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Parasitologie

LOUSE SPECIES (PHTHIRAPTERA: AMBLYCERA, ISCHNOCERA) COLLECTED ON THE COMMON COOT, *FULICA ATRA* (LINNAEUS, 1758), AND THEIR MICROHABITAT SELECTION

par

Roumayssa ZIANI[1], Borhane-Eddine Cherif ZIANI[2],

Bilal DIK[3], Faïza MARNICHE[4] & Amel LAZLI[1]

Mallophaga are permanent ectoparasites, extremely specific to their hosts that can have harmful affects on the host by transmitting a range of pathogens. This study was conducted at Lake Tonga (National Park of El Kala in northeastern Algeria), between January 2017 and December 2018. Chewing lice collected from 57 live-captured Common Coot *Fulica atra* (Linnaeus, 1758) (Aves: Gruiformes: Rallidae) were studied. The data was taken from the lake by random collection method. Lice were slide mounted and identified. First, the feathers of each bird were inspected macroscopically and all louse specimens observed were collected, moreover some of the birds examined were treated with a synthetic Pyrethroïd spray on the plumage of each body part. Five species of chewing lice (Phthiraptera: Amblycera, Ischnocera) were isolated from hosts: *Fulicoffula lurida* (Nitzsch, 1818) (Philopteridae), *Incidifrons fulicae* (Linnaeus, 1758) (Philopteridae), *Laemobothrion* (*Eulaemobothrion) atrum* (Nitzsch, 1818) (Menoponidae), *Pseudomenopon pilosum* (Scopoli, 1763) (Menoponidae) and *Rallicola fulicae* (Denny, 1842) (Philopteridae). The birds were found to be infested with at least one of these

1. Laboratoire d'Écologie Fonctionnelle et Évolutive, Université Chadli Bendjedid, BP 73, 36 000 El Tarf, Algérie.

2. Centre de Recherche scientifique et technique en Analyses Physico-Chimiques (CRAPC), Bou Ismail, Tipaza, 42 000 Algérie.

3. Selçuk University, Faculty of Veterinary Medicine, Department of Parasitology, 42 250 Selçuklu, Konya, Turkey.

4. Laboratoire de Zoologie, École Nationale Supérieure des Sciences Vétérinaires, Alger, Algérie.

Auteur correspondant : Roumayssa ZIANI, E-mail : <ziani.roum2@gmail.com>.

chewing louse species. *Rallicola fulicae* was the most frequent louse species, being present on all the studied coots. The prevalence, mean intensity of infestation and mean abundance of the lice from Common Coots were recorded. The localization of lice on the host's body was also studied. Louse populations exhibited distinct patterns of spatial distribution on the host, largely as a result of their distinct preferences for certain microhabitats.

Keywords: Chewing lice, Amblycera, Ischnocera, Microhabitat, Lake Tonga, Algeria.

Les espèces de poux (Phthiraptera: Amblycera, Ischnocera) collectées sur la foulque macroule *Fulica atra* (Linnaeus, 1758) et sélection de leur microhabitat

Les Mallophages sont des ectoparasites permanents, extrêmement spécifiques à leurs hôtes, qui peuvent avoir des effets nocifs sur l'hôte en transmettant une gamme d'agents pathogènes. Cette étude a été menée sur le lac Tonga (Park National d'El Kala, dans le nord-est de l'Algérie), pendant la période s'étendant de janvier 2017 à décembre 2018, où des espèces de Mallophages sur cinquante-sept individus de Foulque macroule *Fulica atra* (Linnaeus, 1758) (Aves : Gruiformes : Rallidae) capturé vivants et par une méthode aléatoire de collecte, ont été étudiés. Tout d'abord, les plumes de chaque oiseau ont été inspectées macroscopiquement et tous les spécimens de poux observés ont été collectés. Ensuite, certains des foulques examinés ont été traités avec un spray synthétique Pyrethroïde sur le plumage de chaque partie de leur corps. Les poux étaient montés sur des lames et identifiés. Cinq espèces de Mallophages (Amblycera, Ischnocera) – *Fulicoffula lurida* (Nitzsch, 1818) (Philopteridae), *Incidifrons fulicae* (Linnaeus, 1758) (Philopteridae), *Laemobothrion (Eulaemobothrion) atrum* (Nitzsch, 1818) (Menoponidae), *Pseudomenopon pilosum* (Scopoli, 1763) (Menoponidae) et *Rallicola fulicae* (Denny, 1842) (Philopteridae) – ont été isolés à partir des hôtes. Les oiseaux étaient infestés par au moins une de ces espèces de poux. L'espèce de poux *Rallicola fulicae* était la plus fréquente chez toutes les foulques étudiées. La prévalence, l'intensité moyenne de l'infestation et l'abondance moyenne des poux ont été enregistrées. La localisation des poux sur le corps de l'hôte a également été étudiée, les populations de Mallophages ont montré en effet des schémas distincts de répartition spatiale sur l'hôte en grande partie du fait de leurs préférences divergentes pour certains microhabitats.

Mots-clé : Mallophages, Amblycera, Ischnocera, Microhabitat, Lac Tonga, Algérie.

Introduction

Birds are hosts to a range of arthropod parasites. This makes them excellent models for exploring the ecological and evolutionary dynamics of host-parasite associations (HUGHES & PAGE, 2007). They are structurally composite and offer a great selection of microhabitats for ectoparasites. An individual bird can be considered as a "mobile island" supporting a dynamic community of these organisms. Their distribution on the hosts varies with the parasite concerned; some show no preference while others tend to be limited to definite areas on the body (PRICE, 1980). Chewing lice (Phthiraptera: Amblycera, Ishnocera) are permanent obligate ectoparasites that are distributed throughout most bird families worldwide (PRICE *et al.,* 2003). While some species feed on feathers and skin scales (DIK & HALAJIAN, 2013), others feed on blood (JOHNSON & CLAYTON, 2003). Chewing lice complete their life cycle on a single host (SERRA-FREIRE & MELLO, 2006). Heavy louse infestations may have adverse affects on the host, leading to a degradation of plumage quality, decrease in host productivity and some pathological effects. Some of them are vectors for zoonotic diseases that result in higher mortality (DIK *et al.,* 2011).

The Common Coot, *Fulica atra* (Linnaeus, 1758) (Aves: Gruiformes), is an aquatic bird of the family Rallidae that is highly gregarious in winter and strongly territorial during the breeding season (CRAMP & SIMMONS, 1980). It is a partly sedentary and migratory species (HARRISON, 1982). This waterbird shows great adaptability to different environmental conditions. It is abundant in Europe, Asia and North Africa. In Algeria, it is widespread and commonly extends in particular to Lake Tonga, which is a Ramsar site of ornithological importance in the El Kala section (SAMRAOUI & SAMRAOUI, 2008). This site contains a variety of natural wetlands that provide nesting sites for a considerable diversity of avian species and important staging posts and wintering sites for migrating aquatic birds (BOULKHSSAÏM *et al.,* 2006).

OLSEN & OROSZ, (2000) recorded that waterbirds transmitted to humans some pathological factors through natural or accidental pathways and caused pathological effects that can lead to death. Hence, migration can lead to the fast spread of infectious diseases across the globe (ALTIZER *et al.,* 2011), affecting not only the host but also its biotic environment with the potential to significantly alter local population dynamics (FULLER *et al.,* 2012). During the cold season in North Africa, many coot pairs breed and are joined by individuals from northern European populations. Conversely, others spend the winter in Spain and North Africa. In the wetlands of the National Park of El Kala, the total coot population fluctuates between 20 000 and 50 000 individuals in winter and the total abundance varies between 510 and 1000 couples in the breeding season (ZITOUNI *et al.,* 2014) whilst, they might be contaminated and faced for additional risks.

FELSŐ & RÓZSA (2006) reported that chewing louse species infest aquatic birds in various parts of the world such as in North America, New Zealand, Romania, Australia, Denmark, Turkey and Hungary, while numerous scientific surveys have evoked the mechanisms that determine the distribution of these parasites in the landscape. Studies carried out on louse populations of the coot have been published by RÉKÁSI & KISS (2006) VENZAL *et al.* (2007), GARBARINO *et al.* (2013), CRUZ *et al.* (2017) and DIK *et al.* (2017). However, there is a lack of knowledge about the geographic distribution and consistency of chewing louse species on waterbirds in North Africa, particularly in Algeria, even though the Mediterranean climate is considered to provide ideal habitats for ectoparasites in numerous wetlands of ornithological importance. Most previous studies have focused on Chickens, Herons, Passeriformes, Pigeons, Peacocks and Storks (ROUAG-ZIANE *et al.,* 2007; ROUAG-ZIANE & CHABI, 2008; MEDJOUEL *et al.,* 2013; ABDESSAMED *et al.,* 2014; BAZIZ-NEFFAH *et al.,* 2015; TOUATI *et al.,* 2015; MARNICHE *et al.,* 2017; MEGUINI *et al.,* 2018; TOLBA *et al.,* 2018; KABOUDI *et al.,* 2019).

In this context, the main objective of the present study was to determine the diversity, prevalence, abundance and intensity of lice infestations of common coots living on Lake Tonga and to document their distribution on the different parts of the bird's body. Knowledge of feather lice distributions and their taxonomic composition may help to verify the phylogenetic relationships of birds and it allows improved diagnoses, prevention, and control of vector-borne diseases by parasitologists, ornithologists, or even evolutionary biologists. Consequently, the current study aims to further knowledge of the geographical distribution of chewing louse species in Algeria.

Materials and methods

Study area

The fieldwork was conducted from January 2017 to December 2018 at Lake Tonga, a Ramsar site in the National park of El Kala (Northeastern Algeria, coordinates: 36° 51' 44.73" N8° 29' 47.1156" E (Figure 1). This freshwater lake of about 2600 ha serves as a nesting site for several waterbird species, with high winter concentrations of White-headed duck, *Oxyura leucocephala* (Scopoli, 1769), Ferruginous duck, *Aythya nyroca* (Güldenstädt, 1770), Marbled Duck, *Marmaronetta angustirostris* (Ménétries, 1832), Black-tailed Godwit, *Limosa limosa* (Linnaeus, 1758), and northern Lapwing, *Vanellus vanellus* (Linnaeus, 1758), among others.

The lake is connected with the sea by an artificial channel and about 80% is covered by emergent vegetation, with large open water areas covered by the White

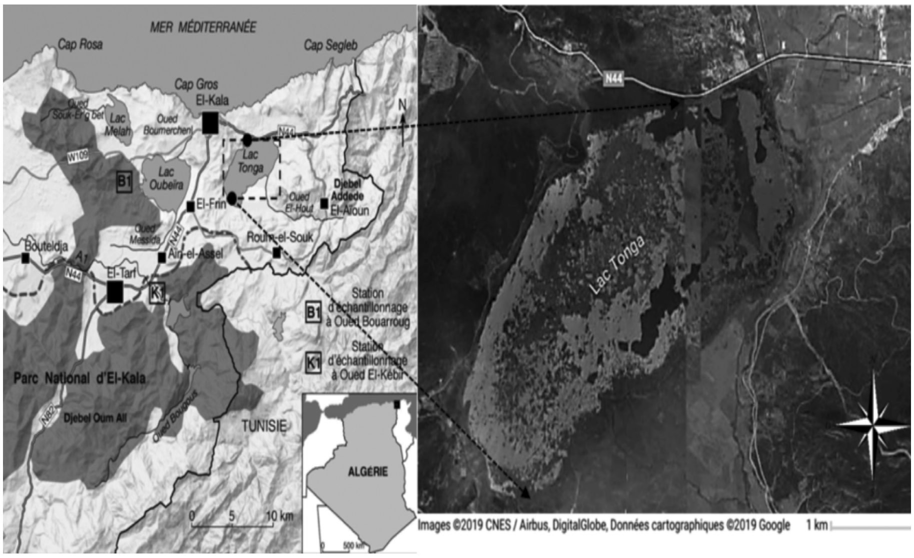

Figure 1

Location of the study site, Lake Tonga.
Localisation du site d'étude « Lac Tonga ».

water lily, *Nymphae alba*, especially during the breeding season (LAZLI *et al.,* 2014). Lake Tonga is experiencing increasing pressures, such as bank erosion, eutrophication and poaching. The current urbanization and increasing requirements for water for the rural community have further exacerbated the need for conservation actions to be carried out locally (LAZLI *et al.,* 2014; MENASRIA & LAZLI, 2017).

Bird capture and collection of chewing lice

In order to determine the prevalence of chewing lice infestation on each part of the body, fifty-seven coots, were live-trapped randomly at a rate of two to three individuals per month using mist-nets of 16-mm mesh size, without harm to the hosts. After tying the legs together, each bird was manually checked for louse infestation by a thorough visual examination of all areas of the body (WALTHER & CLAYTON, 1996), lasting about 15 minutes for each Coot. Individual feathers were deflected to look for the presence of lice, which were detached using a fine brush, over a white piece of paper, and taken randomly from the head, neck, back, abdomen, wing, rump and tail using a light source, thumb pens and a hand magnifying lens. The different body regions of coots were examined separately to determine if specific lice are associated with a given body region. Some of the birds were sprayed with synthetic Pyrethroïd insecticides or Avispray (Tetramethrin + Piperonil + Butoxide) on the plumage of each body part, which are not harmful to birds when pulverized on feathers (CLAYTON & DROWN, 2001). After the collection of lice, the birds were released into their natural habitat.

The collected louse specimens were sent to the Laboratory of Functional and Evolutionary Ecology at the University of El Tarf, where they were transferred into Petri dishes containing 70% alcohol to eliminate plumage remnants, and a number was assigned to each dish. Lice were then cleared in 10% potassium hydroxide (KOH) for one day to emulsify debris and to diminish body contents, washed in distilled water, dehydrated in an increasing alcohol series (70%, 80%, 90% and 99%), and then mounted on slides in Canada balsam, according to the methodology described by PALMA (1978) and PRICE *et al*. (2003).

The louse species identification was carried out in the Laboratory of Zoology at the Superior National Veterinary School of Algiers based on the morphological criteria according to the descriptions in PRICE *et al*. (2003) and DIK *et al*. (2011) after exhaustive examination under a Leica DM500 binocular phase-contrast microscope. Species authentication was conducted in the Department of Parasitology of the Veterinary Faculty of Selçuk University, Turkey, by Prof. Dr Bilal Dik.

Parasitism rate analysis

The following parasitological parameters were evaluated according to BUSH *et al*. (1997) and MARSHALL (1981):

– *dominance*: the number of individuals of a parasite species as a percentage of the total number of individuals collected from examined birds;

– *prevalence*: the proportion of the members of a taxon infested with ectoparasites;

– *mean intensity*: the number of individuals of a particular ectoparasite species on infected hosts;
– *mean abundance*: the number of individuals of a particular ectoparasite species on examined birds;
– *Sorensen Index*: a measure of the similarity of two habitats, calculated using the formula « Cs = 2J / (a+b) » ; where *a* is the number of species present at site a, *b* is the number of species present at site b and *J* is the number of species common to both sites a and b.

Data Management and Statistical study

The data were recorded in a spreadsheet and mathematically treated with Microsoft Excel 2016 (16.0.7167.2060) and the parasitism parameters calculated using statistical software for Quantitative Parasitology V 3.0, (ROZSA *et al.,* 2000). Statistical analysis was done using R© V 3.5.2 Program via the Rcmdr package. The chi-square test was used to evaluate associations between the selected parameters (infestation rate, seasons and body regions). A *p-value* of less than 0.05 was considered to be statistically significant.

The similarity matrix of the Sorensen parameter was obtained using the R statistical program by applying the package "betapart" using the beta.pair function of multiple-site dissimilarities accounting for the spatial turnover and the nestedness components of beta diversity, and the sum of both values. The pattern of dispersion was evaluated using Morisita's Iδ-index (MORISITA, 1962) for intraspecific aggregation, such as patchy, random or uniform dispersion. This index of dispersion is defined as the deviation from random dispersion and can be tested using critical values of the Chi-squared distribution with n-1 degrees of freedom:

$$\mathbf{Imor} = \mathbf{n} \times \left(\sum_{i=0}^{n}(\mathbf{xi}^2) - \sum_{i=0}^{n}(\mathbf{xi})\right) / \left(\sum_{i=0}^{n}(\mathbf{xi})^2 - \sum_{i=0}^{n}(\mathbf{xi})\right)$$

Where:
xi is the number of individuals in sample **i**, and **n** is the number of samples (i=1, 2…, n).

The spatial patterns of species were classified through Morisita's standardized index (MORISITA, 1959, 1962; AMARAL *et al.,* 2015) as uniform (hyperdispersed), when characterized by Imor values between 0 and 1; in clumped patterns it falls between 0 and n. For random patterns, Imor = 1 and counts in the samples follow a Poisson frequency distribution.

The deviation from the null hypothesis of randomness was tested using critical values of the Chi-squared (χ2) distribution with n-1 degrees of freedom and α = 0.05. The confidence interval around 1 was calculated by the Clumped Mclu and uniform Muni indices (MORISITA, 1959, 1962, AMARAL *et al.,* 2015):

$$\mathrm{Mclu} = \frac{(\chi 2\ \mathrm{Lower} - \mathrm{n} + \sum_{i=0}^{n}(\mathrm{xi}))}{(\sum_{i=0}^{n}(\mathrm{xi}) - 1)}$$

$$\mathrm{Mclu} = \frac{(\chi 2\ \mathrm{Lower} - \mathrm{n} + \sum_{i=0}^{n}(\mathrm{xi}))}{(\sum_{i=0}^{n}(\mathrm{xi}) - 1)}$$

Where: $\chi 2$ Lower and $\chi 2$ Upper refer to e.g. 0.025 and 0.975 quantile values of the $\chi 2$ with n-1 degrees of freedom and $\alpha = 0.05$.

The Kernel density estimator (SILVERMAN, 1986) was applied to investigate species densities and distributions, using ArcGIS 10.3 software and the Spatial Analyst package (ESRI, 2016).

Results

The database for the entire study period contained 2950 individual entries, relating to all louse species (all stages). Five louse species, belonging to two suborders (Ischnocera and Amblycera), were identified from the 57 coots examined. Adults and nymphs of all louse species were present on the coots throughout the year. Birds were found to be infested by three Ischnoceran species belonging to 3 genera (*Fulicoffula, Incidifrons* and *Rallicola*) and 2 Amblyceran species belonging to two genera (*Laemobothrion* and *Pseudomenopon*). The taxonomically most diverse louse family was Philopteridae, with three genera. Each bird was infested with at least one chewing louse species.

Table 1 shows the different species of chewing lice collected from the studied coots. Three species Philopteridae were identified: *Fulicoffula lurida* (Nitzsch, 1818) (Figure 4.f), *Incidifrons fulicae* (Linnaeus, 1758) (Figure 4.c) and *Rallicola fulicae* (Denny, 1842) (Figure 4.d and e). The two species of Menoponidae were *Pseudomenopon pilosum* (Scopoli, 1763) (Figure 4.a and b) and *Laemobothrion (Eulaemobothrion) atrum* (Nitzsch, 1818) (Figure 4.g). In this study, *R. fulicae* had the highest infection rate (100%), followed by *F. lurida* (89%), *P. pilosum* (85%) and *L. (E.) atrum* (75%). The lowest infestation rate was presented by *I. fulicae* (59%). Thus, Ischnoceran lice were found in significantly higher abundance on *F. atra*. Each bird had multiple infestations by different species of lice, getting from double to forth infestation lice. The prevalence for individual species, the total mean intensity and mean abundances are given in Table 1. The mean intensity of the louse species *R. fulicae* was the highest registered during this study (21.544), followed by *F. lurida* which infested 43 of the 57 coots, with a mean intensity of 8.333. In addition, 51 coots out of 57 were infested by the louse species *F. lurida*, which showed a mean intensity of 6.163.

During the sampling period, the maximum increase in the population size was achieved in the winter months and infestation rates were higher in the cold season than the hot one; the difference between infestation rates was statistically significant in March and in November (cold season) relative to other months (Figure 3). Lice were abundant enough to allow spatial analyses, and were distributed heterogeneously across the body regions of coots. Some louse species preferentially occupied more than one body part, whereas others were only found on certain parts of the host's body (Figure 2).

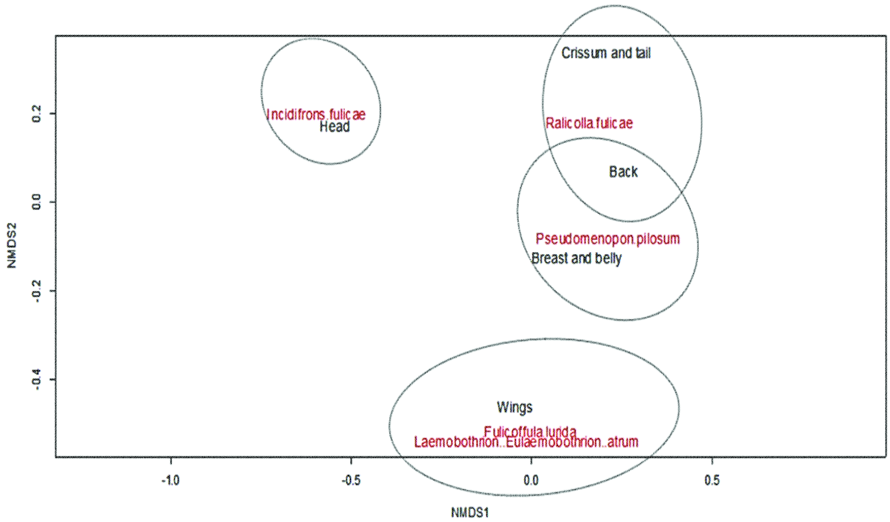

Figure 2

Non-metric multidimensional scaling of chewing louse species distributions according to body part performed using the isoMDS function in the MASS package of the R(x64 3.5.2) program.

Mise à l'échelle Multidimensionnelle non métrique de la distribution des espèces de poux selon la partie du corps effectuée en utilisant la fonction isoMDS dans le package MASS dans le programme R(x64 3.5.2).

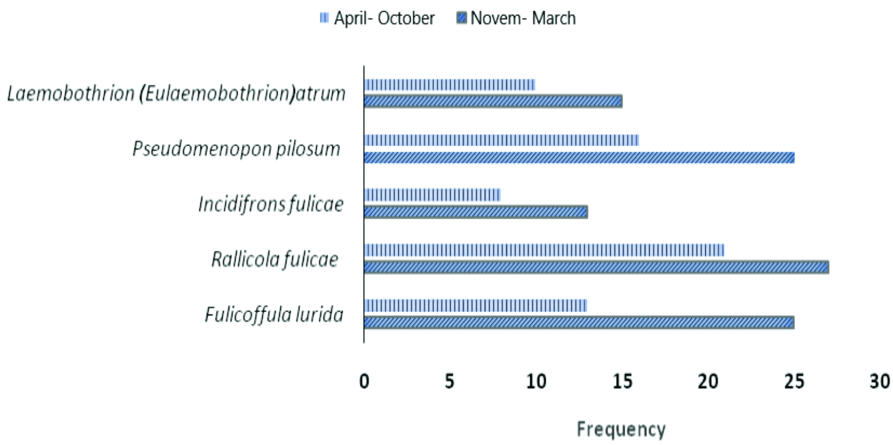

Figure 3

Frequency of louse species according to seasons.

Fréquence de répartition des espèces de poux en fonction des saisons.

Table 1

Infestation parameters for coots for the whole study period (2 years). Hosts of both sexes (n = 57) were captured in the same area. 95% of confidence intervals are in brackets and *p*-values are based on a chi-square test.

Paramètres d'infestation des foulques pour toute la période de l'étude (2 ans). Les hôtes de tous les sexes inclus (n=57) ont été capturés dans la même zone. Des intervalles de confiance de 95% sont entre parenthèses et les p-values *sont basées sur le test du khi deux.*

Parasite species	Number of parasites (n)	Infested birds	Uninfected birds	Infestation prevalence %		Mean abundance	Mean intensity	Dominance	chi-square *P*-value
				Ap[a]	Tp[b]				
Laemobothrion (E.) atrum	265	43	14	75.44	85.1 ± 9.1	4.649	6.163	0.108	< 0,05*
Rallicola fulicae	1228	57	0	100	0.02 ± 0.01	21.544	21.544	0.500	< 0,05*
Incidifrons fulicae	210	34	23	59.65	73.84 ± 0.13	3.684	6.176	0.085	< 0,05*
Pseudomenopon pilosum	329	49	8	85.96	90.66 ± 0.06	5.772	6.714	0.134	< 0,05*
Fulicoffula lurida	425	51	6	89.47	92.54 ± 0.05	7.456	8.333	0.173	< 0,05*

[a]**Ap**: apparent prevalence (proportion of infected hosts), [b]**Tp**: estimate of true (or "informed") prevalence at 95% confidence intervals based on the assumption of a uniform distribution for the sensitivity test (0.60, 1.00) and the specificity test (0.90, 1.00). *Statistically significant (p≤0.05).

[a]***Ap****: prévalence apparente (proportion d'hôtes infestés),* [b]***Tp****: estimation de la prévalence vraie (ou « informé ») à 95% d'intervalle de confiance, en tenant compte des hypothèses sur le test de sensibilité sous forme de distribution uniforme (0.60, 1.00) et spécificité en tant que distribution uniforme (0.90, 1.00),* statistiquement significatif (p≤0.05).*

Table 2 shows that the value of the Sorensen parameter "Cs" between Wings and Belly-Brest is greater than that between the other body regions, but the values are minimal between the following body parts: Wings/Head, Belly-Brest/Crissium-Tail, and Wings/Crissium-Tail. Generally, *L. (E.) atrum* and *F. lurida* were localized

Table 2

Sorensen similarity matrix.

Matrice de similarité de l'indice de Sorensen.

Sorensen indexes (Cs)*	**Wings**	**Breast and belly**	**Crissum and tail**	**Head**
Breast and belly	0.111			
Crissum and tail	0.600	0.667		
Head	0.667	0.428	0.334	
Back	0.334	0.428	0.334	0.5

Table 3

Spatial distribution of the louse species and indexes for intraspecific aggregation at n-1 degrees of freedom [Morisita Iδ-Index (Imor and Imst) (Morisita, 1959, 1962) of dispersion, *Mclu* and *Muni* indices (Hairston *et al*. 1971, Krebs 1999)].

Répartition spatiale des espèces de poux et indices d'agrégation intraspécifique à n-1 degré de liberté [Indice de Morisita Iδ (Imor et Imst) (Morisita, 1959, 1962) de dispersion, indices de Mclu et Muni (Hairston et al. 1971, Krebs 1999)].

Spatial distribution		***Laemobothrion (Eulaemobothrion) atrum***	***Rallicola fulicae***	***Incidifrons fulicae***	***Pseudomenopon pilosum***	***Fulicoffula lurida***
Wings		350	55	0	15	385
Breast and belly		25	320	15	185	50
Crissum and tail		0	75	0	0	0
Head		0	12	290	0	0
Back		0	45	0	25	0
Dispersion indexes						
Iδ Index	Imor[a]	4.376	2.197	4.531	3.457	3.980
	Imst[b]	0,922	0.648	0.941	0.806	0.872
	Mclu[c]	1,019	1,014	1,023	1,032	1,016
	Muni[d]	0,991	0,993	0,988	0,984	0,992
Var/Mean Ratio (VMR)		0.25	0	0.41	0.14	0.11
	p-chisq	< 0,05*	< 0,05*	< 0,05*	< 0,05*	< 0,05*

[a]**Imor**: unstandardized Morisita index; [b]**Imst**: standardized Morisita index; [c]**Mclu**: clumpedness index; [d]**Muni**: uniform index. * Statistically significant (p≤0.05).

[a]**Imor** : indice Morisita non standardisé ; [b]**Imst** : indice Morisita standardisé ; [c]**Mclu** : indice d'agrégation, [d]**Muni** : indice uniforme. * Statistiquement significatif (p≤0.05).

between the grooves of the wings feathers and were absent from back and tail. *P. pilosum* and *R. fulicae* were found on the breast and on the small down feathers of the belly, while *I. fulicae* infested the head and skin of the breast, being absent from the back, wings and tail.

The spatial distribution and pattern uniformity of the louse species on the host body and indexes for intraspecific aggregation, were calculated in order to better, discuss the louse populations' dynamics in the host birds (Table 3). Herein, the Morisita index was used to evaluate the spatial distribution patterns of louse species on the Common coot body.

The spatial distribution of louse species is different. In the aggregate classification, importance was attributed to the way the equation was envisaged and on the meaning of the maximum index values. The distribution of lice can be considered as uniform, since their behavior is with one and more individuals per body region.

R. fulicae was found mostly on the neck, back, breast and venter, while its nymphs were found on all of these body regions as well as on the wings. *P. pilosum* was frequently found over the breast and belly regions of the body (185 lice in total), but the nymphs of this species were found almost solely on the breast. In contrast, adults, nymphs and eggs of *L. (E.) atrum* were confined mostly to the wings. The preferred microhabitats of *I. fulicae* and *F. lurida* were the head and wings, respectively (Table 3).

The spatial patterns of all louse species were classified using Morisita's standardized index (MORISITA, 1962, AMARAL *et al.,* 2015) as aggregate (clumped

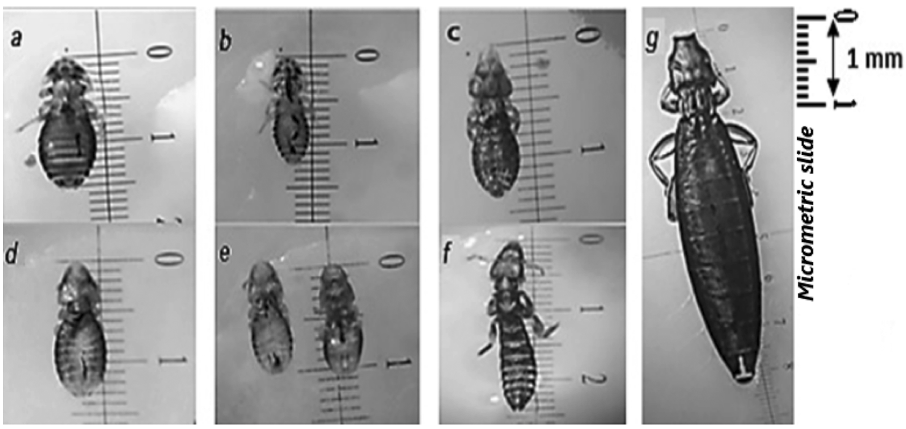

Figure 4

Chewing louse species identified on the studied coots. Scales in mm using Micrometric slide.
a. *Pseudomenopon pilosum* (female); **b**. *Pseudomenopon pilosum* (male); **c**. *Incidifrons fulicae* (male); **d**. *Rallicola fulicae* (female); **e**. *Rallicola fulicae* (males); **f**. *Fulicoffula lurida* (male); **g**. *Laemobothrion (Eulaemobothrion) atrum* (female).

Espèces de poux mallophages identifiées sur les foulques étudiées à l'aide d'une loupe binoculaire stéréoscopique Leica 20x 40x, une lame micrométrique a été placée pour mesurer leurs dimensions.

pattern of distribution), with values higher than 1 and less than n. The confidence interval is verified by the clumpedness index (mclu) and the uniform index (muni), which had values around 1.

In addition, the variance-to-mean Ratio (VMR) was also measured and attended to the comparison and validation of the results obtained by the application of the Morisita index (AMARAL *et al.,* 2015). The VMR index indicated a binomial distribution of the majority of the louse species that are spread across all the body regions, with the exception of *R. fulicae*, which showed a random distribution.

Discussion

Field investigations similar to the current study have been carried out on aquatic birds in various parts of the world. It would appear that host interaction levels control the structure of bird-lice populations. However, there have been few studies to date on ectoparasites infesting aquatic birds in Algeria, and even less is known about their geographic distribution.

ROUAG-ZIANE *et al.* (2007) performed the first study on ectoparasites of common coots in Lake Tonga, between October 2004 and March 2005. They reported the abundance of all louse species found during the present work, with a prevalence of 100% for *P. pilosum, R. fulicae* and *F. lurida*, 53% for *I. fulicae* and 24% for *L. (E.) atrum*. In contrast, the present study found *F. lurida* and *P. pilosum* to have prevalence of 89.47% and 85.96%, respectively, whilst, *R. fulicae* was the dominant louse species, with the highest infection rate, 100%. These differences might be due to periods and to the prevailing weather conditions for each study. The extension of the study to coot populations at other sites and to other bird species that share the same habitat could reveal valuable information about the dispersion patterns and the implied biological relationships (CRUZ *et al.,* 2017), although many factors should be taken into relation when comparing the quantitative results of various studies, including the site characteristics, sample dimensions, method of the study, age of hosts, and the time of year (SHANTA *et al.,* 2006). Species of the genera *Fulicoffula, Laemobothrion, Pseudomenopon* and *Incidifrons* are known to parasitize different species of birds, but coots host more lice than other genus of waterfowl. A study by GARBARINO *et al.* (2013) of 13 hunter-killed waterfowl species from Georgia and Alabama found that lice taxon richness was higher on *Fulica* ($P < 0.001$) than the other waterfowl genera in their study, with the American Coot, *Fulica americana* (Gmelin, 1789), showing the highest abundance with *Fulicoffula* sp., *Fulicoffula longipila* (Kellogg, 1896), *Incidifrons transpositus* (Kellogg 1896), *Rallicola advenus* (Kellogg, 1896) and *Laemobothrion* sp.

CANARIS & WALDMANN (2017) studied the mean abundance of mallophagan species on *F. americana* in the Chihuahua Desert, Middle Rio Grande Valley, Texas, and Upper Rio Grande Valley, Colorado. They found that 5 species of lice (*I. transpositus, F. longiphila, L. (E.) atrum, P. pilosum* and *R. advenus*) were present at both localities on coots. The prevalence was 100% for *I. transpositus* in Colorado, whereas *L. (E.) atrum* was the least prevalent. Nevertheless, *P. pilosum* and *R. advenus* were the most abundant lice at all studied localities. CICCHINO (2011) listed three species of lice from the Andean Coot, *Fulica ardesiaca* (Tschudi, 1843) in Argentina: *R. advenus F. longipila* and *P. pilosum*. Furthermore, CRUZ *et al.* (2017) found 10 out of 16 individuals (62.5%) of this waterbird infested by the same louse species from Colta Lake, Ecuador.

In VENZAL *et al.* (2007) the authors collected *L. (E.) atrum, P. pilosum, Fulicoffula* sp. and *Rallicola wernecki* (Emerson, 1955) from the Red-grated Coot, *Fulica armillata* (Vieillot, 1817). DIK *et al.* (2017) in Turkey, listed the same five louse species reported in the present work on 14 Eurasian Coots, *F. atra* with a prevalence of (100%). Moreover, RÈKÁSI & KISS (2006) reported a high louse infestation level on *F. atra* in Northern Dobrogea, Romania. The louse species *Laemobothrion (Laemobothrion) maximum* (Scopoli, 1763) is a cosmopolitan species and has been reported to parasitize 50 species of Falconiformes. It was isolated from the Black Kite *Milvus migrans* (Boddaert, 1783) and occurred on goshawks *Accipiter gentilis* (Linnaeus, 1758) as well, by PRICE *et al.* (2003).

However, in southern Iraq, only two species of lice, *Fulicoffula gallinula* (Carriker, 1953) and *Incidifrons* sp. (Blagoveshtchensky, 1951), were found on *F. atra* in the study of AWAD & MOHAMMED (2015). In El Basrah Province, of the same country, HATEM *et al.* (2017) found that 20 coots *F. atra* out of a total of 25 in were infested with three louse species: *F. gallinula* (80%), *P. pilosum* (60%) and *F. lurida* (40%). In addition, in the same study the louse species *F. gallinula* and *P. pilosum* were isolated from the Dunlin, *Calidris alpine* (Linnaeus, 1758), (Scolopacidae). In contrast, the louse species *F. gallinula*; which it's normal host is Moorhens; has not been reported from coots previously in the world.

RÉKÁSI (1993) collected *Rallicola cuspidatus* (Scopoli, 1763) and *Pseudomenopon scopulacorne* (Denny, 1842) from the Water Rail, *Rallus aquaticus* (Linnaeus, 1758) in Hungary. In addition, PALMA & JENSEN (2005), reported *R. cuspidatus*, *Fulicoffula rallina* (Denny, 1842) and *P. scopulacorne* from this waterbird, in the Faroe Islands, as well as *F. lurida, I. fulicae, L. (E.) atrum, P. pilosum* and *R. fulicae* from *F. atra*. LAYAKHOVA & KOTTI (2011) recorded *Rallicola cuspidata* (Scopoli, 1763), *F. lurida*, *Pseudomenopon tridens* (Burmeister, 1838) and *L. (E.) atrum*, from *F. atra*, along with *Incidifrons ralli* (Scopoli, 1763) from *Rallus aquaticus, Pseudomenopon qadrii* (Eichler, 1952) and *I. ralii* from the Spotted Crake (*Porzana porzana*) (Linnaeus, 1766), and *Laemobothrion vulturis* (Fabricius, 1835) from the Black-crowned night heron, *Nycticorax nycticorax* (Linnaeus, 1758) in Central Ciscaucasia,

Flying birds are infested with chewing lice more than do sedentary ones, because of differences in mobility and ability to change habitat through migration (ROSE, 2005) whereas during this period, birds collect at common food sources; hence the transmission of lice from bird to bird can occur through direct contact during mating and brooding or via roosting and dusting activities (TURNER, 1971).

TOMÁS *et al.* (2016) found that infestation rates were significantly higher (100%) in the orders Anseriformes, Phoenicopteriformes and Gruiformes. According to these authors, 22 out of 63 colonial birds they sampled and examined in Portugal, of which 18 out of 61 were migratory birds and had higher infestation rates of lice comparing with territorial ones. The same conclusion was reached by GIRIŞGIN *et al.* (2013) for birds in northwestern Turkey, where colonial birds were more significantly infested than territorial ones. JOHNSON *et al.* (2005), found several louse species on waterbirds of the Rallidae and Dendrocolaptidae, including *Rallicola (Rallicola) fuliginosa* (Carriker, 1963) on the Tawny-winged woodcreeper, *Dendrocincla anabatina* (Sclater, 1859) and *Rallicola (Rallicola) columbiana* (Carriker, 1966) on the Amazonian barred woodcreeper *Dendrocolaptes certhia* (Boddaert, 1783). They also found that *F. longipila* and *I. transpositus* parasitized *F. americana*.

In addition to attachment, the various genera of Philopteridae are often specialized morphologically and behaviorally for living in a single microhabitat of the plumage (e.g. wing, head and/or body feathers) where lice can avoid host preening (JOHNSON *et al.,* 2012). Differences in the form and size of feathers also appear to increase the habitat heterogeneity and morphological adaptations for the segregation of parasites (CROMPTON, 1997). For a better interpreting of invasion events, the Morisita parameter was employed during the present study of the distribution of lice on the body of coots to determine their preferred microhabitats. The results showed that the distribution of lice forms clusters and groups in particular parts of the host body and that each habitat would have both characteristic (non-dominant proportional) or general (more numerous) species. During the present work, *R. fulicae* had a distribution like that of generalist species, since it was found on every bird sampled. ADAM (2007) stated that the genus *Rallicola* (Johnston & Harrison, 1911) is constituted of 55 species, which parasitize the Guiformes and Chardriiformes. In particular, *R. fulicae* was reported from coots before by CONSTANTINEANU *et al.* (1958), BECHET (1959) in Romania. Thus, its ability to feed on blood may allow it to be more of a generalist or it may have greater dispersal abilities, making it tolerated than other louse species on the coots. Conversely, *L. (E.) atrum,* which is an Amblyceran, did not display such distribution.

Infestation with chewing lice populations fluctuates throughout the year. It has been found to increase in cold months, probably because the birds reduce their mobility and remain in their nests for longer (CLAYTON & WALTHER, 2001). In the National Park of El-Kala, the highest numbers of *F. atra* were recorded during the winter period, when wintering and migratory populations are added to the resident sedentary ones. As a result, the lice prevalence on coots was not constant from April to November, whilst there was markedly a drop in June and a significant peak in October. Thus, updated and local information is required to understand the infestation of chewing louse species on other waterbirds in the region.

Conclusion

In summary, five Mallophaga species – *Fulicoffula lurida, Incidifrons fulicae, Laemobothrion (Eulaemobothrion) atrum, Pseudomenopon pilosum,* and *Rallicola fulicae* – were collected from Common coots of Lake Tonga (National Park of El Kala). The dominant chewing louse species were *R. fulicae* (100%), *F. lurida* (89%) and *P. pilosum* (85%). Each species of chewing lice showed specific localization on the coot's body. Data obtained in this study suggest that Algeria, as a part of the Mediterranean region, is an important area for avian phthirapteran research and numerous louse species can be studied in different wetlands across the country. The extension of the study to populations of coots at other sites and other species inhabiting the same place could reveal important information about the dispersion patterns and the implied biological relationships.

Further investigations are required to understand the host-parasite ecology of a wide range of bird species over the country, as well as the different defense mechanisms of the birds against the various Mallophaga.

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