,* 2012). These water birds had probably left the region to winter in the wetlands of the Sahel (Isenmann & Moali, 2000). It was only from mid-March onwards that significant numbers were observed, albeit fluctuating from year to year (Lazli *et al.,* 2012).

According to work carried out in the Guerbes-Sanhadja region of eastern Algeria, the Ferruginous Duck is observed throughout the Guerbes-Sanhadja complex. It preferentially occupies Garaet Hadj-Taher throughout the year in both the wintering and breeding seasons, with a higher tendency during the wintering period, mainly from November to January (Charchar 2017, Merzoug 2015).

Ferruginous Duck populations appear to be declining in some parts of Asia (e.g. Turkey, Turkmenistan, Ukraine), while in Europe they fluctuate according to different trends (decreasing, increasing in Spain, Romania...etc.). North African populations have been maintained, with the species recovering in some countries (Tunisia, Morocco) and increasing in others (Algeria) (Robinson & Hughes 2006, Lazli 2011). It has been noted that this diving duck has a sedentary breeding status in most of our wetlands (Lazli 2011, Lazli *et al.,* 2012) The maximum of its numbers was recorded during the postnuptial transit period, followed by a gradual decrease in the model of a Gaussian curve. This decrease can be explained by the departure and migration of the majority of individuals from their wintering sites to their breeding grounds (Houhamdi 2002, Houhamdi & Samraoui 2008).

**2. Spatial occupation of wetlands by Ferruginous Duck**

As the species is made up of two more or less distinct populations, a wintering one and a sedentary breeding one, we can easily observe them because of their behavior. The overwintering population is often larger, and often occupies the most tranquil sites (deep, clear of vegetation, far from disturbance, alongside other overwintering Anatidae who display the same behavior). The sedentary breeding population, often separate from the first, is made up of small numbers and is distributed in areas rich in helophytes (*Typha angustifolia, Phragmites australis, Scirpus maritimus*, etc.). These water bird generally travels alone or in small groups (Fig. 30).

It should be noted that in Lake Fezzara and the Mekhada Marsh, given their large surface areas, only the groups observed on the banks were studied (Fig. 30).

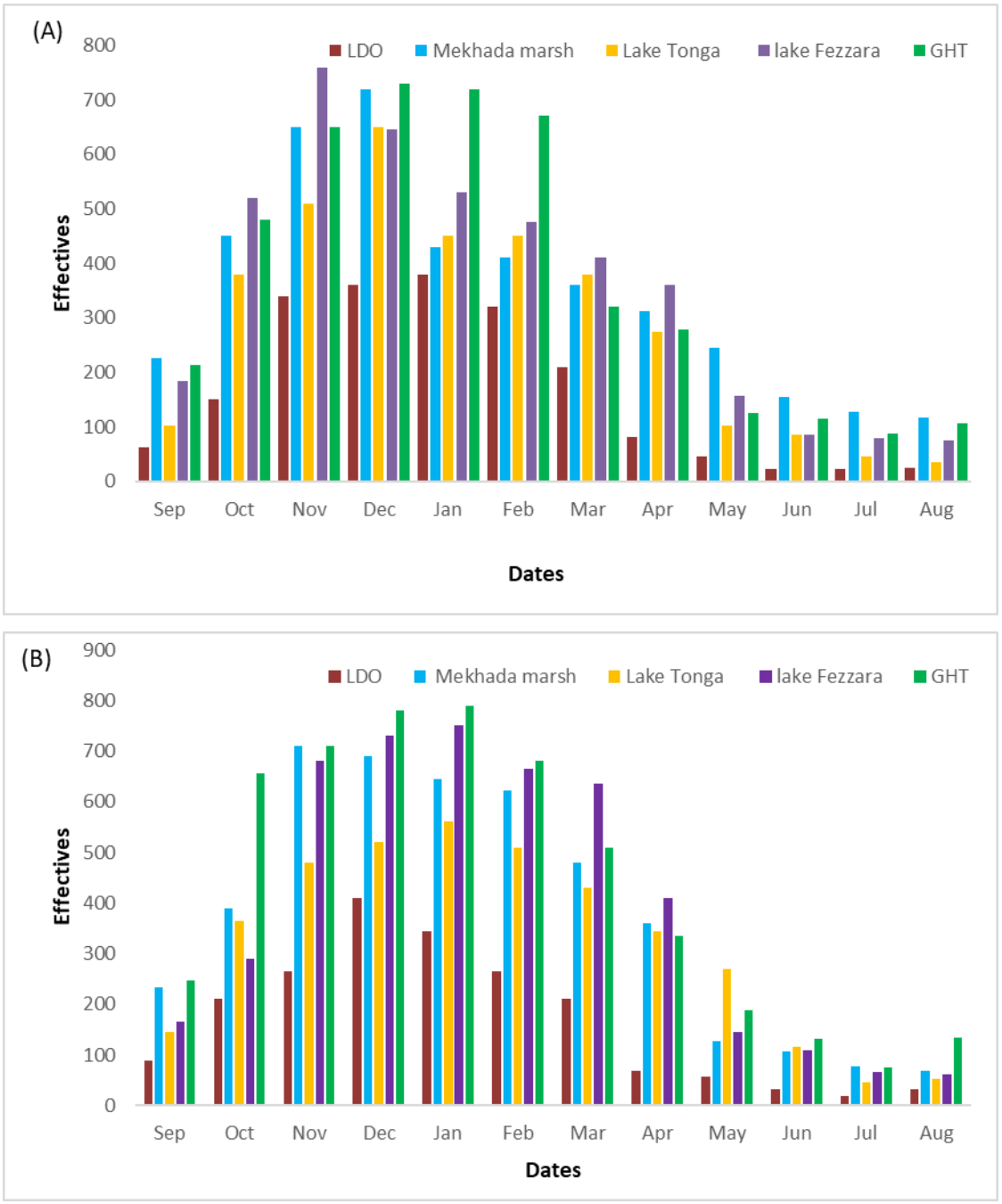



**Fig. 30. Trends in effectives of Ferruginous Duck *Aythya nyroca***

**(A) (A): 2021/2022 and (B): 2022/2023.**

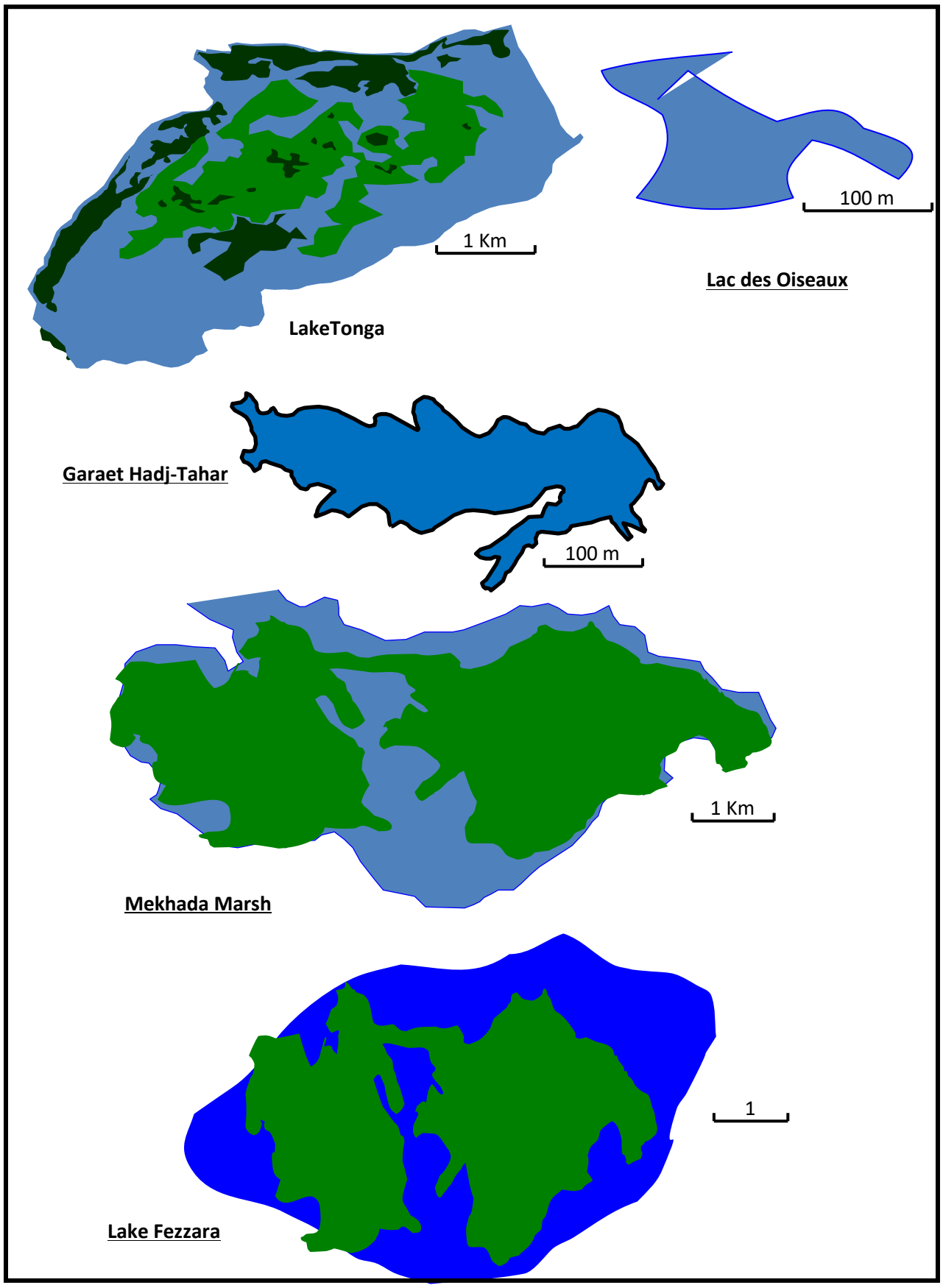



**Fig. 31. Spatio-temporal occupation of wetlands by the Ferruginous Duck *Aythya nyroca***

**Photo 4. General view of Lac des Oiseaux (Taken by Ines Houhamdi on April 02, 2022)**

**Phot o 5. General view of Garaet Hadj-Tahar (Taken by Ines Houhamdi on January 11, 2021)**

**Photo 6. General view of the Mekhada Marsh (Taken by Ines Houhamdi on December 25, 2022)**

**Photo 6. General view of Mekhada Marsh (Taken by Ines Houhamdi on December 25, 2022)**

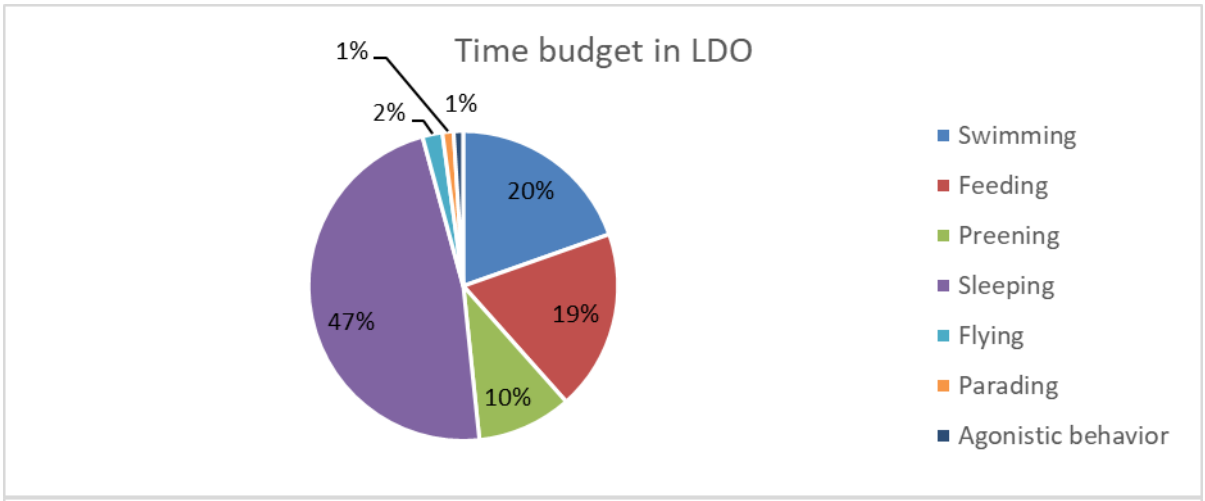
**Photo 7. General view of Lake Fezzara (Taken by Ines Houhamdi on January 02, 2022)**

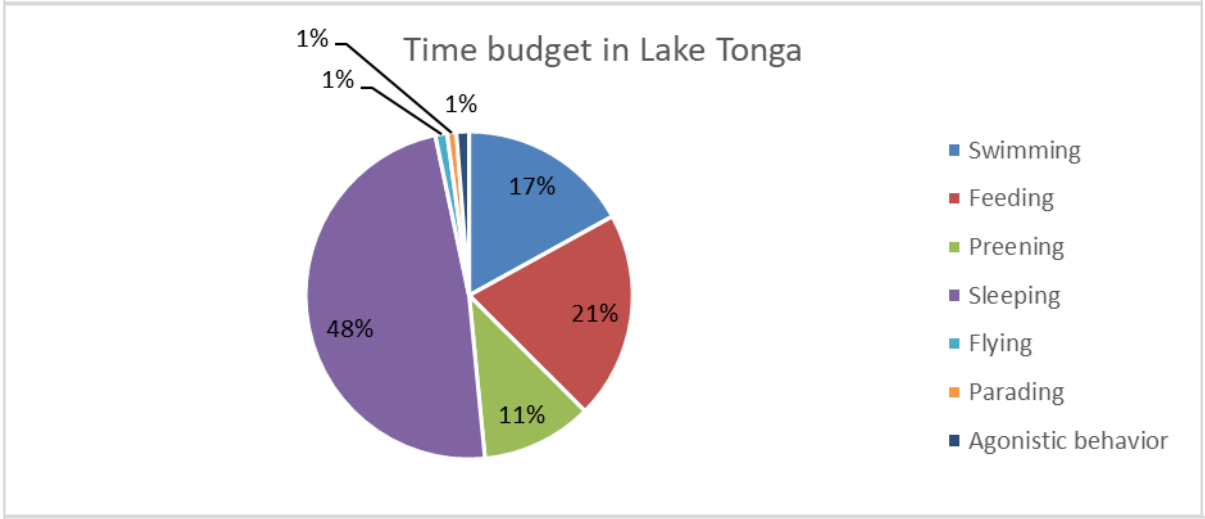
**3. Study of the diurnal activity rhythm of the Ferruginous duck**

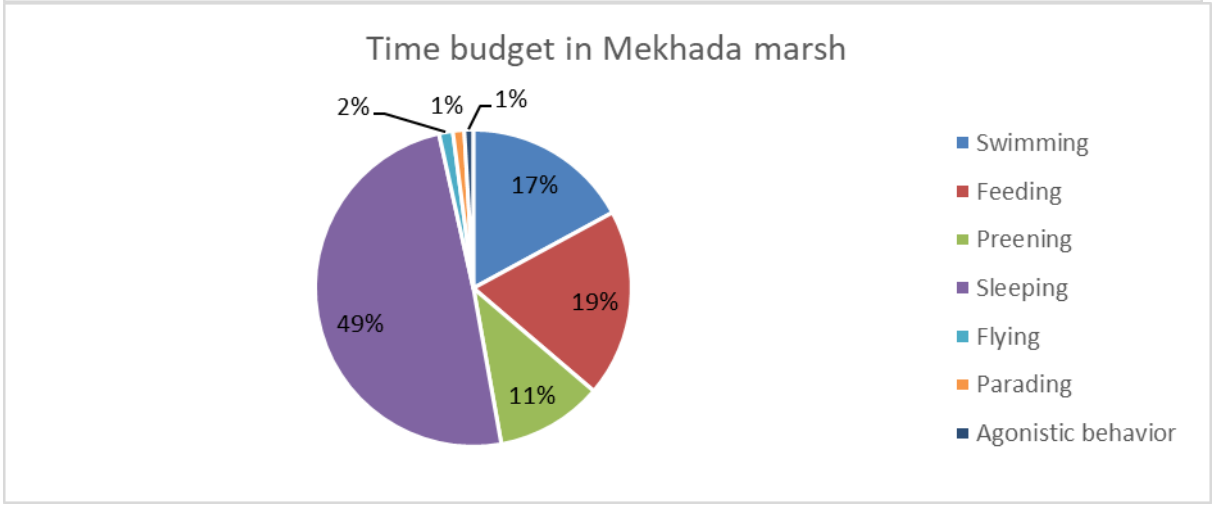
Monitoring of the diurnal activities rhythms of Ferruginous Duck *Aythya nyroca* during the 2022/2023 study year showed that sleep is the activity that dominates the balance of these time budgets and represented the main activity of this species with a percentage of 47,42% at Lac des Oiseaux, 48.25% at LakeTonga, 49.33% at Mékhada marsh, 50.17% at Lake Fezzara and 46.17% at Garaet Hadj-Tahar (Fig. 31). Feeding follows with a percentage of 19.58% at Lac des Oiseaux, 20.50% at Lac Tonga, 19.17% at Mékhada marsh, 19.50% at Lake Fezzara and 22.58% at Garaet Hadj-Tahar (Fig. 31). Swimming ranks third with a percentage of 18.83% at Lac des Oiseaux, 17% at Lake Tonga, 17.08% at Mékhada marsh, 16.08% at Lake Fezzara and 14.25% at Garaet Hadj-Tahar. Grooming comes fourth with a

percentage of 9.92% at Lac des Oiseaux, 11% at Lake Tonga, 10.92% at Mékhada marsh, 9.92% at Lake Fezzara and 12.42% at Garaet Hadj-Tahar. Flight, courtship and antagonism are poorly represented (Fig. 31). The percentages are 2.08%, 1.17% and 1% at Lac des Oiseaux, 1.17%, 0.92% and 1.25% at Lake Tonga, 1.42%, 1.17% and 0.92% at Mékhada marsh, 2.25%, 1% and 1.08% at Lake Fezzara and 1.17%, 1.75% and 1.67% at Garaet Hadj-Tahar (Fig. 31).

Fredrickson and Drobney (1979), Reinecke (1981) and Tamisier and Dehorter (1999) consider that activity time budget analysis is an essential tool for determining the wintering and breeding requirements of waterbirds. Our results corroborate those found at Lac des Oiseaux (wilaya of El-Tarf, Algeria), where the main activity was sleep (43.5%), followed by swimming (30.7%), feeding (17.2%), grooming (5.9%) and flying (2.7%) Houhamdi and Samraoui (2008) and those published by Aissaoui *et al,* (2011) who report that sleeping is the predominant activity (41.9%), followed by feeding (30.8%) in four main wetlands in eastern Algeria (Mékhada marsh, Lac des Oiseaux, Lake Oubeïra and Lake Tonga). Other activities considered to be of secondary importance. However, our results differ from those obtained in the wetland eco-complex of Jijel (Algeria), where the Ferruginous Duck exhibits a diurnal behavior dominated by the feeding activity, which ranks first with more than a third of the total time budget, i.e. 39.94% in the El-Kennar marsh and 38.18% in the Béni-Bélaid lake. This is followed by the activity of sleeping or resting, with 27.35% in the El-Kennar marsh and 25.22% in the Béni-Bélaid lake. In third place comes swimming activity, with rates of 17.27% in the El-Kennar marsh and 21.66% in Lake Béni-Bélaid (Mayache 2008). Maazi (2009) found that swimming was the main activity at Garaet Timerganine (45.9%), followed by sleeping (42.1%)


Time budget in LDO
1%
2%
1%
20%
19%
10%
47%
Swimming
Feeding
Preening
Sleeping
Flying
Parading
Agonistic behavior


Time budget in Lake Tonga
1%
1%
1%
17%
21%
11%
48%
Swimming
Feeding
Preening
Sleeping
Flying
Parading
Agonistic behavior


Time budget in Mekhada marsh
2%
1%
1%
17%
19%
11%
49%
Swimming
Feeding
Preening
Sleeping
Flying
Parading
Agonistic behavior

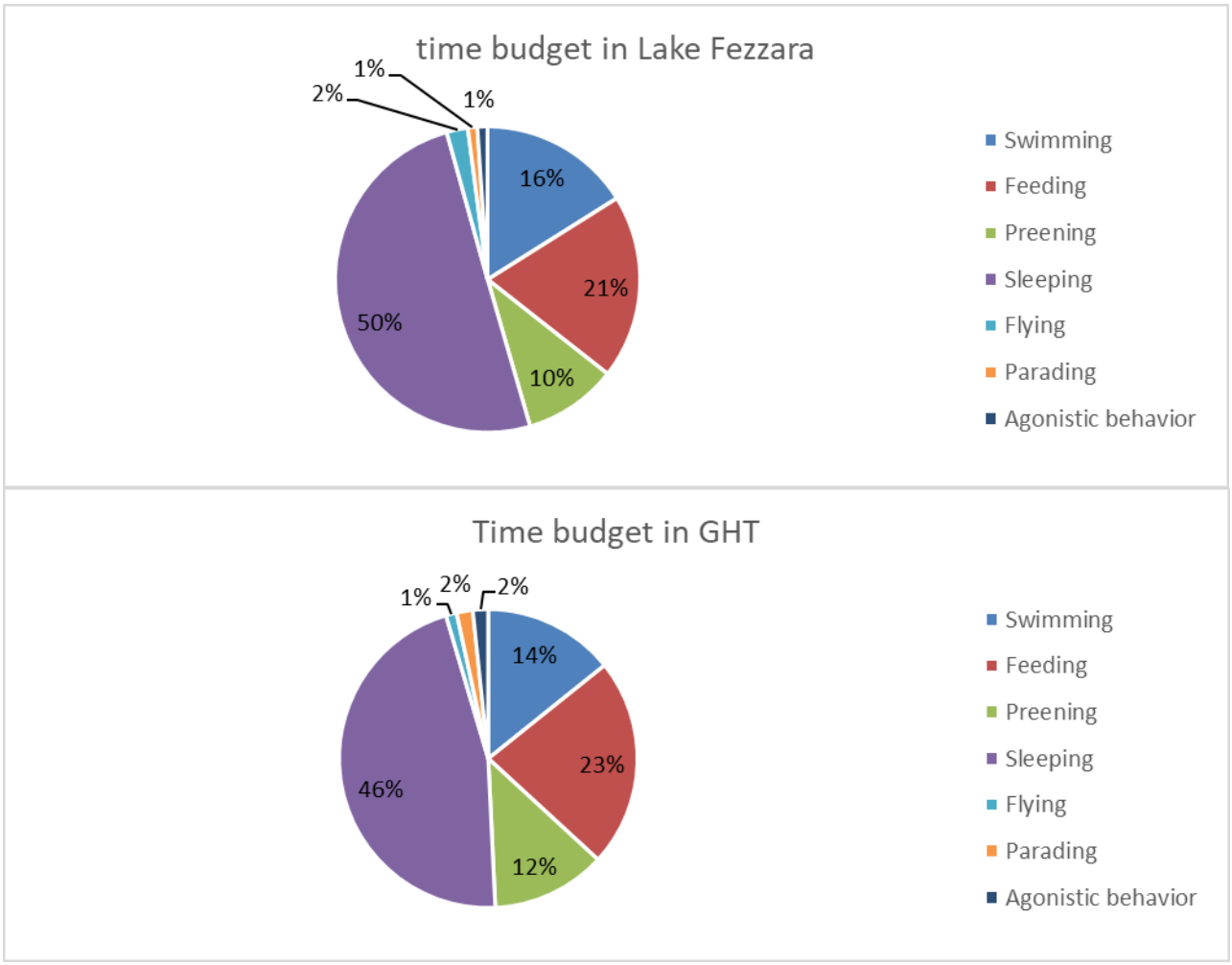



**Fig. 32. Assessment of diurnal activities rhythms (Year 2022/2023).**

**4. Monthly activity trend**

The monthly evolution of the diurnal activities rhythms of the Ferruginous Duck was marked by a diverse variation throughout the month at the five study sites. At the beginning of September, sleep gradually increased, reaching maximum values in January. More or less stable values were recorded for the rest of the year (Figs. 32; 33, 34, 35 and 36). Feeding is present and stable throughout the year, with a slight decline around February (Fig. 32). As with all waterbirds, swimming is an essential activity. It is evenly distributed from September to August, with low levels noted in January, February and March (Figs. 32; 33, 34, 35 and 36). Grooming is a daily activity carried out by the bird throughout the day, and ranks fourth in the overall balance of diurnal activities rhythms. Grooming is particularly low in January (Figs. 32; 33, 34, 35 and 36). Flying occurs mainly as a result of massive disturbances of the bird group, caused by Harpoon *Circus aeruginosus* or by poachers' rifle shots, either from the banks or using flat-bottomed boats to move through the aquatic vegetation (personal

observations). Parading and antagonism occupy a very minor place in the balance sheet of ferruginous duck activities rhythms, exhibiting very low rates throughout the year, and are only observed from March onwards (Figs. 32; 33, 34, 35 and 36).

Thus, like the majority of Anatidae wintering in Algerian wetlands, the diurnal activities of the Ferruginous Duck are similar to those of the Winter Teal *Anas crecca crecca* and the Eurasian wigeon*Anas penelope,* which spend a significant part of their time dozing during the day (Houhamdi & Samraoui, 2001, 2003). Finally, it's important to point out that all the activities engaged in by this diving duck took place in the water.

**4.1. Sleeping**

September and February, the first half of January and the end of May were all quiet for the Ferruginous Duck. In fact, sleep represents a phase of reduced energy expenditure. This reduces heat loss and increases sleep duration, enabling this duck to maintain mainly the lipid reserves needed to withstand low ambient temperatures (Tamisier, 1972, Tamisier and Dehorter 1999). Maintaining lipid reserves at the end of the wintering period is also important to prepare for the long prenuptial migration. Our results are similar to those of Mayache (2008) and Lardjane- Hamiti (2014), in which rest largely dominates the balance sheet for the winter period.

Given the high energy requirements for migration (Tamisier 1972) and reproduction (Paulus 1980), energy expenditure is even lower in March (Figs. 32; 33, 34, 35 and 36). Sleep duration is high, but the time devoted to energy-intensive activities (swimming, feeding) remains more or less low compared to sleep (Bredin *et al.,* 1986),

Daytime sleep is the best way to restore and make the most of essential energy reserves during migratory flights (Rave and Baldassare, 1989; Tamisier and Dehorter, 1999), and to ensure successful reproduction in the same wintering areas for sedentary birds, or in the breeding grounds for the wintering population (Hill & Ellis, 1984, Hohman & Rave, 1990; Green *et al.,* 1999).

Ducks sleep in open water, drifting close to shore. They then return to doze in more central areas of the water by swimming (in light winds) or flying (in strong winds) (Hill & Ellis, 1984, Loucif *et al.,* 2019, Abdi *et al.,* 2016). Whatever behavior they choose, daytime sleep is often interrupted. The bird watches for potential predators, determines their position in relation to the banks, or positions itself in relation to another individual (formed into pairs) or the group as a whole. The duck can be physically active during its sleep: it can swim tens of meters, sometimes even keeping its head under its wings (Tamisier 1972).

**4.2. Feeding**

Feeding activity is often associated with diving and has been observed in Ferruginous Duck during the breeding season. This activity was observed in sedentary breeding individuals which, from March onwards, began to accumulate energy reserves enabling them to successfully build nests in lakes (Tamisier & Dehorter 1999). As with all diving ducks, this activity necessarily combines movements (nesting) that facilitate access to underwater food to minimize intraspecific and interspecific competition with other species (Tamisier & Dehorter 1999, Narsis *et al.,* 2022). In spring, waterbirds generally require vigorous fattening in preparation for the breeding season (Irwin and O'halloran, 1997). Feeding activity is often nocturnal in Anatidae (Tamisier, 1972, Houhamdi, 2002, Houhamdi and Samraoui, 2001, 2002, 2003, Narsis *et al.,* 2019,). The feeding behavior of ducks during the breeding season varies considerably within and between species, depending on location and timing (Paulus 1988). The same authors report that strong winds and precipitation reduce the food consumption of non-breeding Anatidae.

Human disturbance during the day could also be an important factor in the decline observed during April (Figs. 32; 33 and 34). Indeed, this activity represents a means of replenishing energy reserves after migratory transitions (Tamisier & Dehorter 1999). This may be linked to the juvenile waterbirds' need for more food, which also requires a high daily energy intake due to moulting during this period. Anatidae may resort to diurnal feeding, probably to meet energy requirements not fully satisfied nocturnal feeding. This may also be explained by possible threats to waterbirds at night (Tamisier *et al.,* 1995).

**4.3. Swimming**

Swimming was observed at all five sites during the study period (Figs. 32; 33, 34, 35 and 36). Swimming is often associated with feeding and flying. In fact, the search for food in Ferruginous Duck leads to displacement; similarly, after flight, they swim, either to return to specific locations, or to join other birds. Swimming is often considered an atypical behavior in Anatidae and is essentially social, enabling the population to move progressively to cope with wind drift (Tamisier 1972). It sometimes corresponds to a means of returning to normal activity after disturbances, and also enables young ducks to form pairs and exhibit mating behavior during the winter (Houhamdi 1998, 2002, Houhamdi & Samraoui 2008, Merzoug *et al.,* 2014).

**4.4. Preening**

Plumage maintenance has been recorded with significant values at the start of the wintering season (Fig.x), corresponding to feather rearrangement and maintenance after

postnuptial migration to the wintering area (Houhamdi 2002, Houhamdi & Samraoui 2001, 2003, 2008). Among the earliest wintering species, plumage maintenance was a primitive activity, replacing damaged feathers in waterbirds crossing the Mediterranean to winter in our wetlands (Skinner & Smart 1984, Tamisier *et al.,* 1995). Grooming to maintain plumage involves several aspects, including the arrangement of feathers after each flight; ducks feel the need to tidy up their plumage. Similarly, when winds are strong, this type of behavior is often observed: cleaning, where the duck removes foreign materials from its plumage with its beak (parasites or old feathers during moulting).

**4.5. Flying**

Flight is an activity caused by disturbance. Mainly noted with low values (Figs. 32; 33, 34, 35 and 36) only when necessary and often caused by many factors, the main cause being poaching and overflight by Marsh Hawks *Circus aeruginosus*. Individuals of this species also show signs of fleeing after a change of shedding site (personal observations).

When temperatures are very high, the amount of water in the water bodies gradually decreases, creating favorable conditions for predators and local inhabitants to approach. Ferruginous ducks (Kestenholz, 1994, Bakhouche *et al.,* 2013, Draidi *et al.,* 2013) change location as soon as humans approach the *Typha angustifolia* clumps and move on to deeper areas (personal observations).

**4.6. Parading**

Courtship includes wing movements and head nodding. It is observed in solitary males moving in circles over females. It is only observed from March to July, at low rates (Figs. 32; 33 and 34).

**4.7. Antagonism**

This activity is rarely observed (Figs. 32; 33, 34, 35 and 36). The peak of this aggressive activity was in May and June, which coincides perfectly with the breeding season.

The assessment of diurnal activities carried out on Ferruginous duck at the five wetlands of international importance covered by this study highlights the dominance of primordial activities over comfort activities, in this case sleeping, feeding and swimming (Figs. 32; 33, 34, 35 and 36). From this, we can conclude that all the sites studied are exploited as shedding grounds by the Ferruginous Duck as for the majority of wetlands in Algeria and throughout the Mediterranean basin (Tamisier 1995, Aissaoui *et al.,* 2009, 2011, Houhamdi & Samraoui 2008, Lardjane-Hamiti *et al.,* 2013, Bensizrara *et al.,* 2013, Merzoug *et al.,* 2014, Loucif *et al.,* 2019, Abdi *et al.,* 2018).

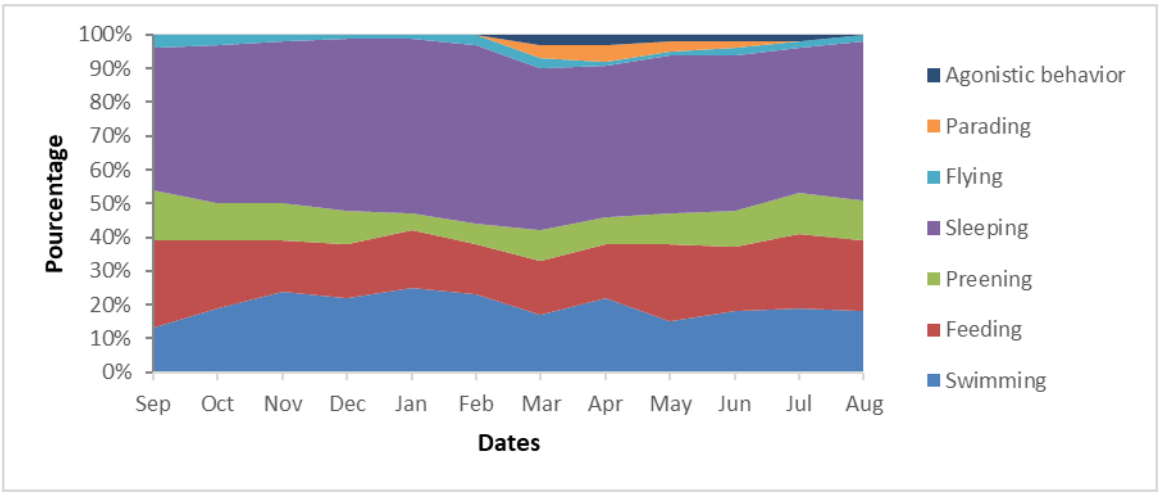



**Fig.33. Evolution of diurnal activities of Ferruginous Duck in Lac des Oiseaux (2022/2023)**

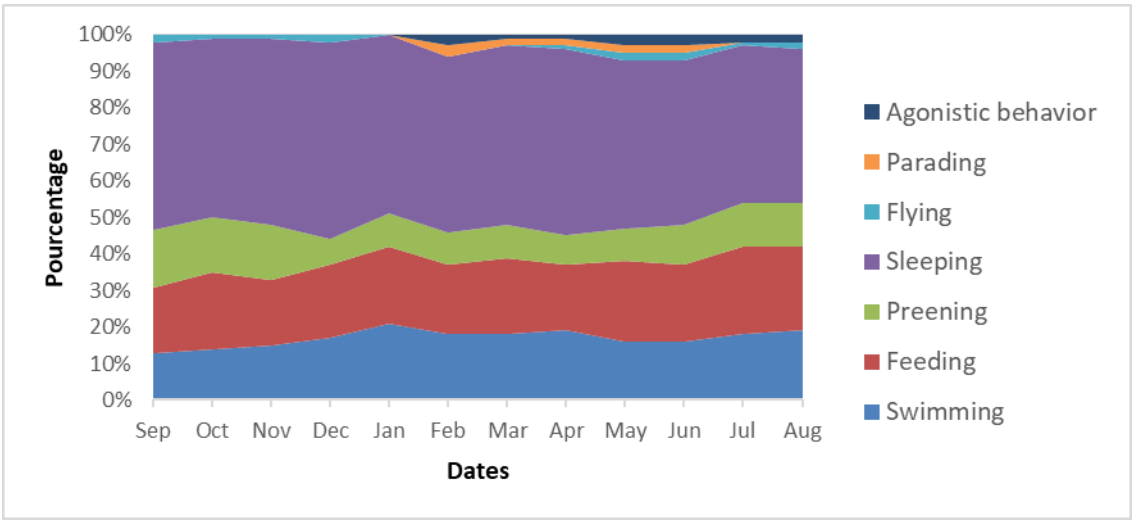



**Fig. 34. Evolution of diurnal activities of Ferruginous Duck in Lake Tonga (2022/2023)**

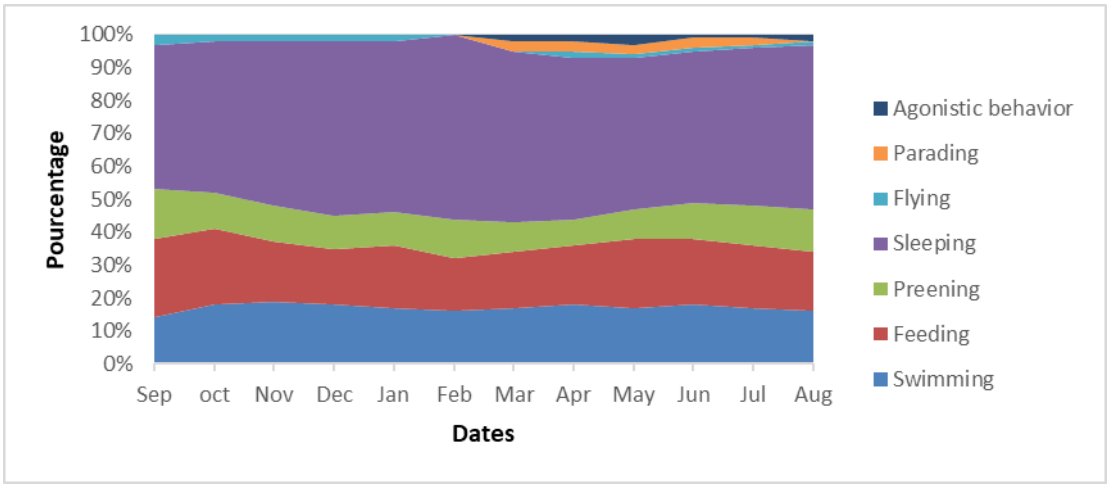



**Fig. 35. Evolution of diurnal activity of the Ferruginous Duck in the Mékhada marsh (2022/2023)**

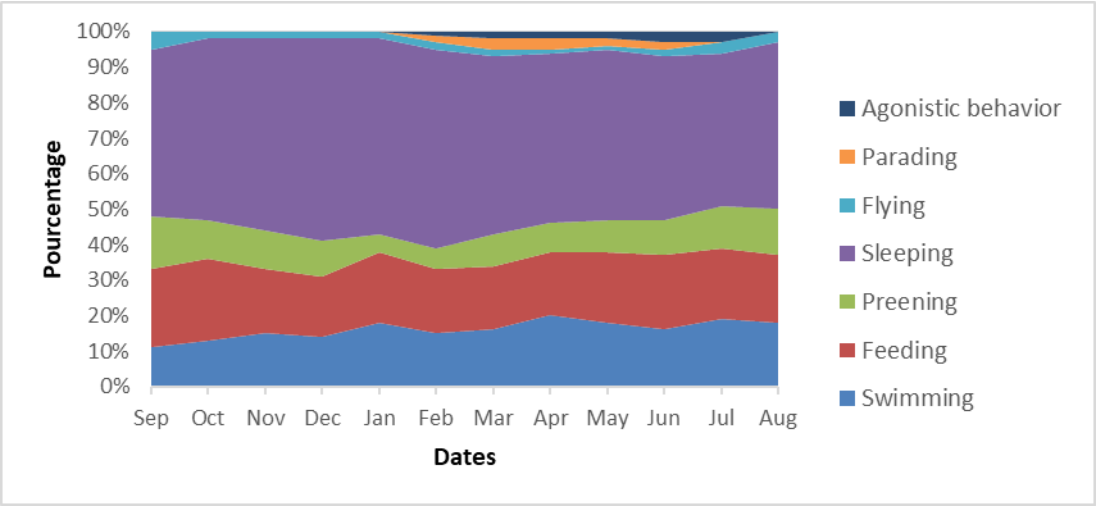



**Fig. 36. Evolution of diurnal activities of Ferruginous Duck in Lake Fezzara (2022/2023)**

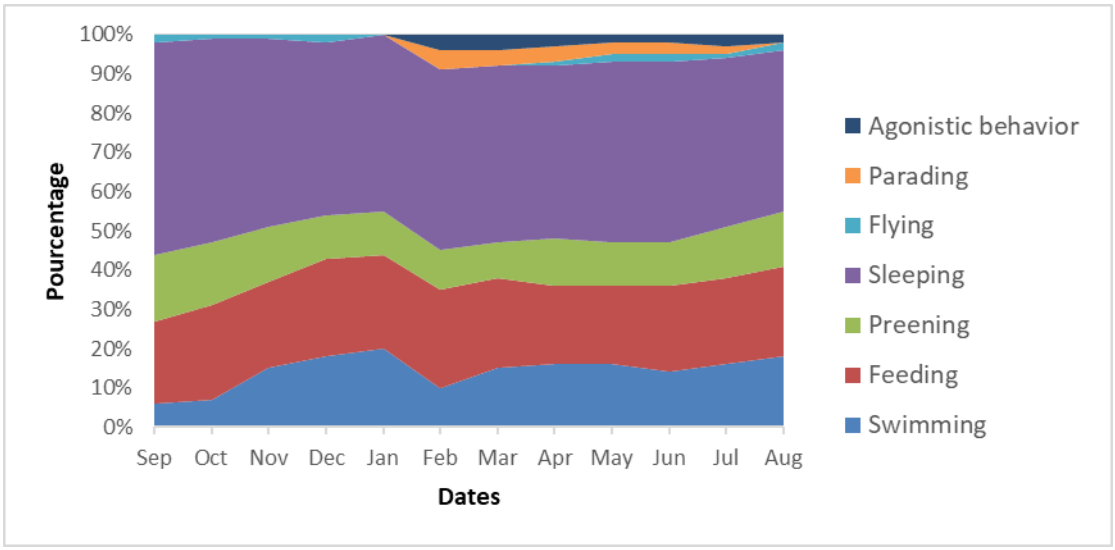



**Fig. 37. Evolution of diurnal Ferruginous Duck activity in Garaet Hadj-Tahar (2022/2023)**

## 5. Multivariate statistical processing

Multivariate statistical processing using COA was carried out on the time budget data of Ferruginous Duck *Aythya nyroca* wintering in the wetlands of extreme north-eastern Algeria, mainly Lac des Oiseaux (Wilaya El-Tarf) and Garaet Hadj-Tahar (Wilaya Skikda).The distribution of the activities measured over time is shown by the 1x2 factorial plane of the Lac des Oiseaux (Wilaya d'El-Tarf) and the Garaet Hadj-Tahar (Wilaya de Skikda) in eastern Algeria, mainly the Lac des Oiseaux (Wilaya d'El-Tarf) and the Garaet Hadj-Tahar (Wilaya de Skikda). The factorial plane is 76% and 74% respectively. At Lac des Oiseaux, the F1 ordinate factor (47% of inertia) contrasts the wintering season with the breeding season (Fig. 37). We also observe that flight activity characterizes the start of wintering (August and September), then during the wintering months proper (November to

March), we observe the main activity (sleeping), which is often associated with water movement (swimming). Nuptial activities (courtship and agonistic activities) characterize the months of March and April, and finally, during the months of May, June and July we record feeding activities and plumage maintenance (Fig. 37).

The same pattern is observed at Garaet Hadj-Tahar (Fig. 38). Graph 1x2 of the CFA, which gathers respectively 59% and 25% of the inertia, also shows us the distribution of these activities over time. Sleep and grooming characterize the first occupants of the water body, i.e., during September and October, then during November, December and January the dominant activity is feeding, which is observed only in the water and is associated with positioning flight, which enables the birds to group together, especially in wintering populations. During the following months (March, April, May and June), we observe the main activity (sleeping), which is observed in almost half of all gregarious Ferruginous Duck species. February is characterized by courtship, bickering and antagonism (Fig. 38).

So, generally speaking, Ferruginous Duck occupancy of these two bodies of water adopts more or less similar strategies. The sleeping activity that dominates these diurnal balances is recorded mainly during wintering periods, when temperatures are at their lowest. The first occupants of these hydrosystems often show ways of recovering and conserving the energy supplied during post-nuptial migrations. Courtship activities are noted just before the breeding season.

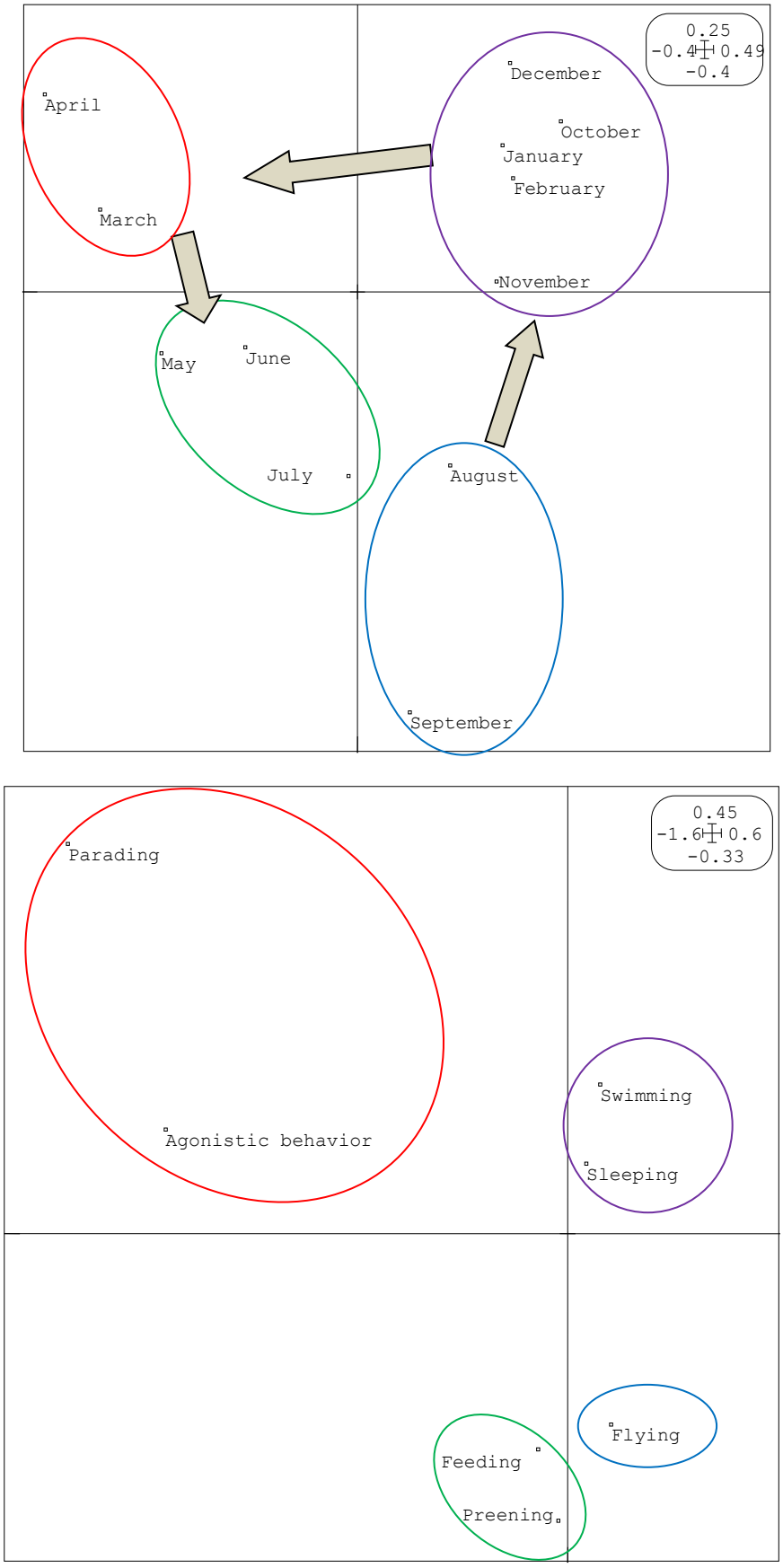



**Fig. 38. 1x2 factorial design of Correspondence Analysis (Rhythms of diurnal activities of the Ferruginous Duck *Aythya nyroca* in Lac des Oiseaux (2020/2023). Axes of inertia: 0.47, 0.29, 0.17 & 0.03.**

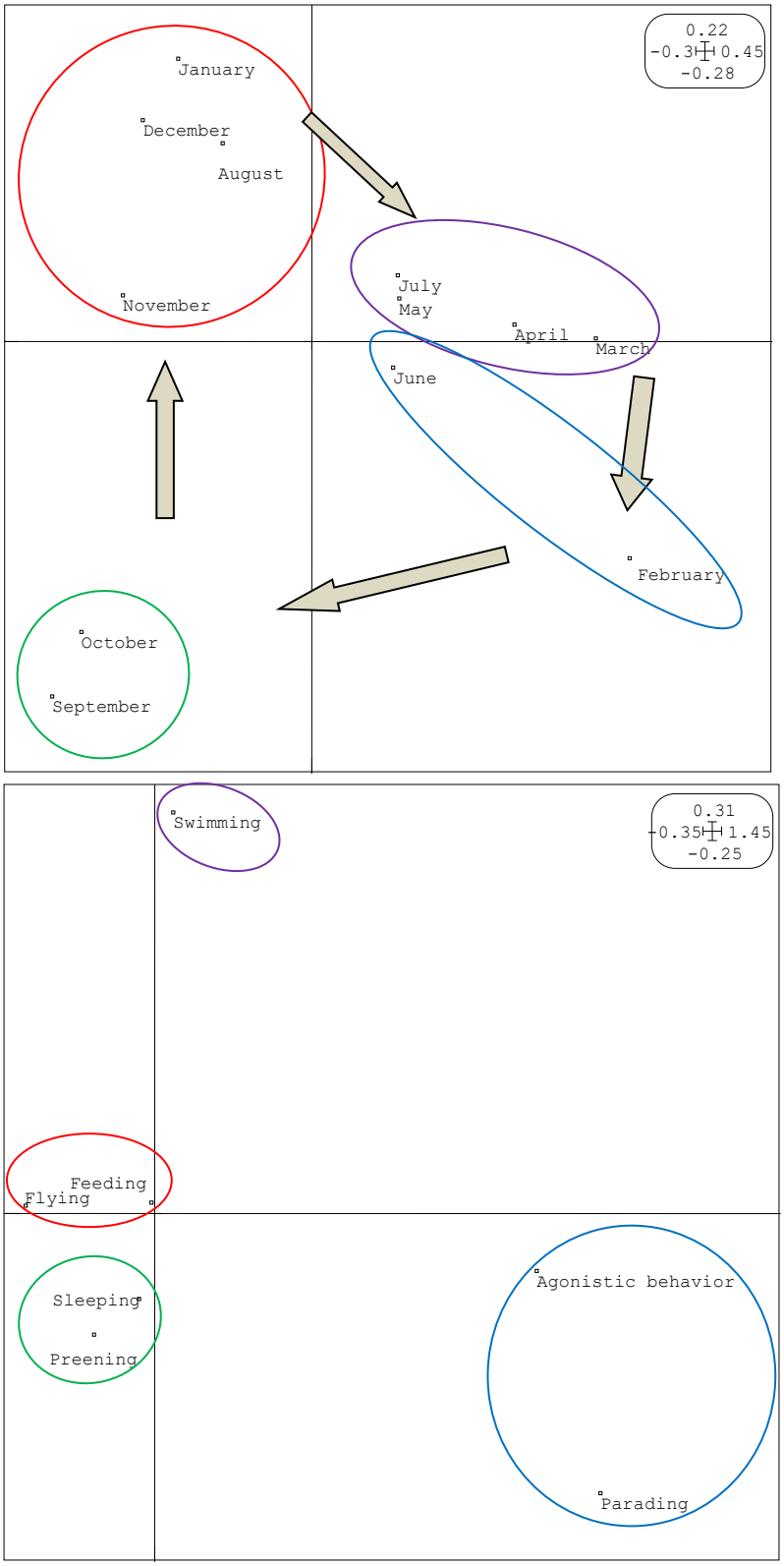



**Fig. 39. 1x2 factorial design of the Correspondence Analysis (Rhythms of diurnal activities of the Ferruginous Duck *Aythya nyroca* in Garaet Hadj-Tahar (2020/2023). Axes of inertia: 0.59, 0.25, 0.08 & 0.03.**

# Chapter 4: Ecoethology of the White-headed Duck *Oxyura leucocephala*

**1. Trends in White-headed Duck numbers:**

Linked to brackish waters, the White-headed *Duck Oxyura leucocephala* is one of the rarest and most endangered birds in Europe and Africa, a victim above all of intense hunting pressure. The White-headed Duck is relatively easy to spot when asleep, thanks to its long, almost vertical tail.

It is a breeding species in eastern Numidia, especially in Lake Tonga and Lac des Oiseaux (Chalabi 1990, Maazi 1991, Samraoui *et al.*, 1992, Boumezbeur 1990, 1993, Boukhalfa 1996, Houhamdi & Samraoui 2002)

However, when fishing, it spends little time on the surface of the water. As a result, it often goes unnoticed in gatherings of scaups (Houhamdi & Samraoui 2002).

Inhabiting the wetlands of Europe, North Africa and Western Asia, this species is unfortunately under threat. Habitat loss and hunting have drastically reduced its population, making its conservation a top priority for ornithologists and scientists (Isenmann & Moali 2000). In addition to habitat loss and hunting, interbreeding with the Ruddy duck, an invasive species native to North America, poses a serious threat to the species' genetic purity (Samraoui & Houhamdi 2002). Conservation programs aim to protect their habitat and control Ruddy Duck populations.

The Algerian population of White-headed Duck has often been underestimated and little studied. Information is limited to around 40 pairs, usually nesting in the eastern coastal wetlands of the Guerbes-Sanhadja complexes (Samraoui & De Belair 1997) and El-Kala (Boumezbeur 1993, Isenmann & Moali 2000, Houhamdi & Samraoui 2002). Its nesting has recently been noted in other wetlands of the country, namely in the high plains of Constantinois and precisely in Garaet Timerganine (Wilaya d'Oum El-Bouaghi) (Houhamdi *et al.*, 2009). In the Annaba region (Chetibi *et al.*, 2013) noted its nesting at the Boussedra marsh. In the west of the country, its presence has been noted in large numbers at Dayet El-Ferd (Wilaya de Tlemcen), (Oudihat 2011).

In this section, we describe changes in the numbers of this diving duck species over two consecutive years, 2020/2021 and 2021/2022, in five highland wetlands: Garaet Timerganine (Oum El-Bouaghi), Garaet Ouled Amara (Khenchela), Chott El-Hodna (M'sila), Boughezoul Dam (Médéa) and Bougara Dam (Tissemssilt) reveal its regular presence in the majority of all our surveys. Generally speaking, these early waterfowl have been occupying water bodies since September (Fig. 39).

At the start of the wintering season during the first year of the study, numbers fluctuated between 5 and 210 individuals at Garaet Timerganine, between 44 and 78 at Garaet Ouled Amara, between 23 and 56 at Chott El-Hodna, between 34 and 65 at Boughezoul Dam and between 12 and 102 at Bougara Dam. The peak in numbers was reached in January at Garaet Timerganine, in May at Garaet Ouled Amara and Chott El-Hodna, and in April at both dams, corroborating the pre-mating passage of wintering waterbirds or those that frequented the dams during the pre-migratory aggregation period towards the northern shores of the Mediterranean, i.e. their usual nesting grounds. The second year was marked by a complete drought at the study sites, with only a few individuals visiting Garaet Oued Amara (4 individuals), Chott El-Hodna (7 individuals) and Boughezoul Dam(15 individuals) at the start of the wintering season, The Bougara dam more or less hosted large numbers during the months of October and November (125 individuals), after which there was a considerable drop in numbers and an almost total absence of individuals, due to zero rainfall during this period of the year.

According to Oudihat's findings in 2018, the White-headed Duckhas been observed in the high plateaus in the Wilaya of Khanchela. These numbers vary between 16 and 112 individuals at Garaet Ouled Amara and between 18 and 85 individuals at Garaet Ouled M'barek. In the wetlands of M'sila (Chott El-Hodna: the largest wetland in the highlands), numbers ranged from 23 to 59 individuals. In the Wilaya of El-Médea, at the Boughezoul Dam, a peak of 77 individuals was observed. The Bougara dam was home to the White-headed Duck for 12 months, with 148 individuals recorded (Fig. 39).

Generally speaking, a comparison of the sites' carrying capacity enables us to classify them as follows: Bougara Dam (24% of the total number of people surveyed), Garaet Ouled Amara (23% of the total number of people surveyed), Chott El-Hodna (22% of the total number of people surveyed), Garaet Timerganine (17% of the total number of people surveyed) and finally Boughezoul Dam (5% of the total number of people surveyed).

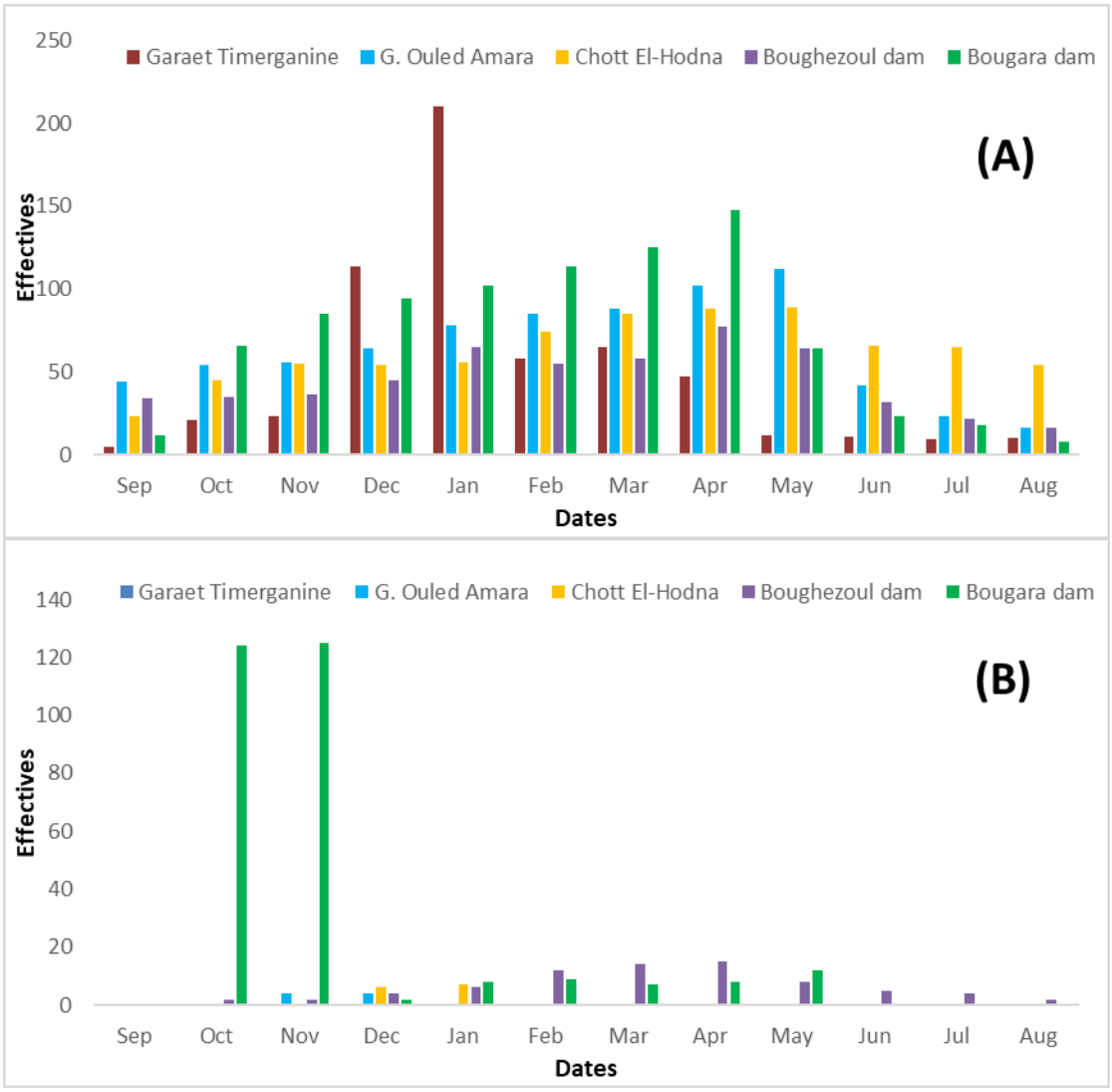



**Fig. 40. Trend in effectives of White-headed Duck *Oxyura leucocephala* at five lakes (A): year 2020/2021 and (B): year 2021/2022.**

**2. Spatial occupation of the five wetlands by the White-headed Duck**

In the five wetlands covered by our study, the White-headed Duck occupies the deepest parts of the water bodies. Generally, we observe groups and pairs of this diving duck in the center of these hydrosystems (Fig. 40), often mixed with other scaups (Ferruginous Duck *Aythya nyroca* and Common Pochard *Aythya ferena*). These places, far from any kind of disturbance, seem to offer peace and quiet and good food availability, enabling these birds to better exploit these hydrosystems. The same findings have been noted in all Algerian wetlands frequented by this species (Chalabi 1990, Maazi, 1991, Samraoui *et al.*, 1992, Boumezbeur 1990, 1993, Boukhalfa 1996, Isenmann & Moali 2000, Houhamdi 2002, Houhamdi & Samraoui 2002, Metallaoui *et al*., 2009, Chettibi *et al.*, 2013, Lazli *et al.*, 2014).

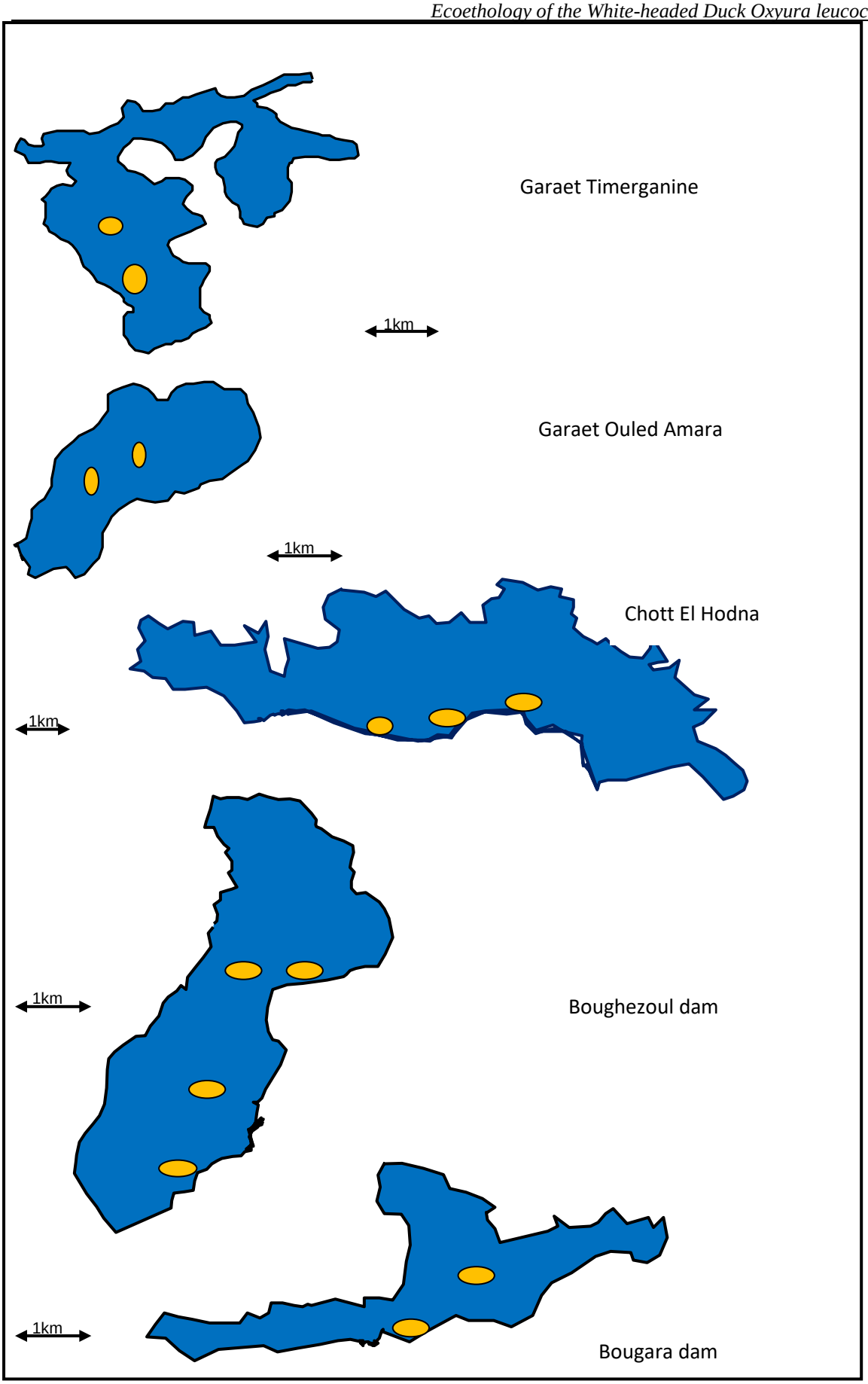



**Fig. 41. Spatial and temporal occupation of the five wetlands by the White-headed Duck *Oxyura leucocephala*.**

**Phot o 8. General view of Garaet Timerganine (Taken by Ines Houhamdi, May 19, 2021)**

**Photo 9. General view of Garaet Ouled Amara (Taken by Ines Houhamdi on May 20, 2021)**

**Photo 10. General view of Chott El-Hodna (Taken by Ines Houhamdi on May 25, 2021)**

**Photo 11. General view of the Boughezoul Dam (Taken by Ines Houhamdi, on May 28, 2021)**

**Photo 12 General view of the Bougara dam (Taken by Ines Houhamdi on June 03, 2021)**

### 3. Follow-up on diurnal activity patterns

In this part of our work, we collected information on the diurnal activities of the White-headed Duck *Oxyura leucocephala* by carrying out weekly outings over a 12-month cycle from September 2021 to the end of August 2022 at five study sites in the Algerian highlands (Garaet Timerganine, Garaet Ouled Amara, Chott El-Hodna, Boughezoul Dam and Bougara Dam).

During the wintering season, daytime activity patterns are dominated by resting/sleeping, with 39% at Garet Timerganine, 43% at Garaet Ouled Amara, 42% at Chott El-Hodna and 53% at Boughezoul Dam (Fig. 41). In almost all sites, the White-headed Duck

shows the same behavior over an annual cycle, dominated by sleep, with the exception of e Bougara Dam, where feeding dominates the balance of activity rhythms with 40%. It is followed by swimming with 24% at Garaet Timerganine and Garaet Ouled Amara respectively, 22% and 23% at Chott Hodna and Boughezoul Dam (Fig. 41). Sleeping comes second at Bougara Dam with 25%. Feeding is the third most common activity, with percentages of 18%, 15%, 13% and 10% for the Garaet Timerganine and Ouled Amara sites, Chott El-Hodna and Boughezoul dam respectively, while swimming is the third most common activity at Bougara Dam. Toileting follows with 13%, 11%, 14%, 8% and 10% at Garaet Timerganine, Garaet Ouel Amara, Chott El-Hodna, Boughezoul and Bougara Dams. Theft, an activity generally provoked by predators, hunting and the passage of grazing animals, is present with low percentages varying between 4% and 9% (Fig. 41).

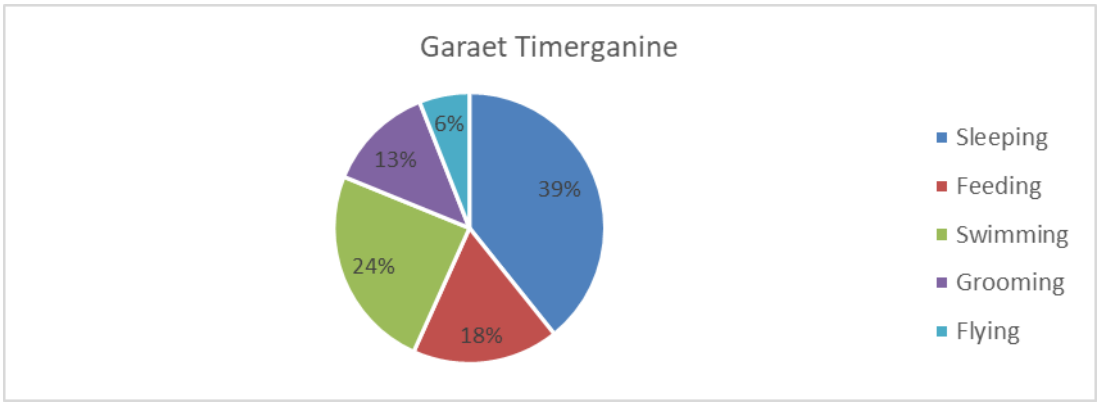
The monthly trend in White-headed Duck activity rates measured in the highlands is illustrated in the figures below (Fig. 41). Generally speaking, we note that variations are low at all sites. The graphs below illustrate that sleeping is the dominant activity at almost all sites, with the exception of Bougara dam, where feeding outweighs all other activities (Fig. 41).

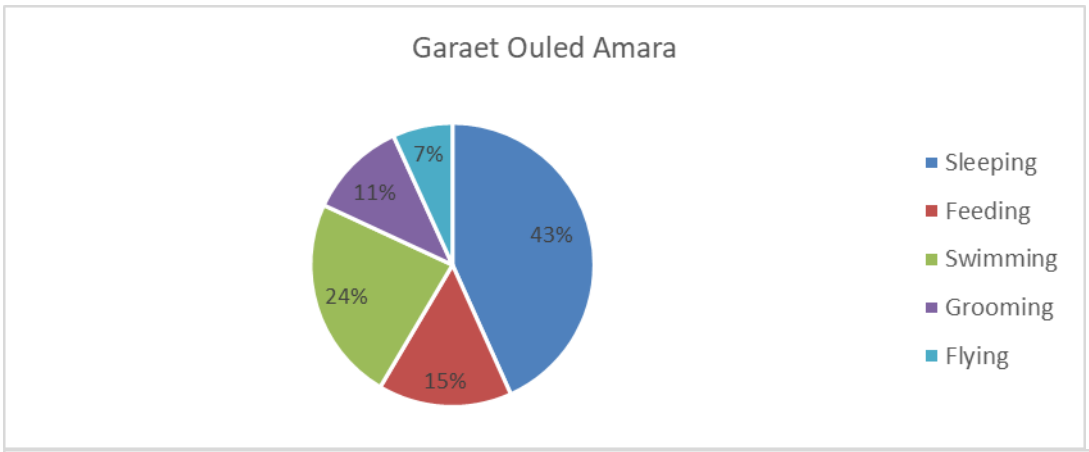
Monitoring the behavior of the White-headed Duck in the Algerian High Plateaux shows that its diurnal time budget in some sites is dominated by sleeping activity (G. Timerganine, G. Ouled Amara, C. El-Hodna and Boughezoul D.) and in others by feeding activity (Bougara D.). The results obtained during our study in the following sites: G. Timerganine, G. Ouled Amara, C. El-Hodna and Boughezoul D. are not in agreement with those found in the wetland eco-complexes of El-Kala National Park (Boumezbeur, 1993), those obtained by Metallaoui *et al*, (2009) at Garaet Hadj-Tahar (Skikda) and in the high plateaux (Oudihat 2018) where feeding dominates the balance.

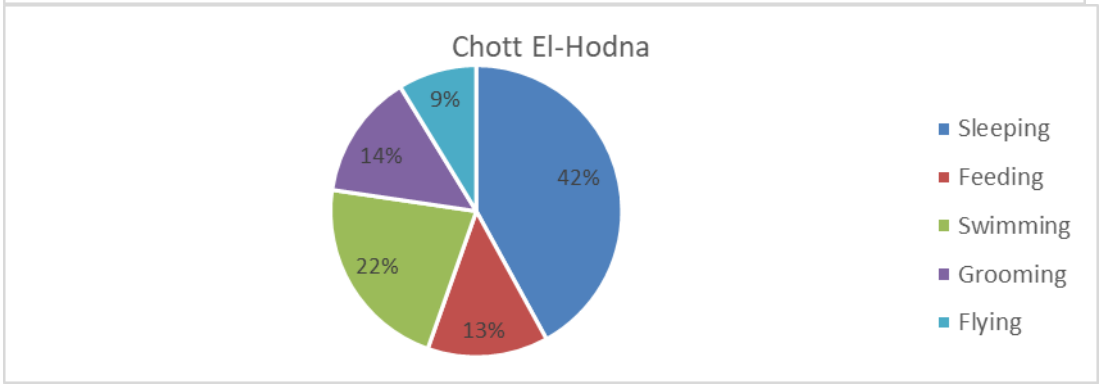
Another study has shown that there are differences between the wintering and breeding behavior of this duck. The first, naturally long phase involves two major activities: swimming and sleeping. During the breeding season, breeding birds feed frequently and often swim to actively search for food (Houhamdi *et al.*, 2009; Chettibi *et al.*, 2013).

The study by Lazli *et al,* (2014) carried out during the pre-nesting to post-nuptial moult period showed the existence of differences between the behavior of males and females during each period (pre-nuptial, breeding, post-nuptial). They showed that sleep activity dominates the males' time budget. The females' time budget is dominated by feeding in the pre-breeding and breeding periods, but sleep takes over in the post-breeding period, which is the case in our study. These sites are, of course, ideal for this Anatidae species (Lazli *et al.*, 2014).

Feeding activity by White-headed Duck at the Bougara dam is observed in the water and throughout the wintering season using two methods: the first involves selecting food with the bird's beak on the surface of the water when the bird is full, and the second involves dipping the bird's head into the water. This site therefore represents a feeding ground for this species.



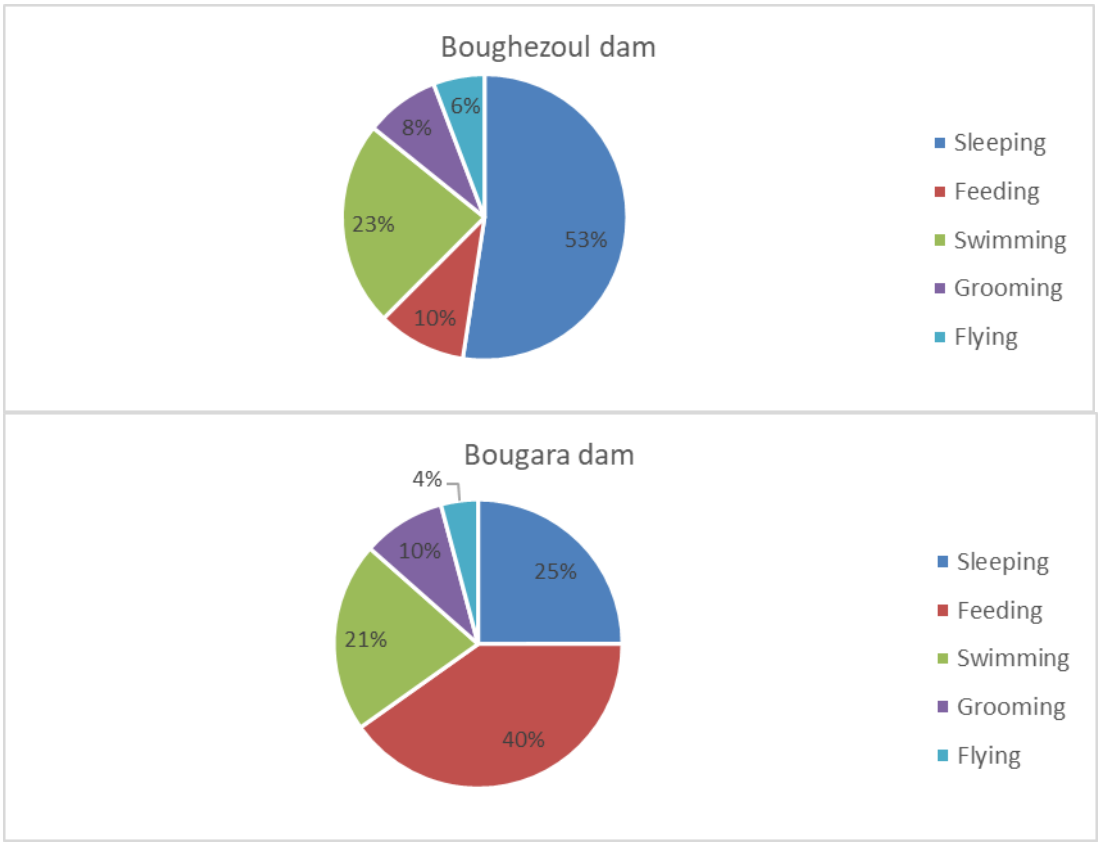



**Fig. 42. Assessment of diurnal activities rhythms of the White-headed Duck**

### 3.1 Monthly monitoring of activities:

In this section, we present the results obtained month by month from the diurnal activity rhythms of the White-headed Duck, which were marked by diverse variation throughout the months at the five study sites. The analysis showed that at the beginning of September, sleep was more or less stable throughout the year at the four study sites (Garaet Timerganine, Garaet Ouled Amara, Chott El-Hodna and Boughezoul Dam) (Fig. 42). Feeding was recorded throughout the observation period with more or less balanced values, with a slight increase from June onwards, which is synonymous with an increase in energy requirements, likely associated with reproduction, chick rearing, and molting processes.

Sleep is a major activity in water birds (Tamisier & Dehorter 1999) and is the best way to conserve energy (Tamisier 1972a, 1972b, 1972c). Our study revealed that the main daily activity of these ducks during the wintering period is sleep, which corroborates with the results of Chettibi (2014) and Green *et al.,* (1999) who also reported that sleep was the dominant activity.

The monthly trend in White-headed Duck activity rates measured in the highlands is illustrated in Figure 43 Generally speaking, we note that variations are low at all sites. The

graphs below illustrate that sleeping is the dominant activity at almost all sites, with the exception of the Bougara Dam, where feeding outweighs all other activities (Fig. 44).

During our survey, we noticed that this species spends a lot of time swimming and feeding together. Swimming is synonymous with escape; unlike other Anatidae, when this duck senses a threat or is attacked by a predator, it swims away from the area (Houhamdi *et al.*, 2009). It's also similar to changing places to occupy other areas than other waterfowl found at the same time, particularly Common Pochard *Aythya ferena*, which are often more numerous.

Preening is often seen mainly during the wintering season (Fig. 45), as feather care is important for the birds. It enables them to prepare for their prenuptial migration and to prepare for the new breeding season (Tamisier & Dehorter 1999, Houhamdi & Samraoui 2001, 2003, 2008, Khemis *et al.*, 2017, Bouchaala *et al.*, 2017a, b).

Flying is observed at all study sites, with low percentages throughout 2021/2022 (Fig. 46). This activity is caused by disturbance, grazing animals or predators.

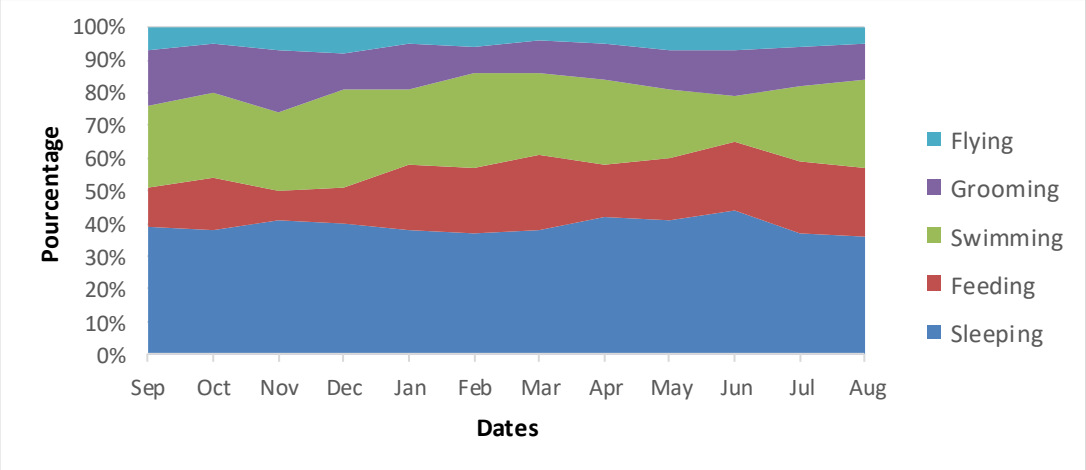



**Fig. 43. White-headed Duck diurnal activities trends at Garaet Timerganine.**

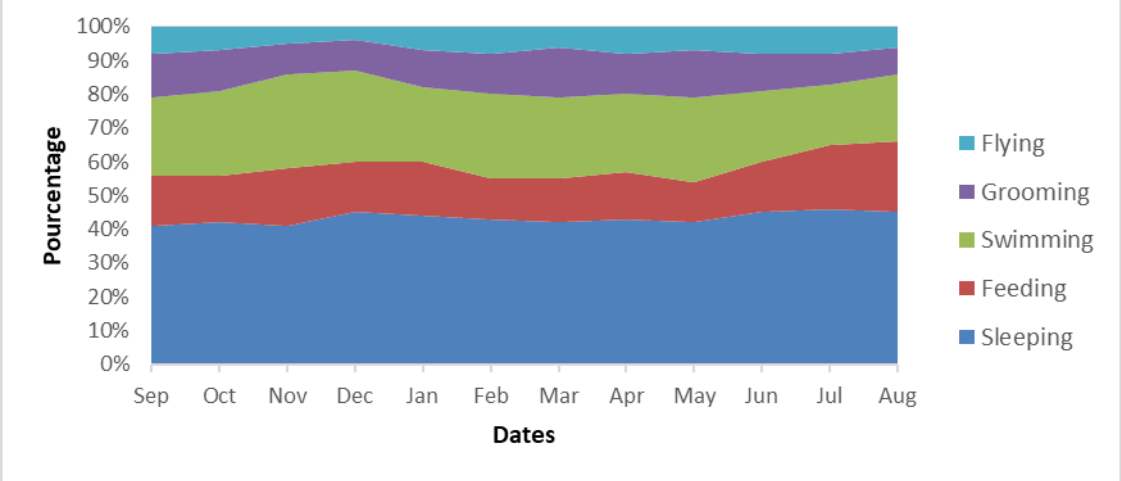



**Fig. 44. White-headed Duck diurnal activities trends at Garaet Ouled Amara**

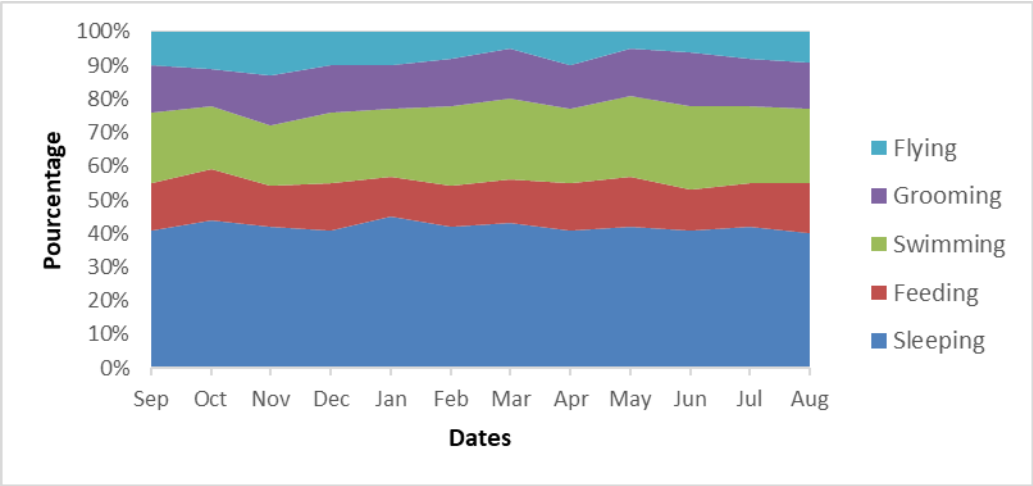



**Fig.45. White-headed Duck diurnal activities trends at Chott Hodna.**

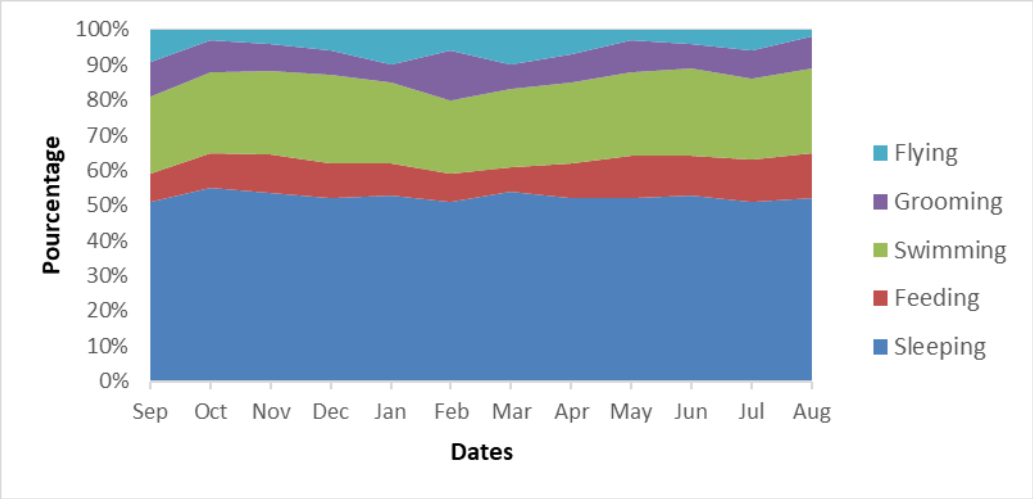



**Fig. 46. White-headed Duck diurnal activities trends at Boughezoul Dam**

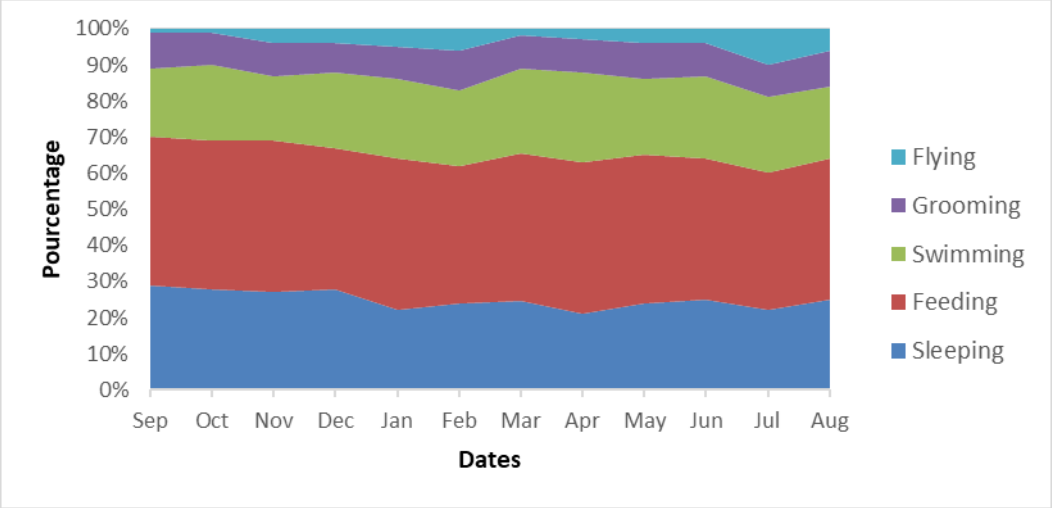



**Fig. 47. White-headed Duck diurnal activities trends at Bougara Dam.**

## 4. Multivariate statistical processing

Multivariate statistical processing using factorial correspondence analysis (FCA) on balances of diurnal activities rhythms of the White-headed Duck in two wetlands: Garaet Timerganine and the Bougara dam reveals a temporal organization of its activities. We observe a distribution of activities characterizing each period, even each month (Fig. 47). In fact, these graphs show us periods.

At Garaet Timerganine and on the 1x2 factorial plane of the CFA, which holds 86% of the information (ordinate factor 1: 56% and abscissa factor 2: 31%), we observe three more or less distinct periods: the first is made up of September and October, which is characterized by the observation of the arrival of the first wintering individuals at Garaet. These are mainly engaged in sleeping activities (Fig. 47). This activity is often combined with flying and grooming (Fig. 47). The second period runs from November to April. During the first two months, November and December, we observe intense swimming activity (Fig. 47). Then, from January to April, this activity is noted, but at lower rates. During this period, we witness the formation of small groups and pairs in preparation for the nesting of this species in this wetland. Finally, the third and last period takes place in May, June, July and August. During this period, feeding activity is observed. This diurnal feeding helps to prepare for the breeding season, and also allows the breeding birds to regain their energy (Fig. 47).

At the Bougara Dam, the factorial map of the FCA also shows three less distinct periods, with the same inertia rate of 86%. Sleep characterizes the first occupants of the dam, who indulge in daytime sleep-in order to recuperate the energy used during post-nuptial migrations (Fig. 48). This activity is mainly recorded during the first four months of the study (September to December). The second period covers the months from January to May. During this period, feeding activity dominates. On this daytime feeding ground, these fattening favours good energy recovery, enabling good preparation for the new breeding season. Finally, during the three remaining months (June, July and August), when the water level is at its lowest, we observe a reduced number of nesting birds grooming and flying to reposition themselves (Fig. 48).

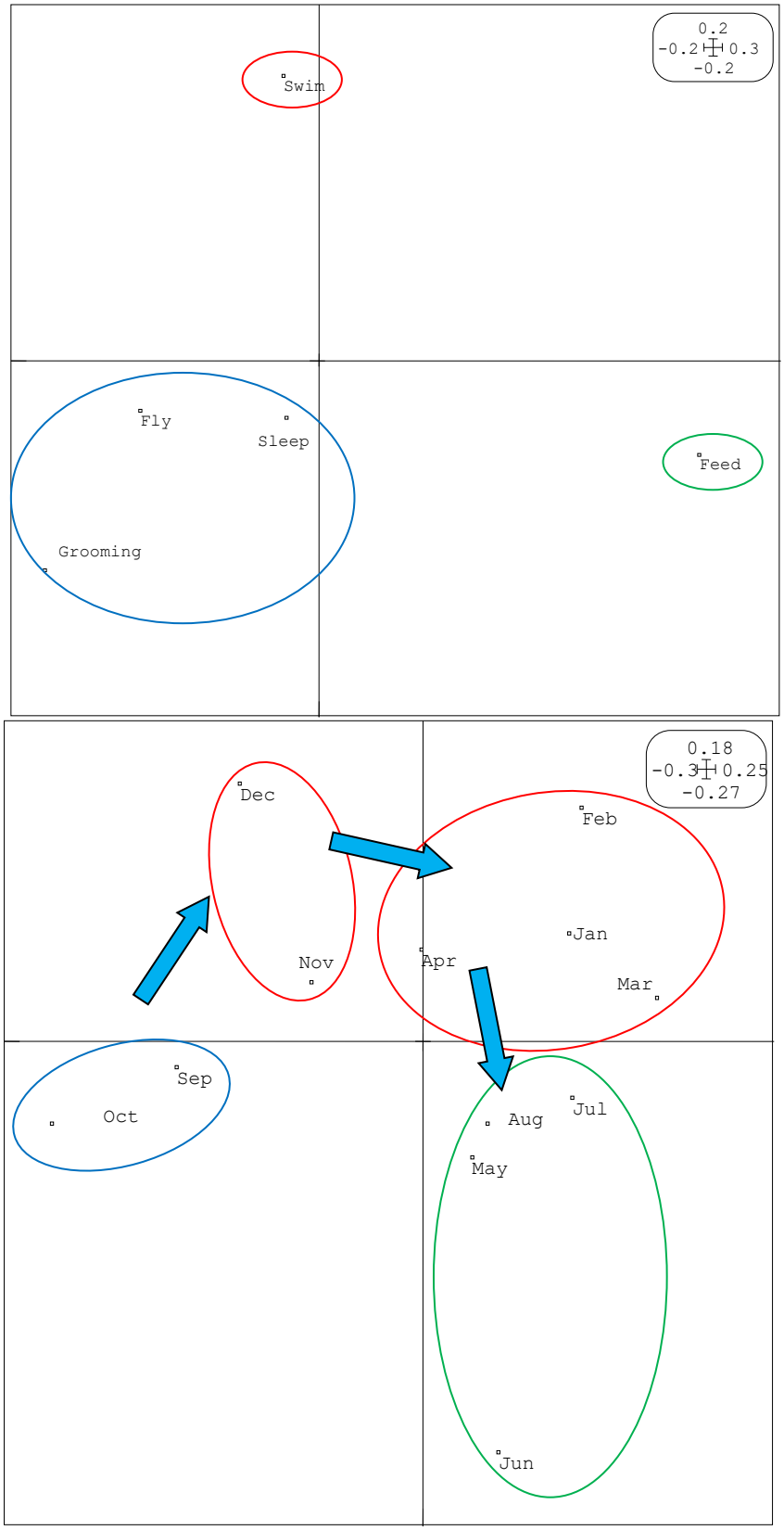



**Fig. 48. 1x2 factorial plane of the Correspondence Analysis (diurnal activities rhythms ofthe White-headed Duck *Oxyura leucocephala* in the Garaet Timerganine (September 2021/August 2022). Axes of inertia: 0.56, 0.31, 0.09& 0.02.**

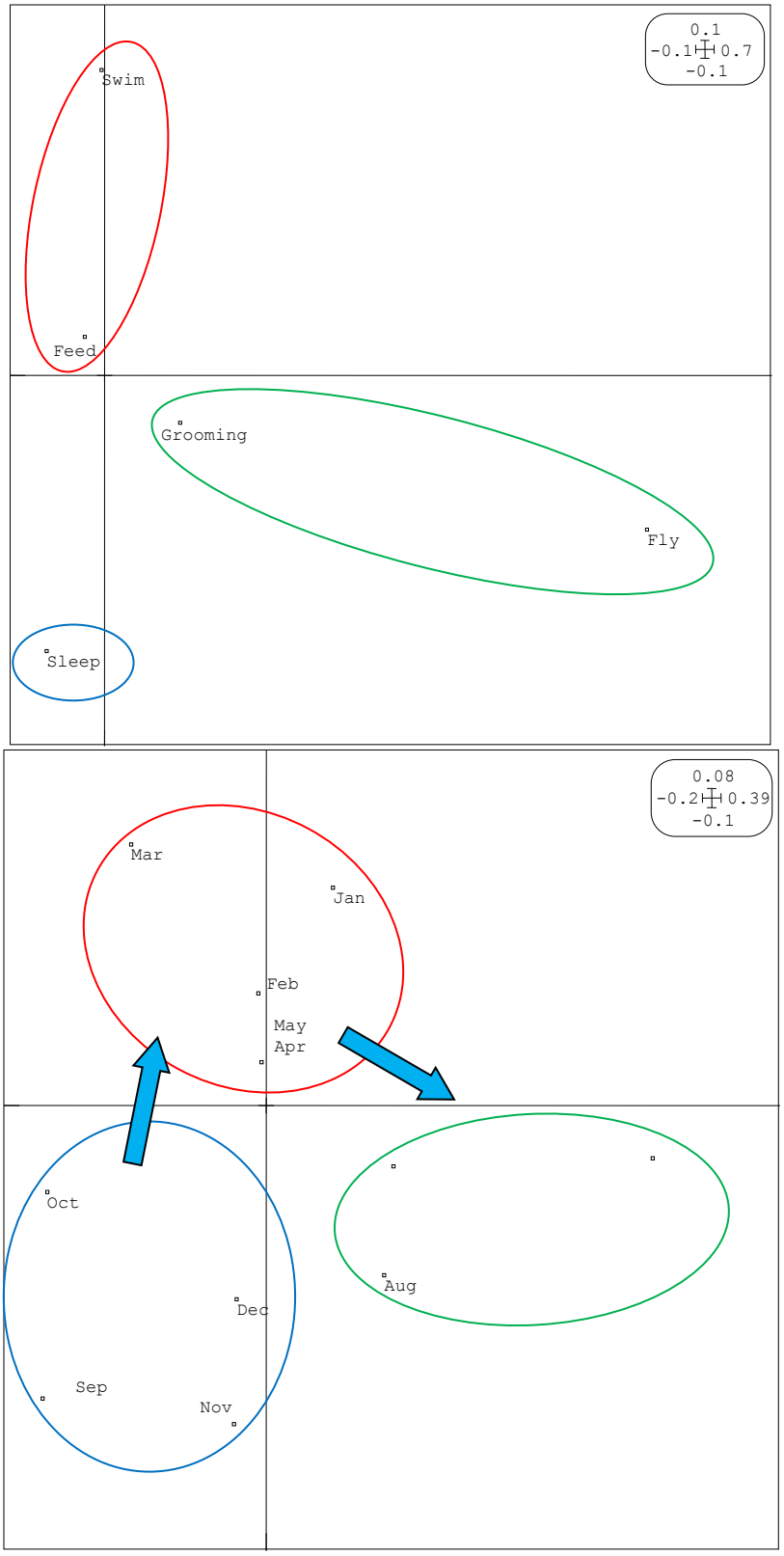
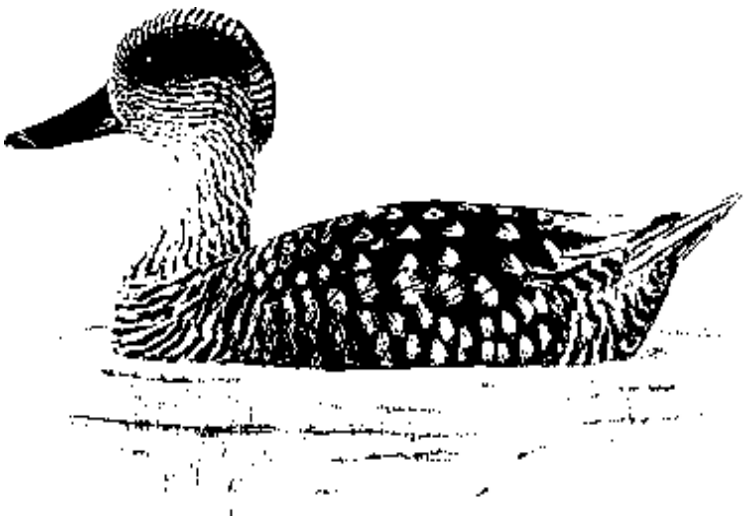



**Fig. 49. 1x2 factorial plane of the Correspondence Analysis (diurnal activities rhythms of the White-headed Duck *Oxyura leucocephala* in the Bougara Dam (September 2021/August 2022). Axes of inertia: 0.77, 0.15, 0.03& 0.02.**

# Chapter 5: Ecoethology of the Marbled Teal *Marmaronetta angustirostris*



## 1. Phenology of the Marbled Teal in Chott Oum Raneb

This teal species is known for its mottled hue, vulnerability, shyness and gregariousness, and makes its home in intermediate-sized, shallow bodies of water with a certain amount of vegetation, as well as marshy areas (Charchar *et al.,* 2019). Considered a rare species, it has undergone a rapid decline over the last few decades, due to massive degradation of breeding areas, hunting pressure and anthropogenic action in certain local and global water bodies (Aberkane *et al.,* 2013, 2014).

Algerian populations of Marbled Teal *Marmaronetta angustirostris* are among the least studied in the species' geographical range. Population estimates have never been carried out on a regular basis, and ecological monitoring has only been carried out in environments with a high reception potential in the northeast (Charchar 2017), the southern Constantinois Highlands (Maazi 2009, Aberkane 2014, Aberkane *et al.,*2013, 2018) and the Oued Righ Valley in the country's northern Sahara (Bouzegag 2008, 2015).

To this day, even if for geopolitical reasons we don't know the exact numbers of Marbled Teal, specialists remain vigilant and mobilized for the biomonitoring of this bird totally infodicated to aquatic environments (Aberkane *et al.,*2018).

Monitoring of the Marbled Teal population over three consecutive seasons (2020-2021, 2021-2022 and 2022-2023) in the wilaya of Ouargla at the Chott Oum Raneb Ramsar site reveals its regular presence, with numbers fluctuating between 11 and 212 individuals for the first season, 43 and 240 individuals for the second season and 63 and 215 individuals for the third season (Fig. 49).

We observed a maximum number of individuals during the month of October in all three study seasons (212 individuals, 240 individuals and 215 individuals for the 3 consecutive years) (Fig. 49).

During our study we noticed that the Marbled Teal is grouped into two populations, a breeding and local or autochthonous population and a migratory population which corroborates with the data published by Bouzegag *et al.,* (2013) in the Oued Righ Valley.

At the start of our study during 2020-2021, we noted that the number of individuals was 125, then the curve evolved to reach a peak in October, after which numbers gradually declined to just a dozen individuals (11) towards the end of the first year of study. In the second year, 2021-2022, the Marbled Teal colonized the lake from the start of the wintering season. Peak numbers were recorded in October, with 210 individuals, after which the curve declined, with numbers dropping off towards the end of April. During the third study season,

we observed a peak of 215 Anatidae in October, followed by a gradual decline towards the end of the season (Fig. 49).

This species is therefore considered to be a migratory bird that makes temporary stopovers in coastal water bodies (Charchar 2017). This observation corroborates previous findings (Metallaoui & Houhamdi 2008, 2010). Thereafter, these Anatidae continue their migration towards the wetlands of the Sahara and the High Plateaux, which serve as both wintering and breeding sites for the Marbled Teal, as various studies have demonstrated (Isemmann & Moali, 2000, Aberkane *et al.*, 2013; Bouzegag *et al.*, 2013).

Overall, population dynamics follow a bell-shaped (Gaussian) curve. At the start of occupation, numbers are low. They then gradually increase, generally peaking in October. Thereafter, there is a gradual decline until only sedentary individuals remain (Fig. 49).

From the point of view of abundance, the Kruskal-Wallis test reveals the existence of a very highly significant difference ($p<0.05$) between years and between months in this body of water (Figs. 50 and 51). The highest numbers were noted during the third year of monitoring and mainly during the months of October, showing the role that these two wetlands play in maintaining populations of this Anatidae.

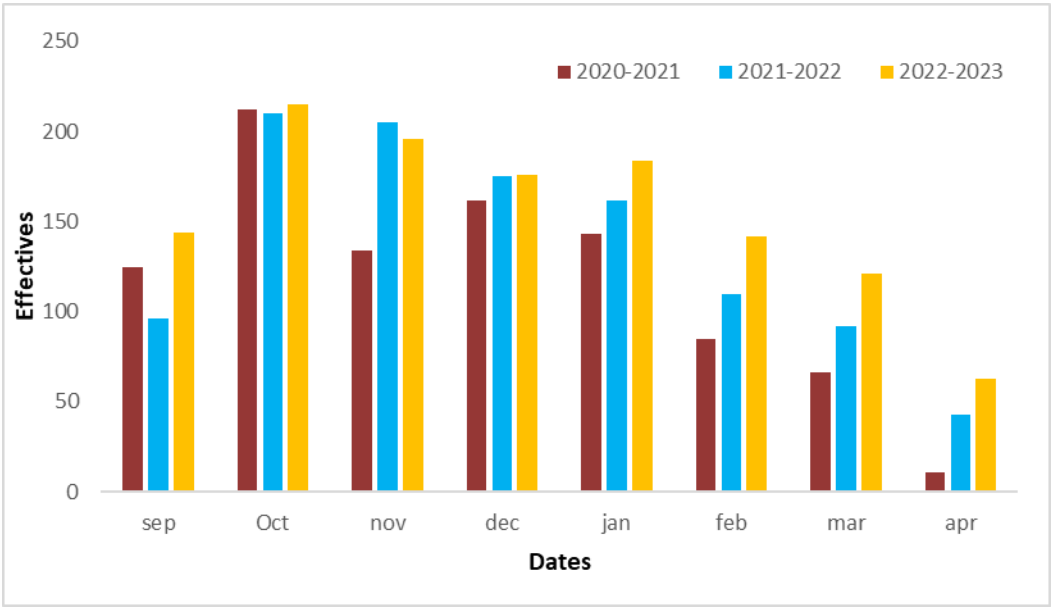



**Fig. 50. Changes in Marbled Teal numbers in Chott Oum Raneb**

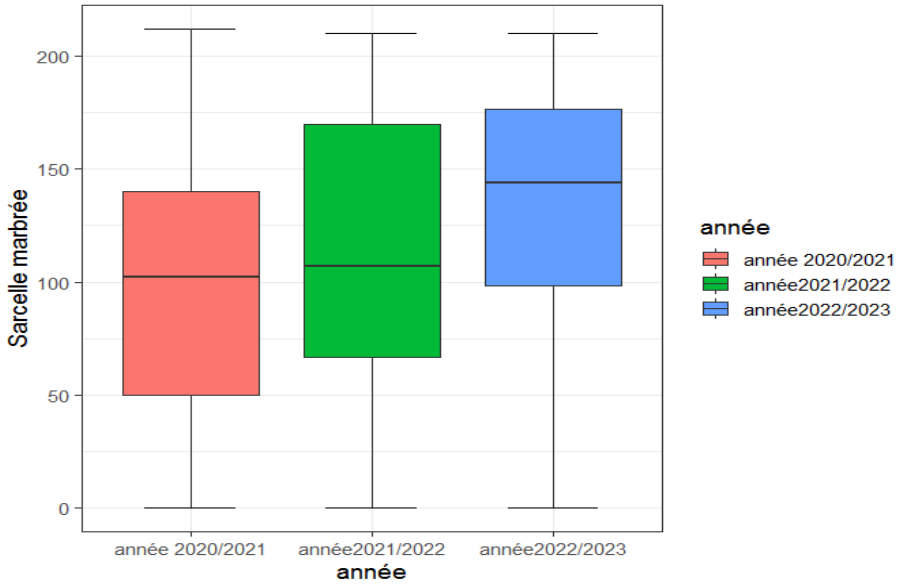



**Fig.51. Average number of Marbled Teal between three years**
**We used the following abreaviations: Marbled teal = Sarcelle marbrée, year= année.**

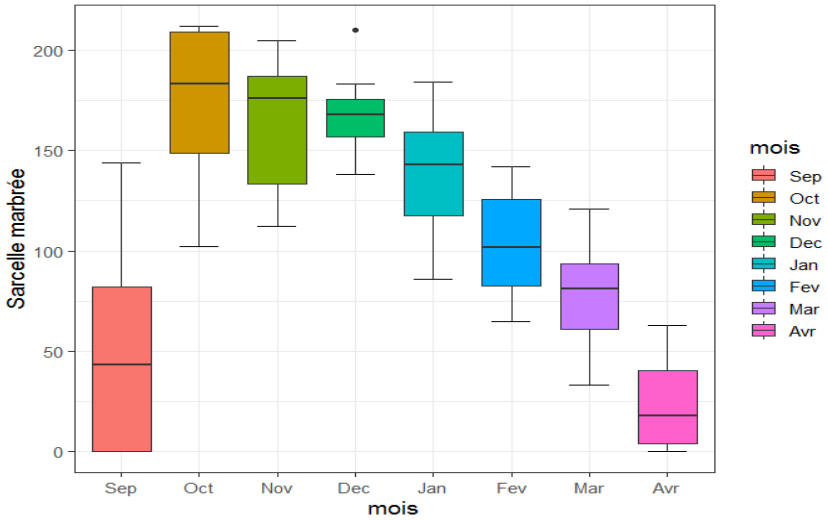



**Fig. 52. Evolution of Marbled Teal numbers**
**We used the following abreveations: Marbled teal =Sarcelle marbrée, months=mois.**

## 2. Spatial occupation of the Chott Oum Raneb by the Marbled Teal

The gregarious *Marmaronetta angustirostris* marbled teal are often seen in the center of the lake and on the small islands bordering the chott (Fig. 52). These places, far from disturbance, offer peace and quiet, and in fact most of the waterbirds frequenting the wetland during early winter, apart from the Greater Flamingo *Phoenicopterus roseus*, congregate here.

As the wintering period progresses, the water level in the chott becomes higher and marbled teal numbers gradually increase. They begin to colonize the northern and central sectors of the lake (Fig. 52). These Anatidae, known for their gregarious behavior, gather

mainly in these two areas and subscribe to sleeping and/or swimming. Towards the end of the day, these ducks, in the company of Greater Flamingos, Ruddy Shelducks *Tadorna ferruginea 22*and numerous Redshanks and Scolopacids, gradually approach the main sewer feeding this Saharan wetland.

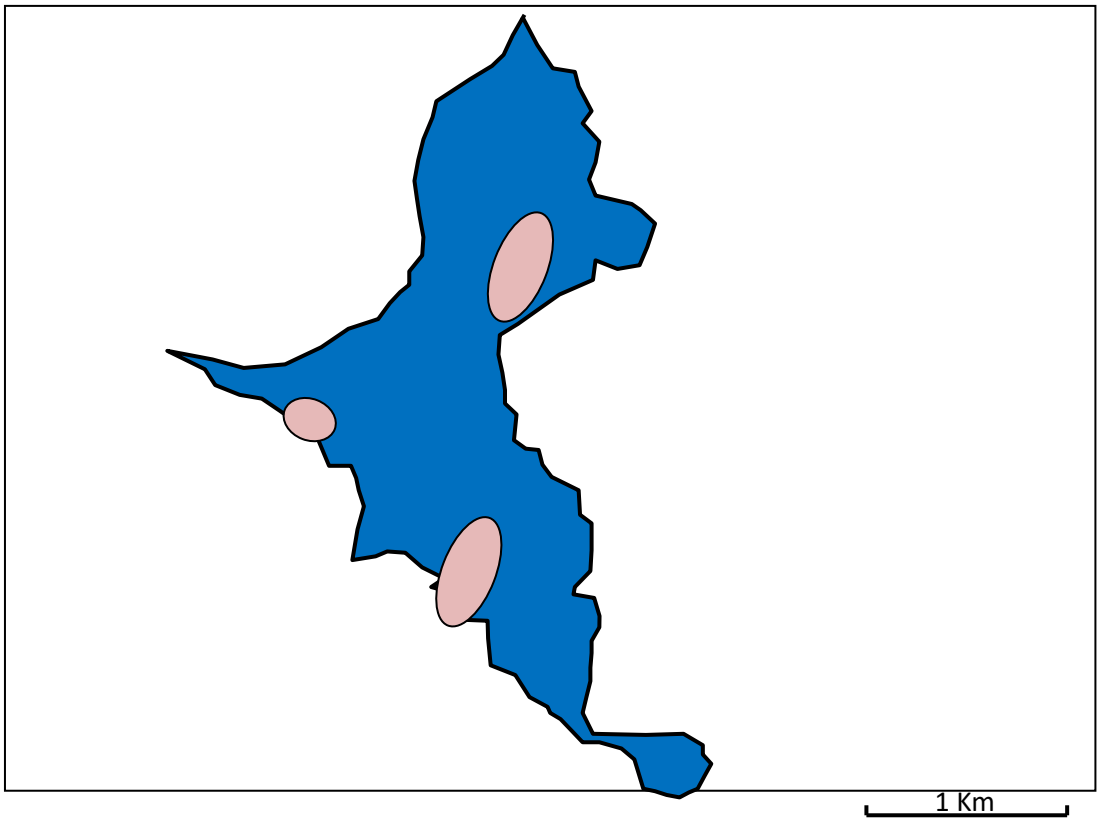



**Fig. 53. Spatio-temporal occupation of Chott Oum Raneb by Marbled Teal *Marmaronetta angustirostris***

**Photo 13. General view of Chott Oum Raneb Lake Fezzara (Taken by Ines Houhamdi on 2022)**

**3. Monitoring the activity rhythms of the Marbled Teal:**

Analysis of the diurnal activity rhythms of the Marbled Teal *Marmaronetta angustirostris* wintering at Chott Oum Raneb was carried out over three consecutive seasons. The study was carried out from September to April. Five of the marbled teal's main activities were studied: sleeping, grooming, swimming (known as comfort activities), feeding and flying. The results are as follows:

Monitoring of diurnal activity rhythms over three wintering seasons (2020-2021, 2021-2022 and 2022-2023) showed that the main activity dominating the balance sheets was feeding, with percentages of 46%, 43% and 46% respectively for the three study seasons (Fig. 53). This situation can be explained by different needs at different times of the year. At the start of wintering, young birds (juveniles) need more time to feed and build up the reserves essential to their metabolism. Towards the end of this period, Marbled Teal need to accumulate as many resources as possible in anticipation of the breeding season, which is particularly demanding (Maazi 2009). However, our study revealed that this species generally favored diurnal feeding, confirming previous data from the Algerian Sahara (Bouzegag *et al.*, 2013). This observation contrasts with behavior observed in Spain and Morocco, where feeding is mainly nocturnal (Green and Hamzaoui 2000, Perez-Garcia *et al*., 2023).

Sleep comes second in the balance sheet, with percentages of 25% for 2020-2021, 27% for 2021-2022 and 2022-2023 (Fig.53). In this teal species, sleep ranks second only to feeding among the main activities. This activity, which plays a crucial role in Anatidae as demonstrated by several studies (Tamisier & Dehorter 1999, Houhamdi & Samraoui, 2001, 2003, 2008, Houhamdi *et al.*, 2008, 2009), is generally observed in the water for this particular species.

Followswimming occurs from the start to the end of the wintering season, with percentages of 19%, 14% and 20% respectively in the three seasons (Fig. 53). This behavior is mainly observed in the middle of the day (Houhamdi *et al.*, 2008, Maazi 2005, 2009). It concerns individuals that have moved away from the main group. These birds swim rapidly across the center of the water body, scouring its surface to find and rejoin their group.

Grooming or plumage maintenance is an activity observed mainly in the water and rarely on the banks of the chott. This activity accounted for 9%, 15% and 5% respectively in the three years (Fig. 53).

Flying plays a minimal role in this balance. It occupies the last position with less than 2% of this diurnal time budget (Fig. 53). This behavior is frequently triggered by two types of

disturbance. On the one hand, it can be triggered by the presence of diurnal predators, notably the Marsh Harrier (*Circus aeruginosus*). Secondly, it can be initiated by the flight of a bird belonging to another Anatidae species, a phenomenon known as contagious flight.

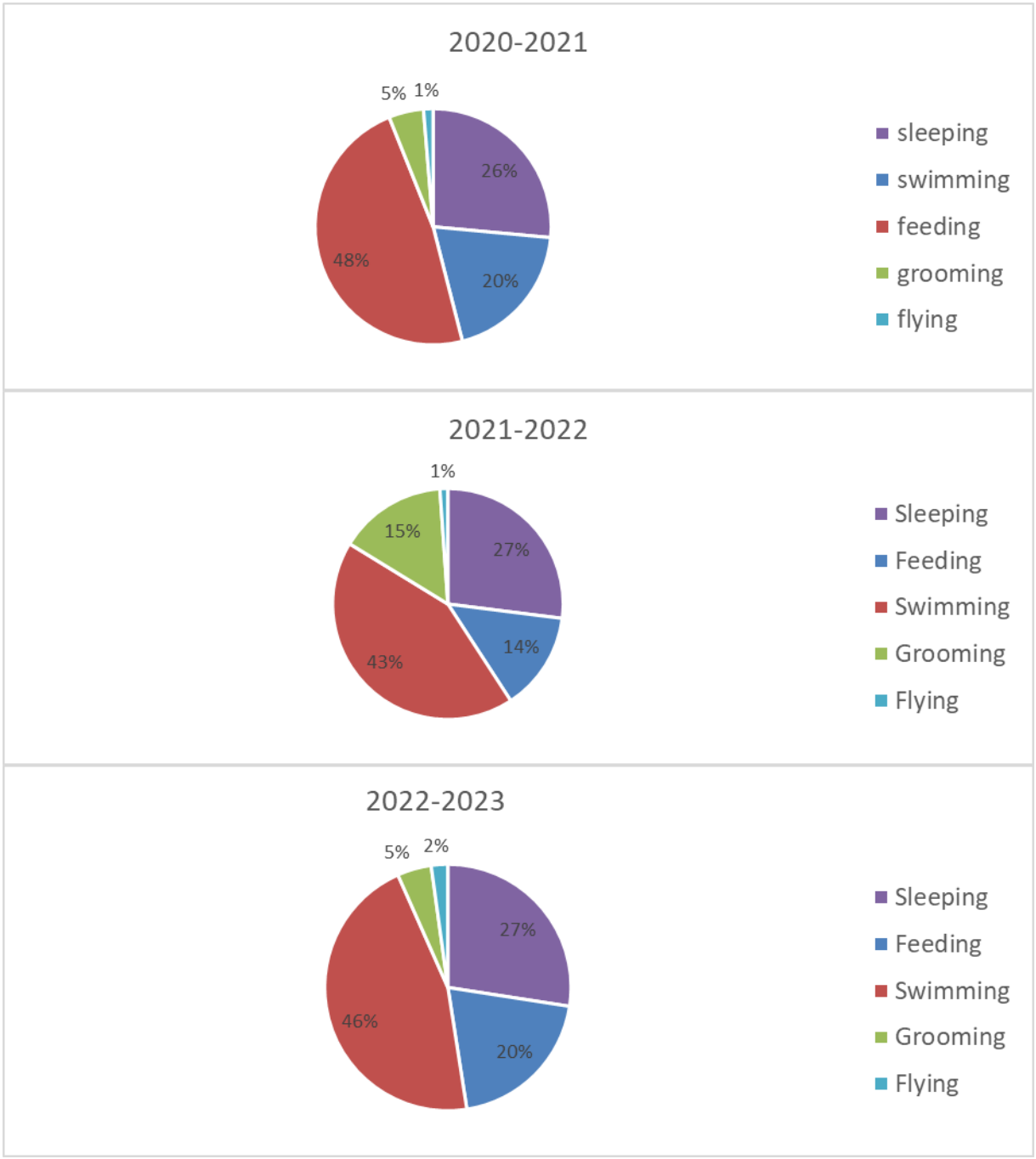



**Fig.54. Diurnal activities rhythms of marbled teal *Marmaronetta angustirostris* at Chott Oum Raneb**

### 3.1. Variations in the diurnal activity rhythms of the Marbled Teal *Marmaronetta angustirostris*

Monitoring the rhythms of these diurnal activities over the wintering season for three successive years, 2020-2021, 2021-2022 and 2022-2023, shows us that feeding, with an annual average varying between 48.5% and 50.25%, is the most important activity. This vital activity, which ranks first in all three balances, increases progressively from the start of the wintering season to the end (Fig.54). According to the study by Bouzegag (2013), it was noted that these ducks prefer to feed by tilting their bodies (75%) rather than searching for food by dipping their heads (25%). Maximum values were recorded during the month of March in the first year and during the month of April in the remaining two years. Two distinct peaks of activity were observed. The first, recorded at the beginning of February, corresponds to a period when individuals need to replenish their energy reserves depleted by migration. The second peak, observed in April, coincides with the teal's preparation for departure. At this time, they intensify their feeding for two reasons: firstly, to accumulate sufficient energy in anticipation of the long migratory journey ahead, and secondly, to prepare for the nesting season, which promises to be particularly physically demanding (Green & Hamzaoui 2000, Aberkane *et al.*, 2013, Charchar *et al.*, 2019).

Sleep, the second activity observed in Marbled Teal, occurs throughout the wintering season, with peaks recorded in September and minimum values observed in April, for all three years of monitoring, with annual averages of 27.75%, 30.5% and 29.87% in 2020/2021, 2021/2022 and 2022/2023 respectively (Fig. 55 et 56). In Anatidae, sleep is often considered the best means of energy conservation (Tamisier 1972a, 1972b and 1972c). For Anatidae (including dabbling and diving ducks), rest and sleep during the day are essential after long migratory journeys. These species tend to congregate, whether in the water, on banks, or in the intertidal zones of wetlands (Amorabda *et al.*, 2015, Merzoug *et al.*, 2015, 2015, Abdi *et al.*, 2016, Tabouche *et al.*, 2016).

Swimming peaks were recorded during the months of December and January in all three seasons of observation, with annual averages fluctuating between 15.65% and 21.87%. This activity is often associated with feeding activity in the majority of Anatidae, or with regrouping with the rest of the group (Fig. 55 and 56).

Grooming and plumage maintenance is an activity observed throughout the study period (Fig. 55 and 56). It ranks fourth in this assessment, with annual averages of 10%, 17.12% and 4.87% in 2020/2021, 2021/2022 and 2022/2023 respectively. The maximum was noted during the month of March for the first year, during the month of January for the second year of

observation, and during the month of April for the last year. This observation highlights a specific need among migratory birds (Tamisier & Dehorter 1999, Houhamdi 2002). This group, made up of both young individuals (juveniles) and adults having just completed their moulting period, feels a heightened need to take care of their plumage. This behavior reflects the crucial importance of feather maintenance for these birds at this particular stage of their life cycle.

Swimming is rarely seen during the wintering season, with small peaks in September for study years 2020-2021 and 2021-2022. In 2022-2023, we observed flights throughout the study period, with the exception of January. For all three years of monitoring, we observed an increase of between 1.25% and 2.37% (Fig.54, 55 and 56). This is explained by their arrival on the water and by the fact that they try to regroup with the rest of the group, as teal swim when they have satisfied their needs for food, sleep, grooming and when they still have free time (Tamisier 1972b, Aberkane 2013).

Studies on the time budget of the Marbled Teal *Marmaronetta angustirostris* are rare, both worldwide and in the Western Palearctic region (Cramp & Simmons 1977, Maazi 2005, 2009, Bouzegag *et al.,* 2013, Aberkane 2014, Charchar 2017). The majority of existing studies have focused on the breeding ecology of this species (Green 1998).

In Algeria, only three theses have been devoted to studying the ecology of the Marbled Teal: Bouzegag (2013) in the Oued Righ Valley, Algerian northern Sahara, Maazi 2009, Aberkane (2014) in the Eastern Algerian Highlands and Charchar (2017) in the Guerbes-Sanhadja wetlands of the Eastern Algerian coastline) and thus this modest work brings new data on the ecoethology of this vulnerable species in wetlands located further south in the Sahara where difficulties of movement and climate make these environments not very accessible from this specific region of Algeria.

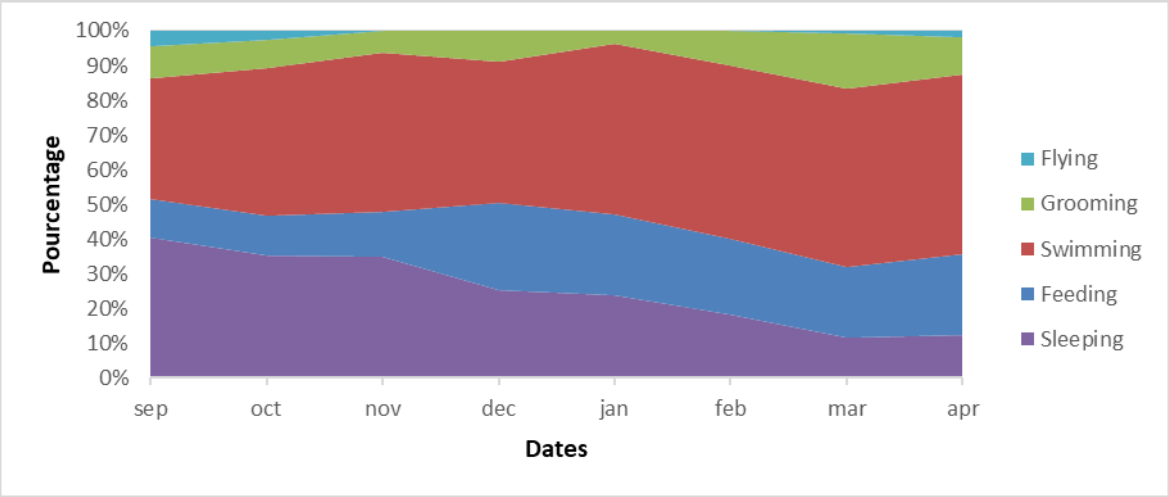



**Fig. 55: Evolution of the diurnal activities of marbled teal at Chott Oum Raneb (year: 2020/2021).**

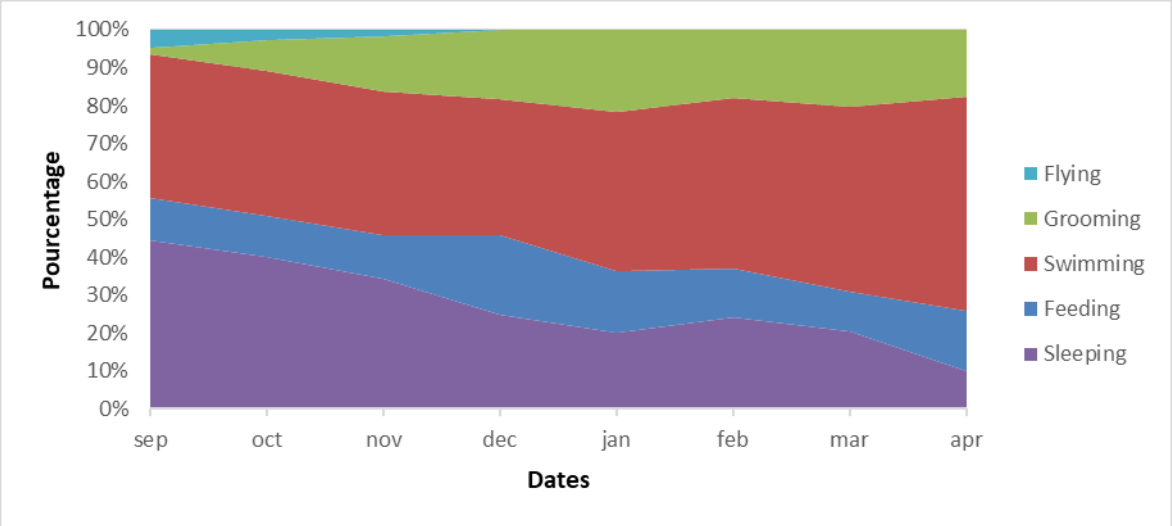



**Fig. 56. Evolution of the diurnal activities of marbled teal at Chott Oum Raneb (year: 2021/2022).**

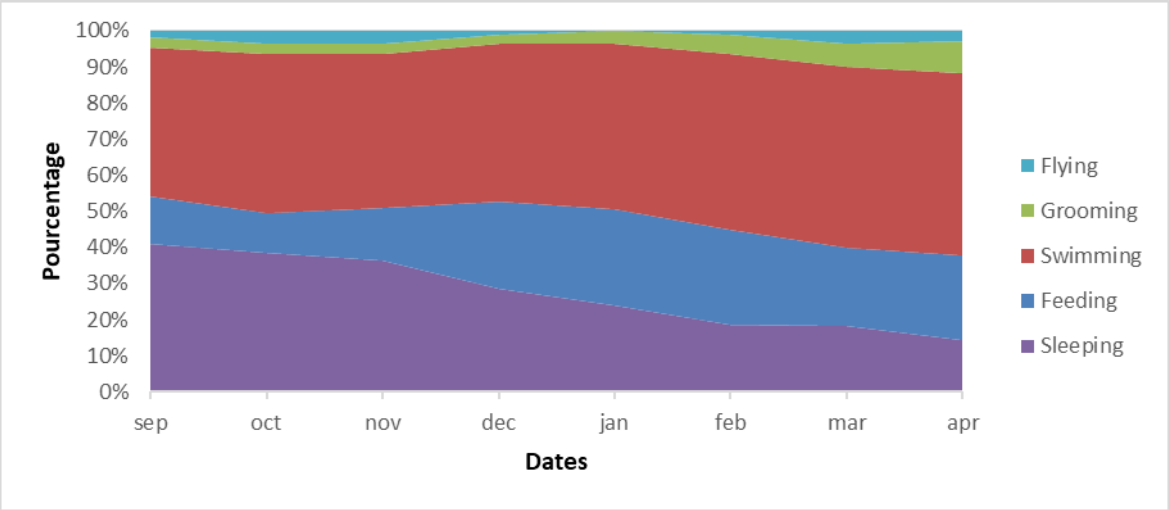



**Fig. 57. Evolution of the diurnal activities of marbled teal at Chott Oum Raneb (year: 2022/2023).**

### 3.2. Annual variations in daytime activity of the Marbled Teal

**Sleeping:** Marbled Teal sleep activity was high in the second year of observation, 2021-2022, with a percentage of 30.5%, followed by 29.87% in 2022-2023 and 27.75% in 2020-2021. The activity is still preferred on the water and not on the banks of the lake (Fig. 57).

**Swimming:** Swimming generally takes place in the center of the lake, and was at its best in 2022-2023 with a percentage of 21.87%, followed by 20.5% in 2020-2021 and 15.62% in 2021-2022 (Fig. 57).

**Feeding:** The first year of observation, 2020-2021, saw the highest percentage of feeding activity (50.25%), followed by 2022-2023 (49.87%) and 2021-2022 (48.5%). Despite its nychthemeral rhythm for all Anatidae species, this activity experienced high values for this teal species (Fig. 57).

**Grooming:** ranks fourth. This comfort activity ranks after swimming with a percentage of 17.12% during the second year of the 2021-2022 study, followed by the 2020-2021 year with a percentage of 10% and finally the 2022-2023 year with a percentage of 4.87% (Fig. 57).

**Flying:** flying ranks last after grooming, and was rarely observed during the study period, with low percentages ranging from 1.37% in 2020-2021, 1.25% in 2021-2022 and 2.37% in 2022-2023. It is significant in the last year of the study (Fig. 57).

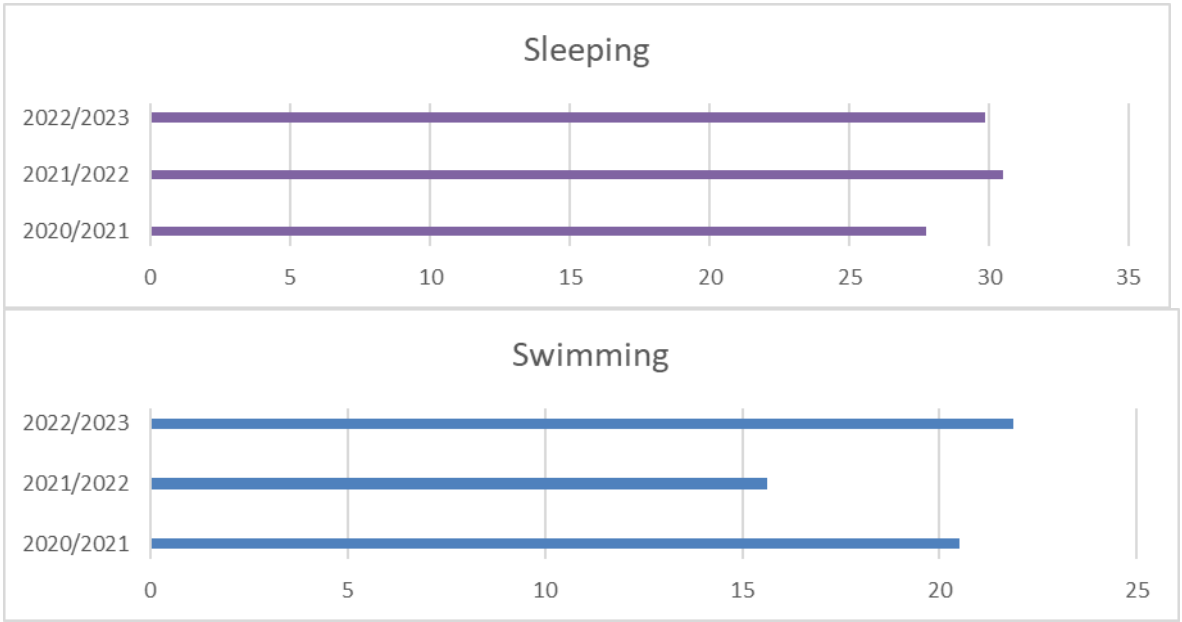



**Fig. 58. Comparison of activities over the three years of the study**

## 4. Multivariate statistical processing

In the multivariate analysis of these data collected over the entire study period, i.e. over the three wintering seasons (2020/2021, 2021/2022 and 2022/2023), we considered only the 1x2 factorial map of the CFA, which holds 88% of the information. The factorial map shows, on the one hand, that the wintering season is subdivided into three more or less distinct periods and, on the other hand, there is a clear separation between the post-nuptial and pre-nuptial periods (Fig. 58).

In fact, the first period (September and October) represents the start of wintering, when we record fairly frequent flight activity by the first occupants of the lake (Fig. 58). During this post-nuptial period, the water level is at its lowest and we mainly observe eclipsing individuals. This activity can be summed up as frequent flights, represented essentially by repositioning flights and flights induced by the flight of a single bird (marbled teal or another species of Anatidae or Greater Flamingos), which is often contagious and

triggers the flight of all adjacent groups of birds. These are short-lived, and the birds quickly return to the chott.

The second period, mainly represented by the months of November, December and January, is characterized by the recolonization of the lake by Marbled Teal and other waterbird species (Fig. 58). This period is known as wintering proper, and during this period the numbers of these birds gradually increase, with the majority of individuals engaging in the main activity (sleeping), which is noted with high rates especially during the month of November. This activity is often associated with morning and evening grooming and the maintenance of feathers damaged by trans-Saharan migration. This is especially true of the following two months, December and January.

The third period (February, March and April) marks the end of the wintering season. This is known as the pre-breeding period, when the birds display two main activities (feeding and swimming). These two activities are often combined in this species (Fig. 58). Feeding is mainly observed on the surface. This period also sees the start of pair formation. The Marbled teal, which have been gregarious throughout the seasons, begin to separate and form small groups of two to four individuals. Parade activity is also noted, but at very low levels.

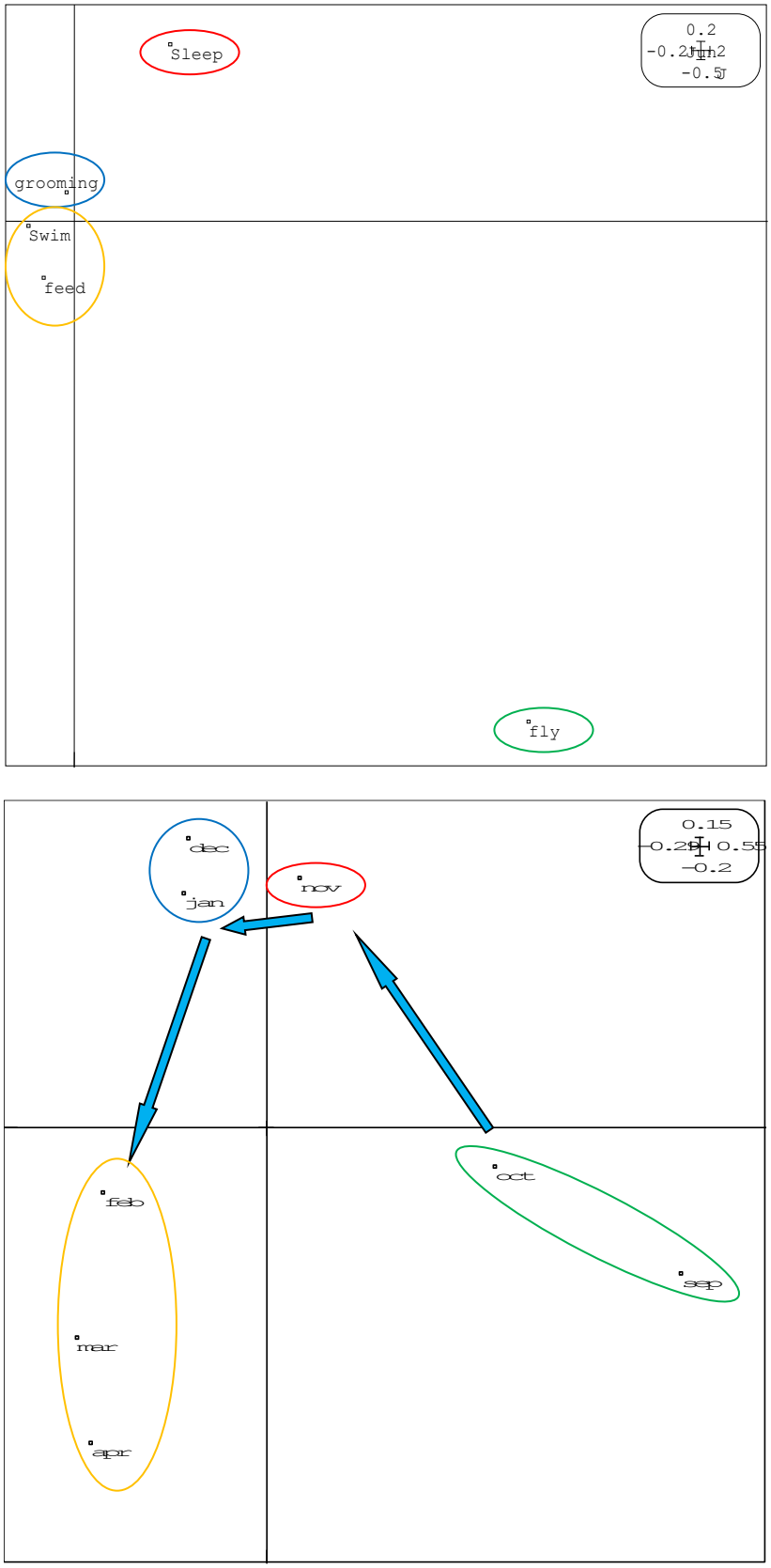



**Fig. 59. 1x2 factorial plane of Correspondence Analysis (Diurnal activities rhythms of Marbled Teal *Marmaronetta angustirostris* wintering in Chott Oum Raneb (2020/2023). Axes of inertia: 0.74, 0.14, 0.08 & 0.03.**

# Chapter 6: Effect of abiotic descriptors on aquatic avifauna

**1. Study of water quality in wetlands**

Analysis of physicochemical and bacteriological parameters reveals significant variations between the four wetlands studied (Fig. 59). The results show a marked gradient in electrical conductivity (EC), with significantly higher values in Chott Gadaine (site 4), suggesting greater mineralization of the water in this zone. This phenomenon is consistent with the observations of Hacini *et al,* (2016) in their study of the Chott Merouane in Algeria, where they also noted high variability in mineralization. Major ion concentrations (Cl., $Mg^{2+}$, $Ca^{2+}$) follow a similar pattern, particularly high in the Chott Gadaine, in line with the findings of Boudibi *et al.*, (2019) on wetlands in the Algerian Highlands. Turbidity shows notable variation between sites, being particularly high in Garaet Hadj-Tahar (site 2), potentially due to greater biological activity or sediment inputs (Fig. 59).

With regard to nutrient parameters, phosphate ($PO_4^{3-}$) and nitrite ($NO_2^-$) concentrations show significant inter-site variations. These variations are reminiscent of those observed by Aliat *et al,* (2016) in their study of wetlands in northeast Algeria, where they highlighted the influence of agricultural activities on nutrient levels. Ammonium levels ($NH_4^+$) are particularly high in site 1 (Boussedra Marsh), which could indicate organic pollution, a phenomenon also documented by Reggam *et al.*, (2015) in their study of wetlands in the El-Kala region.

These results highlight the complexity and variability of the wetland ecosystems studied, with several factors possibly explaining these variations. Geological and hydrogeological influences seem to play a predominant role, particularly in the case of Chott Gadaine. This observation concurs with the findings of Benziane *et al,* (2012) on the importance of local geological features in the chemistry of Algerian chotts waters. The high mineralization observed could be attributed to intense evaporation and water-rock interactions, as demonstrated by Djabri *et al.*, (2014) in their study of eastern Algerian aquifers.

Anthropogenic impact is also significant, as evidenced by the high levels of nutrients and bacterial contamination observed at some sites. These results align with the work of Bouchaala *et al,* (2019) on the Guerbes-Sanhadja wetland eco-complex, which documented the increasing influence of human activities on water quality. Spatial variations in bacteriological parameters could be linked to the proximity of urban or agricultural areas, a phenomenon previously described by Bouzid and Djelita (2012) in their study of the Seybouse basin.

From an ecological point of view, the variability of physicochemical parameters between sites suggests the existence of distinct ecological niches, as emphasized by Samraoui and de Bélair (1997) in their pioneering work on wetlands in northeastern Algeria. According to recent studies by Bouldjedri *et al,* (2011), these differences may have important implications for local biodiversity, particularly for aquatic avifauna.

Although this study provides valuable information, certain limitations need to be considered, notably the lack of representation of seasonal variability, a crucial aspect highlighted by Samraoui and Samraoui (2008) in their long-term study of Algerian wetlands. Future studies could benefit from a more detailed temporal analysis, as recommended by Metallaoui *et al,* (2010) in their work on the ecology of wetlands in north-eastern Algeria.

Although this study provides valuable information, certain limitations need to be considered, notably the lack of representation of seasonal variability in the data presented and the lack of historical data limiting our understanding of long-term changes. Future studies could benefit from a more detailed temporal analysis, the integration of additional biological indicators and the examination of relationships between measured parameters and local biodiversity.

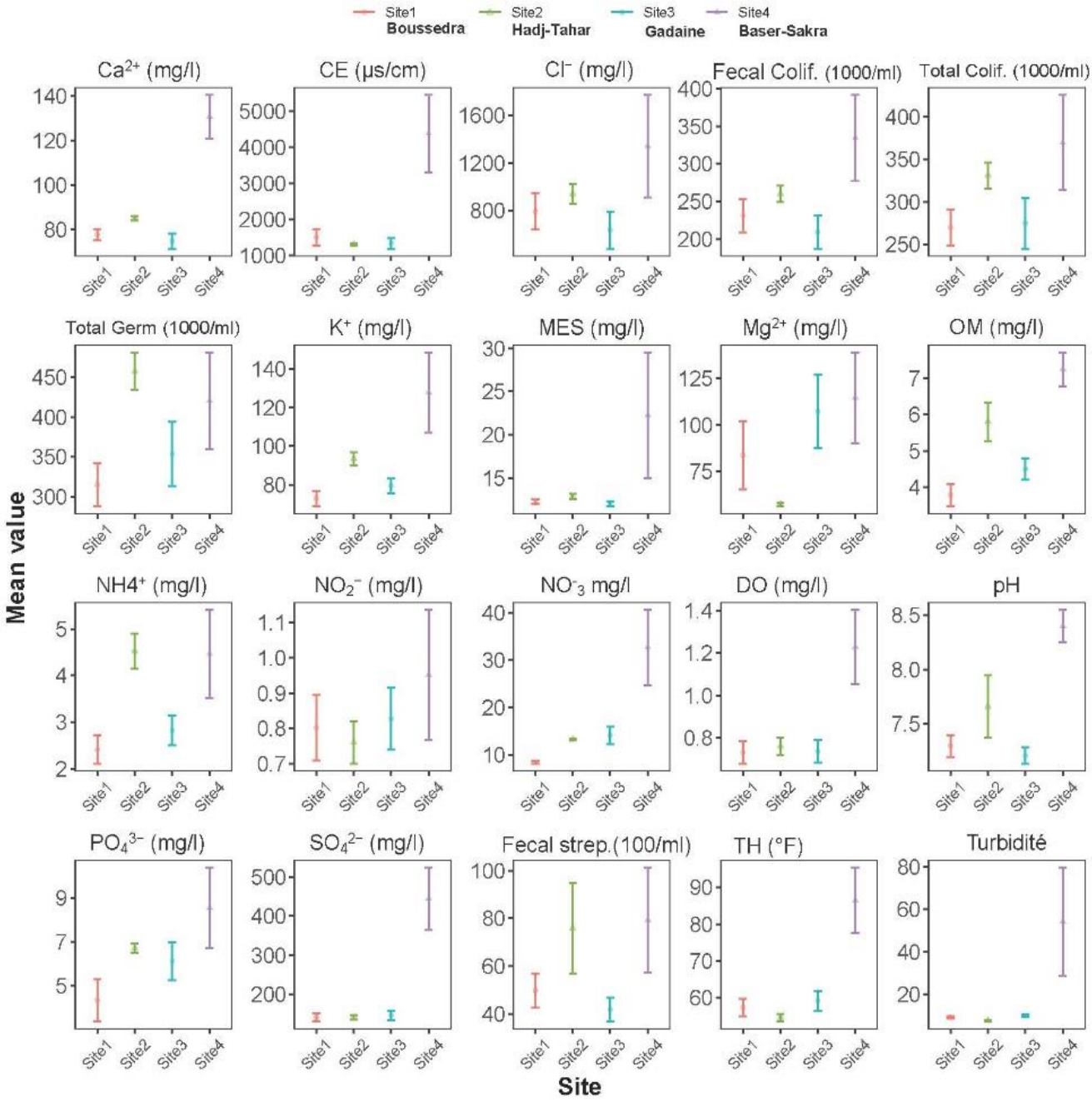



**Fig. 60. Physicochemical and bacteriological parameters in the four studied wetlands.** Abbreviations: site1: Boussedra marsh, site2: Garaet Hadj-Tahar, site3: Sebkhet Baze-Sakra, site4; Chott Gadaine. For each parameter, we show average and 95% confidence intervals. We used the following abbreviations: *Streptococcus fecalis*= Strep.fec; Faecal coliforms = Coli. fec; Total coliforms = Coli. tot; Phosphate ion = $PO_4^{3-}$; Total germs= Ger. tot; Ammonium ions =$NH_4^+$ ; Electric conductivity = CE; turbidity = turbidité; Temperature = TH; Nitrites = $NO_2^-$; Calcium ions = $Ca^{2+}$; Sulphates = $SO_4^{2-}$; Suspended matter in water = MES; Optical density = DO; Potassium = $K^+$ ; organic matter = OM; Chloride = $Cl^-$; Magnesium = $Mg^{2+}$.

## 2. Temporal pattern of bird abundance

Four of the five species were recorded throughout the year at all sites (Figure 1). Flamingos were only observed on the high plateaus (Sabkhet Bazer-Sakra and Chott Gadaine) throughout the monitoring period. There was a significant difference in bird numbers between sites for White-headed Duck ($\chi^2$=71.2, df=3, P< 0.0001) and Marbled Teal ($\chi^2$=30. 7, df=3, P< 0.0001), but not for Ferruginous Duck ($\chi^2$=3.52, df=3, P= 0.32) and Mallard Duck ($\chi^2$=4.0, df=3, P=0.25) (Fig. 60). Comparing coastal and highland sites, we found a significant difference in the number of birds in White-headed Duck ($\chi^2$=58.9, df=1, P < 0. 0001), Marbled Teal ($\chi^2$=26.6, df=1, P< 0.0001), but not in Ferruginous Duck ($\chi^2$=3.09, df=1, P= 0.07) and Mallard Duck ($\chi^2$=2.45, df=1, P=0.11) (Figure 1a).

The greatest abundance was generally recorded during the wintering season, followed by a sharp decline in numbers in spring and summer. For all species, the change in spring abundance was between 71.6% and 98.8% compared with winter abundance (Tab. 3). The seasonal difference in abundance was significant for all species (Marbled Teal$\chi^2$=14.8, df=3, P< 0.0001; White-headed Duck$\chi^2$=12. 5, df=3, P< 0.005; Ferruginous Duck$\chi^2$=36.7, df=3, P< 0.0001, Mallard Duck$\chi^2$=34.8, df=3, P< 0.0001) except for Greater Flamingo ($\chi^2$=2.6, df=3, P = 0.4).

**Tab. 3. Minimum and maximum abundance of the five studied species during the study period in four sites in Northeast Algeria. The change in abundance between winter and spring is also given in brackets as a percentage.**

| Wetland | White Headed Duck | Ferruginous Duck | Marbled Duck | Mallard Duck | Greater Flamingo |
|---|---|---|---|---|---|
| **Boussedra Marsh** | 44-155 (71.6%) | 48-450 (89.3%) | 2-26 (92.3%) | 12-750 (98.4%) | 0-0 (0%) |
| **Garaet Hadj Tahar** | 25-267 (90.6%) | 37-586 (93.7%) | 2-38 (94.7%) | 23-864 (97.3%) | 0-0 (0%) |
| **Sabkhat Bazer Sakra** | 2-82 (97.6%) | 12-523 (97.7%) | 8-76 (89.5%) | 23-1450 (98.4%) | 1860-10500 (82.3%) |
| **Chott Gadaine** | 3-25 (88%) | 6-480 (98.8%) | 8-83 (90.4%) | 42-956 (95.6%) | 650-8600 (92.4%) |

No difference in waterbird abundance was found between rural and urban wetlands for any species (Ferruginous Duck W = 299.5, P = 0.82, Marbled Teal W = 318.5, P = 0.53; White-headed Duck W = 330.5, P = 0.38; Mallard Duck W = 304.5, P = 0.74; Greater Flamingo W = 308.5, P = 0.66).

In the wetlands where the Greater Flamingo is present (Sabkhat Bazer-Sakra and Chott Gadaine), it was the most abundant species, with peaks of 10,500 and 8,600 individuals in January, respectively. Mallard Duck was the most abundant species at all sites, peaking in February. Maximum abundance was reached at Garaet Hadj-Tahar (864 individuals). The Ferruginous Duck is the third most abundant duck, peaking in January. The maximum number of this species was recorded at Garaet Hadj-Tahar, with 586 individuals. Marbled ducks were more numerous in highland sites (max = 76 and 83 for Sabkhet Bazer-Sakra and Chott Gadaine, respectively) than in coastal sites (max = 26 and 38 for Boussedra marsh and Garaet Hadj-Tahar, respectively), while the White-headed Duck showed greater numbers in coastal sites (max = 147 and 267 individuals for Boussedra Marsh and Garaet Hadj-Tahar, respectively) than in highland sites (max = 82 and 25 individuals for Sabkhat Bazer-Sakra and Chott Gadaine, respectively).

Our estimates of the abundance of five species during the study period are similar to those reported in other studies at different sites in northeastern Algeria (Houhamdi & Samraoui 2002, Metallaoui *et al.,* 2008, 2009, Lazli *et al.,* 2011, 2012a, 2014b, Bouaguel *et al.,* 2013, Aberkane *et al.,* 2014, Rizi *et al.,* 2019, Charchar *et al.,* 2019, Hennouni *et al.,* 2021, Loucif *et al.,* 2021). Our results showed a marked difference in species abundance between sites. Greater Flamingos were recorded in large numbers (4000-6000) in the wetlands of the high interior plains, but the species was not recorded in the north. Records of the Greater Flamingo in the freshwater areas of northeastern Algeria have been rare, and if they have been recorded at all, it has been in small numbers (Loucif *et al.,* 2020). This is mainly due to the habitat preferences of the species, which prefers large brackish and saline wetlands (Bouzegag *et al.,* 2013, Bensaci *et al.,* 2015), and the low frequency of such habitats in the coastal zone. The White-headed Duck and Ferruginous Duck, which have already been recorded at various sites in the North (Houhamdi 2002, Houhamdi & Samraoui 2008, Metallaoui *et al.,* 2008, 2009, Lazli *et al.,* 2011, 2012a, 2014b, Rizi *et al.,* 2019, Hennouni *et al.,* 2021, Loucif *et al.,* 2021), were more abundant in coastal wetlands. Both species prefer freshwater lentic wetlands that have a dense emergent vegetation fringe and are rich in aquatic plant seeds and macroinvertebrates (Green 1998, Sánchez *et al.,* 2000).

The Marbled Teal showed higher numbers in high plain wetlands, which is consistent with previous observations showing that species tend to be present in greater numbers in semi-arid and arid environments (Aberkane *et al.,* 2014). Such a geographical pattern in marbled duck population size is not yet well understood and is quite different from our previous knowledge of the species' ecology in the Mediterranean region (Green 2001,

Charchar *et al.,* 2019) recorded 34 individuals in the Guerbes-Sahhadja wetland eco-complex in the coastal zone, which is within the range of abundances recorded in the current study. An updated review of the species' ecology is required to better understand its ecological requirements and adaptation.

### 3. Nest monitoring

Nesting was recorded for all species and all sites, with the exception of the Greater Flamingo (Fig. 60). Mallard and Ferruginous Duck were the most abundant species, with the number of active nests varying between 31 (Chott Gadaine) and 79 (Garaet Hadj-Tahar), and 18 (Sabkhet Bazer-Sakra) and 51 (Garaet Hadj-Tahar), respectively. The White-headed Duck was relatively more abundant at coastal sites (32 nests at Boussedra Marshand 39 nests at Garaet Hadj-Tahar) than at high plain sites (8 nests at Sabkhet Bazer-Sakra and 4 nests at Chott Gadaine). The Marbled Teal is fairly rare, with numbers varying between 3 (Boussedra marsh and Garaet Hadj-Tahar) and 8 (Sabkhet Bazer-Sakra).

The nesting phenology of the four breeding species varied (Fig. 60). The Mallard duck was the earliest, starting in January, while the other three species started in April or May. Breeding duration (number of months) for all species was similar in both regions (Fig. 60).

As a common waterbird, the Mallard duck generally had a greater number of nests in both coastal and high plain sites. This dominance and plasticity are expected given that the species has a cosmopolitan distribution and can adapt to a variety of ecological conditions, including anthropogenic disturbance (Anderson 1977). The Ferruginous Duck has also shown a high frequency of nesting in coastal and high plain wetlands, suggesting broad dietary and physiological plasticity. Loucif *et al,* (2021) showed that the reproductive output of the Ferruginous Duck was high in the coastal region - 9.8 ± 0.7 eggs with a hatching success of 66% - but such studies on the reproductive biology of the species are still lacking in the inland high plains. We found that the White-headed Duck bred both on the coast and in the highlands, but that the number of nests was lower in the highlands. Breeding outside the coastal zone was rarely reported. Our observation is therefore remarkable and enhances our understanding of the species' ecology and distribution. The number of nests recorded in the two coastal wetlands was comparable to other studies assessing other wetlands in the region (Chettibi *et al.,* 2013, Aberkane *et al.,* 2014).

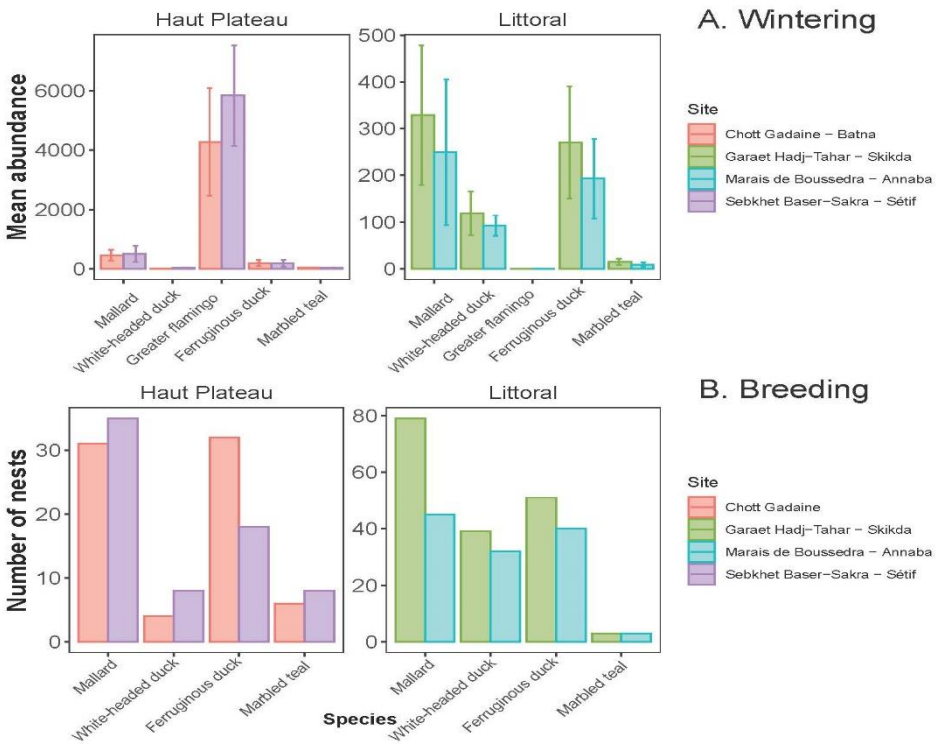



**Fig. 61. Annual abundance (A) and nesting records (B) of five waterbirds in four sites in Northeast Algeria.**

## 4. Analysis of abiotic parameters

The principal component analysis (PCA) we carried out was based on two types of data: physicochemical parameters (six in total) and the counts of five species of aquatic birds, observed in four different wetlands. This analysis explains 60.1% of the total variability, distributed between two principal components: the first (PC1) accounts for 31.5% of the variance, while the second (PC2) explains 28.6%.

For PC1, we observed positive correlations with electrical conductivity (EC), ammonium ($NH_4^+$) and the presence of fecal streptococci. On the other hand, this component is negatively correlated with the White-headed Duck population (see Table 4). Spatially, PC1 reveals that the Sebkhat Bazer-Sakra site shows few similarities with Garaet Hadj-Tahar and Gadaine. The latter two sites show more similarities with the Boussedra marsh, although the Boussedra marsh and Chott Gadaine only partially overlap (Fig. 61).

**Tab. 4. Correlation between variables used in PCA analysis with the two first PC axes. Values in bold show correlations rho > 0.6.**

| Variable | PC1 | PC2 |
|---|---|---|
| Fecal streptococcus | **0.69** | -0.07 |
| NO3 | 0.57 | 0.55 |
| NO2 | 0.12 | 0.40 |
| NH4 | **0.70** | 0.08 |
| MO | **0.74** | 0.41 |
| CE | **0.77** | 0.13 |
| White-headed duck abundance | -0.56 | -0.11 |
| Ferruginous duck abundance | **-0.64** | 0.51 |
| Marbled duck abundance | -0.22 | **0.87** |
| Mallard duck abundance | -0.49 | **0.80** |
| Greater flamingo abundance | 0.08 | **0.90** |

For PC2, strong positive correlations concern the abundance of several species: Greater Flamingo, Marbled Teal, Mallard duck and Ferruginous Duck. This component is also positively related to nitrite ($NO_2$), nitrate ($NO_3$) and organic matter (OM). Spatial analysis via PC2 confirms the marked distinction between Sebkhet Bazer-Sakra and Boussedra marsh. Garaet Hadj-Tahar shows greater similarities with the Boussedra marsh, while Chott Gadaine has features in common with all three other sites (Fig.61).

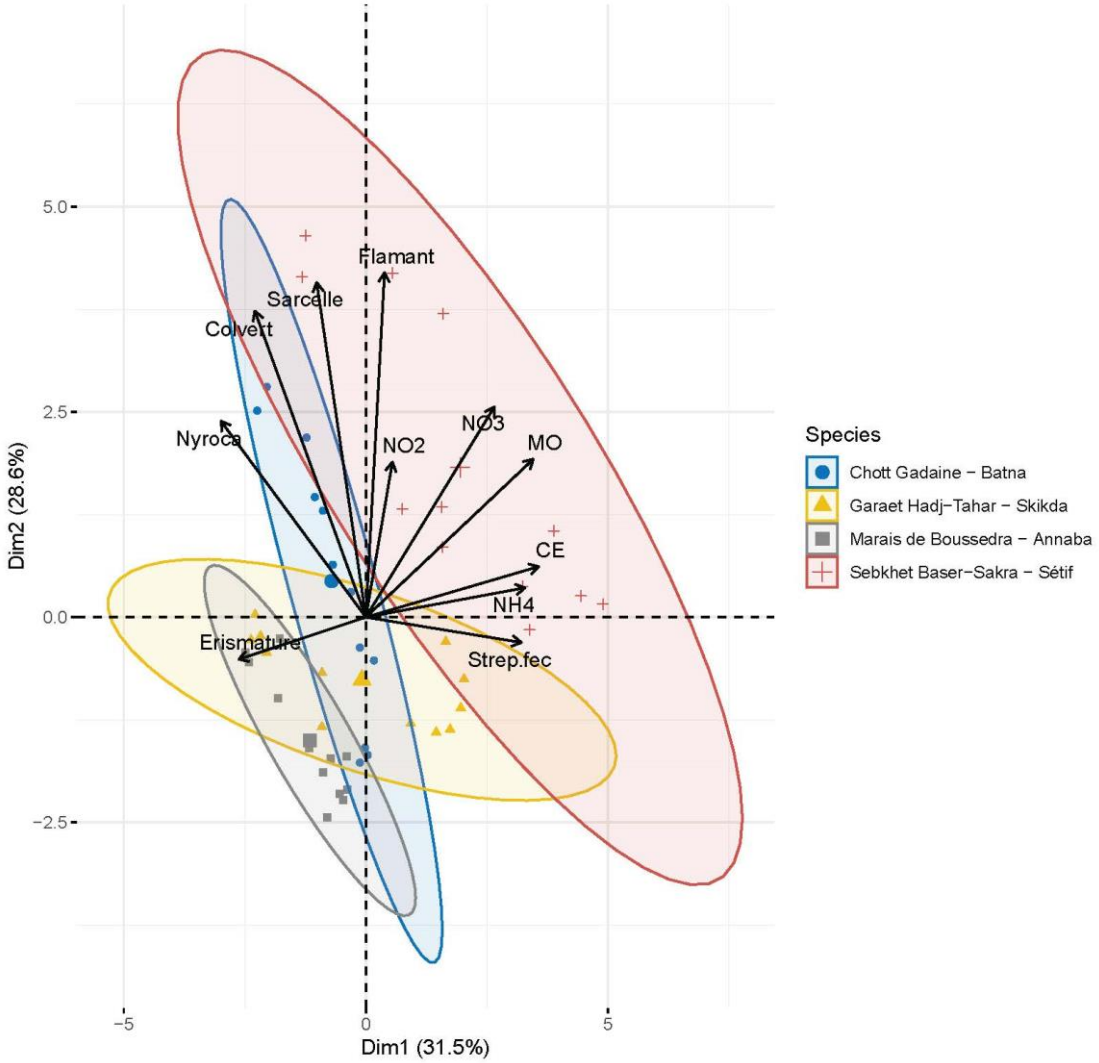



**Fig. 62. Principal Components Analysis biplot based on seven physicochemical parameters of the water and abundance of five waterbird species in four wetlands in Northeast Algeria.**

We used the following abbreviations: White-headed duck = Erismature à tête blanche; Ferruginous duck = Fuligule nyroca; Mallard Duck = Canard colvert; Marbled teal = Sarcelle marbrée; Greater Flamingo = Flamant rose; Nitrites = $NO_2^-$; Nitrates = $NO_3^-$; organic matter = MO; Electric conductivity = CE; Ammonium ions =$NH_4$; *Streptococcus fecalis* =Strep. fec;

Microbiological analysis of the water in both rural and urban wetlands shows significant contamination and high levels of bacteria. The Sebkhet Bazer-Sakra area stands out for a particularly high level of faecal contamination compared with the other sites studied, although this does not seem to affect the diversity of species living there. The high concentration of organic matter, mainly from the droppings of a large bird population, explains the presence of various microorganisms such as staphylococci, *Pseudomonas*,

*Shigella* and *Salmonella*. The decomposition of this organic matter varies according to the oxygenation of the environment (Toumi *et al.,* 2016, Mezbour *et al.,* 2018, Saker *et al.,* 2019).

Our observations confirm the crucial importance of urban wetlands for avian biodiversity and ecosystem functioning (Green & Elmberg, 2014). These areas are essential habitats for many bird species, whether for wintering, breeding or as migratory stopovers. In a context of increasing urbanization, it is becoming a priority to study the evolution of bird populations in Important Bird Areas (IBAs) located in urban environments (Rosa *et al.,* 2003).

It is crucial to assess the behavioral (such as reduced flight distance) and physiological (such as pollutant tolerance) adaptations of waterbirds in the face of anthropogenic disturbance. This knowledge will help optimize wetland preservation in human-modified environments (Andrade *et al.,* 2018).

Our study has certain limitations, notably the omission of environmental parameters that could potentially determine species presence. Factors such as water body morphology, peripheral vegetation and human disturbance (poaching, visitation) could have a more significant influence on species distribution and abundance (Green, 1998, 2001). In Spain and Morocco, for example, there is an increasing tendency for white-headed ducks and Marbled teal to nest near wastewater treatment plants, attracted by favorable conditions in terms of water level and tranquility (Pérez-García *et al.*, 2023). For future research, the integration of these variables appears essential to better understand the factors influencing the presence of species in the region studied.

# Conclusion

The Anatidae family of diving and dabbling ducks is represented in Algeria by sixteen species, four of which are regular nesters in many wetlands: Mallard duck *Anas platyrhynchos,* Ferruginous Duck *Aythya* nyroca, White-headed Duck *Oxyura leucocephala* and Marbled Teal *Marmaronetta angustirostris*. Two other species have recently been cited as nesting: the Ferruginous Duck *Aythya ferena* and the Northern Shoveler *Spatula clypeata*. The former in Lake Réghaia and the latter in the wetlands of eastern Algeria. The Phœnicopteridae family is represented by two species: the Greater Flamingo *Phœnicopterus roseus* and the Lesser Flamingo *Phœniconaias minor*. The former is a flagship or key species of the Algerian Highlands and Sahara, where it nests in a large number of salt and brackish water bodies.

Our contribution to the study of the behavior of these five breeding waterbird species in our hydrosystems has revealed that our wetlands play a dual role for this avifauna: a diurnal feeding ground for two of them (the Greater Flamingo and the Marbled Teal) and a diurnal staging ground for the other three (the Mallard duck, the Ferruginous Duck and the White-headed Duck).

The Greater Flamingo is an abundant water bird in the wetlands of the High Plateaux and Sahara. The species is well represented in two lakes: Lac El-Goléa (wilaya of Ghardaia) and Chott Oum Raneb (wilaya of Ouargla). This wader is often observed with numbers fluctuating between 5,000 and 7,500 individuals. Monitoring of its diurnal behavior in these two bodies of water has shown that feeding is by far the most frequently observed activity. It accounts for three-quarters of the total, i.e. 73% in Chott Oum Raneb and 74% in Lac El-Goléa.) The same is true of the Marbled Teal, where diurnal fattening is recorded at Chott Oum Raneb, with rates varying between 43 and 46%, i.e. almost half of the daily count of individuals present at the site. This species, classified as vulnerable, has been observed in numbers approaching 200 individuals in this wetland, with total abundances varying between 45 and 180 individuals in other Saharan continental hydrosystems.

The feeding activity of these two species, whose behavior has been little studied on the southern shores of the Mediterranean, manifests itself in different ways. Flamingos trample through the shallow soil, turning on their heels to capture hidden Anostracae and especially *Artemia salina* cysts, then nod and swallow them by filtering the ingested water. Flamingos then change places as they walk. The Marbled Teal feeds while swimming. These two activities, feeding and swimming, are closely linked in the majority of Anatidae, where birds often feed by moving on the water and feeding with their beaks on the surface, or by immersing their heads up to their necks, or by tilting their bodies. Rarely have we observed dives that last only a few seconds, after which the bird emerges from the water. Other

activities (walking, swimming, grooming, sleeping, parade, antagonism and flight) are also noted, but at low and variable rates.

The study and monitoring of the diurnal behavior of the other three species studied, namely the Mallardduck, Ferruginous Duck and White-headed Duck, in the most favorable wetlands showed that these hydrosystems play the role of a diurnal shedding ground, since sleeping activity dominates the diurnal time budgets of these birds. For the Mallard duck at Lake Tonga (wilaya of El-Tarf), for example, feeding activity accounts for over 40% of the total budget. It is observed in the water and on the banks of the lake. In the same body of water and in other neighboring wetland sites (Lac des Oiseaux, Mékhada marsh, Lake Fezzara and Garaet Hadj-Tahar), which have different physiognomies and structures, the Ferruginous Duck also exhibits a total balance dominated by sleeping activity, which accounts for between 46.17% and 50.17% of the total balance. Five natural and man-made lakes in the Hauts Plateaux: Garaet Timerganine (wilaya of Oum El-Bouaghi), Garaet Ouled Amara (wilaya of Khenchela), Chott El-Hodna (wilaya of M'sila, Bouguezoul dam (wilaya of Médéa) and Bougara dam (wilaya of Tissemssilet), Sleep dominates by far the diurnal budgets of the White-headed Duck at the first four wetlands. This activity is recorded at rates ranging from 39% to 53%, whereas at the last site (Bougara Dam), feeding activity is widely observed. It has about the same rate, i.e. 40%, which represents an exception for the species and for all the Algerian wetlands already studied. We believe that hunting pressure and poaching during the night and day hinder the logical course of these sensitive birds' feeding activity, so that they continue to fatten up more during the day to replenish the reserves needed for their movements, migrations and preparation for their breeding season. Other activities known to be of primary importance, as well as comfort and secondary activities, are also noted, but at low levels.

It should be noted that the observed numbers of these five species are very high in all the wetlands studied. The study of the use of the lake area by these species showed a good correlation between the location of the main plant groups, the density and the frequency of distribution of these birds. Scirpaies, Phragmitaies and Typhaies of these bodies of water are home to a large number of insects, macro and micro invertebrates and amphibians, and therefore constitute bioresources of food that attract these birds. Their seeds, like those of other Cyperaceae species, are rich in fiber, low in protein and carbohydrates, and their presence is synonymous with the frequentation of a site by waterbirds. They also represent a major and fairly accurate indicator of the potential carrying capacity of a gully, and at the same time enable a rapid assessment of the biological value of wetlands.

Greater Flamingos, known for their gregarious behavior, generally use all areas of wetlands free of vegetation. We often observe them grouped together in places farthest from disturbance (national and secondary roads, etc.). These very shy waders are very sensitive to human disturbance. The slightest flight of one bird will cause the whole group to take to the wing, following increasingly rapid flight on foot. This behavior is often observed in wintering and/or passing populations at our study sites. Water quality, type and depth are also determining factors in the daytime use of these aquatic ecosystems. Marbled Teal and Flamingo are often observed in shallow, salt- or brackish-water wetlands. Mallard duck, Ferruginous Duck and White-headed Duck prefer freshwater hydrosystems, where they can be found in deep, helophyte-rich areas.

Generally speaking, our data collected over four consecutive years provide new insights into the structure of these breeding birds in our hydrosystems, but also raise numerous questions concerning the stability and sustainability of these populations and stands. Similar studies spread over several years, as well as monitoring the reproduction of these waterbirds, remain major elements in the ecological understanding of these species, and will undoubtedly deepen our knowledge of the functioning of our wetlands, which despite everything remain little studied and documented, despite the role they play in maintaining animal and plant biodiversity.

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# Appendices