Diversity and distribution of avian lice on Greater Flamingo chicks (*Phoenicopterus roseus*) in Algeria

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ABSTRACT

The ecological diversity and distribution of ectoparasites on Greater Flamingo chicks (*Phoenicopterus roseus*) were investigated in Algeria at two distinct sites: Ezzemoul (Hauts Plateaux) and Safioune (Sahara) at the end of the breeding seasons of 2009 and 2011. Results from the first records for the Greater Flamingo in North Africa, indicate that they were infested by the following louse species: *Colpocephalum heterosoma* Piaget and *Triniton femoratum* Piaget (Menoponidae); *Anaticola phoenicopteri* (Coinde) and *Anatoecus pygaspis* Nitzsch (Philopteridae). These data support the hypothesis of a connectivity of the Greater Flamingo metapopulation across the Mediterranean region. The results also suggest that there was a spatial segregation in the distribution of the various louse species across distinct body parts of their hosts. Adaptive explanations for this niche partitioning are suggested.

Keywords: *Colpocephalum, Triniton, Anaticola, Anatoecus*, host body distribution, Algeria

1. INTRODUCTION

Interactions between wild birds and ectoparasites have received a substantial amount of research attention by ecologists (Loye and Zuk, 1991; Clayton *et al*., 2010) because the distribution and dynamics of parasites may drive population processes of their hosts by influencing survival and productivity (Anderson and May, 1978; Hudson and Dobson, 1989; Dobson and Hudson, 1992; Albon *et al*., 2002). Areas of interest include the influence of host morphology and behaviour on ectoparasite numbers and distribution (Murray, 1990), and their vertical or horizontal transmission (Clayton and Moore, 1997; Brooke, 2010). Many studies reported that close proximity of individuals facilitates host infestation with colonial birds harbouring a large number and a great diversity of ectoparasites (Rózsa *et al*., 1996; Clayton and Moore, 1997). Thus, chewing lice usually are transferred by direct contact and, less frequently, by louse flies (Keirans, 1975). Their feeding can damage feathers, and scratching in response to infestation can cause additional damage. Heavy louse infestations may cause anaemia, weight loss, and death (Price and Graham, 1997; Johnson and Clayton, 2003; Price *et al*., 2003). Moreover, for various reasons such as host preening and resource competition (Reiczigel and Rózsa, 1998), avian ectoparasitic communities are spatially structured on the host, so are often being confined to specific parts or regions of the bird's host (Clay, 1949; Nelson and Murray, 1971; Choe and Kim, 1987, 1988).

Algeria, the largest country in Africa, can be broadly divided into three climatic belts characterised by alternating wet and dry seasons. There is a latitudinal gradient from the sub- tropical coastal northeast to the semi-arid Hauts Plateaux and, further south, to the arid climate of the Sahara. The hypersaline lakes, used for breeding and foraging by Greater Flamingos, are mostly located in the Hauts Plateaux and the Sahara and are "pulsed" habitats characterised by a high productivity of *Artemia salina* and other fairy shrimps during wet spells (Samraoui *et al*., 2006a). This abundance of trophic resources makes these saline lakes attractive breeding sites, wintering sites and stopovers for thousands of migrating waterbirds (Samraoui and Samraoui, 2008; Samraoui *et al*., 2011). For many years, North African wetlands were thought to support a few thousand wintering Greater Flamingos and serve as a "crèche" for immature birds (Johnson and Cézilly, 2007). Recent studies have, however, altered this traditional view and revealed the important role played by North African wetlands in the dynamics of a wide range of species of waterbirds across the western Mediterranean region (Boulkhssaim *et al*., 2006; Baaloudj *et al*., 2012). Over the last 10 years, The Greater Flamingo seemed to have expanded its nesting range across Algeria with numerous breeding attempts and successful breeding outcomes at three distinct sites: Ezzemoul (Hauts Plateaux) (Samraoui *et al*., 2006b; 2010); El Goléa in the Sahara (Bouzid *et al*., 2009), and one new site in the northern Sahara, Safioune (Mesbah *et al*., 2011). Birds from arid

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regions have been shown to host far less lice than their conspecifics from more humid regions (Moyer *et al.*, 2002). As part of a larger effort to survey the ectoparasites of North African waterbirds, document their possible influence on the dynamics of their hosts, and investigate possible geographical differences in composition and abundance, the present study investigates the diversity and the distribution of feather lice on Greater Flamingos chicks *Phoenicopterus roseus*, at two distinct Algerian sites, Ezzemoul and Safioune.

2. METHODS

2.1. Study area

The fieldwork was conducted at two distinct salt lakes: Garaet Ezzemoul located in the semi- arid Hauts Plateaux, northeast Algeria and Safioune located in the hyperarid northeastern Sahara (Figure 1). Garaet Ezzemoul (35°53.137′N, 06°30.200′E) is a temporary salt lake of 6000 ha, at an altitude of 900 m above sea level. Its annual mean temperature is 15.5 °C and its average annual rainfall is less than 400 mm (Samraoui *et al.*, 2006b). The water depth rarely exceeds 50 cm and the period of flooding (October–March) depends on the annual rainfall received by the lake's watershed. Safioune (32°19′16″ N, 5° 22′6″ E, altitude 129 m) is a vast salt lake north of the oasis of Ouargla. Its annual mean temperature is 22.5 °C and its average annual rainfall is 40.7 mm. Safioune benefited in 2010 from the drainage of Chott Aïn El Beïda, a Ramsar site, and Sidi Khouiled, sites which had previously assumed a drainage function in the area.

2.2. Material and methods

As a part of a long-term population study of the Greater Flamingo, we investigated ectoparasites harboured by chicks at two Algerian salt lakes, Ezzemoul and Safioune. Chicks were captured prior to fledging, in July 2009 and 2011 at Ezzemoul, and in April 2011 at Safioune. A total of 54 and 63 chicks were examined at Garaet Ezzemoul in 2009 and 2011, respectively, whereas 33 chicks were inspected at Safioune. Chicks were aged between 6 and 10 weeks, the youngest retaining some down while the oldest were fully feathered. Each bird was held for a total of 5 minutes during which time ectoparasites were collected from three distinct parts of the body: head, wings, and flanks. Ectoparasites were detected with the naked eye, removed by hand and preserved in 70% ethanol. Lice were subsequently mounted as permanent

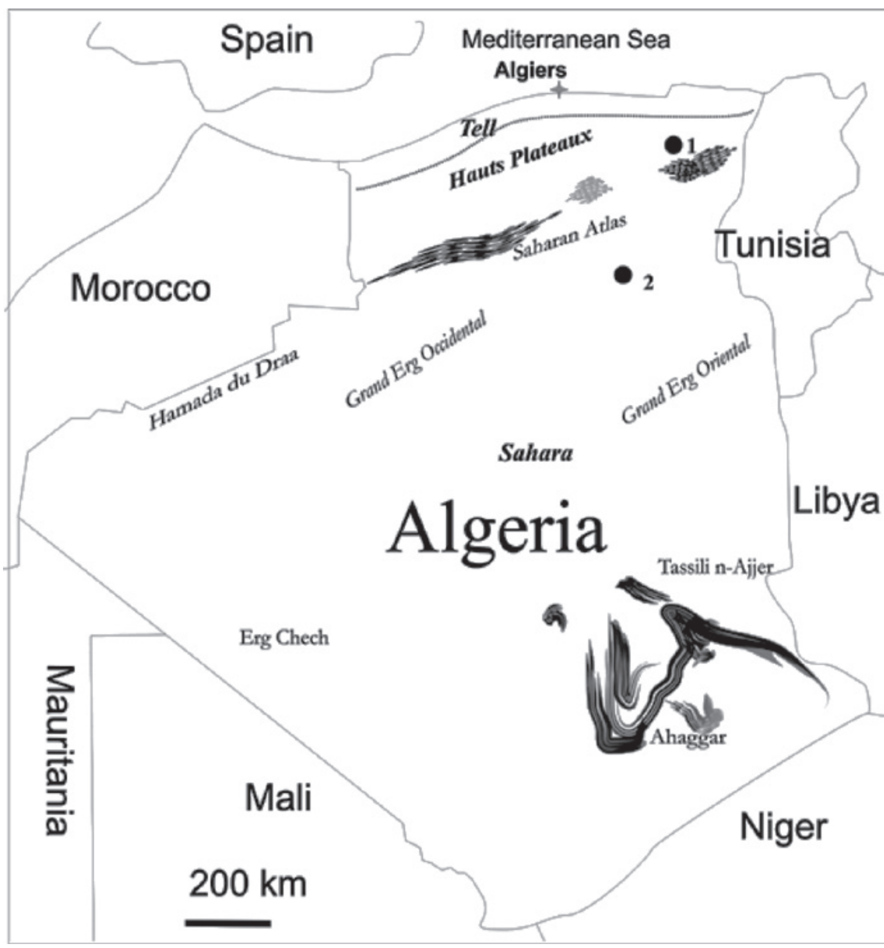

Figure 1 Map showing the study sites: Ezzemoul (1), and Safioune (2).

slides following the technique of Palma (1978), and deposited in the entomology collection of the Laboratoire de Recherche et de Conservation des Zones Humides (L.R.Z.H.), University of Guelma. Identification proceeded with the help of various keys (Séguy, 1944; Price *et al.*, 2003; Wall and Shearer, 2008). The following indices of infestation were used: prevalence (*P*, %), abundance (A, sp.), range of intensity (I, sp.) (Margolis *et al.*, 1982; Bush *et al.*, 1997). Data analysis (Fisher's exact test, Kruskal-Wallis rank sum test) was carried out using using R (R Development Core Team, 2009) and significance was accepted at $P = 0.05$.

3. RESULTS

3.1. Ectoparasites composition

The ectoparasites community recorded on Algerian Flamingos consisted mainly of the following louse species (Mallophaga), recorded at both study sites: *Colpocephalum heterosoma* Piaget (Menoponidae) and *Triniton femoratum* Piaget (Menoponidae); *Anaticola phoenicopteri* (Coinde) (Philopteridae) and *Anatoecus pygaspis* Nitzsch (Philopteridae) (Table 1).

3.2. Variation of infestation between sites and between years

At Ezzemoul, 18 chicks (33.3%) and 17 chicks (27.0%) were infested by chewing lice in 2009 and 2011, respectively, whereas at Safioune 13 chicks (39.3%) were found to be infested. The level of infestation did not differ between the three samples (Fisher's Exact Test for count data: $P = 0.11$). In all three sampling events, the prevalence of all four species of ectoparasites was similar (Fisher's Exact Test for count data: $P > 0.40$ for all three samples). Overall, at Ezzemoul, 115 and 91 lice were collected from 18 and 17 Greater Flamingo chicks in 2009 and 2011, respectively. But, at Safioune in 2011 (the first successful breeding), only 77 lice were collected from 13 birds. The number of ectoparasites per individual bird ranged from one to 10 (mean 6.38) and one to eight (mean 5.35) at Garaet Ezzemoul respectively in 2009 and 2011. Similarly, at Safioune it varied from three to 10 (mean 5.92). We have observed at both study sites that each infected bird was parasitised by only one species of mallophaga with the ectoparasites community being dominated by *A. phoenicopteri* (12.86%) and (11.11%) at Ezzemoul in 2009 and 2011, respectively, whereas at Safioune *A. phoenicopteri* exhibited the highest level of bird's infestation (15.15%) and mean abundance. In sharp contrast, at Ezzemoul *Anatoecus pygaspis* was only encountered on two birds (3.70%) and three birds (4.76%) in 2009 and 2011, respectively. Likewise, at Safioune we recorded this species and *Triniton femoratum* on the body of two birds with the same percentage (6.06%). There were however no differences in mean abundance of ectoparasites between the three sampling events (Kruskal–Wallis rank sum test: $P = 0.23$). Likewise, there were no differences in mean intensity between the three sampling events (Kruskal–Wallis rank sum test: $P = 0.37$).

3.3. Spatial distribution on host

The ectoparasites were differentially abundant across distinct regions on the body of chicks (head, wings, flanks) during the two years of study at Ezzemoul and Safioune. Although differences in occurrence of all four louse species between the sampled body parts were not significant (Kruskal–Wallis rank sum test: $P = 0.06$),

Table 1 Feather lice collected from Greater Flamingo chicks at Ezzemoul (2009 and 2011) and Safioune (2011) with prevalence, abundance and mean intensity of ectoparasites.

Ectoparasites	Sites	Infested hosts	Prevalence (%)	Mean abundance (± SD)	Mean intensity (± SD)
Colpocephalum heterosoma (Menoponidae)	Ezzemoul 2009	5/54	9.25	0.53 ± 1.70	1.61 ± 2.63
	Ezzemoul 2011	4/63	4.76	0.22 ± 1.01	0.82 ± 1.78
	Safioune 2011	4/33	12.12	0.51 ± 1.41	1.30 ± 1.97
Triniton femoratum (Menoponidae)	Ezzemoul 2009	4/54	7.40	0.48 ± 1.51	1.16 ± 2.17
	Ezzemoul 2011	3/63	4.76	0.22 ± 1.01	0.82 ± 1.78
	Safioune 2011	2/33	6.06	0.27 ± 1.13	0.69 ± 1.67
Anaticola phoenicopteri (Philopteridae)	Ezzemoul 2009	7/54	12.86	0.92 ± 2.69	2.77 ± 4.06
	Ezzemoul 2011	7/63	11.11	0.67 ± 1.92	2.47 ± 3.01
	Safioune 2011	5/33	15.15	1.03 ± 2.5	2.61 ± 3.43
Anatoecus pygaspis (Philopteridae)	Ezzemoul 2009	2/54	3.70	0.27 ± 1.31	0.83 ± 2.14
	Ezzemoul 2011	3/63	4.76	0.17 ± 0.88	0.64 ± 1.56
	Safioune 2011	2/33	6.06	0.51 ± 2.03	1.30 ± 3.02

their differential abundance on distinct areas of the body of their hosts in all three sampling events suggest that there may be spatial partitioning within the lice infra-community (Figure 2). *Colpocephalum heterosoma* is largely abundant on the wings (Fisher's Exact Test: $P < 0.0001$), *Triniton femoratum* is dominant on the flanks (Fisher's Exact Test: $P < 0.003$), *Anaticola phoenocopteri* is most likely to be found on the wings (Fisher's Exact Test: $P < 0.0001$) and *Anatoecus pygaspis* is almost exclusively encountered on the head (Fisher's Exact Test: $P < 0.0001$).

4. DISCUSSION

4.1. Connectivity of the Greater Flamingo colonies

In the present study, Greater Flamingo chicks were found at both study sites, Ezzemoul and Safioune, to be infested by four chewing louse species: *Colpocephalum heterosoma, Triniton femoratum, Anaticola phoenocopteri* and *Anatoecus pygaspis*. Our results match closely those based on a similar study carried out in the Camargue, southern France, that identified the same four species and

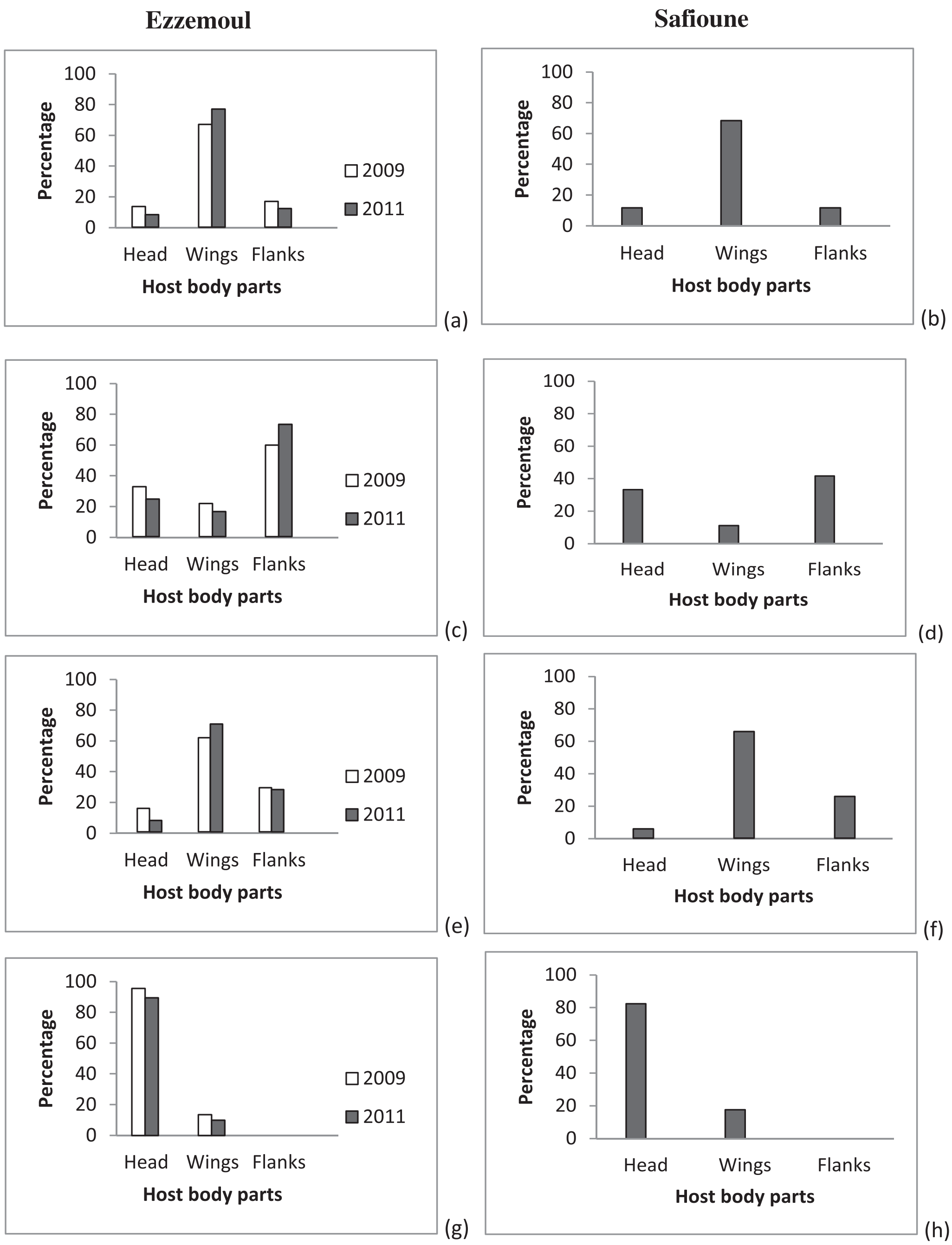

Figure 2 Relative abundance and spatial distribution of (a & b) *Colpocephalum heterosoma;* (c & d) *Triniton femoratum*; (e & f) *Anaticola phoenicopteri;* (g & h) *Anatoecus pygaspis* on three distinct body parts of Greater Flamingo chicks at Ezzemoul (2009 and 2011) and Safioune (2011).

an additional single specimen of *Colpocephalum salimalii* Clay, 1951 (Palma *et al*., 2002).

Scattered wetlands across the Mediterranean landscape may pose a constraint to the dispersal of waterbirds (Fahrig and Merriam, 1985; Taylor *et al*., 1993; Amat *et al*., 2005). Large scale exchange of individuals between Greater Flamingo colonies has already been highlighted by ringing and molecular data (Balkiz *et al*., 2007; Boucheker *et al*., 2011; Geraci *et al*., 2012). The data at hand support the hypothesis of a high degree of connectivity between the different Mediterranean Greater Flamingo colonies which share a common pool of ectoparasites.

Level of infestation

The prevalence, mean abundance and mean intensity of all four louse species did not differ among the three sampling events. The level of infestation depends on the concentration or density of birds with ectoparasites spreading easily within a dense population. As chewing lice are permanent ectoparasites that complete their entire life cycle on the host where they feed mainly on feathers, dead skin, blood or secretions, they are incapable of independent mobility and transmission occurs during periods of direct contacts between hosts (Clay, 1974; Clayton and Tompkins, 1994; Lee and Clayton, 1995; Johnson and Clayton, 2003). Thus, the number and the variety of ectoparasites are greater on colonial birds than on territorial birds (Rózsa *et al*., 1996).

Spatial and temporal variation among sites

Our study did not indicate any between-year variation in the composition of the ectoparasites hosted by the Greater Flamingo *Phonicopterus roseus* during breeding seasons of 2009 and 2011 (Figure 3). Variation in the parasitic fauna may be linked to climatic factors such as temperature, humidity, vegetation which may limit distribution (Johnson and Clayton, 2003) but the hyperarid (Sahara) and the semi-arid (Hauts Plateaux) Algerian climates do not appear to influence the distribution of the recorded louse species. The recorded ectoparasites may be specially adapted to hypersaline environments as salt exposure is known to influence the distribution of feather mites (Dowling *et al*., 2001).

4.2. Spatial distribution on the host

Results show that ectoparasites inhabited distinct areas of the body (head, wings and flanks) of Greater Flamingo chicks both at Ezzemoul and Safioune (Figures 4 and 5). Some ectoparasites exhibit no microhabitat preferences while others tend to confine themselves to, or even restrict themselves to, limited areas on the body of the host (Clay, 1949; Choe and Kim, 1988; Palma *et al*., 2002). Preening is the main defensive behaviour of birds against harmful ectoparasites (Muzaffar, 2000; Clayton *et al*., 2005). Parasites that share resources can reduce competition by being spatially segregated (Mouillot *et al*. 2003). Spatial segregation probably results from exploitation rather than interference competition among parasites and differences in the size and shape of the feathers seem to provide the necessary habitat heterogeneity for parasites to segregate (Crompton, 1997).The distribution of chewing lice on the host has been reported to be specific for each species of louse. Both *Anaticola phoenocopteri* and *Colpocephalum heterosoma* were mostly found on the wings but on separate hosts. Nelson and Murray (1971) in their ecological study of lice from domestic pigeons also found *Colpocephalum* mostly on the wings, and on the tail. It seems that ectoparasites species avoid direct competition by occupying separate microhabitats. A similar pattern of habitat partitioning between two species of ticks: *Ixodes*

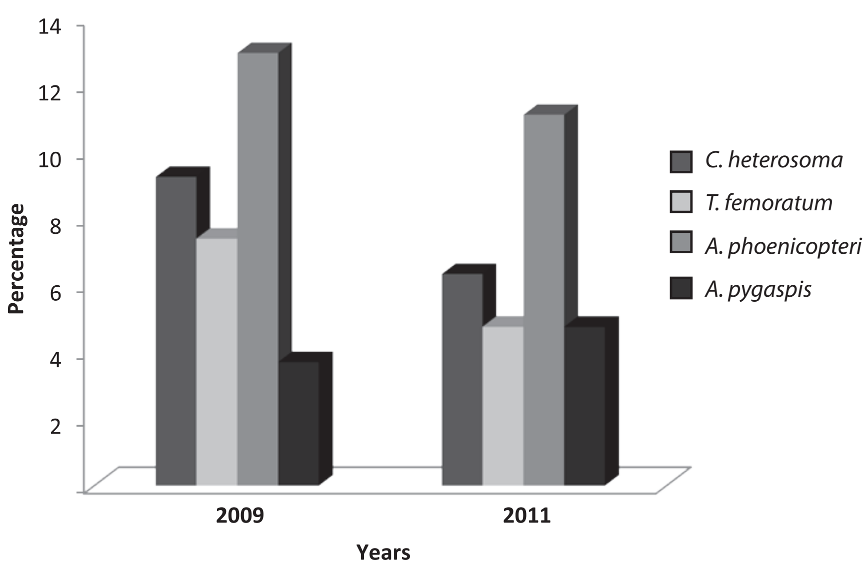

Figure 3 Temporal variation of prevalence at Ezzemoul.

Figure 4 Views of the Greater Flamingo colony at Ezzemoul.

Figure 5 Views of the Greater Flamingo colony at Safioune.

uriae and *I. signatus* has been observed on murres and kittiwakes on the Pribilof Islands (Choe, 1982). In agreement with previous studies reporting that slender elongate lice occupy wing feathers (Clay, 1949, 1974; Palma *et al*., 2002), a greater proportion of *Anaticola phoenocopteri*, a long and narrow bodied species, was encountered on the wings. Slimmer, more elongate lice are free to exploit the remainder of the host's body since they can move easily and rapidly among the feathers to avoid the host's beak. Most studies suggest that feather morphology and the ability of lice to escape preening are the major factors determining the distribution of lice on birds (Bush *et al*., 2006). Finally, the very high proportion of *Anatoecus pygaspis* found on the head of

Great Flamingo chicks confirms the adaptive zone of slow, triangular-headed Ischnocera as typical "head lice'' that avoid preening (Clay, 1949, 1974; Palma *et al.*, 2002; Johnson and Clayton, 2003).

The original aim of this study was to identify the louse species hosted by Greater Flamingo chicks and document their distribution across the host's body. Although the spatial distribution of chewing lice is in part attributed to feather morphology and chemistry (Dumbacher *et al.*, 1992; Kose *et al.*, 1999; Johnson and Clayton, 2003), due to severe time constraint during the ringing operations, we did not perform a comparative and probably instructive analysis of lice abundance and distribution according to feather development (down v.s. full feathering). There is, therefore, a need to explore this aspect in future studies, explore patterns of ectoparasite aggregation (Fowler and Williams, 1985) and extend this effort to other bird species as, until now in North Africa, little attention has been devoted to the study of ectoparasites and their impact on the dynamics of birds.

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