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The first recorded reproduction of the Greater Flamingo *Phoenicopterus roseus* in Algeria: behavioural and ecological aspects

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Following several decades of unsuccessful attempts at locating breeding colonies of the Greater Flamingo Phoenicopterus roseus in Algeria, breeding was recorded on a natural islet of Garaet Ezzemoul, a seasonal salt lake near the town of Aïn M'lila in the Hauts Plateaux. This successful mass breeding event by at least 5 379 breeding pairs followed two failed attempts due to human disturbance at the same site during preceding years. Egg-laying started relatively late (mid-May) with precocious pairs nesting in the middle of the islet and at a higher nest density. Estimated breeding success was notably high (~5 000 chicks) with apparent good hatching rate and chick survival. Ring sightings indicated that the breeding population was made up in part of adults born in Spain, France and Sardinia, supporting evidence of a metapopulation of nomadic birds breeding and wintering across the Mediterranean Basin. Garaet Ezzemoul does not benefit from any conservation status and is not labelled as a Ramsar site in contrast to some of the neighbouring wetlands. In the light of the key role played by this site, at the regional scale, its status should be reassessed and in view of the threats facing it, urgent conservation measures should be initiated. Local authorities have reacted swiftly in response to the discovery of the breeding colony of the Greater Flamingo, and administrative steps are being taken to formally protect Garaet Ezzemoul.

Introduction

Striking advances have been made during the past decades in our understanding of the breeding biology of the Greater Flamingo *Phoenicopterus roseus* in Mediterranean Europe (Allen 1956, Brown 1959, Johnson 1983, 1997a, 2000, Rendón Martos *et al.* 1991, Rendón Martos 1996, Studer-Thiersh 2000). In sharp contrast, little is known about the life history of the Greater Flamingo in Algeria (a more arid environment that is considerably different from Europe) where current knowledge of the species is limited to winter counts (Isenmann and Moali 2000). There are several reasons for this lack of knowledge. Mainly, research has been hampered by the scarcity of local ornithologists and the general difficulty of monitoring a highly nomadic species over a vast territory of 2 382 000km^2. Although the Greater Flamingo population in North Africa is part of a larger regional metapopulation spread over the western Mediterranean Basin (Johnson 1983, 1997b, Nager *et al*. 1996), very little is known about the role of North African wetlands in metapopulation processes that may be crucial for the survival of the species, i.e. the rates of natal and breeding exchanges (Gilpin and Hanski 1991, Hanski and Gilpin 1997, Hanski 1998) between this region and the rest of the Mediterranean.

Some aspects of the ecology of the Greater Flamingo, such as the limited number of known breeding sites (Conway 2000) and the vulnerability of the species to disturbance (Cézilly *et al*. 1995), are a matter of great concern. Effective conservation measures targetting this species need to be addressed. The last documented successful breeding event of the Greater Flamingo in North Africa occurred in Tunisia at Sidi Mansour and Chott Djerid in 1991 (Johnson 1995). Despite the large number of salt lakes (*chotts*, *sebkhas*) in Algeria that are spread across the Hauts Plateaux and the Sahara, no breeding colony has ever been recorded, despite decades of surveys by ornithologists (Lavauden 1924, Heim de Balsac and Mayaud 1962, Ledant *et al.* 1981, Isenmann and Moali 2000). Recently, two unsuccessful breeding attempts were recorded at Garaet Ezzemoul, a temporary salt lake. The causes of the lack of success of breeding at Garaet Ezzemoul — human disturbance — were identified (Saheb *et al.* in press). The present study, conducted in 2005, was initiated to monitor a third successive breeding attempt at Garaet Ezzemoul, after steps were taken to limit human disturbance.

Study area

The wetland complex of Oum El Bouaghi, located in the eastern Hauts Plateaux, includes a diverse network of wetlands used by a large number of wintering and breeding waterbirds (Boulkhssaïm *et al.* 2004, Ouldjaoui *et al.* 2004, Saheb *et al.* 2004). The study area has a semi-arid climate, with an annual mean temperature of 15.5°C and an average annual rainfall of less than 400mm. The landscape is dominated by temporary salt lakes locally known as '*chotts'*, '*garaas'* or *'sebkhas'*(Figure 1). Garaet Ezzemoul (35°53. 137'N, 06°30.200'E) is an astatic salt lake of 6 000ha, at an altitude of 900m above sea level. The islet, where breeding

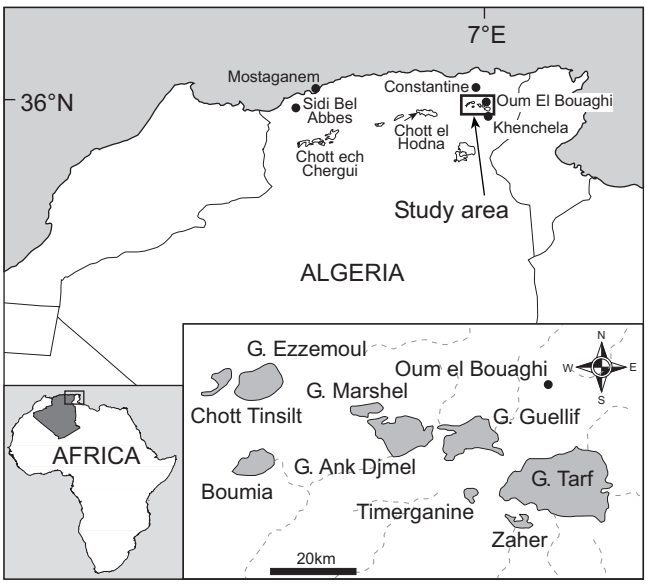

Figure 1: Study area — the wetlands complex of Oum El Bouaghi

took place, has an area of 0.87ha and is located in the northern part of Garaet Ezzemoul. A distance of 1 080m separates it from the northern shore. The water depth (which rarely exceeds 50cm) and period of flooding (November–June) depends on the annual rainfall in the watershed of the lake where, in its western part, salt extraction is carried out. Garaet Ezzemoul is not protected and is the only major wetland within the Oum El Bouaghi wetland complex not to be classified as a Ramsar site.

Methods

The fieldwork was conducted between March and mid-September 2005, with observations carried out at least twice a week. The number of observers varied between two and five. We used a telescope with 20–60x zoom, to conduct regular censuses of Greater Flamingos in the area. Great care was taken not to disturb the breeding colony and thus observations were limited to monitoring the colony from the lake's shore until hatching was well in progress. Diurnal watches were set up to guard against human intrusion. In addition to diurnal observations, on two occasions, monitoring was carried out to obtain qualitative data on nocturnal movements. Some adults wore PVC leg bands bearing codes (Johnson 1989), which were read from a mobile hide which elicited no fear response from incubating or foraging adults. Despite our precautions, two poachers entered the colony on 27 June. We intervened to ward off the intruders and the incident, which lasted roughly two hours, did not seem to have any negative consequences, as adults and chicks promptly resettled. The incident provided us with an opportunity to weigh and measure a limited number of chicks and eggs (n = 60). We recorded chick mass (±1g with a 600g Pesola spring balance), total tarsus and head and bill length (tip of bill to back of skull, ±0.1mm with Vernier calipers). Egg length and width were measured using Vernier calipers (±0.1mm). In the Camargue, body mass and total tarsus length of chicks have been measured prior to fledging since 1977 (Johnson 1983). We used a dataset from 2005 from the Camargue, to compare chick measurements between that area and Garaet Ezzemoul.

Once adults and chicks had left the colony at the end of the breeding season, we measured the size of the islet and counted the number of nests. Five quadrates of 16m² were set up along a transect through the length of the colony, to assess nest density. Nest heights (base to rim), nest diameter (at the top) and distance (top edge to top edge) between nests were measured along a similar transect. The date of the start of egg laying was estimated by backdating the date of the first chick hatched, using a mean incubation period of 30 days (Cramp and Simmons 1977).

Statistical analyses were performed using Statistica 6.0. Probability levels <0.05 were considered significant. Values are presented as means ± standard deviation. To estimate an average body condition of chicks, we used the slope of a linear regression analysis of mass on total tarsus length, after logarithmic transformation (Cézilly *et al.* 1995). One-way ANOVA analyses followed by *post hoc* Tukey tests were performed to study the effect of year on egg size (egg dimensions from 2004, collected at Garaet Ezzemoul after the unsuccessful breeding attempt, were used).

Results

The islet was first occupied on 21 April but it was deserted for a few days (23–27 April) before occupancy was resumed. Three weeks later (mid-May), egg laying was initiated and an estimated 5 000–6 000 pairs settled to breed on the islet. Nesting took place first in the central part of the islet, and a total of 5 379 nests (4 509 counted nests and an estimated 870 obliterated nests) were spread over a surface of about 0.25ha.

Egg laying lasted from mid-May to early July, whereas hatching was spread from mid-June to early August (Figure 2). The mean egg dimensions (Table 1) were significantly smaller in 2005, compared to similar data collected at the same site during the unsuccessful breeding attempt in 2004 (length: $F_{1,238} = 29.6$, $P < 0.001$; breadth: $F_{1,238} = 62.4$, $P < 0.001$, n = 240) (Figure 3).

The regression of log (mass) on log (total tarsus) of chicks (aged between 1 and 15 days) was significant ($y = -1.04 + 1.96x$; $r^2 = 0.97$, n = 90; $P < 0.001$) (Figure 4). The slopes of the allometric (mass-total tarsus) relationship were significantly different between Garaet Ezzemoul and the Camargue (ANCOVA, $F_{3,726} = 14\,700$, $P < 0.001$, tarsus*site: $t = -8.14$, $P < 0.001$), with a much steeper slope at the former (1.96 ± 0.02 and 1.53 ± 0.04, respectively). However, removing the chicks measured on the nest (i.e. aged Day 1 or 2; Figure 4) makes the difference between the two slopes no longer significant ($F_{3,698} = 6\,228$, $P < 0.001$, tarsus*site: $t = -1.85$, $P = 0.06$).

The estimated breeding success, arbitrarily set as the estimated number of fledged chicks relative to the estimated number of nesting pairs, was relatively high (92%). An estimated 5 000 chicks formed a 'crèche' and, gradually, moved away from the islet in mid-August (Figures 5–6). Fledging

Figure 2: A close-up view of the breeding colony at Garaet Ezzemoul

Table 1: Nest and egg measurements of Greater Flamingos breeding at Garaet Ezzemoul, Algeria, in 2005

	Mean ± SD	Min.	Max.	n
Egg length (mm)	89.5 ± 4.6	80.4	100.6	60
Egg breadth (mm)	54.0 ± 2.0	49.1	58.5	60
Nest internal diameter (cm)	20.0 ± 2.1	14.0	25.0	120
Nest external diameter (cm)	36.9 ± 2.9	30.0	44.0	120
Nest height (cm)	11.9 ± 3.8	5.0	26.0	120
Nearest nest distance (cm)	20.0 ± 7.4	5.0	45.0	120

was noted at the end of August but, in mid-September, most chicks were still grouped inside a crèche which occupied the centre of the salt lake as water receded and access to the islet became easier for terrestrial predators.

Inspection of the islet in early September, once breeding was over, revealed only two eggs and a total of 206 dead chicks in and around the immediate surrounds of the nesting area. This chick mortality, representing less than 4% of the total number of chicks, is clearly an underestimate, as many dead chicks possibly remained undetected.

Nest density averaged 2.8 nests per m² and was highest near the centre of the nesting colony, tapering off towards both ends of the east-west transect through the colony (respectively, from east to west: 2.2, 2.8, 3.8, 2.6, 2.1 nests per m²). The mean distance (edge to edge) between nests was 19.9cm (Table 1). Nest height was significantly positively correlated with nest diameter ($r = 0.26$, $P = 0.005$, $n = 120$; Figure 7). Between April and mid-July, large branchiopods (Anostraca) (e.g. *Artemia salina*) and diptera larvae of *Ephydra* sp. were abundant in Garaet Ezzemoul, as well as in neighbouring salt lakes. Adults were observed during the day, feeding chicks that were still being brooded. There were no observations of older chicks being fed by adults. It is likely that they were fed during the night when movements of adults peaked. In mid-July, Chott Tinsilt, an adjacent salt lake, started to dry up and foraging adults switched to another seasonal salt lake — Garaet Ank Djmel — and, to a lesser extent, to Garaet Boulehilet (35°44.699'N, 06°47.431'E), a freshwater pond. Both sites are less than 35km from Garaet Ezzemoul and they respectively harboured a large number of ostracods and macro invertebrates (B Samraoui, unpubl. data). Around 30 000 Greater Flamingos could be seen foraging there in August and September, whereas Garaet Ezzemoul and Chott Tinsilt were practically devoid of adults. Attempts to read the bands on ringed adults in Garaet Ank Djmel proved difficult, but we succeeded in locating two adults from the Garaet Ezzemoul colony.

Discussion

The nesting of Greater Flamingos at Garaet Ezzemoul is the first breeding record of the species in Algeria. There is little doubt that local salt lakes, long perceived as just stopovers and wintering sites (Ledant *et al.* 1981), may have acted as unrecorded breeding grounds for decades, if not centuries (Saheb *et al.* 2006). The size of the breeding colony at Garaet Ezzemoul, with over 5 000 pairs, makes it one of the most important in the West Palearctic (Johnson 1983, 2000).

The number of recorded nests might be an underestimate of the number of breeding pairs, as re-utilisation of nests — a

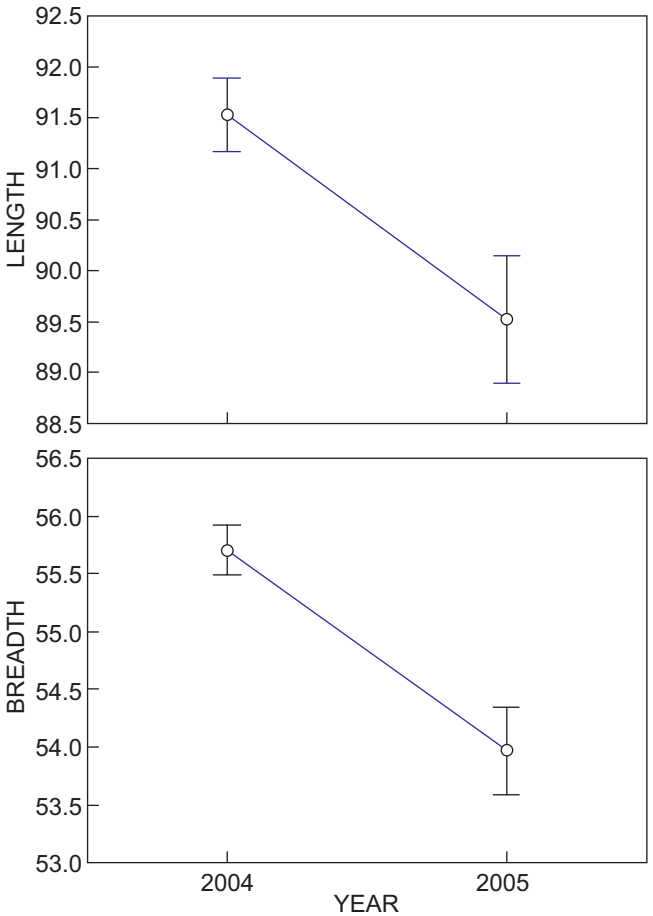

Figure 3: Results of a one-way ANOVA test illustrating the differences in egg size between 2004 (n = 240) and 2005 (n = 60)

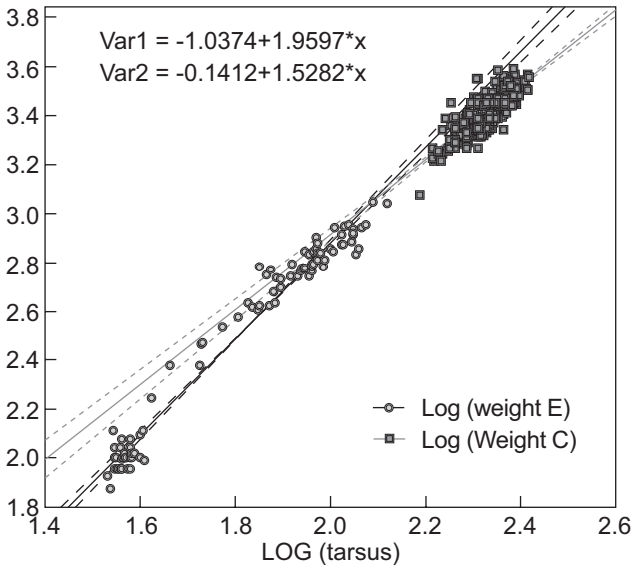

Figure 4: Relation between log (weight) and log (tarsus). Circles represent chicks (n = 90) from Garaet Ezzemoul (2005); squares represent comparative data (n = 641) from the Camargue (2005)

common feature at Fuente de Piedra (Rendón-Martos 1996) — was not taken into account. Nest density was well within the known range of 2–3 nests per m² described at another natural breeding site in Mauritania (de Naurois 1969). In the Camargue, nests are at a lower density (1.3 nests/m²) (Swift 1960). The higher nest density recorded in the centre of the colony suggests that predation is higher at the edges, and also that nests located in the centre may be better protected against flooding or strong winds. The soil texture of the islet, made up mainly of sand and rocks, may explain why the average nest height was relatively low. The size of nests is known to vary with the substrate, with larger nests made of clay and smaller ones made of sand (Johnson 1997a).

Nesting started relatively late in the season and egg laying was spread over at least 50 days, much longer than the average 40 days recorded in Europe (Johnson 1997a). Indeed, the two previously-known attempts at breeding in Algeria (2004 and 2005) both occurred much later in the season (Saheb *et al* 2006) than in Europe, where laying starts generally between February and May (Rendon-Martos *et al.* 1991). The reason for this remains uncertain, although altitude (900m) could be a factor. Besides the food required by females to start egg laying and the resources required for chick development (Perrins 1970), a whole set of proximate factors constrains the start of reproduction in birds (Meijer and Drent 1999). Fairy shrimps and other aquatic invertebrates are a substantial source of food for the Greater Flamingo (Johnson 1983). Although the diet of the Greater Flamingo is fairly well known, virtually nothing is known about the phenology and spatial variability of food available for Greater Flamingos in Algeria (Samraoui and Dumont 2002, Samraoui *et al.* in press). Even when foraging sites are easily accessible, a female nesting too late may put her egg or chick at a high predation risk if the breeding site dries up too quickly.

Why egg size differed significantly between two successive years (2004 and 2005) is uncertain. Two suggested determinants of egg size are female size and temperature (Ojanen 1983). In May and June 2004, it rained heavily and both months were uncharacteristically cold, so weather conditions might have influenced egg size. High water levels due to abundant rainfall are also known to positively influence the number of breeding pairs, chick body condition and growth rate (Rendón-Martos *et al.* 1991, Cézilly *et al.* 1995, Rendón-Martos 1996). Rainfall had been substantial over the previous three years (2003–2005) within the eastern Hauts Plateaux, and both the abundant trophic resources (B Samraoui, unpubl. data) and the close proximity of foraging sites probably account for the breeding and its high success rate.

Even though the age classes are different, the log transformation allows a comparison of the allometric relationship between mass and total tarsus length (Reiss 1989). The slope of the regression taken as an index of body condition was higher in Garaet Ezzemoul compared to the Camargue (1.96 and 1.53, respectively). It was also higher than any similar value previously recorded in the Camargue (range of slopes recorded between 1984 and 1991: 1.15–1.69 — Cézilly *et al.* 1995), but this difference is no longer significant when young chicks that had just hatched are not taken into account.

Figure 5: Younger chicks (less than two weeks of age) initiating a crèche within the colony

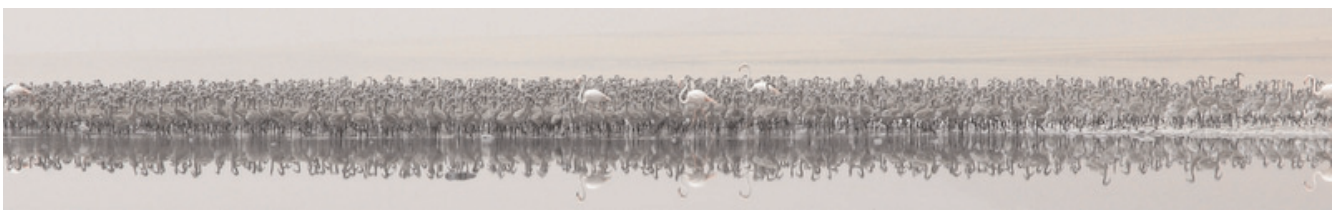

Figure 6: Older chicks (over four weeks of age) forming a crèche and starting to drift from the colony

Foraging sites may be located within a 200km radius from the breeding ground (Rendón-Martos *et al.* 2000), but within the Algerian Hauts Plateaux, in favourable years, the number and diversity of wetlands concentrated within a relatively small area may be advantageous for incubating parents to meet their own and their nestlings' energy demands.

Our diurnal (as well as a limited set of nocturnal) observations confirmed what has previously been found in Spain (Rendón-Martos *et al.* 2000): older chicks were not fed during the day and were presumably only fed at night when commuting between the breeding colony and foraging sites peaked. Thus, the distance (probably less than 60km around Garaet Ezzemoul) covered by foraging parents does not seem to influence the timing of chicks' feeding. Diurnal flights were relatively limited in number, suggesting that nocturnal movements between the breeding colony and foraging sites may have a lower energetic cost to parents (Rendón-Martos *et al.* 2000).

Predation has been suggested as the main source of nestling mortality in birds (Ricklefs 1969, Salathé 1983). It is thus interesting to speculate on our estimation of reproductive success, which probably does not take into account losses due to predation outside the islet. The Yellow-legged Gull *Larus michahellis*, the main predator of the Greater Flamingo in Europe (Salathé 1983, Rendón-Martos 1996), however, is relatively rare in the region. As chicks grew up, some left the crèche, safely located in the middle of the lake, and for unknown reasons (food?) wandered in very small groups along the shores where they were at times picked up by people or attacked by birds of prey (*Buteo* sp. and *Aquila* sp.). This predation, however, although a real threat, is unlikely to substantially change the estimated breeding success. In May and June, several hundreds of moulting adult Greater Flamingos were seen at Garaet Tarf. Here we observed the capture of flightless flamingos by poachers, who run down exhausted birds in a way similar to that cited by Brown (1955) at Lake Rukwa. A systematic search of the site, which probably acted as a foraging site, did not reveal the presence of a breeding colony.

How can we account for the estimated high breeding success? The successful breeding observed at our study site might explain how flamingos can compensate for recurrent massive losses by taking full advantage of favourable breeding opportunities when they occur. The estimated breeding success is possibly an adjustment reflecting the trade-off between rare successes and repeated failures. Flight surveys may, however, be needed to provide more accurate data for a long-term monitoring of breeding success.

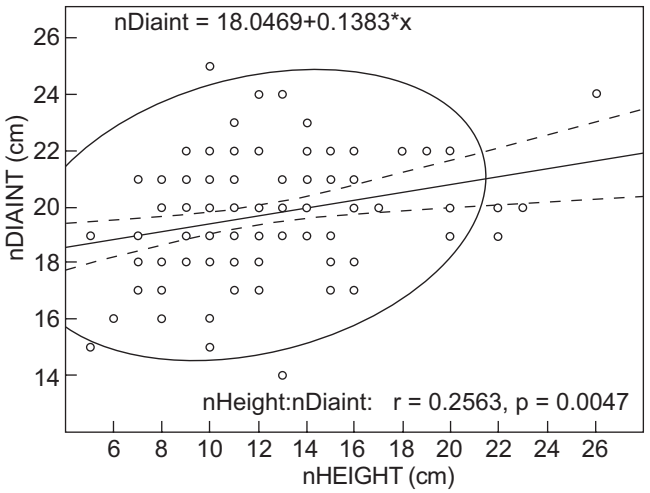

Figure 7: Relationship between nest internal diameter (nDIAINT) and nest height (nHEIGHT)

Reading bands worn by individual breeding birds enabled us to ascertain that at least 30 adults — ringed as nestlings in Spain, France and Sardinia — were breeding at this colony. Data on age structure of the colony at Garaet Ezzemoul and previous reproductive experience of confirmed breeders will be provided elsewhere (Boulkhssaïm *et al*. in prep.). The bands also allowed us to confirm that some individuals appeared to incubate nests continuously for at least three consecutive days. The observation of rings confirms the extensive dispersal of mature Greater Flamingos across western Mediterranean countries, a common strategy of waterbirds from arid regions (Andersson 1980, Briggs 1992, Frederick *et al.* 1996, Nager *et al.* 1996). Identifying and monitoring all breeding sites may allow data on lifetime reproductive success to be collected from banded individuals and provide a clearer picture of the life history of the Greater Flamingo.

The Mediterranean population of the Greater Flamingo has increased over the past decades (Wetlands International 2002) and birds hatched in the Camargue have been recorded breeding in the Camargue, Spain, Italy, Turkey and Mauritania (Johnson 2000). The same author was the first to suggest a link between breeding performances in the Camargue and extreme climatic conditions in Tunisia (Johnson 1983). Because of a severe drought, no breeding took place in Spain in 2005 and one is tempted to link this event to breeding at Garaet Ezzemoul. However, Greater Flamingos show strong fidelity to the site of their natal colony (Nager *et al.* 1996). Previous attempts at breeding at Garaet Ezzemoul in 2003 and 2004 (and probably before that) also seem to discount the hypothesis of a significant spill-over from south Europe. Ringing schemes involving banding flamingo nestlings with Darvic bands were initiated in 1977, 1986 and 1997, respectively in the Camargue (France), Fuente de Piedra (Spain) and Molentargius (Sardinia, Italy). Unfortunately, no such scheme has ever been set up in North Africa and thus locally-hatched flamingos would go undetected in our study.

Current research has emphasised the importance of Algerian salt lakes as vital wintering, moulting and breeding grounds for the Greater Flamingo and other waterbirds (Boulkhssaïm *et al.* 2004, Ouldjaoui *et al.* 2004, Saheb *et al.* 2004) and this warrants a re-assessment of the role of the salt lakes in metapopulation dynamics vital to the Greater Flamingo. Indeed, the number of breeding individuals (over 5 000 pairs), the higher number of foraging Greater Flamingos (around 35 000), and moulting birds (hundreds) in the eastern Hauts Plateaux, as well as the number of fledged chicks (over 5 000), exceeds all expectations. This large number clearly indicates that the role of North African wetlands acting as source areas to maintain the Mediterranean metapopulation of Greater Flamingos has not been fully evaluated.

Breeding colonies of Greater Flamingo are vulnerable to human disturbance. Past human intrusions at Garaet Ezzemoul have caused mass desertions (Saheb *et al.* in press). The site has been inexplicably left off the Algerian list of Ramsar sites. Conservation initiatives have involved local people and addressed, as a priority, landscape use (human encroachment, river damming and poaching) and the potential impact of broad-scale changes in climate (Hughes 2000) that present a challenge to the survival of the Greater Flamingo in North Africa. These initiatives, if instituted, should provide effective protection to the Greater Flamingos and other waterbirds at Garaet Ezzemoul. Recent national and international support for the safeguarding of Garaet Ezzemoul has been forthcoming and it is hoped that such a directed effort will quickly succeed.

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