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Modelling climate influences on population dynamics and diurnal time budget of the Shelduck (*Tadorna tadorna*) wintering in Ramsar wetlands of Algeria

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Abstract

Several North African wetlands are classified as wetlands of international importance (Ramsar sites and Important Bird Area) because thousands of Shelducks (*Tadorna tadorna*) winter in these habitats. However, Shelduck's patterns of habitat use in these protected wetlands during the wintering season are still hindered by lack of information in arid and semi-arid regions regarding population dynamics and the effects of climate variables. This ornithological survey aims to study population dynamics and temporal patterns of diurnal activities of the Shelduck at two Ramsar and Important Bird Area sites (Chott Tinsilt and Sebkhet Ezzemoul) with respect to the effect of climatic parameters of the habitat in order to deepen our understanding of wintering strategies and habitat use. Populations were weekly censused from 06:00 to 19:00 during the entire wintering season (September 2015–May 2016). Diurnal behavioural activities were monitored at the same rate, and then the variation of time budget was tested using generalized linear model to determine the effects of climate variables and conspecific density dependence. The Shelduck was observed at both sites from the end of November and remained there until the total desiccation of both lakes in early May. Trends of Shelduck's population dynamics differed between the two sites. Generalized linear models revealed the significant effects of temperature, wind speed and number of snowy days on population dynamics. Feeding was the main diurnal activity of the Shelduck at both sites with 80.2% of time budget at Chott Tinsilt (mainly feeding at lake shores) and 82% at Sebkhet Ezzemoul (mainly feeding in water). The generalized linear models showed that the variation of time budget allocated to different diurnal activities was not density-dependent, but rather it was negatively affected by the increase of air temperature. Significant effects of the interaction between population size and some climatic variables were found and discussed. During the whole wintering season, Chott Tinsilt and Sebkhet Ezzemoul play an important ecological role since they offer a wide-ranging diurnal forging habitat and a shelter for thousands of this waterfowl.

Keywords

Chott Tinsilt, Sebkhet Ezzemoul, Shelduck *Tadorna tadorna*, population dynamics, wintering phenology, diurnal activities, time budget, climatic drivers

Introduction

North African wetlands, located between two major international flyways: the Eastern Atlantic flyway and central European flyway, play an important role for migratory birds, as an ecological bridge between the two obstacles posed by the Mediterranean Sea on the one hand and the Sahara Desert on the other.[1] This ecoregion harbours high diversity of wetlands that are considered Important Bird Area (IBA) because of their various ecological importance, especially as wintering and staging sites during the migration of birds between Palearctic and Afrotropic.[1–3] Besides, several Algerian wetlands are of crucial importance for the conservation and reproduction of several rare, endangered or restricted-range avian species such as the Audouin's Gull (*Larus audouinii*), White-headed Duck (*Oxyura leucocephala*), Ferruginous Duck (*Aythya*

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nyroca), Marbled Teal (*Marmaronetta angustirostris*)[3,4] and Eleonora's Falcon (*Falco eleonorae*).[5,6] Despite their multiple ecological services and values, only few studies have demonstrated the ecological role of North African wetlands in the maintenance of migratory waterbirds.[7–15] Nevertheless, and with all the studies cited above, the subject is far from being fully addressed, in particular when considering climate change and drought effects that are escalating on all North African ecosystems, including wetlands. Therefore, investigating the effects climate is needed to identify trends of populations dynamics and phenologies of waterbirds in order to address scientific gaps and lacunae and accordingly guide management planning and conservation actions.

Wetlands of the highlands (Hauts-Plateaux) in north-eastern Algeria represent a unique eco-complex including about 20 waterbodies with certain ecological importance.[3,16,17] This eco-complex has been underestimated despite the fact that it is known as the wintering ground of many waterbird species and plays an important role in the transit of migratory birds. Studies have shown another ecological function of this eco-complex: wintering and stopover of thousands of waterbirds and proven reproductions, unsuspected until their discovery, of thousands of pairs of many bird species. For example, one of the largest breeding colonies of Flamingo (*Phoenicopterus roseus*) in the Mediterranean Basin was found at Garaet Ezzemoul in 2004,[18,19] and several species for which phenological status has always been described as wintering or occasional visitor, such as the Common Shelduck *Tadorna tadorna*,[2] Ruddy Shelduck *Tadorna ferruginea*, Avocet *Recurvirostra avosetta*,[20] Black-winged Stilt *Himantopus himantopus*,[20,21] Slender-billed Gull *Larus genei*, Gull-billed Tern *Sterna nilotica*[22] and many other species have successfully nested in this eco-complex.[3]

Gregory et al.[23] show that the number of bird species that are negatively affected is almost three times greater than the number of species that benefit from climate change. Although temperatures have not increased much recently, it is surprising to realize how much of the impact is already visible on breeding populations of birds across all continents of the globe.[24,25] Birds respond unevenly to global warming, but generally species that do not rapidly acclimate with climate change are expected to experience a steep population decline.[26,27] In the Palearctic, climate change seems negatively affecting bird species subservient to cold regions, 'that is, with northern latitudinal range', but it has a positive impact on other species such as the White Stork, a long-distance migrant that usually spends winter in sub-Saharan Africa, while nowadays several individuals do not migrate and wintering in breeding grounds in southern Europe and North Africa.[23,28,29]

Despite the global awareness with the signing of the Ramsar[30] Convention in 1971, to which 169 states nowadays ratify, wetlands continue to decline dramatically. How in this case can we still hope to protect them, knowing that all the measures that can be taken will at best only slow down their degradation and that their preservation sometimes runs up against other management policies, such as agriculture, rural development, river and estuarine management, tourism and various socio-economic activities.[16] The eco-complex of wetlands located in north-eastern Algeria remains neglected and little studied compared to its high ecological potential and its multiple ecosystem functions and services that have invaluable environmental values. Also a huge gap is noted regarding studies of climatic effects on the ecology of wintering migratory birds (e.g. population trends, breeding biology and phenology, foraging activities, etc.) in this eco-complex. Recent studies, which are still being actively performed, suggest that the ecological status of waterbirds deserves an update and that this eco-complex is one of the largest wintering and breeding areas for waterbirds in the Mediterranean Basin.[1,31,32]

This study aims to update existing information on a wintering species – the Common Shelduck – in two inland wetlands classified as 'Ramsar site' of this eco-complex (Chott Tinsilt and Sebkhet Ezzemoul) by presenting data on its population dynamics. It should be noted that the Shelduck is one of the most widespread waterfowl species in these two sites and has allowed the classification of these wetlands as a Ramsar site by justifying Criteria 5 and 6 of the Ramsar Convention.[33,34]

Besides, in order to deepen our understanding of the ecological role of these two salt wetlands for this key species during the wintering season, the spatiotemporal variation of diurnal activity rhythms is investigated in each of the two sites at different time scales. This would help better understand the wintering strategy of this species and to test if behavioural patterns and foraging activities' 'site use' differ or not between the two sites during the wintering period of the species. The importance of studying the variation of time budget patterns in the Shelduck will make it possible to know and understand the behaviour of birds and how they use and exploit their habitat at different phases of wintering. When a bird species exhibits any behaviour, it is a response to a necessity and to biological and ecological requirement. Knowing the spatiotemporal variation of the diurnal activities is necessary to understand what birds need and what their requirements are in space and time.[35]

The study also investigated the effect of some climatic parameters combined with population size on population dynamics and the variation of diurnal activities of the Shelduck in these intermittent wetlands. Among the assumptions tested in this study is that the time budget allocated to activities that do not require high vigilance is expected to increase when the density of the group is important, since the more flock individuals there are on site, the vigilance increases;[36] thus, many individuals may engage in activities that are not permitted in low-density situations such as sleeping, preening and so on. In contrast, we predict that time budget of other behavioural activities such as aggression between conspecific individuals increases in large flocks.[37] In North Africa, monitoring studies on the behaviour of waterbirds are numerous, particularly in Algeria,[7–9,32] but no study has investigated the effect of climatic parameters on the variation of behavioural activity patterns and time budget of these waterbirds in North African wetlands. For this reason, we have examined in this work the effects of certain climate variables and their interactions with population size of the Shelduck on the different diurnal activities of this species.

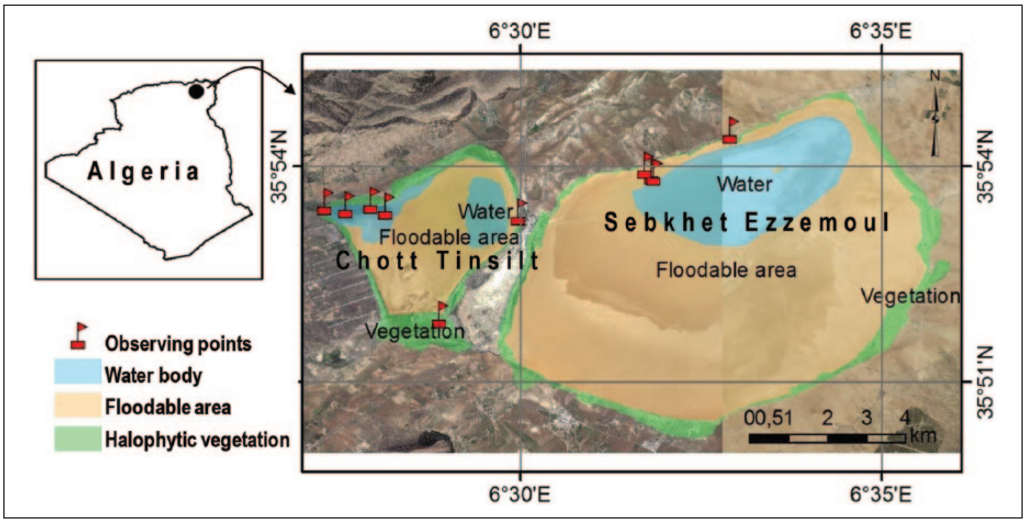

Figure 1. Geographical location of Chott Tinsilt and Sebkhet Ezzemoul, two Ramsar sites at the Province 'Wilaya' of Oum-El-Bouaghi in north-eastern Algeria.

Materials and methods

Presentation of the two study wetlands

Chott Tinsilt (Ramsar code: 1418, IBA code: DZ011). With an area of 2154 ha, Chott Tinsilt (35°53′N, 06°29′E) is a salt intermittent lake belonging to the eco-complex of wetlands in the region of Hauts-Plateaux. The floodable area is about 1000 ha[38] (Figure 1). It has been classified as a Ramsar[34] site since 12 December 2004. Chott Tinsilt is fed mainly by rainwater of the Wadi Ben Zerhaïb[33] and with small quantities of wastewater discharged from the city of Souk Naamane on the north-west side of the lake. Wetland water is brackish with a moderate salinity, alkaline pH and a depth that does not exceed 5 cm.[33] The wetland is surrounded by a vegetal belt in the form of grassy meadows dominated by the herbaceous layer, which is represented by two families *Chenopodiaceae* (*Atriplex halimus, Salcola fruticosa, Salicornia fruticosa*) and *Aizonaceae* (*Aizoon hispanicum*).[39] The site is also a wintering ground for various species of waterbirds including *Anatidae*, flamingos and shorebirds. It is also a privileged breeding site for many waterbird species such as *T. tadorna, T. ferruginea, Anas platyrhynchos, A. nyroca, Fulica atra, Himantopus himantopus, R. avosetta, Charadrius alexandrinus, Chroicocephalus genei* and *Gelochelidon nilotica*.[3,19,22,32]

Sebkhet Ezzemoul (Ramsar code: 1896, IBA code: DZ012). This wetland is located in north-eastern Algeria at the province of Oum-El-Bouaghi near the town of Ouled Zouaï (35°05′N, 06°30′E; Figure 1). It is an intermittent salt lake of about 6765 ha, which is used for the extraction of salt. The wetland was listed in the Ramsar[34] Convention since December 2009. Typical plant species of the vicinity of the site include *S. fruticosa, Suaeda fruticosa, A. halimus, Juncus maritimus, Peganum harmala, Thymelaea hirsuta, Morondia arvensis* and *Thymus hirtus*.[39] The waterbody is usually frequented by a multitude of waterbirds including *Anatidae* and shorebirds as well as the emblem species of the region the Flamingo (*P. roseus*) which has the largest nesting colony in the Mediterranean Basin and North Africa.[2,18,19,40]

Both sites are located in the semi-arid bioclimatic zone of North Africa characterized with cold-rainy winters and hot-dry summers. Following Budyko's climate classification, the area has a semi-arid, whereas Köppen classification indicated cold steppe arid climate (BSk). Moreover, the region has an aridity index of 0.38 indicating a semi-arid climate with De Martonne's index = 16 and moisture index = –62% (deficit precipitation = 650 mm/year; Table 1). Two periods characterized the climate (Figure 2): a dry period that lasts more than 6 months (mid-May to November) and humid period that stretches between November and early May. The dominant winds blow from southwest, west and northwest with an annual average speed of 5.8 ± 3.1 km/h (Table 2). Common in summer, the Sirocco wind has a desiccating action[41] and is blowing from the south. Rains are torrential and irregular over seasons and years. Annual rainfall varies between 196 and 370 mm with an average 33.3 ± 10.0 mm/month. The minimum temperature was recorded in January with 2.7°C and maximum in July with 32.7°C (Table 2).

Census techniques

The weekly monitoring of Shelduck populations in the two wetlands (Sebkhet Ezzemoul and Chott Tinsilt) was carried out from September 2015 to May 2016 using a long-distance land telescope (KONUS-SPOT: 20×60), binoculars (HIRSCH-LIEGE: 10×50) and a digital camera (NIKON D5300: 18×105). During bird counting, complete count was applied when Shelduck's flock was at a distance of less than 200 m and the population size did not exceed 200 individuals. However, when the number of individuals was greater than 200 or the group of birds was distant (>200 m), a quantitative estimate was performed by dividing the visual field into several bands, and then the number of individuals in an average band was counted and multiplied as many times as bands.[42]

Table 1. Climatic classifications and indices of the Chott Tinsilt and Sebkhet Ezzemoul (Province of Oum-El-Bouaghi) in north-eastern Algeria.

Climatic information	Value/class
Location	
Latitude (North)	6.489°
Longitude (East)	35.956°
Altitude (m)	980
Climate characteristics	
Köppen class	BSk B = Arid climate S = Steppe k = cold
Budyko climate	Semi-arid
Radiational index of dryness	3.066
Budyko evaporation (mm/year)	385
Budyko runoff (mm/year)	15
Budyko evaporation (%)	96.3
Budyko runoff (%)	3.7
Aridity	Semi-arid
Aridity index	0.38
Moisture index (%)	−62
De Martonne index	16
Precipitation deficit (mm/year)	650
Climatic NPP	700
NPP(temperature)	1829
NPP(precipitation)	700
NPP is precipitation limited	
Gorczynski continentality index	32.3

NPP: climatic net primary production in g DM/m²/year.

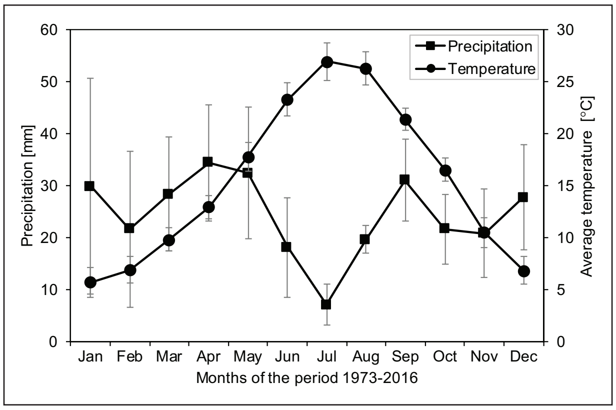

Figure 2. Pluviothermic diagram of Gaussen and Bagnouls of Chott Tinsilt and Sebkhet Ezzemoul (Province of Oum-El-Bouaghi) in north-eastern Algeria applied for the period 1973–2016. Solid squares and circles are monthly averages, whereas vertical bars are ±standard deviations.

Diurnal activity monitoring

Patterns of the diurnal activities of the Shelduck were monitored weekly during the same period (September 2015–May 2016) at each site. Each survey consisted of measuring time budget of diurnal activities every hour during the whole day from 06:00 to 19:00, the equivalent of 14 h of monitoring per day. Given the large size of the two sites studied and the distribution of birds in small scattered groups, the Instantaneous Scan Sampling 'SCAN' method[43] was used in surveying diurnal activities. This classical technique is frequently applied in studying time budget of waterbird behavioural activities, in particular *Anatidae* species.[2,7–9,32] The SCAN method consists of observing a bird group, allowing to record the instant activities of each individual, then the time percentage of each activity is deduced. It has the advantage of being applicable in sites where waterbirds are not always observed for long periods. It also eliminates the choice of individuals unlike the Animal Focal Sampling 'FOCUS' method.[35,43] By monitoring the trend of bird behaviour during all the day, the results are grouped in averages. The observer makes a succession of transects traced virtually through the group on which the telescope is oriented and then the observed birds that sleep, feed, courtship and so on are counted. If the number of visible birds in the telescope is still too high, the individuals in the midline of the field of view are sampled from the closest to the farthest.[35]

Sampling protocol takes into account all individuals uniformly, it provides an instantaneous overview of the behaviours exhibited by a set of individuals, and these data are converted into time according to the following principle: if, for example, 40% of birds feed for 1 h, that means 40% of the hour surveyed (i.e. 24 min = (40 × 60 min)/100) was devoted to feeding by all the birds. The distribution of this type of information every hour of the survey provides a general overview on the rhythm of activities for the day. The final result of these observations is therefore an averaged pattern of time budget. It represents an instantaneous daily activity budget that can be converted into monthly average or overall pattern of the whole wintering season of these activities.[35]

During each survey, nine behavioural activities were retained,[35] namely, (1) feeding in water and (2) feeding at edges, which includes the foraging action primarily by filtering the mud cream while loafing or swimming in shallow water (feeding in the water) or at lake shores (feeding at edges). Four feeding techniques were included under this behaviour: (a) surface digging where the bird lays its beak on the surface of the bare sediment and ploughs its surficial layer, (b) scything/dabbling observed in the surface mud or through 1–10 cm depth of water, (c) head-dipping observed in a water layer with 10–25 cm depth and (d) up-ending observed in water with 25–45 cm depth; (3) preening is the action of cleaning and maintaining the plumage during moulting, using mainly the beak. Partial or total bathing, stretching and shaking phases often accompany plumage grooming; (4) sleeping is the state of simple drowsiness or deeper sleep when the duck head is observed turned backward with their beak slipped under the large scapular feathers that adorn their back; (5) loafing consists of moving on the mud (especially at the lake edges) and/or on shallow water where there is not enough water to swim; (6) swimming is the action of moving on the surface of the waterbody; (7) flying is the act of moving between diurnal/nocturnal resting and foraging habitats, including spontaneous movements during courtship and flight reactions associated to a predator or anthropogenic disturbance; (8) courtship represents specific movements associated with pair formation when the male attracts its breeding partner

Table 2. Long-term monthly climatic data (1973–2016) of Chott Tinsilt and Sebkhet Ezzemoul (Province of Oum-El-Bouaghi) in north-eastern Algeria.

Meteorological parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave./sum
Average temperature (°C)	6.1 ± 1.4	7.5 ± 1.3	9.8 ± 1.1	12.6 ± 1.1	16.2 ± 1.4	20.7 ± 1.6	24.3 ± 1.8	24.3 ± 1.6	21.6 ± 1.1	16.1 ± 1.1	11.1 ± 1.4	7.3 ± 1.3	14.8 ± 1.4
Maximum temperature (°C)	11.1 ± 3.7	13.3 ± 3.2	15.6 ± 3.0	18.8 ± 2.7	23.2 ± 2.9	27.7 ± 3.0	32.7 ± 3.8	32.7 ± 3.4	29.3 ± 2.7	22.7 ± 3.2	17.2 ± 3.4	12.1 ± 3.9	21.4 ± 3.2
Minimum temperature (°C)	2.7 ± 4.8	3.9 ± 4.7	5.5 ± 4.7	7.1 ± 4.5	10.6 ± 4.1	15 ± 4.2	17.7 ± 3.9	18.2 ± 4.0	16.7 ± 4.4	11.1 ± 5.2	6.6 ± 5.2	3.2 ± 5.2	9.9 ± 4.6
Precipitation (mm)	39 ± 20.8	34 ± 15.0	43 ± 11.0	32 ± 11.2	50 ± 12.7	35 ± 9.6	12 ± 3.9	13 ± 2.6	27 ± 7.8	29 ± 6.7	51 ± 8.6	35 ± 10.1	33.3 ± 10.0
Potential evapotranspiration (mm)	29.4 ± 11.4	36.7 ± 8.7	61.0 ± 15.1	80.6 ± 18.6	116.1 ± 16.2	137.3 ± 15.8	163.7 ± 19.9	168.5 ± 14.6	116.1 ± 10.6	69.2 ± 13.2	42.4 ± 12.9	28.5 ± 10.6	87.5 ± 14.0
Ground frost frequency (%)	21	15	8	4	0	0	0	0	0	0	5	19	6
Effective rain (mm)	37	32	40	30	46	33	12	13	26	28	47	33	376
Effective rain ratio (%)	94	95	93	95	92	94	98	98	96	95	92	94	94
Rainy days	7	6	7	5	7	5	1	2	3	4	8	6	61
Solid precipitation ratio (%)	9	6	3	1	0	0	0	0	0	0	2	6	3
Water vapour pressure (hPa)	7.6 ± 1.5	7.5 ± 1.8	8.5 ± 1.6	9.6 ± 2.1	11.8 ± 2.5	14.3 ± 3.6	14.5 ± 4.3	14.8 ± 5.0	14.3 ± 4.6	12.5 ± 2.6	9.3 ± 1.7	8.0 ± 1.4	11.1 ± 2.7
Wind speed (km/h)	5.4 ± 3.7	6.1 ± 3.99	7.9 ± 4.1	7.2 ± 4.0	6.1 ± 3.7	5.8 ± 3.7	4.7 ± 2.4	6.5 ± 2.3	5.8 ± 1.9	4.3 ± 2.4	4.3 ± 2.4	5.4 ± 2.5	5.8 ± 3.1
Sun frequency (%)	43.8 ± 11.6	48.4 ± 10.9	53.6 ± 8	53.5 ± 7.5	60.3 ± 6.1	63.1 ± 4.3	73.9 ± 4.7	72.3 ± 3.3	65.5 ± 6.2	56.2 ± 6.5	47.3 ± 10.2	44.1 ± 11.7	56.8 ± 7.6
Day length (h)	09:58	10:50	11:55	13:03	14:01	14:29	14:16	13:27	12:22	11:14	10:14	09:42	12:08
Sun hours (h)	04:22	05:14	06:23	06:59	08:27	09:09	10:32	09:43	08:06	06:19	04:50	04:17	07:02

and (9) agonistic behaviour includes intra- and inter-specific bickering between Shelduck individuals, often observed when competing for food and/or during pair formation.

Meteorological data

Since migration, population dynamics and phenology of wintering waterbirds as well as their diurnal and nocturnal activities depend on climate conditions,[44,45] specifically in wintering grounds, the effects of the main climate variables that most likely control functioning of wetland ecosystems were investigated. Short-term raw meteorological data (August 2015–May 2016) were used to compute weekly climate parameters based on the average or sum of daily values recorded during 7 days preceding the date of bird surveying. The weekly climate parameters retained for this analysis were T – average of mean temperatures (°C), H – average of daily mean air humidity (%), PP – cumulative daily precipitation (mm), V – average of daily mean wind speed (km/h), RA – number of rainy days and SN – number of snowy days. These climate parameters were chosen as they represent the most controlling factors of water level fluctuations, wetland biogeochemistry and food/habitat quality, quantity and availability.[17,46,47] Therefore, they are expected to influence patterns of habitat use, population dynamics and daily/seasonal behavioural activities in waterbirds using wetlands as wintering grounds. Data were provided from the meteorological station of Batna, Algeria (coordinates: 35.55N, 6.18E; elevation: 1052 m a.s.l.; WMO station code: 60468).

Statistical analysis

Since the shape of curvature representing temporal changes in numbers of individuals of most waterbird populations wintering in North African wetlands follows a humped curve (Gaussian distribution) displaying the arrival in autumn, wintering, then departure in early spring,[12] the variation of population size was modelled using a generalized additive model (GAM) using a smooth function. The variations of weekly population sizes were fitted as a smooth function of surveyed weeks using Gaussian distribution error and 'identity' link function. This non-parametric modelling approach is advocated as temporal trends of population dynamics are not specified by some explicit functional form due to the synergetic and irregular influences of various ecological factors in wetland ecosystems.[41] Population dynamics of the Shelduck was modelled in each study site separately using the package {mgcv} in R version 3.3.2.[48] The function 'predict()' of the R package {stats} was used to predict population size changes of the Shelduck in each site based on previous GAMs. A set of 100 predicted values of population size was generated for the whole study period, that is, nearly every 2 days from September to May.

The effects of the main climate variables that most likely control functioning of wetland ecosystems (*T, H, PP, V, RA* and *SN*) were investigated using generalized linear models (GLMs). First, the effects of climate conditions on the variation of Shelduck's population size within each study site were fitted to GLM with Poisson distribution error (count data) with identity link. The variation of time budget of each diurnal activity at each site was modelled using a GLM (Gaussian family and identity link) that tested conspecific density-dependent effects crossed with influences of the climate variables. The interactions between population size and climate variables were included in every model (for each behavioural activity per site). Thus, a total of 18 GLMs were conducted for diurnal activities in the two study sites.

For the spatiotemporal variation of diurnal activities, Pearson chi-squared test was applied to examine dependency between time budgets of different activities and the two study sites. Moreover, two-way analyses of variance (ANOVAs) were conducted to test the variation of every diurnal activity following the effects of sites, months and their interactions. Tukey's post hoc test followed significant ANOVAs ($p < 0.05$) to determine homogeneous groups of study months and sites. Finally, a correspondence analysis was performed based on a contingency table including weekly time budget values of diurnal activities and study weeks in order to categorize characteristic activities of the study months/seasons.

Results

Population dynamics

Trend of population dynamics. The Shelduck was observed in the two study wetlands at the end of November and remained there until the total desiccation of the two waterbodies in early May. At the beginning, Shelducks arrived gradually with small groups composed of 26 individuals observed during the third and fourth weeks of November at Chott Tinsilt, whereas 200 individuals were observed during the fourth week of November at Sebkhet Ezzemoul (Figure 3).

Then and for the whole period that follows, the number of individuals begins to increase in the two sites but not in the same way. In Sebkhet Ezzemoul, a sharp increase in numbers (1203–1700 individuals) was noted from the second week of December until the first week of January, whereas in Chott Tinsilt the increase was relatively slower and with a smaller population size compared to Sebkhet Ezzemoul. This increase of individuals at Chott Tinsilt was recorded from the fourth week of December with 439 individuals that gradually increased until the second week of February recording 950 individuals. The peak at Sebkhet Ezzemoul was recorded during the first week of January with a population of 1905 individuals, while at Chott Tinsilt population peak was recorded during the third week of February with a population size equal to 1240 individuals (Figure 3). Finally, population collapse in the two waterbodies, this time, was abrupt at Chott Tinsilt and slow at Sebkhet Ezzemoul. Populations decreased from late February and early March (1000 individuals) until the fourth week of April (117 individuals) at Chott Tinsilt, and from the beginning of February (1040 individuals) until the beginning of April with 56 individuals at Sebkhet Ezzemoul.

During the occupation and use of the wetland, Shelducks settle early in the mornings to feed at the north side on the shores of Chott Tinsilt and at the west side inside the waterbody of Sebkhet Ezzemoul and gradually settle in water until the end of the day (Figure 4). It should be pointed out that as soon as the common Shelduck with the Ruddy Shelduck (*T. ferruginea*) and the Mallard (*A. platyrhynchos*) arrive at both sites, these ducks have been subject to intensive hunting pressure, especially between the first and third weeks of December at Chott Tinsilt because of the easy access to this waterbody, in particular on the north-western side of the site where ducks come foraging near the shores of the lake.

The GAMs modelling population size changes of the Shelduck revealed a highly significant effect of smoothed term (weeks of survey) whether at Chott Tinsilt ($F = 52.64$, $p < 0.0001$) or Sebkhet Ezzemoul ($F = 9.59$, $p < 0.0001$). GAM indicated 94.7% of deviance explained at Chott Tinsilt and 75.2% at Sebkhet Ezzemoul. Based on previous GAMs, predicted Shelduck's population at Sebkhet Ezzemoul is expected to reach a peak of 1459 individuals in the fourth week of December, whereas the Shelduck Chott Tinsilt is predicted to reach a peak of 1076 individuals in the fourth week of February (Figure 5). The predicted lines using GAM were almost indistinguishable from the lines produced by loess function displayed in Figure 3.

Effects of climatic variables on population dynamics. The meteorological conditions seem to influence the numbers of the Shelduck in the same way in both study sites, except for the wind speed which negatively affected the number of individuals at Sebkhet Ezzemoul but positively that of Chott Tinsilt (Figure 6). The GLMs revealed that air temperature negatively and significantly influenced the variation in numbers of the Shelduck at both sites. Shelduck's numbers decreased significantly with the increase of wind speed at Sebkhet Ezzemoul (GLM: $p = 0.003$), but with no significant effect at Chott Tinsilt ($p = 0.241$). In the latter, the number of snowy days had a positive and significant effect ($p < 0.001$) on the variation of the wintering population size. According to the GLMs, the other climatic parameters (i.e. air humidity, precipitation and number of rainy days) have no significant influence in the two study sites (Table 3).

Variation in diurnal activities

Annual time budget of diurnal activities. Throughout the wintering season 2015–2016, rhythms of diurnal activities of wintering Shelducks at the two Ramsar sites were monitored during 207 h of study in Chott Tinsilt and 103 h in Sebkhet Ezzemoul. The analysis of patterns of Shelduck's daily activities showed that feeding activities dominated other activities in both sites with 80.2% in Tinsilt and 82% in Ezzemoul. Shelducks fed more at water edges (62.1%) rather than in water (18%) at Chott Tinsilt, while feeding activity was higher in water (62%) than on wetland edges (20.1%) of Sebkhet Ezzemoul (Figure 7). The other activities were slightly represented (<6%) in both sites. According to Pearson chi-squared test, a significant dependency

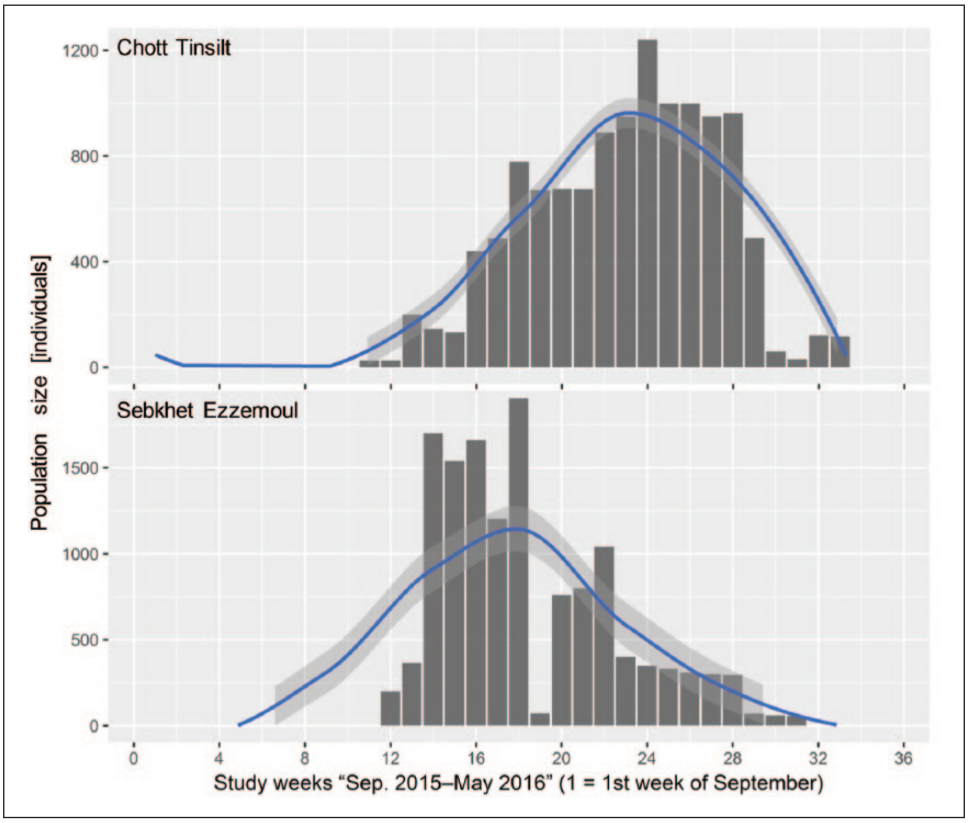

Figure 3. Weekly variations of population size of the Shelduck (*Tadorna tadorna*) in Chott Tinsilt and Sebkhet Ezzemoul during the wintering season 2015–2016. Continuous blue lines are LOESS curves (locally weighted polynomial) fitted to the data with a 90% confidence interval region in light grey.

was recorded between diurnal activities and study sites (chi-squared test: $\chi^2 = 47.52$, $df = 8$, $p < 0.0001$).

Spatial and monthly variations of diurnal activities. ANOVAs revealed that the monthly time budget allocated for the activities: feeding at edges, feeding in water, preening and loafing differed significantly between the two study sites. Although the variation in time spent for the activities: feeding at edges, preening, loafing, swimming and courtship differed significantly between months, only feeding in water, preening, loafing, swimming and agonistic behaviour showed significant effects according to the interaction 'sites × months' (Table 4). The variation of monthly time budget assigned to feeding at shores was significant ($p < 0.05$), with maximum observed in January (52.1% ± 26.8%) and the minimum in November (36.1% ± 31.5%). This activity was significantly higher at Chott Tinsilt (Table 5). It should be noted that both sites were dry during September and October (Figure 3). The highest time budget of feeding in water was (85.8%) recorded at Ezzemoul in November, whereas the lowest was recorded at Chott Tinsilt in November (9% ± 0.8%). The highest value of preening was recorded in April (10.3% ± 3.5%) versus the lowest in January, February, March and December with values ranging between 2.7% and 4.7%. December recorded significantly higher time budget rates of sleeping (5.3% ± 5.7%) than January, February, March and April, which have the lowest values (2.8%–4%). Tukey's test showed two groups of time budget allocated to courtship, March (0.2% ± 0.2%) and April (1.1% ± 0.8%) as group A, and November, December, January and February (0%) as group B. Agonistic behaviour was the highest in December, February, March and April with values ranging between 0.01% and 0.09%, whereas the lowest values were recorded in November and January (Table 5).

Weekly time budget of diurnal activities. During March at Chott Tinsilt, the species devoted on average 90.4% of the time budget to feeding; likewise, during December in Sebkhet Ezzemoul the species spent 89.3% of the time budget on this vital activity. It should be remembered that the time budget allocated to feeding had a seasonal average of 80.2% in Tinsilt and 82% in Ezzemoul (Figure 8). At Chott Tinsilt, preening was an important activity at the beginning of the study, with the highest average recorded in November with 11.7% (annual average = 5.4%). This activity showed a gradual decline until March and then a slight increase in April. At Sebkhet Ezzemoul, after feeding came flying with an annual average of 4.4%. This activity was very common at the beginning of the study until April. The species spent up to 5% of the time budget in this activity during March (Figure 8). Similarly, at Chott Tinsilt, time budget allocated to flying averaged 3.9%.

The Shelduck allocated less time to preening at Sebkhet Ezzemoul compared to preening time recorded at Chott Tinsilt as well as other activities recorded on the same site. The highest value was recorded during the second week of

Figure 4. Flocks of the Shelduck feeding in the water at Sebkhet Ezzemoul (December 2015; upper photo) and on banks at the north side of Chott Tinsilt (January 2016; bottom photo) (photographs taken by Adel Bezzalla).

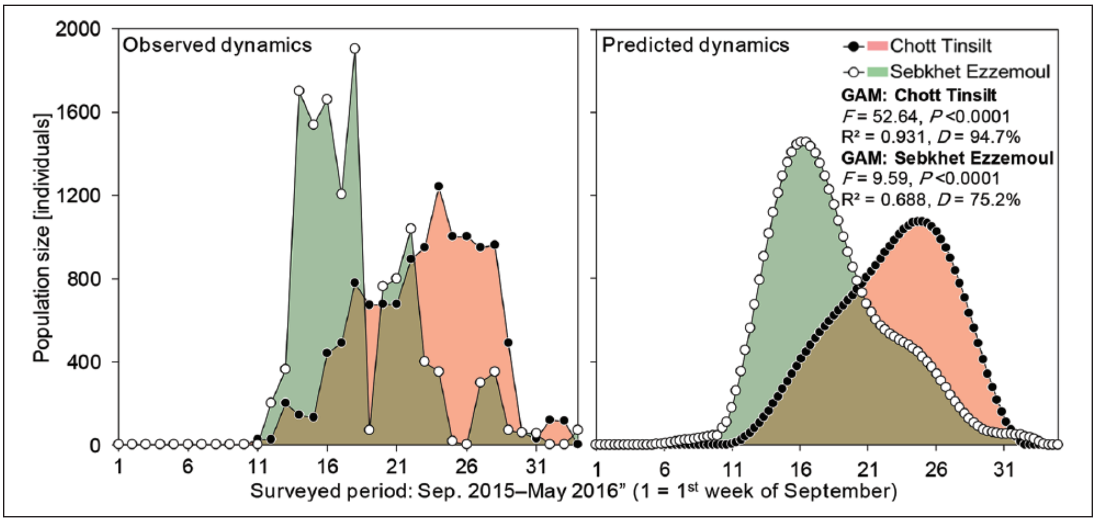

Figure 5. Observed and predicted population dynamics of the Shelduck wintering in Chott Tinsilt and Sebkhet Ezzemoul (north-eastern Algeria). Predicted population sizes are based on generalized additive models (GAMs) summarized as *F*: *F*-statistics and *p*: *p*-value that approximate significance of the smooth term 'weeks'. R^2: adjusted *R*-squared and *D*: deviance explained are proxies of the fit.

April with a peak of 14.9% coinciding with high temperatures (~23°C). At Chott Tinsilt, the increase of time allocated to sleeping was recorded in December. However, at Ezzemoul the peak of this activity was recorded during April with an average of 6.5%.

Swimming and loafing sometimes represent side activities for this species in the two study sites. At Sebkhet Ezzemoul, Shelducks forage while swimming, whereas at Tinsilt they feed while loafing. Swimming was less important at Chott Tinsilt compared to Ezzemoul. However, it was important at the late November with a peak of 13.5% and at late March and early April at Ezzemoul with 12.6%. On average, the Shelduck allocated 3.3% of annual time budget at Tinsilt and 4.2% at

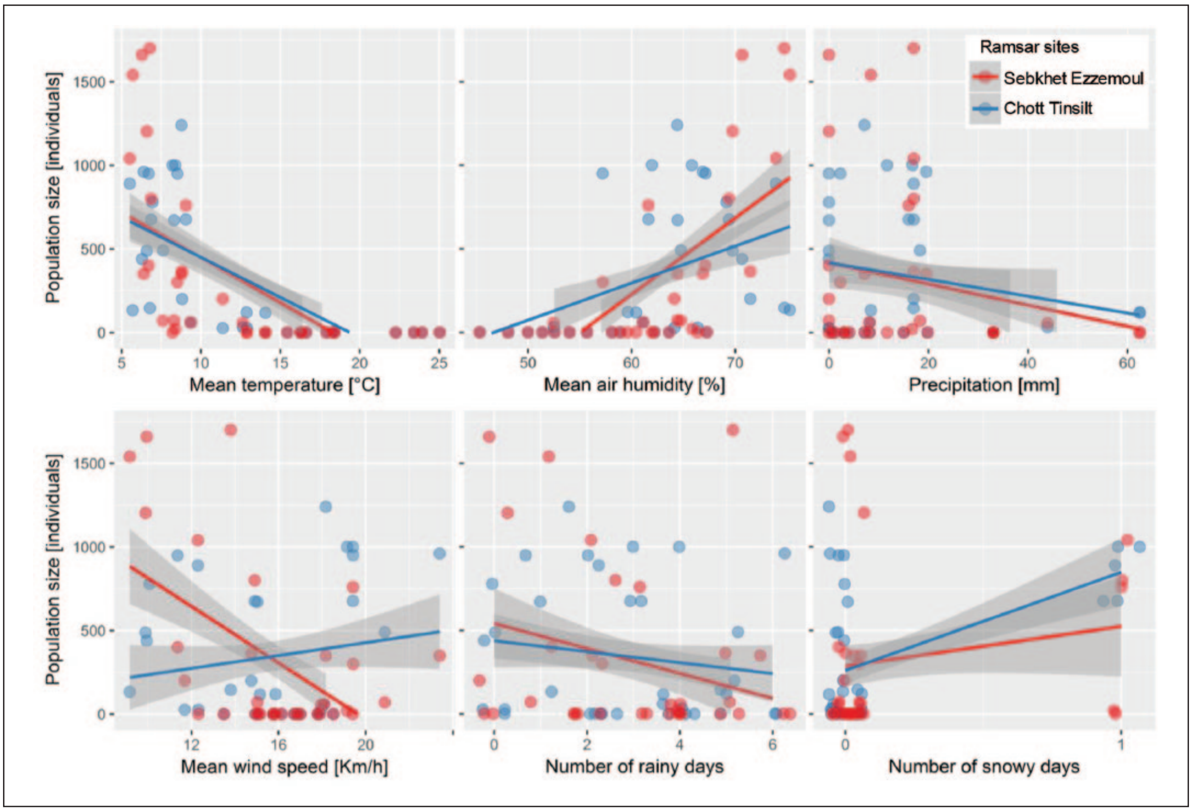

Figure 6. Effect of air temperature, air humidity, precipitation, wind speed and numbers of rainy and snowy days on the variation of population size of Shelducks (*Tadorna tadorna*) wintering in Chott Tinsilt and Sebkhet Ezzemoul (north-eastern Algeria). The solid lines represent a linear regression with a GLM fit with 95% confidence regions in light grey.
GLM: generalized linear model.

Table 3. Generalized linear models (GLMs) testing the effects of meteorological variables on the variation of Shelduck's population size at Chott Tinsilt and Sebkhet Ezzemoul (north-eastern Algeria).

Coefficients	Chott Tinsilt				Sebkhet Ezzemoul			
	Est.	*SE*	*t*	*p*	*Est.*	*SE*	*t*	*p*
Intercept	1231.0	1415.4	0.87	0.392^{ns}	3685.7	2103.6	1.75	0.091^{ns}
Mean temperature	−55.2	19.0	−2.90	0.007**	−66.3	28.3	−2.34	0.026**
Mean air humidity	−10.7	15.4	−0.70	0.491^{ns}	−12.7	22.8	−0.56	0.584^{ns}
Precipitation	−4.2	3.4	−1.23	0.229^{ns}	−7.0	5.1	−1.37	0.183^{ns}
Mean wind speed	31.4	26.2	1.20	0.241^{ns}	−126.9	38.9	−3.26	0.003**
Number of rainy days	−6.7	45.3	−0.15	0.883^{ns}	124.2	67.4	1.84	0.076^{ns}
Number of snowy days	301.9	139.2	2.17	0.039**	83.9	206.9	0.41	0.688^{ns}

Est.: estimate, *SE*: standard error, *t*: *t*-value, *p*: probability value.
***$p < 0.001$; **$p < 0.01$, $^{ns}p > 0.05$.

Ezzemoul. The Shelduck allocated more time to loafing at Chott Tinsilt compared to Ezzemoul. Time budget of this activity peaked during the third week of November (6.4%) and the second week of April (6.8%) at Chott Tinsilt, whereas at Ezzemoul peaks of 5.3% and 3.1% were recorded during the second week of March and April, respectively. In both study sites, very low averages were noted for the last two behaviours: aggressiveness (0.01%–0.02%) and courtship (0.16%–0.23%). Courtship was more intense at the end of the wintering season (April) at both wetlands (Figure 8).

At Chott Tinsilt, preening and loafing were significantly associated with all activities ($p < 0.05$) except feeding in water, which was only correlated with feeding at edges ($r = 0.67$, $p < 0.001$). Feeding at edges was significantly correlated with swimming ($r = 0.38$, $p = 0.024$) and flying ($r = 0.43$, $p = 0.010$). Swimming was significantly correlated with sleeping ($r = 0.60$, $p < 0.001$). Courtship, aggression and flying were all significantly associated at Chott Tinsilt but not at Sebkhet Ezzemoul. At Sebkhet Ezzemoul, feeding in water was significantly correlated with all activities except for courtship and aggression. The latter was only associated with loafing ($r = 0.42$, $p = 0.012$). Preening and loafing were correlated with all activities except aggression for preening and feeding at edges for loafing (Figure 9).

Daily time budget of diurnal activities. Variations of time budget during the day were recorded in both study sites (Figure 8). At Chott Tinsilt, the Shelduck prefers shoreline feeding, which was by far more important compared to feeding in water; it was observed during the whole day with a maximum of 95.2% the morning at 06:00, then it decreased until the afternoon. Contrary to sleeping, loafing, swimming, courtship and agonistic behaviour, which showed progressive increases during the day, peaks of these activities were recorded at midday and in the afternoon with 3.9%, 5.5%, 4.9%, 1.6% and 0.2%, respectively. Time budget allotted to preening was recorded with the highest values (5.1%) in the afternoon at 18:00.

At Sebkhet Ezzemoul, feeding in water was observed throughout the day with a gradual increase along the day; it reached a maximum of 73.8% in the afternoon around 16:00 and 19:00. A peak of 39.7% of time budget was noted at midday for feeding at edges. In contrast, preening and sleeping peaked with 6.3% and 4.6% in the morning at 06:00, respectively, and after that they gradually decreased. For swimming and loafing, peaks were recorded early in the morning at 06:00 with the averages of 16.6% and 3.2%, and also at the end of the day with 13.5% and 4%, respectively. Time allocated to flying was more or less constant during different hours of the day, except at 11:00 and 13:00 where the maximum was noted with 7.5% and 7.6%, respectively. High values of time assigned to courtship were recorded at evening with about 3.2% of budget time. Agonistic behaviours were rare but mainly recorded at midday around 11:00 with 0.03%.

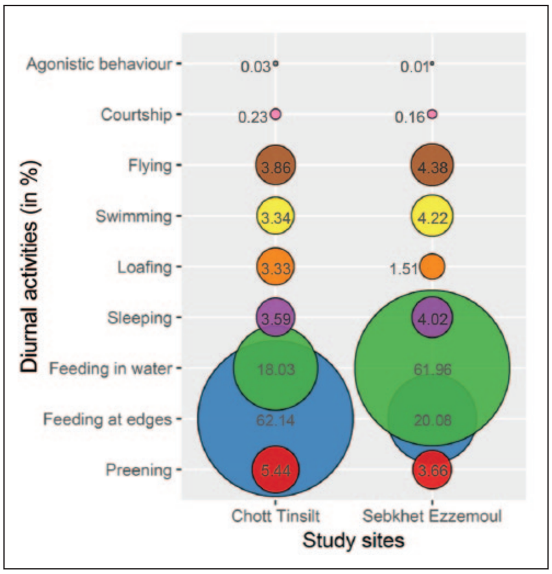

Figure 7. Proportion of the time budget of the various daytime activities of the Shelduck during the wintering season (2015–2016) at Chott Tinsilt and Sebkhet Ezzemoul (north-eastern Algeria).

Temporal patterning of activities. The multivariate statistical analysis performed on Chott Tinsilt data through the correspondence analysis represented 68.29% of the information on the 1 × 2 factorial plot (Figure 10). The correspondence analysis revealed that the first axis (47.23%) separated on the positive side most behavioural activities: sleeping, preening, flying, feeding in water, courtship and aggression from the other activities such as swimming, loafing and feeding at edges that were plotted on the negative side of the axis. The second axis (21.06%) separated on one side the activities of feeding in water and at edges, from the other activities, namely, swimming, flying, preening, sleeping, loafing, courtship and agonistic behaviour.

The correspondence analysis 1 × 2 biplot applied for Sebkhet Ezzemoul held 74.1% of inertia 'total variance' (Figure 10). The first correspondence analysis axis separated swimming, sleeping, loafing, preening, flying, feeding at edges, courtship and agonistic behaviour from the other essential activity that is feeding in water. The second axis separated on one side the activities of feeding at edges and sleeping, and on the other side the other activities, namely, swimming, flying, preening, loafing, feeding in water, as well as courtship and aggression.

The correspondence analysis described the distribution of time budget of diurnal activities measured during weeks of the study period. Time budget allocated to feeding in water was more important during the weeks of February and March in Chott Tinsilt (Figure 10). Whereas sleeping or daytime rest and feeding at edges characterized the

Table 4. Two-way ANOVAs testing the effects of sites, months and their interactions on the variation of diurnal activities of the Shelduck wintering in wetlands of north-eastern Algeria.

Diurnal activities	Model			Sites		Months		Sites × months	
	R^2	$F_{(11,30)}$	p	$F_{(1,30)}$	p	$F_{(5,30)}$	p	$F_{(5,30)}$	p
Feeding at edges	0.813	11.82	<0.001	105.17	<0.001	2.79	0.035	0.14	0.981
Feeding in water	0.909	27.18	<0.001	238.92	<0.001	2.47	0.055	5.58	0.001
Preening	0.763	8.80	<0.001	7.92	0.009	11.58	<0.001	4.80	0.002
Sleeping	0.329	1.34	0.253	0.00	0.948	0.55	0.734	2.35	0.065
Loafing	0.724	7.14	<0.001	17.33	<0.001	5.66	0.001	5.79	0.001
Swimming	0.612	4.30	0.001	2.43	0.129	3.62	0.011	5.54	0.001
Flying	0.092	0.28	0.986	0.22	0.641	0.32	0.898	0.15	0.978
Courtship	0.661	5.31	<0.001	0.00	0.998	9.63	<0.001	0.32	0.898
Agonistic behaviour	0.560	3.47	0.003	1.25	0.272	2.25	0.075	3.18	0.020

ANOVA: analysis of variance; R^2: coefficient of determination; *F*: *F*-statistics; *p*: *p*-value.

Table 5. Monthly values (mean ± SD) of time budget of Shelduck's diurnal activities recorded in Chott Tinsilt and Sebkhet Ezzemoul in north-eastern Algeria.

Months	Sites	Diurnal activities								
		Feeding at edges	Feeding in water	Preening	Sleeping	Loafing	Swimming	Flying	Court-ship	Agonistic behaviour
November	Tinsilt	54.1 ± 5.2^{abc}	9.0 ± 0.8^{d}	11.7 ± 0.7^{a}	5.9 ± 2.9^{a}	6.2 ± 0.2^{a}	8.7 ± 6.7^{b}	4.4 ± 0^{b}	0^{a}	0^{a}
	Ezzemoul	0^{c}	85.8 ± 0^{a}	1.8 ± 0^{b}	0.9 ± 0^{a}	0^{c}	7.0 ± 0^{b}	4.6 ± 0^{b}	0^{a}	0^{a}
	Overall	36.1 ± 31.5^{A}	34.6 ± 44.3^{A}	8.4 ± 5.7^{AB}	4.3 ± 3.6^{A}	4.2 ± 3.6^{AB}	8.1 ± 4.9^{B}	4.4 ± 0.1^{B}	0^{A}	0^{B}
December	Tinsilt	57.7 ± 19.3^{ab}	11.6 ± 6.7^{d}	7.3 ± 4.4^{ab}	8.1 ± 7.4^{a}	5.4 ± 3^{ab}	6.1 ± 3.0^{b}	3.9 ± 3.2^{b}	0^{a}	0^{a}
	Ezzemoul	16.2 ± 14.8^{c}	73.1 ± 14.5^{a}	2.1 ± 0.9^{b}	2.5 ± 0.7^{a}	0.6 ± 0.4^{c}	1.1 ± 0.4^{b}	4.4 ± 1.3^{b}	0^{a}	0.03 ± 0.02^{a}
	Overall	36.9 ± 27.3^{A}	42.3 ± 34.5^{A}	4.7 ± 4.0^{B}	5.3 ± 5.7^{A}	3 ± 3.2^{AB}	3.6 ± 3.3^{AB}	4.2 ± 2.3^{B}	0^{A}	0.01 ± 0.02^{AB}
January	Tinsilt	74.1 ± 10.8^{a}	14.8 ± 7.2^{d}	2.3 ± 1.1^{b}	2.6 ± 1.8^{a}	2.1 ± 0.9^{bc}	2.1 ± 1.1^{b}	2.0 ± 2.0^{b}	0^{a}	0^{a}
	Ezzemoul	30.1 ± 17^{bc}	57.3 ± 9.4^{a}	3.1 ± 0.8^{b}	3.2 ± 2.2^{a}	0.8 ± 0.8^{c}	1.7 ± 2.3^{b}	3.9 ± 4.3^{b}	0^{a}	0^{a}
	Overall	52.1 ± 26.8^{A}	36 ± 23.8^{A}	2.7 ± 1^{B}	2.9 ± 1.9^{A}	1.4 ± 1.1^{B}	1.9 ± 1.7^{B}	2.9 ± 3.3^{B}	0^{A}	0^{B}
February	Tinsilt	57.9 ± 8.3^{ab}	29.9 ± 5.7^{bcd}	2.5 ± 0.6^{b}	2.7 ± 0.4^{a}	1.5 ± 0.3^{c}	1.5 ± 0.7^{b}	4.1 ± 3.7^{b}	0^{a}	0.01 ± 0.02^{a}
	Ezzemoul	18.3 ± 9.3^{c}	63.1 ± 9.5^{a}	3.2 ± 1.0^{b}	5.3 ± 3.9^{a}	1.4 ± 1.2^{c}	4.6 ± 3.1^{b}	4.1 ± 4.5^{b}	0^{a}	0^{a}
	Overall	38.1 ± 22.7^{A}	46.5 ± 19.2^{A}	2.9 ± 0.9^{B}	4.0 ± 2.9^{A}	1.4 ± 0.8^{B}	3.0 ± 2.7^{AB}	4.1 ± 3.8^{B}	0^{A}	0.01 ± 0.01^{AB}
March	Tinsilt	65.0 ± 3.2^{a}	25.4 ± 6.3^{cd}	2.4 ± 0.6^{b}	1.1 ± 0.5^{a}	1.4 ± 0.3^{c}	1.2 ± 0.3^{b}	3.3 ± 4.4^{b}	0.1 ± 0.1^{a}	0.02 ± 0.01^{a}
	Ezzemoul	22.5 ± 15.1^{c}	52.4 ± 10.8^{ab}	3.4 ± 0.4^{b}	5.1 ± 2.7^{a}	2.7 ± 2.4^{abc}	8.3 ± 3.8^{ab}	5.0 ± 3.2^{ab}	0.4 ± 0.2^{a}	0.04 ± 0.07^{a}
	Overall	46.8 ± 24.4^{A}	37.0 ± 16.4^{A}	2.9 ± 0.7^{B}	2.8 ± 2.7^{A}	2 ± 1.6^{B}	4.2 ± 4.4^{AB}	4.1 ± 3.7^{B}	0.2 ± 0.2^{A}	0.03 ± 0.04^{AB}
April	Tinsilt	56.8 ± 11.0^{ab}	14.7 ± 1.0^{d}	10.2 ± 2.6^{a}	2.6 ± 1.3^{a}	5.2 ± 1.1^{ab}	3.5 ± 1.2^{a}	5.7 ± 4.9^{a}	1.2 ± 1^{a}	0.13 ± 0.11^{a}
	Ezzemoul	12.8 ± 4.2^{c}	51.5 ± 15.4^{abc}	10.4 ± 6.5^{a}	6.5 ± 9.2^{a}	4.5 ± 2^{abc}	8.6 ± 5.6^{b}	4.8 ± 3.5^{ab}	1 ± 0.3^{a}	0^{a}
	Overall	42.1 ± 24.3^{A}	27.0 ± 20.2^{A}	10.3 ± 3.5^{A}	3.9 ± 4.7^{A}	5 ± 1.3^{A}	5.2 ± 3.8^{A}	5.4 ± 4.1^{A}	1.1 ± 0.8^{A}	0.09 ± 0.11^{A}
The whole wintering season	Tinsilt	62.1 ± 12.4	18.2 ± 9.0	5.4 ± 4.2	3.6 ± 3.8	3.3 ± 2.3	3.3 ± 3.1	3.8 ± 3.4	0.2 ± 0.6	0.03 ± 0.06
	Ezzemoul	20.1 ± 14.2	62.0 ± 13.7	3.7 ± 2.9	4.0 ± 3.4	1.5 ± 1.7	4.2 ± 3.9	4.4 ± 3.1	0.2 ± 0.3	0.01 ± 0.03
	Overall	43.1 ± 24.9	38.0 ± 24.8	4.6 ± 3.8	3.8 ± 3.6	2.5 ± 2.3	3.7 ± 3.5	4.0 ± 3.2	0.2 ± 0.5	0.02 ± 0.05

SD: standard deviation; HSD: honestly significant difference.
Letters following each value (mean ± SD) indicate the results of Tukey's HSD tests. Values with the different letters are significantly different ($p < 0.05$). Superscript capital letters indicate differences between surveyed months, whereas small letters represent differences between sites crossed with months.

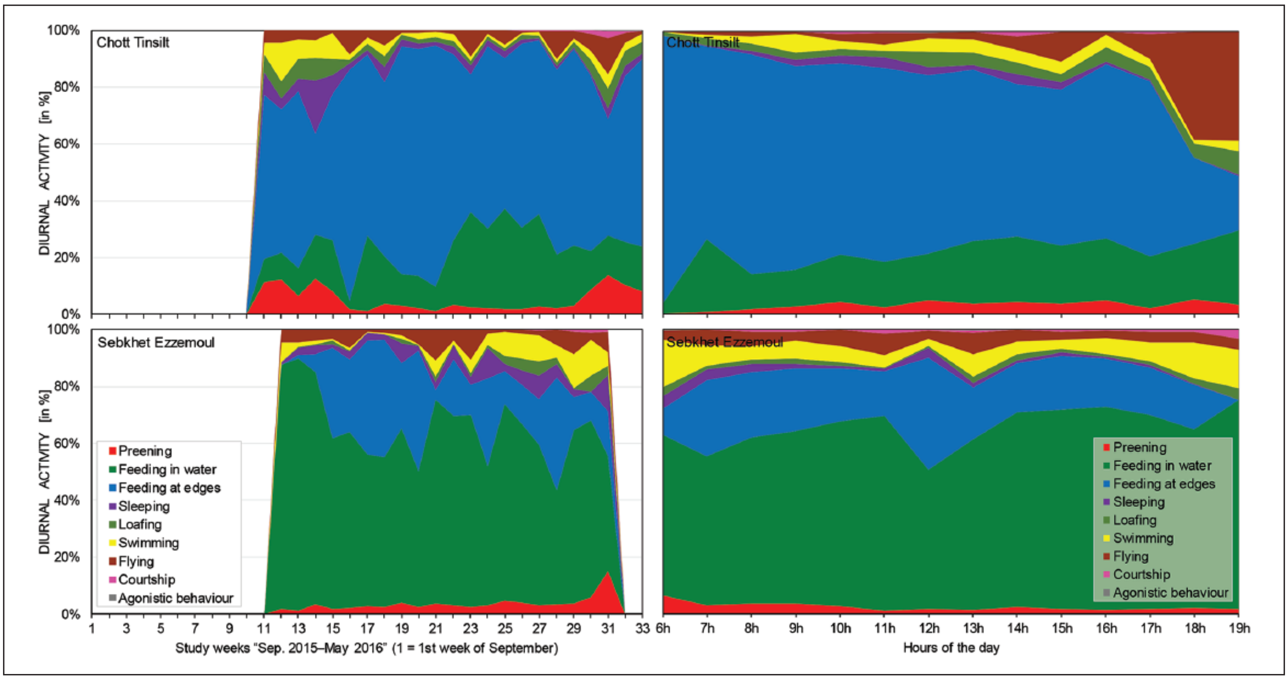

Figure 8. Variation of weekly (left plots) and hourly (right plots) time budgets of diurnal activities of wintering Shelducks (*Tadorna tadorna*) at Chott Tinsilt and Sebkhet Ezzemoul (north-eastern Algeria).

weeks of the coldest months of the wintering season at Sebkhet Ezzemoul, feeding in water held most of the time budget during the actual winter period. This period coincided with seasonal rains that trigger the emergence of

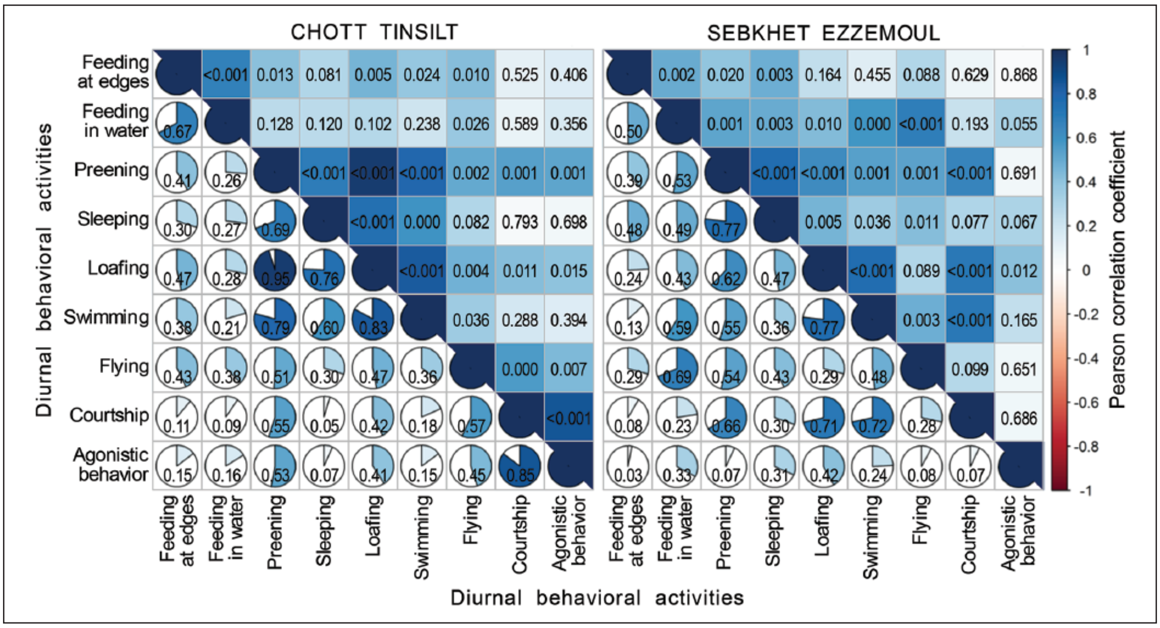

Figure 9. Correlation matrices between time budget allocated to main diurnal activities of the Shelduck wintering at Chott Tinsilt and Sebkhet Ezzemoul (Province of Oum-El-Bouaghi) in north-eastern Algeria. Pearson correlation test values are represented as correlation coefficients (under diagonal and shown by colour and intensity of shading in pie charts and squares) and *p*-values (above diagonal).

aquatic micro- and macroinvertebrates in intermittent lakes of the highlands of north-eastern Algeria,[46] thus offering an abundance of food resources.

At Tinsilt, feeding at edges was mainly the main Shelduck's activity during winter weeks. Swimming, loafing, flying, preening and sleeping were more important during the proper winter period, because during this period the water level of the waterbody was at its full due to the seasonal precipitation. This state of the waterbody facilitated the movements of *Anatidae* and offers a secure shelter in its centre. Courtship and aggression behaviours characterized weeks of April. These two activities were recorded in nesting and breeding pairs at this site.

Effects of population size and climatic variables on diurnal activities

The GLMs revealed that the variation of Shelduck's diurnal activity was not density-dependent, except in Chott Tinsilt for the courtship which was negatively affected by population size ($p=0.017$; Tables 6 and 7). However, the interaction of population size with climatic factors deemed to influence some Shelduck's activities. At Chott Tinsilt, population size interacting with the number of snowy days negatively affected feeding in water ($p=0.004$). Also the interaction with wind speed ($p=0.044$) and air humidity ($p=0.016$) induced a significant increase of courtship. In contrast, the interaction between population size and precipitation had a negative influence ($p=0.029$) on time budget allocated to flying (Table 6). At Sebkhet Ezzemoul, the study interactions significantly influenced only feeding activities: (1) feeding at edges increased significantly ($p=0.031$) with the interaction 'population × precipitation', but decreased with the interactions 'population × rainy days' ($p=0.001$) and 'population × snowy days' ($p=0.019$), (2) whereas feeding in water increased significantly ($p=0.03$) with the interaction 'population × temperature' (Table 7).

Generally, GLMs indicated that air temperature was the most influential climatic factor on the variation of diurnal activities of the Shelduck at the sites we surveyed. At Chott Tinsilt, statistical models showed significant negative effects of temperature on the variation of time budget allocated to feeding at edges ($p=0.001$), feeding in water ($p=0.023$), preening ($p<0.001$), loafing ($p<0.001$), swimming ($p=0.008$), flying ($p=0.001$), courtship ($p<0.001$) and agonistic behaviour ($p<0.001$) of Shelducks (Table 6). Similarly, air humidity negatively influenced preening ($p=0.036$), flying ($p=0.005$), courtship ($p<0.001$) and agonistic behaviour ($p<0.001$). Regarding wind speed, it induced a significant decrease in both loafing and swimming activities. The only significant effects of precipitation and the number of rainy days at Chott Tinsilt were obtained on time budget allocated to courtship, and they affected it positively. The number of snowy days significantly influenced feeding in water ($p=0.002$). Besides, no study climatic variable deemed to have a significant effect on the variation of time budget allocated to Shelduck's sleeping.

At Sebkhet Ezzemoul, the GLMs revealed that all diurnal activities of Shelduck (except feeding at water edges and agonistic behaviour) decreased significantly when air temperature increased (Table 7). These models also indicated that air humidity and wind speed did not influence any of the activities surveyed. In all GLMs performed, precipitation and the number of rainy days significantly affected only feeding in water; precipitation had a negative effect ($p=0.009$), while the number of rainy days showed a

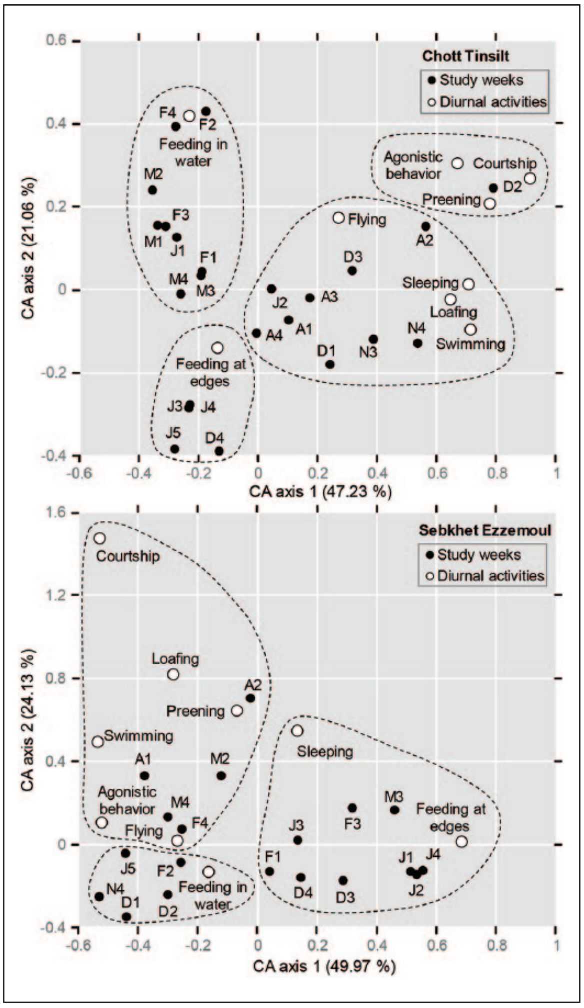

Figure 10. Correspondence analysis biplot for weekly patterns of diurnal activities in the Shelduck at Chott Tinsilt and Sebkhet Ezzemoul in north-eastern Algeria. Solid black circles are month weeks, which are coded using the first letter of the month followed by the number of the week (e.g. the third week of December is displayed as D3).

positive effect ($p=0.011$). Similarly, the number of snowy days had a significantly negative effect on a single activity which is the courtship ($p=0.005$). The agonistic behaviour was the only diurnal activity that was not affected by any climate variable.

Discussion

Population dynamics

Large flocks of the Shelduck (Figure 4) are generally observed at both sites by the end of November – when both sites begin to fill up with water – and remain there until the total desiccation of these sites (early May). Population dynamics of the Shelduck do not follow the same trend in these sites. This can be explained by the fact that at Sebkhet Ezzemoul the Shelduck group was totally wintering due to the large number of individuals arriving in winter, with the maximum number of individuals recorded in the first week of January. We note two groups at Chott Tinsilt: the first is wintering, which arrives at the beginning of winter (with smaller numbers compared to Sebkhet Ezzemoul) and remains until early spring; the second group comprises breeder pairs. It is noteworthy to mention that the Shelduck has mainly a wintering status in wetlands of the high plains of eastern Algeria.[2,14,15]

In Algeria, Shelduck populations are concentrated in the great Sebkhet of Oran, the Macta swamps and the salt marshes of Arzew in the west of the country; and in Garaet Tarf, Garaet Ank Djemel and Garaet Baghai in the east of the country.[2,49] In Europe, the wintering population is estimated at 1700 individuals in Spain, 1300 individuals in Italy and 1000 in France.[50] Several thousand individuals are wintering in the wetland eco-complex of the Hauts-Plateaux region in north-eastern Algeria.[3,20] The cumulative numbers of the Shelduck recorded in this eco-complex of wetlands are about 28,000 in January 2002, 45,000 in December 2003, 68,000 in December 2004 and about 9000 in March 2006.[49] Our results are consistent with the results found by Saether et al.[51] who analysed the effect of climate change on the dynamics of bird populations. According to these authors, two hypotheses are developed to explain the dynamics due to the climate: (1) the first suggests that population fluctuations are closely related to the variations of the climate outside the period of reproduction (i.e. wintering period), where the meteorological conditions play a determining role on the number of surviving birds during this critical period of the year, and (2) the second hypothesis predicts that variations in population size are related to the weather during the breeding season.

With the increase of temperatures in winter, a drop in the number of individuals of the Shelduck and other migratory species (unpublished results) has been observed and even predicted during some seasons. Similarly, Böhning-Gaeze and Lemoine[52] predict an increase in bird species richness in northern latitudes and high-altitude ‘cold regions’, while species richness declines in hot arid zones. Also our findings are coherent with the results found by Brochet et al.[53] that monitored the trend of population dynamics of wintering *Anatidae* and coots. The analysis of population trends revealed a slight increase ($<5\%$) per year. However, they stressed that the effect of site status regarding waterbird hunting was significant for determining species population trends. Thus, not only the average number of flocks but also population trends varied according to protection status of sites. Unfortunately, in our case and despite the fact that both study wetlands are classified as sites of international importance ‘Ramsar site’ and also IBA (‘Important Bird Area’),[3,54] they are under high hunting pressure upon all waterbirds, associated with an irrational exploitation of surrounding vegetation by excessive livestock grazing, not to mention that these sites became uncontrolled junkyard of solid waste.

Moreover, Géroudet[55] showed that the Shelduck in Europe is very sensitive to sudden drops of temperature and cold waves in winter, which forces Shelducks to move towards milder climate regions such as the case of North African wetlands. This is consistent with our results regarding the influence of snowy days on the number of Shelducks, which showed that snow has a positive influence on

Table 6. Summaries of generalized linear models (GLMs) testing the effects of Shelduck's population size and meteorological variables on weekly variations of the amount of time spent carrying out diurnal activities of the Shelduck (*Tadorna tadorna*) wintering in Chott Tinsilt, north-eastern Algeria.

Coefficients	*Est.*	*SE*	*t*	*p*	*Est.*	*SE*	*t*	*p*	*Est.*	*SE*	*t*	*p*
	Feeding at edges				Feeding in water				Preening			
Intercept	275.00	115.40	2.38	0.027*	65.39	36.47	1.79	0.087^{ns}	66.79	23.12	2.89	0.009**
Population	−0.03	0.35	−0.09	0.930^{ns}	0.20	0.11	1.79	0.089^{ns}	−0.06	0.07	−0.90	0.379^{ns}
T	−5.78	1.55	−3.73	0.001**	−1.21	0.49	−2.46	0.023*	−1.20	0.31	−3.86	<0.001***
H	−1.93	1.16	−1.67	0.110^{ns}	−0.50	0.37	−1.37	0.185^{ns}	−0.52	0.23	−2.24	0.036*
PP	−0.08	0.34	−0.25	0.805^{ns}	−0.03	0.11	−0.26	0.798^{ns}	0.04	0.07	0.59	0.561^{ns}
V	−3.87	2.78	−1.39	0.179^{ns}	−1.10	0.88	−1.25	0.225^{ns}	−1.10	0.56	−1.98	0.061^{ns}
RA	3.48	3.21	1.09	0.290^{ns}	1.25	1.02	1.24	0.230^{ns}	1.01	0.64	1.57	0.131^{ns}
SN	65.85	47.14	1.40	0.177^{ns}	−51.23	14.90	−3.44	0.002**	−7.15	9.45	−0.76	0.458^{ns}
Population × *T*	0.01	0.01	1.05	0.304^{ns}	0.00	0.00	0.49	0.632^{ns}	0.00	0.00	1.09	0.286^{ns}
Population × *H*	−0.00	0.00	−0.13	0.897^{ns}	−0.00	0.00	−1.87	0.076^{ns}	0.00	0.00	0.52	0.610^{ns}
Population × *PP*	0.00	0.00	1.05	0.306^{ns}	0.00	0.00	0.95	0.351^{ns}	0.00	0.00	0.14	0.891^{ns}
Population × *V*	0.00	0.01	0.06	0.950^{ns}	−0.00	0.00	−1.43	0.166^{ns}	0.00	0.00	0.71	0.485^{ns}
Population × *RA*	−0.01	0.02	−0.43	0.675^{ns}	0.00	0.00	0.80	0.435^{ns}	−0.00	0.00	−0.27	0.792^{ns}
Population × *SN*	−0.09	0.05	−1.73	0.098^{ns}	0.05	0.02	3.25	0.004**	0.01	0.01	0.68	0.502^{ns}
	Sleeping				Loafing				Swimming			
Intercept	25.03	23.23	1.08	0.294^{ns}	35.57	12.37	2.88	0.009**	46.37	17.06	2.72	0.013*
Population	−0.06	0.07	−0.84	0.410^{ns}	−0.04	0.04	−1.10	0.284^{ns}	−0.05	0.05	−1.02	0.319^{ns}
T	−0.50	0.31	−1.61	0.122^{ns}	−0.65	0.17	−3.92	<0.001***	−0.67	0.23	−2.93	0.008**
H	−0.08	0.23	−0.37	0.719^{ns}	−0.25	0.12	−2.03	0.056^{ns}	−0.30	0.17	−1.76	0.093^{ns}
PP	0.00	0.07	−0.07	0.947^{ns}	0.01	0.04	0.28	0.783^{ns}	−0.00	0.05	−0.05	0.959^{ns}
V	−0.84	0.56	−1.50	0.149^{ns}	−0.69	0.30	−2.30	0.032*	−1.14	0.41	−2.77	0.011*
RA	1.02	0.65	1.58	0.130^{ns}	0.70	0.34	2.05	0.053^{ns}	0.69	0.47	1.45	0.163^{ns}
SN	−2.03	9.49	−0.21	0.833^{ns}	−2.34	5.06	−0.46	0.648^{ns}	2.29	6.97	0.33	0.746^{ns}
Population × *T*	0.00	0.00	1.08	0.294^{ns}	0.00	0.00	1.78	0.089^{ns}	0.00	0.00	0.90	0.379^{ns}
Population × *H*	0.00	0.00	0.64	0.530^{ns}	0.00	0.00	0.70	0.493^{ns}	0.00	0.00	0.62	0.539^{ns}
Population × *PP*	−0.00	0.00	−0.61	0.550^{ns}	−0.00	0.00	−0.12	0.906^{ns}	−0.00	0.00	−0.37	0.715^{ns}
Population × *V*	0.00	0.00	0.42	0.681^{ns}	0.00	0.00	0.41	0.687^{ns}	0.00	0.00	0.98	0.340^{ns}
Population × *RA*	0.00	0.00	0.29	0.776^{ns}	0.00	0.00	0.24	0.810^{ns}	0.00	0.00	0.24	0.815^{ns}
Population × *SN*	0.00	0.01	0.36	0.725^{ns}	0.00	0.01	0.42	0.680^{ns}	−0.00	0.01	−0.20	0.846^{ns}
	Flying				Courtship				Agonistic behaviour			
Intercept	54.73	17.57	3.12	0.005**	9.75	2.22	4.40	<0.001***	0.88	0.23	3.79	0.001**
Population	−0.09	0.05	−1.62	0.120^{ns}	−0.02	0.01	−2.58	0.017*	0.00	0.00	−1.87	0.076^{ns}
T	−0.87	0.24	−3.70	0.001**	−0.19	0.03	−6.24	<0.001***	−0.01	0.00	−4.21	<0.001***
H	−0.55	0.18	−3.15	0.005**	−0.11	0.02	−4.98	<0.001***	−0.01	0.00	−4.16	<0.001***
PP	0.09	0.05	1.82	0.083^{ns}	0.02	0.01	2.68	0.014*	0.00	0.00	3.65	0.002**
V	−0.56	0.42	−1.33	0.197^{ns}	−0.04	0.05	−0.81	0.430^{ns}	−0.01	0.01	−1.60	0.126^{ns}
RA	0.34	0.49	0.69	0.496^{ns}	0.13	0.06	2.14	0.044*	0.01	0.01	1.07	0.298^{ns}
SN	−2.29	7.18	−0.32	0.752^{ns}	−0.27	0.91	−0.30	0.770^{ns}	−0.08	0.09	−0.80	0.433^{ns}
Population × *T*	0.00	0.00	0.55	0.589^{ns}	0.00	0.00	0.06	0.955^{ns}	0.00	0.00	0.91	0.374^{ns}
Population × *H*	0.00	0.00	1.88	0.074^{ns}	0.00	0.00	2.63	0.016*	0.00	0.00	1.76	0.093^{ns}
Population × *PP*	−0.00	0.00	−2.34	0.029*	−0.00	0.00	−1.68	0.109^{ns}	−0.00	0.00	−0.59	0.565^{ns}
Population × *V*	0.00	0.00	0.20	0.847^{ns}	0.00	0.00	2.14	0.044*	0.00	0.00	1.37	0.185^{ns}
Population × *RA*	0.00	0.00	1.98	0.061^{ns}	−0.00	0.00	−1.20	0.243^{ns}	−0.00	0.00	−0.65	0.524^{ns}
Population × *SN*	0.00	0.01	0.49	0.633^{ns}	0.00	0.00	0.89	0.386^{ns}	0.00	0.00	0.93	0.364^{ns}

Climate variables: *T* – mean temperature, *H* – mean air humidity, *PP* – precipitation (mm), *V* – mean wind speed (km/h), *RA* – number of rainy days, *SN* – number of snowy days.
GLM statistics: *Est.* – estimate, *SE* – standard error, *t* – *t*-value, *p* – probability value.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; $^{ns}p > 0.05$.

Shelduck numbers in Chott Tinsilt, given that snow rarely occurs in the semi-arid region of North Africa. But above all, it makes the climate more favourable to Shelducks given the overall hot-dry arid conditions of the region. Our findings are also comparable with the results found by Deceuninck and Quaintenne,[56] which show that cold waves

Table 7. Generalized linear models (GLMs) testing the effects of Shelduck's population density and meteorological variables (*T, H, PP, V, RA* and *SN*) on the weekly variations of the amount of time spent carrying out diurnal activities of the Shelduck (*Tadorna tadorna*) wintering in Sebkhet Ezzemoul, north-eastern Algeria.

Coefficients	*Est.*	*SE*	*t*	*p*	*Est.*	*SE*	*t*	*p*	*Est.*	*SE*	*t*	*p*
	Feeding at edges				Feeding in water				Preening			
Intercept	15.28	47.79	0.32	0.752^{ns}	321.32	125.96	2.55	0.019*	27.15	16.57	1.64	0.116^{ns}
Population	0.12	0.38	0.31	0.762^{ns}	−1.23	0.99	−1.24	0.228^{ns}	0.17	0.13	1.31	0.204^{ns}
T	−0.63	0.63	−1.00	0.328^{ns}	−7.75	1.67	−4.65	<0.001***	−0.61	0.22	−2.78	0.011*
H	−0.10	0.48	−0.20	0.845^{ns}	−2.44	1.28	−1.91	0.070^{ns}	−0.31	0.17	−1.82	0.084^{ns}
PP	−0.06	0.10	−0.59	0.559^{ns}	−0.72	0.25	−2.86	0.009**	0.00	0.03	−0.14	0.892^{ns}
V	0.06	1.17	0.05	0.959^{ns}	−3.81	3.08	−1.24	0.230^{ns}	0.00	0.40	0.01	0.991^{ns}
RA	0.61	1.43	0.43	0.673^{ns}	10.44	3.76	2.78	0.011*	0.45	0.49	0.92	0.369^{ns}
SN	−1.36	6.34	−0.22	0.832^{ns}	−21.26	16.71	−1.27	0.217^{ns}	−2.04	2.20	−0.93	0.363^{ns}
Population × *T*	−0.01	0.01	−0.81	0.430^{ns}	0.04	0.02	2.33	0.030*	−0.00	0.00	−0.40	0.696^{ns}
Population × *H*	−0.00	0.00	−0.47	0.642^{ns}	0.01	0.01	1.16	0.261^{ns}	−0.00	0.00	−1.34	0.194^{ns}
Population × *PP*	0.00	0.00	2.31	0.031*	−0.00	0.00	−0.47	0.645^{ns}	0.00	0.00	1.75	0.095^{ns}
Population × *V*	0.01	0.01	1.56	0.134^{ns}	0.00	0.01	0.32	0.755^{ns}	−0.00	0.00	−1.55	0.135^{ns}
Population × *RA*	−0.02	0.01	−3.78	0.001**	−0.01	0.02	−0.48	0.635^{ns}	0.00	0.00	0.10	0.924^{ns}
Population × *SN*	−0.05	0.02	−2.54	0.019*	0.07	0.05	1.25	0.224^{ns}	−0.00	0.01	−0.61	0.551^{ns}
	Sleeping				Loafing				Swimming			
Intercept	31.94	20.45	1.56	0.133^{ns}	13.09	8.65	1.51	0.145^{ns}	23.17	20.06	1.16	0.261^{ns}
Population	0.00	0.16	0.01	0.996^{ns}	0.11	0.07	1.56	0.135^{ns}	0.01	0.16	0.05	0.965^{ns}
T	−0.61	0.27	−2.27	0.034*	−0.29	0.11	−2.58	0.018*	−0.86	0.27	−3.25	0.004**
H	−0.32	0.21	−1.56	0.134^{ns}	−0.13	0.09	−1.52	0.143^{ns}	−0.25	0.20	−1.23	0.232^{ns}
PP	−0.00	0.04	−0.01	0.994^{ns}	−0.02	0.02	−1.42	0.169^{ns}	−0.08	0.04	−1.98	0.061^{ns}
V	−0.18	0.50	−0.35	0.727^{ns}	−0.04	0.21	−0.21	0.839^{ns}	0.34	0.49	0.69	0.499^{ns}
RA	0.22	0.61	0.36	0.723^{ns}	0.32	0.26	1.23	0.231^{ns}	0.90	0.60	1.50	0.149^{ns}
SN	−2.89	2.71	−1.06	0.299^{ns}	−0.57	1.15	−0.50	0.624^{ns}	−4.13	2.66	−1.55	0.135^{ns}
Population × *T*	−0.00	0.00	−0.06	0.957^{ns}	−0.00	0.00	−1.60	0.125^{ns}	0.00	0.00	0.68	0.502^{ns}
Population × *H*	−0.00	0.00	−0.08	0.940^{ns}	−0.00	0.00	−1.55	0.136^{ns}	−0.00	0.00	−0.03	0.980^{ns}
Population × *PP*	0.00	0.00	0.94	0.359^{ns}	0.00	0.00	1.36	0.187^{ns}	−0.00	0.00	−0.22	0.826^{ns}
Population × *V*	0.00	0.00	0.41	0.688^{ns}	−0.00	0.00	−1.11	0.280^{ns}	−0.00	0.00	−0.88	0.389^{ns}
Population × *RA*	−0.00	0.00	−1.14	0.269^{ns}	0.00	0.00	0.38	0.708^{ns}	0.00	0.00	0.64	0.528^{ns}
Population × *SN*	−0.01	0.01	−0.58	0.567^{ns}	−0.00	0.00	−0.96	0.347^{ns}	0.01	0.01	1.11	0.281^{ns}
	Flying				Courtship				Agonistic behaviour			
Intercept	28.14	18.38	1.53	0.141^{ns}	1.47	1.37	1.07	0.295^{ns}	0.07	0.17	0.44	0.663^{ns}
Population	0.14	0.14	0.95	0.353^{ns}	0.01	0.01	0.98	0.339^{ns}	0.00	0.00	0.69	0.497^{ns}
T	−0.61	0.24	−2.51	0.021*	−0.06	0.02	−3.11	0.005**	−0.00	0.00	−0.60	0.557^{ns}
H	−0.21	0.19	−1.13	0.272^{ns}	−0.02	0.01	−1.62	0.119^{ns}	−0.00	0.00	−0.44	0.663^{ns}
PP	−0.04	0.04	−1.14	0.267^{ns}	0.00	0.00	−1.19	0.247^{ns}	−0.00	0.00	−0.48	0.636^{ns}
V	−0.46	0.45	−1.02	0.321^{ns}	0.04	0.03	1.33	0.198^{ns}	−0.00	0.00	−0.10	0.920^{ns}
RA	0.94	0.55	1.72	0.100^{ns}	0.06	0.04	1.39	0.179^{ns}	0.00	0.01	0.14	0.893^{ns}
SN	−2.92	2.44	−1.20	0.245^{ns}	−0.56	0.18	−3.11	0.005**	−0.01	0.02	−0.44	0.663^{ns}
Population × *T*	−0.00	0.00	−0.72	0.480^{ns}	0.00	0.00	0.13	0.899^{ns}	−0.00	0.00	−0.70	0.489^{ns}
Population × *H*	−0.00	0.00	−0.98	0.341^{ns}	−0.00	0.00	−0.92	0.368^{ns}	−0.00	0.00	−0.70	0.493^{ns}
Population × *PP*	0.00	0.00	0.61	0.547^{ns}	0.00	0.00	0.76	0.458^{ns}	0.00	0.00	0.16	0.876^{ns}
Population × *V*	−0.00	0.00	−0.78	0.447^{ns}	−0.00	0.00	−2.02	0.056^{ns}	−0.00	0.00	−0.41	0.687^{ns}
Population × *RA*	0.00	0.00	0.58	0.567^{ns}	0.00	0.00	0.93	0.362^{ns}	0.00	0.00	0.83	0.415^{ns}
Population × *SN*	0.00	0.01	0.43	0.673^{ns}	0.00	0.00	1.05	0.305^{ns}	−0.00	0.00	−0.33	0.744^{ns}

Climate variables: *T* – mean temperature, *H* – mean air humidity, *PP* – precipitation (mm), *V* – mean wind speed (km/h), *RA* – number of rainy days, *SN* – number of snowy days.
GLM statistics: *Est.* – estimate, *SE* – standard error, *t* – *t*-value, *p* – probability value.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; $^{ns}p > 0.05$.

push Shelducks from the North Sea and the Wadden Sea, particularly with a harsh climate in the Netherlands to settle winter into the southern regions of Europe. This is also true for the large numbers of migratory waterbirds sheltered in North African wetlands.[1] So we can assume that winter in our study sites is milder and more favourable compared to winter in Europe, and thus the number of snowy days has a positive influence on the number of Shelducks wintering in wetlands of semi-arid North African regions. In addition, the negative effect of wind speed on the number of individuals observed in Sebkhet Ezzemoul can be explained by the topology of the landscape in this site. Indeed, the flatness of the site, absence of natural topographical obstacles and its large surface area (6765 ha) make it highly exposed to the wind, which negatively influences foraging activities of waterbirds and force them to choose quieter sites and less exposed to the wind.

Diurnal activities

The Shelduck, both a diurnal and nocturnal species, is known for its feeding behaviour both in water and on the edges of wetlands.[57,58] This behaviour was observed in study sites and the same findings have been reported previously on other wetlands in the Hauts-Plateaux region of north-eastern Algeria.[2,31] According to Bellagoune,[15] feeding activity in a wetland in north-eastern Algeria has been shown to be dominant in the day-time budget of the Shelduck with 66.9%, of which 48.8% of time was spent for feeding in water and 18.1% for feeding at edges. In birds, the selection of high-quality foraging sites/locations depends on several factors.[29] Indeed, Cherkaoui et al.[59] indicate that *Anatidae* occupy wetlands differently depending on habitat characteristics. This reflects the different responses of birds to meet their ecological needs, mainly nutritional requirements.[60] For example, Shelducks actively search for sites that offer more food with high quality and easily accessible, and the opposite is true, that is, a decline in numbers is associated with reduced food resources available on site.[61] Thus, the feeding behaviour is linked to the state of the site based on food supply. In this respect, the literature clearly mentions the presence of variation in the use of wetlands by waterbirds according to the rainy or dry year,[62] water quality[63] and changes in the hydrological regime.[64]

Results of our study reveal that the majority of Shelduck's daytime activities at study sites respond negatively to the rise in air temperature. In general, bird species show different signs of adaptation to change of climatic factors; while some birds react negatively to the increase in temperature, others react positively.[28] According to Crick[24] and Both et al.,[25] there is already evidence of changes in phenology, migration and nesting dates in birds; they also showed that some birds are no longer synchronous with their environment because of changes in climatic factors. In addition, climate conditions can influence and significantly alter the ecology of birds by affecting their morphological growth, physiology, behaviour, phenology, diet composition, feeding niche and their main activities (foraging, reproduction, migration, search for wintering areas, etc.).[27,51,52,60] A change in climate amounts to a change in selection pressure.[26]

The Shelduck allocated more time to feeding in early November, which matches with autumnal rains leading to the filling of the two wetlands. Indeed, Shelduck's diet depends mainly on crustaceans such as *Hydrobia* spp. and *Artemia* spp., the life cycles of which depend on the presence of water,[58,61] hence on the abundance of rains during that period. Also, we note that the effect of snowy days has a negative effect on time budget allocated to feeding in water at Chott Tinsilt, and this is considered normal since the decrease of water temperature caused by the snow negatively influences the emergence of gastropods and larvae of aquatic *Coleoptera* as well as *Branchiopoda* like *Artemia salina*, larvae of *Diptera* and *Cyanophyceae* entering in the Shelduck's diet.[58,65]

During March, at Chott Tinsilt the Shelduck devotes a significant time budget to feeding. Likewise, in Sebkhet Ezzemoul but during December the species allocated a significant time budget to this activity. This temporal pattern is explained by the more favourable weather conditions; that is to say, the Shelduck considers these wetlands as favourable habitats with milder climate conditions compared to cold European countries.[55] Also, feeding was the most extensive activity during the beginning of wintering season because it coincides with the arrival of migrant birds, and thus birds favour this vital activity to recover the losses of weight due to the exerted effort of long-distance migration.[31,35] In Chott Tinsilt, the importance of time budget spent in feeding at the end of wintering season is mainly due to preparation for migratory departure and/or nesting.[66]

Preening was an important activity in the time budget of the Shelduck at the beginning of the study with the highest value recorded in November. This may be due on the one hand to the depth of water which was more or less important in this waterbody, which therefore favours this activity,[67–69] and on the other hand, as soon as the wintering groups of Shelduck arrive after a long migration, the birds are obliged to maintain their plumage by an extensive grooming period.[15,70] Feather grooming decreases gradually until March, then it slightly increases in April which announces the preparation of the Shelduck for spring migration. In waterbirds, grooming is very important for thermoregulation needs as it increases the insulative capabilities,[70] and this is more obvious during cold months in both study sites. Phases of bathing, partial or total, wing stretching and body trembling frequently accompany grooming behaviours.[35]

At Sebkhet Ezzemoul, after feeding comes the activity of flying, and the latter was very common at the beginning of the study until April, the same at Tinsilt. The Shelduck is a fierce species and on the slightest disturbance flies into more secure locations.[21] In contrast, studies on Mallard (*A. platyrhynchos*) show that this species has a relative tolerance for human presence in Moroccan wetlands.[59] Preening at Sebkhet Ezzemoul has lower values compared to Tinsilt and even compared to other activities recorded on the same site. The highest value was recorded during the second week of April which coincides with high temperatures (~23°C). Contrary to our results which indicated negative effects of the temperatures on this activity, Tamisier and Dehorter[35] reported that the temperature pushes the ducks to maintain extensively their feathers.

The increase in time spent in sleeping was recorded in December. This seems to reflect the fact that during this month temperatures are very low and so sleep in ducks is a way to reduce energetic costs due to cold.[21] This is consistent with our results found at Tinsilt and Ezzemoul where indeed the fall in temperatures has a positive influence on sleeping. In fact, these ducks, frequently observed standing on the ground, can also sleep on the banks of shallow wetlands.[35] On the contrary, at Sebkhet Ezzemoul the peak of this activity was recorded in April; perhaps, this is a strategy to store energy, announcing the departure of Shelduck to breeding grounds (beginning of spring migration).

Swimming and loafing are two activities that can be associated with feeding.[2] In Sebkhet Ezzemoul, Shelducks feed while swimming, whereas in Tinsilt they feed while loafing at wetland shores. Swimming is a means of movement on the water and a means for the bird to avoid wind-induced drift which has a negative effect on both activities (swimming and walking) at Chott Tinsilt where Shelducks express these activities in a collective way.[35] The species spent less time in swimming at Chott Tinsilt due to the lack of water at the waterbody; however, the time allocated to loafing was longer compared to Ezzemoul, probably due to the vastness of Ezzemoul waterbody.

In both study sites, tiny time was allocated to the last two behaviours: aggression and courtship, which were significantly correlated with flying at Chott Tinsilt (Figure 9). Time allocated to courtship was notable during April in both sites. All these facts mentioned above are indicators of the beginning of breeding for this species.[2,49] Furthermore, a striking fact that emerges is the tendency to shorten the breeding season of some ducks in south-western France.[71] These authors tested the potential influence of precipitation and average temperature and confirmed that the temperature of April plays a significant role in the course of the breeding season in ducks. Because prey abundance and availability are dependent on environmental conditions,[46,60] adverse temperature and precipitation negatively affect the availability of food resources and feeding conditions of adult ducks and ducklings, which require a diet rich in animal prey with high protein.[57,58,61] In wetlands, air temperature is the driver of water temperature which influences the abundance of prey populations and accordingly controls food webs' functioning[72,73].

Conclusion

Large numbers of the Shelduck are wintering at Chott Tinsilt and Sebkhet Ezzemoul from November until May or the total desiccation of lakes. Population dynamics are uneven in these sites. At Sebkhet Ezzemoul, Shelduck's population was totally wintering-migrant given that the large number of individuals arrived in full winter. At Chott Tinsilt, two populations were distinguished: the large one is wintering and the second comprises some breeding pairs. The climatic factors that control population dynamics are temperature, wind speed and number of snowy days. Besides, temperature is the main climatic factor that significantly and negatively influences all diurnal activities of the Shelduck wintering in the wetlands studied. Statistical models verified that variations of time budget are not density-dependent. Feeding was a constant and the most important diurnal activity throughout the wintering season in both wetlands, which does not seem to be affected by climatic factors (except for temperature). This suggests that inland wetlands of north-eastern Algeria are very suitable wintering and foraging habitats not only for the Shelduck but also for many other *Anatidae* and migrant waterbird species. These findings bring new insights concerning population ecology and diurnal behaviour of this waterfowl in relation to climatic factors of the habitat; still we think that it would be better to widen the study on all continental wetlands of the eco-complex in order to determine the actual ecological values and the functional role of these habitats for migratory and breeding avifauna.

Author contribution

A.B., H.C., M.H. and M.C.M. conceived the study. A.B. conducted the fieldwork and collected the data. H.C. analysed the data. A.B. and H.C. drafted and revised the manuscript. All authors read and approved the manuscript.

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