International Journal for Parasitology: Parasites and Wildlife 6 (2017) 229–232

Contents lists available at ScienceDirect

International Journal for Parasitology: Parasites and Wildlife

journal homepage: www.elsevier.com/locate/ijppaw

Lousy chicks: Chewing lice from the Imperial Shag, *Leucocarbo atriceps*

María Soledad Leonardi*, Flavio Quintana

Instituto de Biología de Organismos Marinos (IBIOMAR), CONICET, Boulevard Brown 2915, U9120ACD, Puerto Madryn, Chubut, Argentina

ARTICLE INFO

Article history:
Received 31 May 2017
Received in revised form
28 July 2017
Accepted 2 August 2017

Keywords:
Chewing lice
Patagonia
Pectinopygus turbinatus
Piagetiella caputincisum
Seabirds
Shag
Transmission

ABSTRACT

Forty-one imperial shag chicks were sampled for lice during the breeding season of 2014 in Punta León, Argentina. We found 2 lice species, *Pectinopygus turbinatus* infesting the body and *Piagetiella caputincisum* present in the oral cavity of the birds. This constitutes the first host record for *P. turbinatus* and the first record for the continental Argentina for *P. caputincisum*. Ninety-three percent of the chicks were infested by at least one lice species. *P. turbinatus* was present in all of the lousy chicks, while *P. caputincisum* infested 84.2% of them. The mean intensity was 29.5 and the range 1–129. There was no difference in prevalence, mean intensity or mean abundance between louse species. However, we found differences among the pattern of infestation of each species. Imperial shag chicks were infested by their parents during their first days of life by *P. turbinatus*, mainly in nymphal stage and by *P. caputincisum* as adult lice. Our results showed differences among lice species that could be related to the restrictions that lice from seabirds faced during their life cycle.

1. Introduction

The Imperial Shag, *Leucocarbo atriceps* King (Suliformes, Phalacrocoracidae) is one of the five species of cormorants inhabiting South America and one of the most abundant seabirds on the Patagonian coast (Yorio et al., 1999; Frere et al., 2005). In Argentina, it is distributed from Punta León (43°S) to the Beagle Channel (54°S), with an estimated of number of 55000 pairs (Frere et al., 2005). The Imperial Shag is a colonial ground-nesting seabird where both parents play an active role in the care and feeding of chicks throughout the breeding cycle (Johnsgard, 1993). This monogamous seabird usually lays a three-egg clutch that hatches asynchronously over 4–5 days (Svagelj and Quintana, 2011a, 2011b; Calderón et al., 2012). This hatching pattern results in age and size asymmetry between chicks, where the probability of fledging drastically decreases with hatching order (Svagelj and Quintana, 2011a). This species exhibits obligate brood reduction where last-hatched chicks from three-hatchling broods usually starve to death within the first week of life, with successful breeding attempts producing one or two-chick broods (Svagelj and Quintana, 2011a, 2011b).

Although much is known about its reproductive biology (Svagelj and Quintana, 2007, 2011a, 2011b; Svagelj et al., 2012) and feeding ecology (Gómez Laich et al., 2012, 2013, 2015; Harris et al., 2014a, 2014b, 2015), there has been a unique report on parasites of this species in Patagonia. Garbin et al. (2008) described a new species of an anisakid species, *Contracaecum chubutensis*, parasitizing Imperial Shags in Northern Patagonia.

Chewing lice (order Phthiraptera) are wingless insects, living as permanent and obligate ectoparasites of birds and mammals (Kim, 1985). Lice can affect the feather and skin of its hosts, causing dermatitis, excessive scratching, and increasingly impaired general condition of some birds to the point of conducted to death (Clayton et al., 2008). However, little is known about lice species infesting seabirds in general and Imperial Shags in particular. Therefore, the main goal of this study is to report the results of a survey of the louse community in Imperial Shag chicks from Punta León colony, one of the main breeding population of this species on the Patagonian coast of Argentina (Frere et al., 2005).

2. Materials and methods

2.1. Lice collection

The study was undertaken at Punta León colony (43° 03′ S, 64° 27′ W), Chubut, Argentina, during the 2014 breeding season. Punta León is a mixed seabird colony (Yorio et al., 1994) where approximately 5000 pairs of imperial shags breed (F. Quintana unpublished data).

Lice were collected using forceps and fixed in 96% ethanol at the field. Chicks were completely examined and manipulation stopped

* Corresponding author.
E-mail address: leonardi@cenpat-conicet.gob.ar (M.S. Leonardi).

http://dx.doi.org/10.1016/j.ijppaw.2017.08.002

when no more lice were seen on the chick or inside its oral cavity. We consider that this technique was reliable to address the goals of the present study because the small size and bare body of chicks (for details see Malacalza and Navas, 1996) allows collecting practically all the lice. Once in the laboratory, lice specimens were classified into nymphs (N) and adult male (M) or female (F) stages.

2.2. Infestation pattern

Infestation parameters were estimated following Rózsa et al. (2000). Prevalence was defined as the frequency of lice occurrence, expressed as a percentage. To set 95% confidence intervals for prevalence we used Sterne's exact method (Reiczigel, 2003). Mean intensity was defined as the mean number of individuals per host in the total sample of infested hosts. We used a bootstrap procedure with 20,000 replications to set 95% confidence intervals of mean intensity (Rózsa et al., 2000). Prevalence was compared between lice species with Fisher's exact test, and mean intensity with a Bootstrap *t*-test. We estimated the lice sex ratio as = males/(males + females). A Spearman rank correlation test was used to examine the relationship between the abundance of the two louse species.

3. Results

A total of 1120 lice were collected. Lice were identified as *Pectinopygus turbinatus* and *Piagetiella caputincisum* by comparing them to described species (Hopkins and Clay, 1952; Price, 1970; Clay, 1973).

3.1. Taxonomic review

Arthropoda.
Insecta.
Phthiraptera Haeckel, 1896.
Ischnocera Kellogg, 1896.
Philopteridae Burmeister, 1838
Pectinopygus turbinatus Piaget, 1880.
Type host: Mycteria senegalensis (Error of the author).
Type locality: Unknown.
Type specimen/s data: Holotype, ♂, slide N°344, Natural History Museum, London, UK.
Other hosts: None.
Site of infestation: the entire body, more abundant under the wings.

Remarks: According to Clay (1973), the genus *Pectinopygus* includes 39 species infesting the orders Suliformes (cormorants and shags), Pelecaniformes, and birds from the genus *Phaethon* (Hughes et al., 2007). However, since the work of Clay, great changes have been made in the taxonomy of cormorants and shags. The classical classification of van Tets (1976) recognized two groups: the cormorants, including freshwater and coastal species belonging to the genus *Phalacrocorax*; and the shags, species associated with open sea, included in the genus *Leucocarbo*. Recently, a molecular study by Kennedy and Spencer (2014) shed light into the classification of these species recognizing 7 clades, represented by 7 different genera. Therefore, a revision of the *Pectinopygus* is needed.

Pectinopygus turbinatus was described by Piaget (1880), as *Oncophorus turbinatus*. The type host was recorded as *Mycteria senegalensis*, a species of tropical storks (Ciconiiformes: Ciconiidae). However, the author made a mistake because *M. senegalensis* does not exist as a valid species, and he did not report a type locality. Later, Hopkins and Clay (1952) revised the holotype and correctly transferred the species to the genus *Pectinopygus*. However, these authors did not mention the correct type host of this species. This constitutes the first known host species for *P. turbinatus*.

However, a detailed description of this species is lacking from the literature. This is the first record of this species from Argentina.

Arthropoda.
Insecta.
Phthiraptera Haeckel, 1896.
Amblycera Kellogg, 1896.
Menoponidae Mjöberg, 1910.
Piagetiella caputincisum Eichler, 1950.
Type host: Leucocarbo atriceps.
Type locality: South Orkney Islands.
Type specimen/s data: Not available.
Other hosts: *Leucocarbo albiventer*, King shag.
Site of infestation: oral cavity.

Remarks: Lice belonging to the genus *Piagetiella* are peculiar since they inhabit the oral cavity of pelicans (Order Pelecaniformes), cormorants and shags (Order Suliformes). Eichler originally described the species as *P. caputincisa*. Further, Price and Palma (1997) corrected the gender and named it *P. caputincisum*. Additionally, Price (1970) reviewed the taxonomy of the genus, including a key to identify the 8 species. This is the first record of this species in continental Argentina.

3.2. Infestation parameters

Ninety-three percent of the chicks were infested by at least one lice species. *Pectinopygus turbinatus* was present in all of the lousy chicks, while *Piagetiella caputincisum* infested 84.2% of them. The mean intensity was 29.5 and the range 1–129. There was no difference in prevalence between louse species (Fisher's exact $p = 0.061$). No differences were observed in the mean intensity ($t = -1.68$, $p = 0.1$) nor in the mean abundance ($Z = -2.13$, $p = 0.06$) between species. Table 1 summarizes the infestation parameters among *P. turbinatus* and *P. caputincisum*.

We found differences in prevalence and mean intensity between stages of lice species. The prevalence and mean intensity of adults *P. caputincisum* were higher than *P. turbinatus* (prevalence 73.2% vs. 41.5%, Fisher's exact $p = 0.007$; mean intensity 5.133 vs 2.82; $t = 2.48$, $p = 0.002$), while for nymphs the difference was reversed (prevalence 61% for *P. caputincisum* vs. 92.7% for *P. turbinatus*, Fisher's exact $p = 0.001$; mean intensity 9.64 vs 17.82, respectively; $t = -2.16$, $p = 0.05$; Fig. 1). The sex ratio did not differ from 1:1 (0.26 ± 0.34, $\chi2 = 5.71$, $p > 0.05$ for *P. turbinatus*; 0.55 ± 0.33, $\chi2 = 6.28$, $p > 0.05$ for *P. caputincisum*). No significant correlation was found between *P. caputincisum* and *P. turbinatus* infestation (Spearman rank tests, $r_s = 0.255$, $p = 0.107$).

4. Discussion

This work constitutes the first parasitological study in the Imperial Shag in Patagonia, Argentina. We recovered two lice species from imperial shags chicks: *Pectinopygus turbinatus* and *Piagetiella caputincisum*. We did not found significant differences in

Table 1
Descriptive statistics of parasite infestation of *Pectinopygus turbinatus* and *Piagetiella caputincisum* in imperial shag chicks from Punta León, Patagonia, Argentina. Numbers in parentheses correspond to the 95% confidence intervals.

	Pectinopygus turbinatus	*Piagetiella caputincisum*
Prevalence	92.7% (80.72–97.97%)	78% (62.34–88.33%)
Mean intensity	19.08 (14.18–28.45)	12.34 (9.50–16.38)
Mean abundance	17.68 (12.61–26.63)	9.63 (6.88–13.20)
Range	1–119	1–39

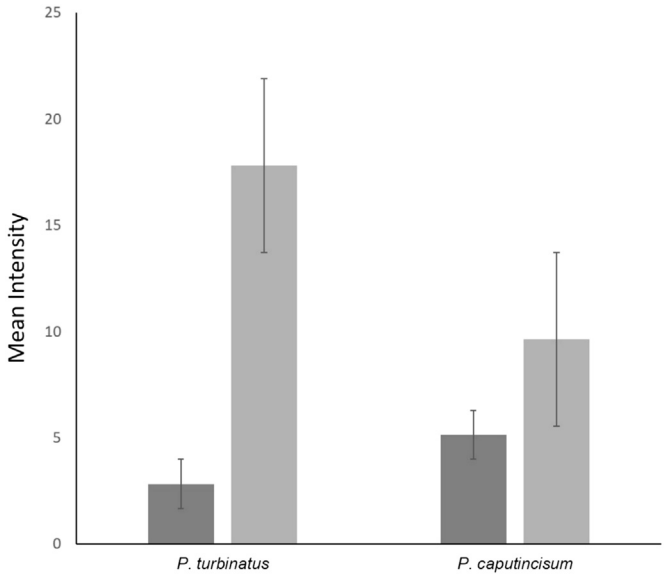

Fig. 1. Mean intensity of instars (adults in dark grey, nymphs in light grey) of the lice *Pectinopygus turbinatus* and *Piagetiella caputincisum* in Imperial Shag chicks from Punta León, Patagonia, Argentina. Vertical bars correspond to the 95% confidence intervals.

prevalence, mean intensity nor mean abundance among lice species. However, *P. turbinatus* was present in all infested chicks while *P. caputincisum* in the 80% of them and we found differences in the pattern of infestation among stages for lice species.

Lice are wingless, obligate and permanent ectoparasites throughout their entire life cycles, living as ectoparasites on the host's surface (Kim, 1985). As consequence, lice have limited opportunities for dispersal, and transmission from one host to another largely depends on physical contact between hosts (Demastes et al., 1998; de Brooke and de, 2010). Therefore, transmission can be potentially either vertical (from a parent onto its offspring) or horizontal (between siblings or during mating) (de Brooke and de, 2010). Although shags are colonial and philopatric breeders (Johnsgard, 1993), the main way of transmission for lice would be from parents to chicks (Leonardi et al., in press). *Piagetiella caputincisum* is transmitted from the parent's oral cavity to chicks during feeding, while *P. turbinatus* infested chicks as soon as they hatch (Leonardi et al., in press). According with recent studies, transmission between siblings seems to be minimal (Leonardi et al., in press).

There is no information about the restriction that lice from seabirds faced during their life cycle. However, Samuel et al. (1982) and Leonardi et al. (in press) suggested that the life cycles of seabirds and their lice are likely to be synchronized. In this sense, *P. turbinatus* was more abundant as nymphs in imperial shag chicks. Lice deposit their eggs on adult seabirds because oviposition and embryonic development requires the feather surfaces and the stable microclimate within the plumage. After hatching, nymphs migrate to new-born chicks where they develop. Down feathers of imperial shag chicks appear several days after hatching and feathers need weeks to develop (Malacalza and Navas, 1996). In the case of *P. turbinatus*, this pattern of transmission would protect lice in immature stages of the exposure to marine condition during the diving of adult shags (Leonardi et al., in press). Contrarily, however, *P. caputincisum* appears to transmit mostly in its adult stage of life. For pelicans, Samuel et al. (1982) suggested that lice reproduce on chicks and moves to adult pouches as nymph 3.

Finally, chewing lice can affect the feather and skin of its hosts, causing dermatitis, excessive scratching, and increasingly impaired general condition of some birds to the point of conducted to death (Clayton et al., 2008). Furthermore, *Piagetiella* lice seems to be potentially more harmful especially for chicks and juvenile birds. As was remarked by Samuel et al. (1982), at high intensities *Piagetella* could case the death of its host. This louse damage the skin surface of the pouches, such damage may also favour the infection with bacteria. Moreover, *P. peralis*, louse species from the American White Pelican *Pelecanus erythrorhynchos*, was associated with a high mortality of juvenile pelicans, it's not clear if they were the main cause of death but contributed to a bad health condition that derived in the death of the birds (Samuel et al., 1982; Clayton et al., 2008). Considering that imperial shag chicks are infested during their first few days of life and the small size of chicks (Malacalza and Navas, 1996), further research is needed to determine the possible effect of *P. caputincisum* on this host.

Conflict of interests statement

M. Soledad Leonardi and Flavio Quintana below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Acknowledgement

We appreciate the important comments and suggestions made two anonymous referees that largely improved the manuscript. We thank institutional and logistic support given by Instituto de Biología de Organismos Marinos (IBIOMAR, CONICET, Argentina) under permits of the Secretaría de Áreas Protegidas y Turismo and the Dirección de Fauna y Flora Silvestre, Chubut Province (Argentina). This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors express their support and defend the Argentinean scientific program.

References

Burmeister, H.C.C., 1838. Handbuch der Entomologie, Berlin, vol. II.
Calderón, L., Svagelj, W.S., Quintana, F., Lougheed, S.C., Tubaro, P.L., 2012. No evidence of extra-pair paternity or intraspecific brood parasitism in the imperial shag *Phalacrocorax atriceps*. J. Ornithol. 153, 399–404.
Clay, T., 1973. The Species Groups of Pectinopygus (Phthiraptera: Philopteridae). Bulletin of the British Museum (Natural History), London.
Clayton, D.H., Adams, R.J., Bush, S.E., 2008. Phthiraptera, the chewing lice. In: Atkinson, C.T., Thomas, N.J., Hunter, D.B. (Eds.), Parasitic Diseases of Wild Birds. Wiley-Blackwell, Ames, Iowa, pp. 515–526.
de Brooke, M., de, L., 2010. Vertical transmission of feather lice between adult blackbirds *Turdus merula* and their nestlings: a lousy perspective. J. Parasitol. 96, 1076–1080.
Demastes, J.W., Hafner, M.S., Hafner, D.J., Spradling, J., 1998. Pocket gophers and chewing lice: a test of the maternal transmission hypothesis. Mol. Ecol. 7, 1065–1069.
Eichler, W., 1950. Über die endoparasitische Lebensweise der Kormoran-Federlinge. Revista di Parassitologia 11, 103–108.
Frere, E., Quintana, F., Gandini, P., 2005. Cormoranes de la costa patagónica: estado poblacional, ecología y conservación. Hornero 20, 35–52.
Garbin, L.E., Diaz, J.I., Cremonte, F., Navone, G., 2008. A new anisakid species parasitizing the Imperial Cormorant *Phalacrocorax atriceps* from the North Patagonian coast, Argentina. J. Parasitol. 94, 852–859.
Gómez Laich, A., Quintana, F., Shepard, E.L.C., Wilson, R., 2012. Intersexual differences in the diving behaviour of imperial cormorants. J. Ornithol. 153, 139–147.
Gómez-Laich, A., Wilson, R.P., Shepard, E.L.C., Quintana, F., 2013. Energy expenditure and food consumption of foraging imperial cormorants in Patagonia, Argentina. Mar. Biol. 160, 1697–1707.
Gómez-Laich, A., Yoda, K., Zavalaga, C., Quintana, F., 2015. Selfies of Imperial

cormorants (*Phalacrocorax atriceps*): what is happening underwater? PLoS One 10, e0136980 doi:10.1371.
Haeckel, E., 1896. Entwurf eines natürlichen Systems der Organismen auf Grund ihrer Stammesgeschichte. II: Systematische Phylogenie der wirbellosen Tiere (Invertebrata). Systematische Phylogenie, Berlin.
Harris, S., Raya Rey, A., Quintana, F., 2014a. Breeding experience and foraging behavior of Imperial Shags (*Phalacrocorax atriceps*). Emu 113, 222–228.
Harris, S., Raya Rey, A., Zavalaga, C., Quintana, F., 2014b. Strong temporal consistency in the individual foraging behaviour of Imperial Shags (*Phalacrocorax atriceps*). IBIS 156, 523–533.
Harris, S., Quintana, F., Ciancio, J., Riccialdelli, L., Raya Rey, A., 2015. Linking foraging behavior and diet in a diving seabird. Mar. Ecol. http://dx.doi.org/10.1111/maec.12327.
Hopkins, G.H.E., Clay, T., 1952. A Checklist of the Genera & Species of Mallophaga. Trustees of the British Museum, London, p. 362.
Hughes, J., Kennedy, M., Johnson, K.P., Palma, R.L., 2007. Multiple cophylogenetic analyses reveal frequent cospeciation between Pelecaniform birds and *Pectinopygus* lice. Syst. Biol. 56, 232–251.
Johnsgard, P.A., 1993. Cormorants, Darters and Pelicans of the World. Smithsonian Institution Press, Chicago.
Kellogg, V.L., 1896. The Mallophaga. Psyche 7, 375–379.
Kennedy, M., Spencer, H.G., 2014. Classification of the cormorants of the world. Mol. Phylogenet. Evol. 79, 249–257.
Kim, K.C., 1985. Coevolution of Parasitic Arthropods and Mammals. Wiley, New York.
Leonardi, M.S., Svagelj, W.S., Gómez-Laich, A., Quintana, F., 2017. The eldest sibling is the lousiest in an obligate brood reducer seabird, EMU, (in press).
Malacalza, V.E., Navas, J.R., 1996. Biología y ecología reproductiva de *Phalacrocorax albiventer* (Aves: Phalacrocoracidae) en Punta León, Chubut, Argentina. Ornitol. Neotrop 7, 53–61.
Mjöberg, E., 1910. Studien über Mallophagen und Anopluren. Arkiv för Zoologi 6, 1–269.
Piaget, E., 1880. Les Pédiculines: Essai Monographique. EJ. Brill, Leiden, p. 714.
Price, R., 1970. The *Piagetiella* (Mallophaga: Menoponidae) of the Pelecaniformes. Can. Entomol. 102, 389–404.
Price, R., Palma, R.L., 1997. Gender correction for a louse (Phthiraptera: Menoponidae) from cormorants. Proc. Entomol. Soc. Wash 99, 587.
Reiczigel, J., 2003. Confidence intervals for the binomial parameter: some new considerations. Stat. Med. 22, 611–621.
Rózsa, L., Reiczigel, J., Majoros, G., 2000. Quantifying parasites in samples of hosts. J. Parasitol. 86, 228–232.
Samuel, W.M., Williams, E.S., Rippin, A.B., 1982. Infestations of *Piagetiella peralis* (Mallophaga: Menoponidae) on juvenile white pelicans. Can. J. Zool. 60, 951–953.
Svagelj, S.W., Quintana, F., 2007. Sexual size dimorphism and sex determination by morphometric measurements in breeding Imperial Shags (*Phalacrocorax atriceps*). Waterbirds 30, 97–102.
Svagelj, W.S., Quintana, F., 2011a. Breeding performance of the Imperial Shag (*Phalacrocorax atriceps*) in relation to year, laying date and nest location. Emu 111, 162–165.
Svagelj, W.S., Quintana, F., 2011b. Egg-size variation in the imperial cormorant: on the importance of individual effects. Condor 113, 528–537.
Svagelj, W.S., Trivellini, M.M., Quintana, F., 2012. Parental investment theory and nest defence by imperial shags: effects of offspring number, offspring age, laying date and parent sex. Ethology 118, 251–259.
van Tets, G.F., 1976. Australasia and the origin of shags and cormorants Phalacrocoracidae. Proc. XVI Int. Ornithol. Congr. 121–124.
Yorio, P., Quintana, F., Campagna, C., Harris, G., 1994. Diversidad, abundancia y dinámica espacio-temporal de la colonia mixta de aves marinas en Punta León, Patagonia. Ornitol. Neotrop 5, 69–77.
Yorio, P., Frere, E., Gandini, P., Conway, W., 1999. Status and conservation of seabirds breeding in Argentina. Bird. Conserv. Int. 9, 299–314.