


Distribution patterns of ectoparasites of Glossy Ibis (*Plegadis falcinellus*) chicks

Laid Touati^{a,b}, Jordi Figuerola^c, Ahmed H. Alfarhan^d and Boudjéma Samraoui^{b,d,*} 

^aBiology and Ecology Department, University of Constantine, Constantine, Algeria; ^bLaboratoire de Recherche et de Conservation des Zones Humides, University of Guelma, Guelma, Algeria; ^cEstación Biológica de Doñana-CSIC, Sevilla, Spain; ^dCenter of Excellence for Research in Biodiversity, King Saud University, Riyadh, Saudi Arabia

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The aim of this study was to identify the ectoparasite community that may be found on the body of Glossy Ibis chicks *Plegadis falcinellus* in two Algerian wetlands, Chatt and Lake Fetzara, during the breeding season of 2010. Birds were parasitized by the following chewing lice (Phthiraptera: Amblycera, Ischnocera) species at both study sites: *Plegadiphilus plegadis* and *Colpocephalum leptopygos* (both Menoponidae), *Ardeicola raphidius* and *Ibidoecus bisignatus* (both Philopteridae). In addition, one tick (larva) *Ixodes ricinus* was also found at Lake Fetzara. All these ectoparasites were recorded in Algeria for the first time. Results showed that chewing lice varied in their spatial distribution at the infra-community level with some species displaying no microhabitat preferences, whereas others confined themselves to specific body parts of their hosts. The recorded frequency pattern of chewing lice followed the negative binomial distribution.

Dviejose Alžyro šlapžemėse (Chatt ir Fetzara ežerai) 2010 metų perėjimo laikotarpiu nustatyta rudojo ibio *Plegadis falcinellus* jauniklių ektoparazitų bendrijos rūšinė sudėtis. Abiejose vietovėse paukščius parazitavo utėlės *Plegadiphilus plegadis* ir *Colpocephalum leptopygos* (Menoponidae), bei *Ardeicola raphidius* ir *Ibidoecus bisignatus* (Philopteridae). Fetzara šlapžemėje aptikta viena erkės *Ixodes ricinus* lerva. Visi šie ektoparazitai Alžyre užregistruoti pirmą kartą. Šeimninke utėlės buvo pasiskirsčiusios nevienodai: vienos jų parazitavo tik specifinėse šeimnininko kūno dalyse, kitoms mikrobuveinės selektyvumas nepasireiškė. Utėlių pasiskirstymas atitiko neigiamą binominį modelį.

Keywords: Phthiraptera; *Plegadis falcinellus*; ectoparasites; distribution; Algeria

Introduction

A range of factors are known to shape the macroparasite burden in hosts (Post and Enders 1970; Combes 2001). Host–parasite dynamics are believed to be driven by both intrinsic (sex, age, immunocompetence, etc.) and extrinsic (habitat, weather, etc.) factors, which invariably lead to a nonrandom distribution of macroparasites across their host population (Anderson and May 1978; Pacala and Dobson 1988; Møller and Rózsa 2005). Many studies have highlighted that the spatial distribution of macroparasites is generally clumped with most individuals bearing none or a low number of parasites and a minority hosting many (Marshall 1981; Shaw and Dobson 1995). This pattern of aggregation, best represented mathematically by the negative binomial distribution, may be a critical factor in stabilizing host populations (Anderson and May 1982). Over the last three decades, it has prompted numerous studies, which have focused on building and testing a theoretical framework explaining links between spatial distribution of macroparasites and regulation of their host population (Dobson and Hudson 1992; Hudson, Dobson, and Newborn 1998; Albon et al. 2002). Birds have been known for decades to harbor a large number and a great diversity of ectoparasites (Herman 1936; Boyd 1951;

Rothschild and Clay 1952) and they have proved to be models of choice for testing various paradigms (Møller 1993; Clayton and Moore 1997).

Whilst the dispersal of some Algerian waterbirds and the connectivity of their habitats have been documented recently (Bouchecker et al. 2011; Baaloudj et al. 2012), much less is known about their ectoparasites and the impact of such parasites and pathogens on population dynamics and dispersal of local birds. Despite increased interest in the role of birds in dispersal of infectious disease vectors (Hubálek 2004; Palomar et al. 2012; Arnal et al. 2014), there is a paucity of such studies in North Africa (Rouag-Ziane et al. 2007; Touati and Samraoui 2013). This study aims to investigate the ecological diversity and distribution of ectoparasites of Glossy Ibis chicks in two North African wetlands, and to shed some light on the structure and patterns of their spatial distribution across their hosts.

Materials and methods

The study area

Algeria, the largest country in Africa, can be broadly divided into three climatic belts characterized by alternating wet and dry seasons. There is a latitudinal gradient

*Corresponding author. Email: bsamraoui@yahoo.fr

from the subtropical coastal northeast to the semi-arid Hauts Plateaux and, further south, to the arid climate of the Sahara. Despite the predominant arid climate, the country holds a large spectrum of wetlands (shallow freshwater ponds, brackish marshes in the North, and vast hypersaline lakes or sebkhas in the South). Algerian wetlands are well-known internationally for their ecological importance: they are important staging posts and wintering grounds for migrating birds (Samraoui and Samraoui 2008; Samraoui et al. 2011). The country also houses important breeding sites for many rare, endangered or biome-restricted species, including the Audouin's gull *Larus audouinii*, white-headed duck *Oxyura leucocephala*, ferruginous duck *Aythya nyroca*, marbled teal *Marmorenetta angustirostris*, and the Eleonora's falcon *Falco eleonorae* (Samraoui et al. 2011). In northeast Algeria, the Glossy Ibis breeds in mixed-heron colonies in various wetlands (Lake Fetzara, Lake Tonga, Dakhla, and Chatt) with various heron species: the night heron *Nycticorax nycticorax*, squacco heron *Ardeola ralloides*, cattle egret *Ardea ibis*, little egret *Egretta garzetta*, grey heron *Ardea cinerea*, and the purple heron *Ardea purpurea* (Bouchecker et al. 2009; Nedjah et al. 2010).

The study was performed at Chatt (36°49.81'N, 07°54.68'E) and Lake Fetzara (36°48'N, 7°31'E) (Figure 1). Chatt is a 2 ha unprotected marsh dominated by *Iris pseudo-acorus*, *Typha angustifolia*, and *Phragmites australis*. Lake Fetzara, a Ramsar Site, is a much larger marsh with an area of 24,000 ha, mainly covered by *Scirpus maritimus*, *Typha angustifolia*, and dense stands of *Phragmites australis*.

Data collection

The fieldwork was conducted during the 2010 breeding season, from mid-April to the end of June. As part of the waterbird monitoring scheme carried out by the Laboratoire de Recherche et de Conservation des Zones Humides (LRZH), ectoparasites were searched for on Glossy Ibis chicks. A total of 166 chicks (92 and 74 chicks at Chatt and Lake Fetzara, respectively) were ringed and measured. Each bird, aged from 10 to 16 days, was handled for a maximum of 5 min during which ectoparasites were collected from the entire body (head, wings, back, breast and belly, legs, and crissum and tail). Chicks were visually inspected and hand-searched for

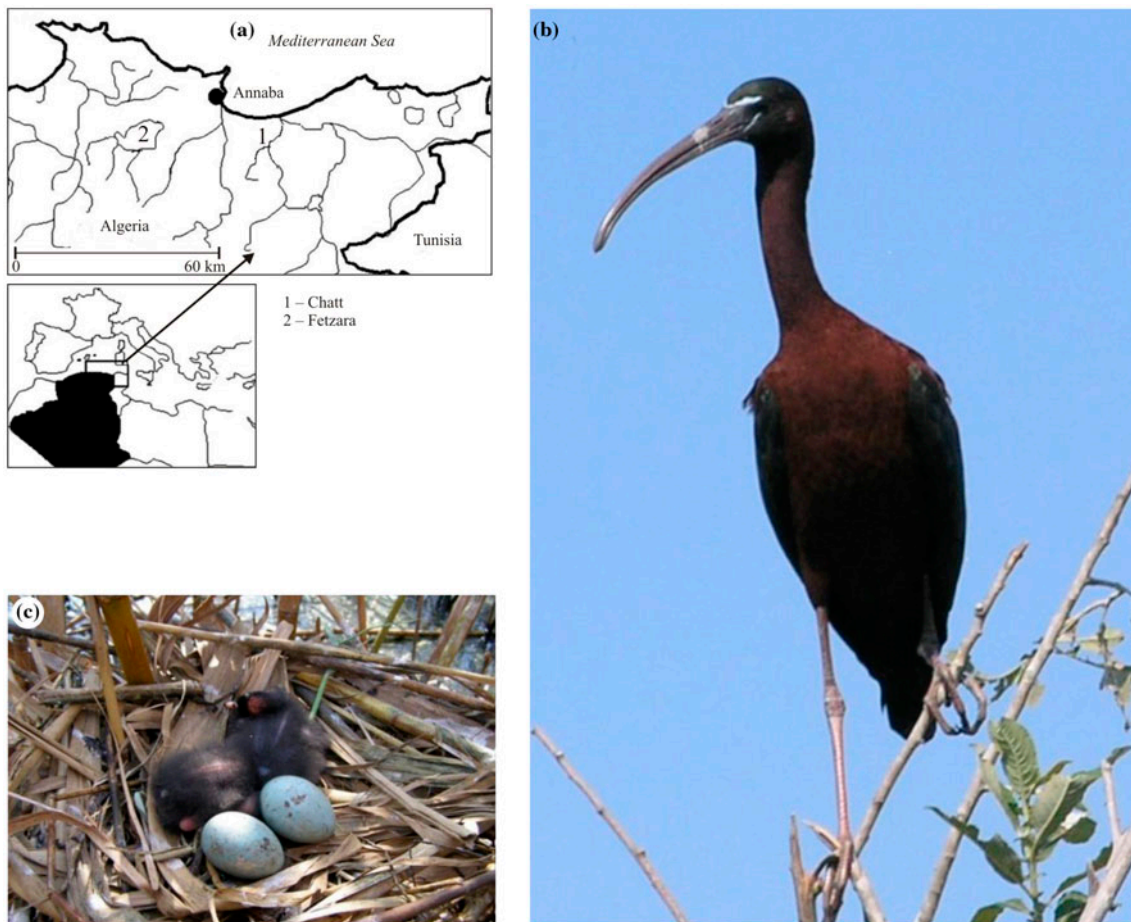


Figure 1. Location map showing study sites (a), with an adult of Glossy Ibis (b), and the Glossy Ibis nest containing chicks and eggs (c).

ectoparasites, which were removed using entomological tweezers and preserved in a tube containing 70% ethyl alcohol for identification at a later stage. All birds included in this study were clinically healthy on physical examination and, once sampling was completed, were safely returned to their nests.

Permanent preparation of ectoparasites

Sampled ectoparasites were washed several times in 70% ethanol to remove plumage remnants. They were later warmed in 10% potassium hydroxide (KOH), rinsed with water and dehydrated through a graded series of ethanol (60%, 70%, and 80%). They were cleared in Xylene and then mounted in Canada balsam on a glass slide. They were identified using various keys (Séguy 1944; Yamaguti et al. 1971; Keirans and Litwak 1989; Keirans 1992; Price et al. 2003; Walker et al. 2003; Wall and Shearer 2008). Collected lice were slide mounted as permanent slides following the technique in Palma (1978) and deposited in the entomological collection of the LRZH. The following indices of infestation were used: prevalence (*P*, %), abundance (*A*), and intensity (*I*).

Statistical analysis

Prevalences were compared using Fisher’s exact tests, whereas mean intensities and mean abundances were tested with permutation tests using the “coin” package in R (Hothorn et al. 2008; R Development Core Team 2014). Significance was accepted at *p* = 0.05. We estimated the exponent *k* for each lice species to quantify the degree of parasite aggregation using both formulae of Southwood (1966):

$$k = (m^2 / (s^2 - m))$$

and Elliot (1977):

$$k = (m^2 - s^2/n) / (s^2 - m).$$

where *n* is the sample size, *s*² is sample variance, and *m* is the sample mean. A kernel density estimator with a Gaussian kernel was used to approximate the probability

density for all chewing lice (Silverman 1986). The shape of the calculated distribution indicated that investigation of a negative binomial distribution fit was warranted and this was investigated using the maximum likelihood estimate of the aggregation parameter *k* (Crawley 2007). An initial aggregation estimate *k* (Southwood 1966) was used to calculate the maximum likelihood estimate for *k*, which was then used to derive negative binomial frequencies. Pearson’s χ^2 tests were then performed to test the hypothesis that the data were negative binomial distributed.

Results

Overall, 258 chewing lice (Phthiraptera: Amblycera, Ischnocera) and seven ticks (Acari) were recovered from the sampled chicks. Four louse species were collected at both Chatt and Lake Fetzara: *Plegadiphilus plegadis* (Dubinin 1938), *Colpocephalum leptopygos* Nitzsch [in Giebel], 1874, both of the family Menoponidae, and *Ardeicola raphidius* (Nitzsch [in Giebel], 1866) and *Ibidoecus bisignatus* (Nitzsch [in Giebel], 1866), both of the family Philopteridae. One species of tick (larva) *Ixodes ricinus* (Linnaeus, 1758) was collected at Lake Fetzara (Table 1). The results indicated that out of 92 chicks examined at Chatt, 52 (56.5%) were infested; whereas at Lake Fetzara, 44 birds out of a total of 74 (59.5%) were found harboring ectoparasites from any group. There were no significant differences in prevalence levels between the two sites (Fisher’s exact test for count data: *p* = 0.75 and CI = 0.55–1.73). At Chatt, the number of lice per individual bird ranged from 1 to 8 (mean = 3.01), whereas louse load on individual birds at Lake Fetzara varied between 1 and 9 (mean = 2.4). In contrast, ticks were present only on two birds (2.7%) at Lake Fetzara (Table 1).

Most birds were parasitized only by one species, but the coexistence of two species of ectoparasites on the same host was noted in 10 birds at Chatt and in five birds at Lake Fetzara. Fewer birds (*N* = 3) were parasitized by three species of ectoparasites; this was observed exclusively at Chatt. The louse species, *P. plegadis*, was the most abundant parasite at both study sites: 44.6%

Table 1. Ectoparasites collected from Glossy Ibis chicks at Chatt and Fetzara in 2010 with prevalence, abundance (±SD), and mean intensity (±SD) of ectoparasites.

Ectoparasites	Sites	Infested hosts	Prevalence (%)	Mean abundance	Mean intensity
<i>Plegadiphilus plegadis</i> (Menoponidae)	Chatt	41/92	44.56	1.17 ± 2.99	2.09 ± 1.98
	Fetzara	29/74	39.18	0.90 ± 1.59	1.48 ± 3.32
<i>Colpocephalum leptopygos</i> (Menoponidae)	Chatt	4/92	4.34	0.07 ± 0.42	0.11 ± 0.47
	Fetzara	8/74	10.8	0.20 ± 1.14	0.34 ± 1.27
<i>Ibidoecus bisignatus</i> (Philopteridae)	Chatt	13/92	14.13	0.26 ± 0.36	0.48 ± 0.87
	Fetzara	7/74	9.45	0.11 ± 1.39	0.18 ± 0.67
<i>Ardeicola raphidius</i> (Philopteridae)	Chatt	5/92	5.43	0.10 ± 0.57	0.17 ± 0.61
	Fetzara	2/74	2.70	0.10 ± 0.93	0.16 ± 0.90
<i>Ixodes ricinus</i> (Ixodidae)	Chatt	0/92	0.00	0.00	0.00
	Fetzara	2/74	2.70	0.10 ± 1.29	0.16 ± 0.96

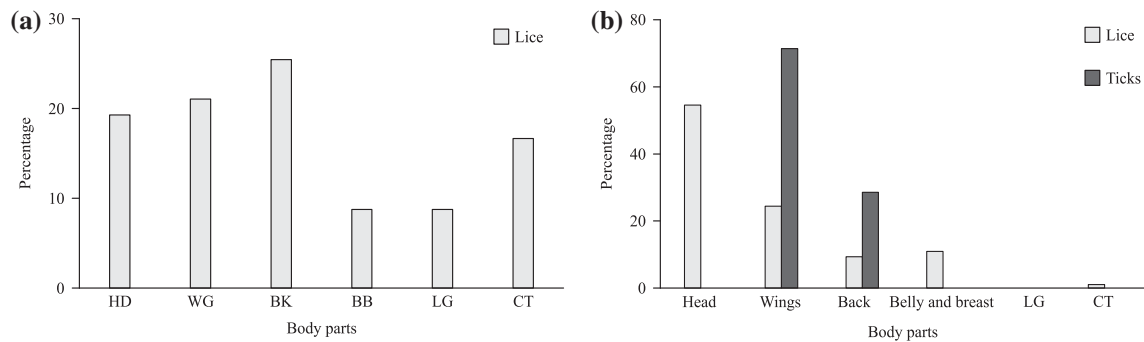


Figure 2. Relative abundance of lice and ticks in different body regions of Glossy Ibis chicks: HD, head; WG, wings; BK, back; BB, breast and belly; LG, legs; and CT, crissum and tail, at (a) Chatt and (b) Fetzara.

(Chatt) and 39.2% (Lake Fetzara). There was no significant difference in the mean abundance of parasitic infection between the two sites (approximate 2-sample Permutation Test: $z = 1.64$, $p = 0.1$). Likewise, there were no differences in the mean intensity (approximate 2-sample Permutation Test: $z = -0.01$, $p = 1$). The prevalence, mean abundance, and intensity are presented in Table 1.

Spatial distribution of ectoparasites on hosts

Chewing lice at Chatt were also abundant in all parts of the body (Figure 2(a)). They were found on the head (19.3%), on wings (21.1%), back (25.4%), breast and belly (8.8%), legs (8.8%), and on the crissum and tail (16.7%). At Lake Fetzara, chewing lice were likewise found on the head (54.6%), wings (24.4%), back (9.3%), breast and belly (11.0%), and the crissum and tail (1.1%) (Figure 2(b)). Ticks were recorded only on the wings (71.4%) and the back (28.6%).

Spatial distribution of lice among hosts

As there were no differences in the mean abundance and mean intensity of parasitic infection between the two study sites, we pooled the data for both sites to investigate the distribution of parasites in various parts of their hosts. Only two species (*P. plegadis* and *I. bisignatus*) were located in all body parts (Figure 3(a) and (c)) and were abundant enough to allow the analysis of their spatial distribution, which was found to be heterogeneous across the body regions sampled (Approximate K-sample Permutation Test: max $T = 4.0$, $p = 0.002$ for *P. plegadis* and max $T = 4.40$, $p = 0.001$ for *I. bisignatus*). Both species preferentially occupied the head, wings, and the back. The other two chewing lice, *C. leptopygos* and *A. raphidius*, were less abundant overall and could only be found in certain parts of the body (Figure 3(b) and (d)): *C. leptopygos* was absent from legs and crissum and tail, whereas *A. raphidius* was absent from the head, back, and belly and breast.

Values of the aggregation parameter k estimated according to Southwood (1966) and Elliot (1977) for each louse species are provided in Table 2. The overall distribution of lice was investigated with a Gaussian kernel density estimator, which indicated that the distribution was unimodal and similar to the negative binomial (Figure 4(a)). The calculated mean (0.664) and variance (1.827) indicated that the data were highly aggregated. The aggregation parameter k (0.379) was calculated and the maximum likelihood estimate of the same parameter (0.316) was computed (Southwood 1966; Crawley 2007). The observed and expected negative binomial frequencies indicated a close fit (Figure 4(b)) suggesting that the recorded parasites were negative binomial distributed. The calculated Pearson's χ^2 test with 2 d.f. (2.25) was much lower than the critical value (5.991) at $p = 0.05$. We thus accept the hypothesis that the data representing the sampled parasites were not significantly different from the negative binomial with the mean = 0.664 and $k = 0.316$.

Spatial distribution of ticks among hosts

At Lake Fetzara, two birds were infested with ticks. Larvae of the single recorded species, *I. ricinus* were confined to the wings (71.7%) and, to a lesser extent, to the back (28.6%) of the bird (Figure 3(e)). They were, however, not abundant enough to permit analysis of their distribution.

Discussion

Five species of ectoparasites (four chewing lice and one species of tick) were found on Glossy Ibis chicks during our study. *P. plegadis* is a known parasite of the Glossy Ibis (Clay and Hopkins 1952; Ledger 1971). Species of the genera of *Colpocephalum*, *Ardeicola*, and *Ibidoecus* are known to parasitize different species of ibis (*Threskiornis* spp. and *Plegadis* spp.) (Hajela and Tandan 1967; Tuff 1967). Prevalence of ectoparasites may be higher in colonial birds due to more frequent contacts among birds (Rózsa, Rekasi, and Reiczigel 1996). The Glossy Ibis

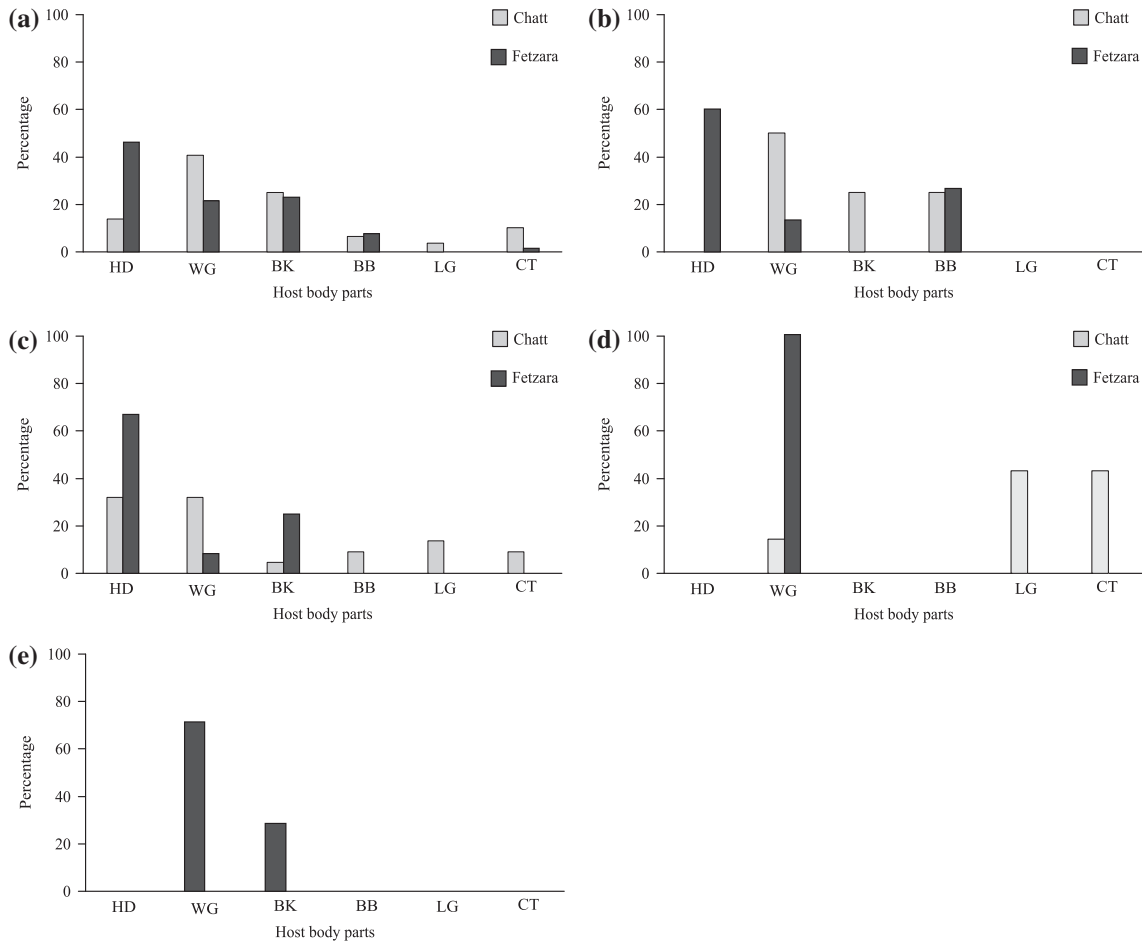


Figure 3. Relative abundance and spatial distribution of: (a) *Plegadiphilus plegadis*; (b) *Colpocephalum leptopygos*; (c) *Ixodes ricinus*; (d) *Ardeicola raphidius*; (e) *Ixodes ricinus* in six body parts of Glossy Ibis chicks: HD, head; WG, wings; BK, back; BB, breast and belly; LG, legs; and CT, crissum and tail.

Table 2. *K* values Southwood (1966) and corrected *k* values (Elliot 1977) for the four recorded louse species.

Species	<i>k</i> (Southwood)	<i>k</i> (Elliot)
<i>Plegadiphilus plegadis</i>	1.62	1.61
<i>Colpocephalum leptopygos</i>	0.34	0.32
<i>Ixodes ricinus</i>	0.51	0.48
<i>Ardeicola raphidius</i>	0.11	0.09

breeds in northeast Algeria in mixed colonies together with numerous species of herons but no data are available for local herons or territorial species which may help draw meaningful comparisons.

In order to shed some light on the relationship between ectoparasites and their hosts, various researchers (Randolph 1975; Fowler and Miller 1984; Fowler and Williams 1985) have analyzed the frequency of macro-parasite distribution and provided clear evidence of models best described by the negative binomial distribution. The binomial exponent *k* may provide a measure of destabilizing effects of the parasite on the host

population and may reflect relative reproductive rates of the parasite and host (Anderson and May 1978). The values of the estimated exponent of the negative distribution *k* obtained in our study correspond to values previously reported in the literature with *k* generally lower than 1 (Shaw and Dobson 1995). A large spectrum of factors (endogenous or exogenous both to hosts and parasites) may determine host selection by the parasite which may be described by a range of ideal free distribution models (Parker and Sutherland 1986; Tregenza 1995; Van der Hammen et al. 2012).

Spatial heterogeneities in free-living organisms are shaped by physical properties of the environment and by biotic processes such as host immunity, predation, and competition (Thieltges and Reise 2007; Tschirren et al. 2007). Our results indicate that ectoparasites varied in their spatial distribution at the infracommunity level, some of them exhibiting no microhabitat preferences, while others confining themselves to some part of the host's body (Clay 1949; Choe and Kim 1988; Palma et al. 2002). Chewing lice, which dominated in number and diversity, are permanent ectoparasites, which

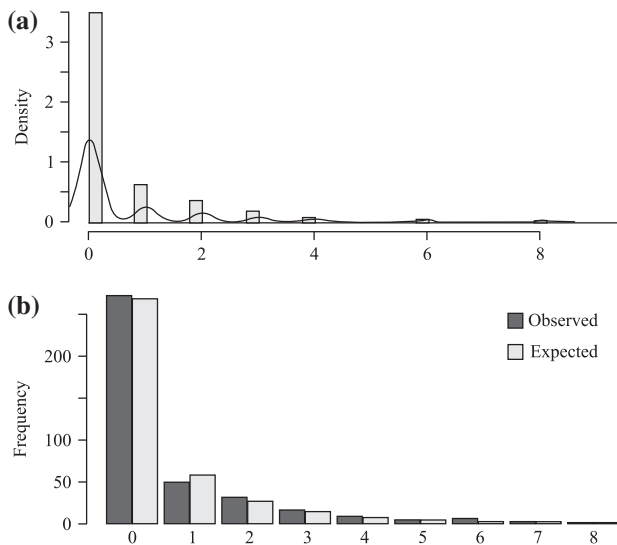


Figure 4. Gaussian kernel density estimates imposed on a histogram of lice data (a). Predicted and observed frequency distribution of Phthiraptera on Glossy Ibis chicks (b).

complete their entire life cycle on the host. As they are incapable of independent mobility, transmission occurs during periods of direct contact between hosts (Johnson and Clayton 2003).

Parasites that share resources can reduce competition by being spatially segregated (Mouillot, George-Nascimento, and Poulin 2003), and it is known that Amblyceran lice live in close contact with host skin, whereas Ischnoceran lice dwell on feathers (Møller and Rózsa 2005). Menoponidae have been documented to feed on a wider range of resources (feathers, feather pith, blood, skin secretions) than Philopteridae, which have a narrower spectrum (feathers and skin debris) (Marshall 1981). Differences in size and shape of feathers and of parasites seem also to provide the necessary habitat heterogeneity and morphological adaptations for parasites to segregate (Crompton 1997). The Common Crow (*Corvus brachyrhynchos*) harbors *Degeeriella rotundata* and *D. secundaria* on its flight feathers, while *Myrsidea interrupta* and *Philopterus corvi* are confined to the plumage of its breast (Morgan and Waller 1941). We recorded that lice of the genus *Colpocephalum* occurred mainly in the wings but were present in other body parts. This result is similar to the one reported from the study of lice in domestic pigeons (Nelson and Murray 1971).

Thus, macroparasite occurrence is associated with particular host environments and this association is stronger in parasites with limited interactions (i.e. ticks) than in those with frequent interactions (i.e. lice) (Mize, Tsao, and Maurer 2011). Segregation in time or space may weaken interspecific interactions (Nilsson 1981) and the distribution might be also affected by the mechanical interference of the host with attached species occurring in inaccessible areas (Marshall 1981; Murray 1987, 1990) and small and/or very mobile species found in

other parts of the body. Head regions cannot be reached by the bill but the abundance of some lice species in the head area may also be explained by their ability to feed on lachrymal secretions (Mey, Cicchino, and González-Acuña 2006). The head is also one of the body areas from which ticks cannot be easily removed by preening and a large number of ticks around the eyes may impair vision (Hoodless et al. 2003). Ticks (larvae, nymphs, and adults) are completely hematophagous and tend generally to select the head of the host, especially the eyes (Boyd 1951). Ticks could also have adverse effects on nestling condition either directly, through blood loss anemia, or indirectly through a disease (Feare 1976). Habitat partitioning between two species of ticks: *Ixodes uriae* and *I. signatus* has been suggested to occur on murre *Uria aalge* and kittiwakes *Rissa tridactyla* on the Pribilof Islands (Choe 1982).

Noteworthy is the fact that lice prevalence may differ markedly between juvenile birds and adults (Kettle 1983; Barrientos et al. 2014) suggesting the need to explore drivers of lice prevalence such as development, host immunity, molt, behavior, and climate (Combes 2001). More extensive data on the distribution of ectoparasites in colonial birds are needed in order to assess the incidence of macroparasites and their influence on host populations. Various studies have revealed an intimate coevolutionary parasite–host history (Thompson 1999; Johnson, Bush, and Clayton 2005; Møller and Rózsa 2005; Boots et al. 2009) and uncovered that the distribution and systematics of Phthiraptera provide a remarkable insight into the phylogeny of their hosts (Clay 1976; Mauersberger and Mey 1993; Smith 2001). Our knowledge of avian parasites, their life histories, transmissibility, and how they affect their hosts' dynamics is increasing at a slow pace in view of the global changes sweeping through most ecosystems.

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ORCID

Boudjéma Samraoui  <http://orcid.org/0000-0002-0608-9021>

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