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# *Pseudolynchia canariensis* (Diptera: Hippoboscidae): distribution pattern and phoretic association with skin mites and chewing lice of *Columba livia* (Aves: Columbidae)

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The examination of 145 specimens of *Pseudolynchia canariensis* (74 males and 71 females) from 31 specimens of *Columba livia* captured between March and April of 2012 in the municipality of Pelotas, southern Brazil, revealed an aggregated distribution of hippoboscid flies. Prevalence and mean intensity of infestation were higher on younger hosts. Approximately 30% of hippoboscid flies exhibited phoretic associations with skin mites of the families Epidermoptidae and Cheyletidae as well as with chewing lice of the family Philopteridae. *Myialges anchora* and *Ornithocheyletia hallae* skin mites exhibited aggregated distributions. On *P. canariensis* only female skin mites were observed, *M. anchora* being the most prevalent and abundant. The abdominal ventral surface, between the metathorax and the first abdominal tergite and the ventral surface of wings of hippoboscid flies were the preferred regions for attachment by skin mites, whereas *Columbicola columbae* was observed attached to the mesotibia of one hippoboscid fly.

**Keywords:** phoresy; rock pigeons; Epidermoptidae; Cheyletidae; Philopteridae

## Introduction

Hippoboscid flies (Diptera: Hippoboscoidea) live most or the entire adult stage on the hairs or feathers of their hosts. Lipopteninae is limited to mammals, while Ornithomyiinae and Hippoboscinae also occur in birds (Maa 1962; Maa and Peterson 1987). The hippoboscid flies exhibits several morphological and physiological adaptations, such as viviparity, a condition strongly associated with the ectoparasitic lifestyle (Meier et al. 1999).

Because they feed on blood, hippoboscid flies affect host fitness (Moyer et al. 2002). For this reason, they are considered one of the most important groups of haematophagous insects of birds and mammals (Baker 1967), as they are responsible for transmitting haemosporidians (Apicomplexa: Haemosporida) to their hosts

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(Levine 1988), making them, for example, more susceptible to predation (Anderson and May 1979).

Hippoboscid flies are also considered potential carriers of parasites, mainly of chewing lice and mites that infest birds (Harbison et al. 2009; Keirans 1975; Marcelino et al. 2009). For many species of parasites with low vagility, this mechanism of dispersion is one of the main forms of colonization of new hosts (Jovani et al. 2001). In addition, phoresy can influence the structure of parasite communities, as some species developed this behaviour to escape competition (Harbison et al. 2008).

*Pseudolynchia* Bequaert, 1926 is a genus containing five species. Of these, only *Pseudolynchia brunnea* Latreille, 1812 is endemic to the American continent (Bequaert 1955). *Pseudolynchia canariensis* Macquart, 1840 presents a large dorsoventrally flattened body, with a small head located immediately adjacent to the prothorax (Bequaert 1952). It is widely distributed and frequently found in dovecotes in Brazil, causing irritation in birds and potentially transmitting the haemosporidian *Haemoproteus columbae* Kruse, 1890 (Gredilha et al. 2008).

Currently, the order Columbiformes is composed only by the family Columbidae (Gill and Donsker 2013). *Columba livia* Gmelin, 1789 can be considered the best-known representative of this genus because of its presence and abundance in many regions of the world (BirdLife International 2009). This species occurs in public parks, squares, and abandoned buildings and has been receiving attention from health organizations, because it may transmit diseases to humans (Marques et al. 2007). In addition, this species has been used as a model for many studies involving parasite–host relationships (Moyer et al. 2002; Harbison et al. 2009; Waite et al. 2012).

In many parts of the world, *P. canariensis* exhibits a high specificity to *C. livia*, resulting in high prevalence rates (Mushi et al. 2000; Marques et al. 2007; Radfar et al. 2012). In addition, phoretic associations of chewing lice and skin mites have been reported, mainly the families Epidermoptidae and Cheyletidae, with *P. canariensis* (Feres and Flechtmann 1991; Macchioni et al. 2005; Valim and Gazêta 2007). This demonstrates the importance of this behaviour in the dispersion and colonization of new hosts by these phoronts (Jovani et al. 2001).

This study was aimed at (1) evaluating infestations of *P. canariensis* on specimens of *C. livia*, in the municipality of Pelotas, Rio Grande do Sul (RS) State and (2) identifying possible phoretic associations between this hippoboscid fly with skin mites and chewing lice.

## Material and methods

Between March and April of 2012, 31 specimens of *C. livia* were captured and examined in Porto de Pelotas (31°46′55″ S, 52°20′01″ W). The climate of the region is humid subtropical defined as Cfa, characterized by hot humid summers, according to the Köppen classification (Moreno 1961). The annual average temperature in the urban area of the municipality of Pelotas is 17.8°C. January is the hottest month and July is the coldest month, with average temperatures of 23.2°C and 12.3°C, respectively. The annual average rainfall is 1369 mm, with rains regularly distributed throughout the year. During the sampling days, the average temperature and relative air humidity ranged between 15.6 and 23.1°C and 68.3 and 83.2%, respectively (Embrapa/UFPel/INMET).

Each specimen of *P. canariensis* was manually collected from the host and placed in Eppendorf tubes with 70% ethanol. In the Laboratory of Ecology of Parasites and Vectors of the Institute of Biology of the Federal University of Pelotas (UFPel), hippoboscid flies were identified with the aid of a stereomicroscope, according to Graciolli and Carvalho (2003) and Bequaert (1955). After identification, the dorsal and ventral regions, thorax, abdomen and wings of each fly were examined in search of mites and their eggs, as well as chewing lice. Their locations in the different regions of the fly and the developmental stages were recorded.

Skin mites were removed with the aid of tweezers, cleared and mounted on slides according to Flechtmann (1975). Identification was carried out under a microscope, according to Fain (1965) and the dichotomous keys by Gaud and Atyeo (1996) and Furmann and Tharshis (1953) for Epidermoptidae and by Smiley (1970) for the identification of Cheyletidae. Chewing lice were mounted in permanent preparations according to Palma (1978) and identified following Price et al. (2003) and Adams et al. (2005).

The effect of host age (young and adult) on the distribution pattern of *P. canariensis* and of the species of skin mites of *C. livia* was analysed with general linear models with quasi-Poisson distribution for the correction of the over-dispersion, as suggested by Crawley (2007). The variation in the number of eggs of the species of skin mites in relation to the sex of *P. canariensis* and the site of attachment of the skin mites were analysed with the F distribution and $p < 0.05$.

The prevalence and mean intensity of infestation were calculated based on the definition by Bush et al. (1997). Parasite indices as well as the index of spatial aggregation of *P. canariensis* and species of phoretic skin mites and chewing lice were analysed with the *K* parameter of the negative binomial distribution calculated using the software QUANTITATIVE PARASITOLOGY 3.0 (Reiczigel and Rózsa, 2005), with $p < 0.05$. Confidence intervals of prevalence and mean intensity of infestation of *P. canariensis*, and all species of phoretic skin mites and chewing lice were calculated.

## Results

We observed 160 specimens of *P. canariensis*, of which 15 escaped during collection. Of the 145 specimens collected, 49% ($n = 71$) were female and 51% were ($n = 74$) male. Of 31 captured individuals of *C. livia*, *P. canariensis* occurred in 93.5% (78.6–99.2%) ($n = 29$) of the birds, with mean intensity of infestation of 5.52 (3.6–8.9). The aggregation pattern of hippoboscid flies differed between young and adult hosts ($\chi^2 = 31.073$; DF = 3;11; $p < 0.001$; Figure 1). A total of 113 specimens of *P. canariensis* were collected from 12 young individuals of *C. livia* captured (mean = 9.4; 8.7 SD), and 47 specimens of *P. canariensis* were observed in 19 adult birds (mean 2.5; 3.9 SD). The average species richness of phoretic skin mites and chewing lice on *P. canariensis*, in adults as well as young of *C. livia* was 1.25.

Of the total hippoboscid flies collected, 30.3% ($n = 44$) had phoretic associations, 50% ($n = 22$) male and 50% ($n = 22$) female. We collected 55 specimens of *Myialges anchora* Sergent and Trouessart, 1907 (Astigmata: Epidermoptidae), four of *Myialges* (*Promyialges*) *lophortyx* Furmann and Tharshis, 1953 (Astigmata: Epidermoptidae), 47 of *Ornithocheyletia hallae* Smiley, 1970 (Prostigmata: Cheyletidae) and one of *Columbicola columbae* Linnaeus, 1758 (Ischnocera: Philopteridae). Only adult female

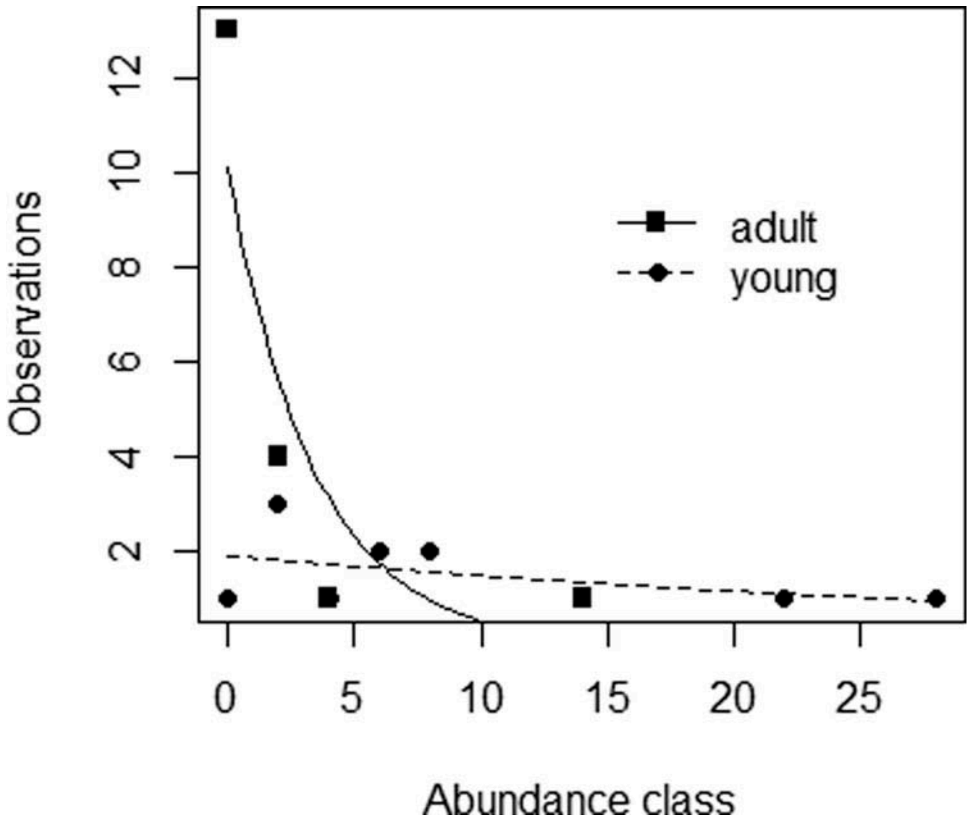


Figure 1. Distribution pattern of the abundance classes of *Pseudolynchia canariensis* on young and adults of *Columba livia* collected between March and April of 2012, in the municipality of Pelotas, RS, Brazil.

skin mites and chewing lice were observed. The number of skin mites and chewing lice on *P. canariensis* did not differ statistically in relation to the age of the *C. livia* host ($\chi^2 = 36.51$; $p = 0.187$). Results for the values of the parameter $K$, prevalence and mean intensity of infestation of phoretic skin mites and chewing lice collected on *P. canariensis* are presented in Table 1.

The skin mite *M. anchora* was the most prevalent and abundant. The dorsal and ventral surface of the abdomen were the regions with more specimens attached (Table 2). Also 52.7% ($n = 29$) of skin mites were surrounded by clusters of eggs, with an average of 38.1 ± 22.5 eggs per ovigerous female ($n = 16$) attached to the dorsal surface of the abdomen. These differences, however, were not statistically significant ($F = 2.65$; DF = 3;23; $p = 0.07$).

Of the total specimens of *O. hallae* collected, 76.6% ($n = 36$) were found between the metathorax and the first abdominal tergite, while the remaining specimens were loose inside the Eppendorf vial and were not associated with any specific region of the hippoboscid flies. No eggs of this species were observed on *P. canariensis*.

Three specimens of *M. lophortyx* were observed on the wings (proximal region of the vein M), on the ventral surface. One ovigerous female was surrounded by 14 eggs.

Table 1. Parameter *K* value, prevalence and mean intensity of infestation of phoretic skin mites and chewing lice collected on *Pseudolynchia canariensis*, between March and April of 2012, in the municipality of Pelotas, RS, Brazil.

| Phoretic species | Parameter *K* value | Prevalence % (95% CI) | Mean intensity of infestation (95% CI) | On *P. canariensis* |
|---|---|---|---|---|
| *Myialges anchora* | 0.293 | 22.1% (15.6–29.7) | 1.72 (1.41–2.06) | oviposition and dispersion |
| *Myialges lophortyx* | – | 2.7% (0.7–6.9) | 1.0 | oviposition and dispersion |
| *Ornithocheyletia hallae* | 0.076 | 12.4% (7.5–18.9) | 2.61 (1.83–4.17) | dispersion |
| *Columbicola columbae* | – | 0.7% | 1.0 | dispersion |

Note: CI, confidence interval; -Cells with en dashes were not calculated due to small sample size.

Table 2. Number of specimens and eggs (within parentheses) of *Myialges anchora* in the different body regions of *Pseudolynchia canariensis* collected on *Columba livia*, between March and April of 2012, in the municipality of Pelotas, RS, Brazil.

| Body regions | Dorsal face | Ventral face | Total |
|---|---|---|---|
| Head | 1 (0) | 5 (73) | 6 (73) |
| Thorax | 1 (0) | 2 (56) | 3 (56) |
| Abdomen | 33 (610) | 13 (190) | 46 (800) |
| Total | 34 (610) | 18 (319) | 55 (929) |

One specimen was loose inside the Eppendorf vial and was not associated with any specific region of the body of *P. canariensis*.

The only specimen of *Columbicola columbae* was attached to the mesotibia of one hippoboscid fly.

Simultaneous infestations were observed in 22.7% ($n = 10$) of infested hippoboscid flies. *Myialges anchora* and *O. hallae* occurred simultaneously on nine occasions, while *M. lophortyx* and *M. anchora* occurred simultaneously twice, and *M. lophortyx* and *O. hallae* on once. The simultaneous occurrence of three species of skin mites was observed on only one hippoboscid fly.

In this study, *P. canariensis* presented an aggregated distribution on *C. livia*. On *P. canariensis*, *M. anchora* and *O. hallae* also exhibited aggregated distributions (Table 1). The *K* parameter of the distribution of *M. lophortyx* and *Columbicola columbae* could not be determined because of the small sample size.

## Discussion

In this study, *P. canariensis* was present on 93.5% of the birds examined. The high prevalence rates of *P. canariensis* on *C. livia* reported in several studies (Dranzoa et al.

1999; Marques et al. 2007) revealed a strong correlation of this ectoparasite with its host. Radfar et al. (2012) observed a higher prevalence of *P. canariensis* on adult individuals of *C. livia* captured in the municipality of Khorasan, in the Iranian semiarid region. However, as in the present study, the intensity of infestation was higher in young birds. A low intensity of infestation of *P. canariensis* on adult individuals of *C. livia* is expected, as they acquire a higher level of immunity against parasites (Merila et al. 1995). In addition, adult birds use the bill and claws as efficient tools in the population control of ectoparasites, including hippoboscid flies (Clayton et al. 2010; Waite et al. 2012).

A slight predominance of male hippoboscid flies was observed in the present study, similar to the findings of Tella and Jovani (2000) regarding *Crataerina melbae* Rondani, 1879 infesting *Apus melba* Linnaeus, 1758 (Aves: Apodidae). On the other hand, Walker and Rotherham (2010) observed a higher predominance of females of *Crataerina pallida* Latreille, 1812 on *Apus apus* Linnaeus, 1758 (Aves: Apodidae). The initial predominance of males in infrapopulations might be due to their early emergence compared with females. However, because of an increase in mortality rates of males during the reproductive period of the species, possibly caused by competition, the number of females becomes higher than that of males (Kemper 1951). Males are also more abundant at the end of the reproductive cycle, as a result of the higher mortality of females during this period (Walker and Rotherham 2010). Females lay puparia outside the host and therefore are absent during some periods (Bequaert 1952), which may coincide with sampling periods. Several studies have reported that females of ectoparasitic insects are frequently more abundant due to their longer life span and dispersion capacity when compared with those of males (Hamilton 1967; Clayton et al. 1992; Dick and Patterson, 2008).

Approximately 30% of the specimens of *P. canariensis* had phoretic associations. This result is lower when compared with those found by Marcelino et al. (2009); Valim and Gazêta (2007) and Macchioni et al. (2005), who reported prevalences of 47%, 51% and 54%, respectively. Although the sampling period was not described in these studies, this variation in the percentage of phoretic associations with *P. canariensis* might be due to distinct climate factors (temperature and humidity), as well as to characteristics of the host populations sampled (population size, social and reproductive behaviours) (Blanco and Frías 2001; Hamstra and Badyaev 2009) in each study site, which might affect the populations and behaviour of ectoparasites.

Specimens of *M. anchora* were more prevalent and abundant phoronts on *P. canarienses*, as also observed by Valim and Gazêta (2007). Representatives of the genus *Myialges* Trouessart, 1906 complete part of their cycle on the skin of birds and have an obligatory association with hippoboscid flies (Fain and Grootaert 1996). Evans et al. (1963) examined the biological cycle of *Myialges macdonaldi* Evans, Fain and Bafort, 1963 and observed that larvae, nymphs, males and non-ovigerous females were present on the host's skin, whereas ovigerous females were attached to hippoboscid flies. As observed by Valim and Gazêta (2007), the number of adults and eggs of *M. anchora* was highest on the dorsal surface of the abdomen of *P. canariensis*. The selection of the abdominal dorsal surface for attachment and later egg-laying might be due to the protection provided by the wings of the hippoboscid fly, mainly against friction by the bird's feathers, which could detach or damage the eggs of this species.

In this study, no egg clutches were found where *O. hallae* specimens were present, as also reported by Valim and Gazêta (2007) and Marcelino et al. (2009). In the phoretic process described by Feres and Flechtmann (1991) for this species, mites were found loosely attached to the body of the hippoboscid fly without the presence of eggs. The absence of egg clutches of *O. hallae* suggests that the interaction with *P. canariensis* is different from those of species of the genus *Myialges*, and its presence is associated only with dispersion strategies (Macchioni et al. 2005).

As observed by Feres and Flechtmann (1991) and Marcelino et al. (2009), we also observed specimens of *M. lophortyx* attached to the wings of *P. canariensis*. The presence of this skin mite in the hippoboscid wings suggests a preference for the attachment on this integument and/or restricted to this site because of the competition with *M. anchora*.

The phoretic association between *P. canariensis* and *Columbicola columbae* was also observed by Macchioni et al. (2005) and Harbison et al. (2008). This species of chewing lice found on the remiges and rectrices of birds, have long appendices that facilitate their attachment to the host as well as the hippoboscid fly (Harbison et al. 2009). In a recent study using *C. livia* as study model, Bush and Malenke (2008) demonstrated that *Campanulotes compar* Burmeister, 1838 was a superior competitor to *Columbicola columbae*, which supports the hypothesis that phoresy, in addition to a dispersion mechanism, might be an escape to competition for this species.

According to Fain (1965), many species belonging to the "phoretic" genera *Microlichus* and *Myialges* have a low level of specificity. Skin mites *M. anchora* have been reported from several other avian hosts, but it does not seem certain that in all these cases the mites really belonged to this species. Cooreman (1944) summarized much of the information on species of these genera, designating insect and avian hosts as well as recorded geographic distribution. According to Bequaert (1952) mites of the genus *Ornithocheyletia* are specific parasites of birds; however, the details of the relationship with hippoboscid flies are still poorly understood.

As reported by Marcelino et al. (2009), the simultaneous infestation by *M. anchora* and *O. hallae* was the most frequently observed on *P. canariensis* in this study. Similar results were also obtained regarding the simultaneous infestations by three species of skin mites, which was only observed once in both studies.

Aggregated distributions were observed in *P. canariensis* on *C. livia*, as well as *M. anchora* and *O. hallae* on *P. canariensis*. This distribution pattern has been reported for parasites of vertebrates (Shaw and Dobson 1995; Poulin 2007; Walker and Rotherham 2010; Amaral et al. 2012), as well as phoretic associations between skin mites and hippoboscid flies (Marcelino et al. 2009). Differences in size, attachment and location sites on the host, and the purpose of attachment (egg laying or transport of adults) can also contribute to the less aggregated pattern exhibited by Epidermoptidae mites (Marcelino et al. 2009).

Based on our findings on *C. livia*, skin mites of the family Epidermoptidae use hippoboscid flies for dispersion and oviposition, preferentially on the dorsal surface of the abdomen and the wings for attachment, respectively. However, *Columbicola columbae* and *O. hallae* use hippoboscid flies only as a form of dispersion, attaching mainly in the region between the metathorax and the first abdominal tergite.

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