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ORIGINAL PAPER

Parasites of chinstrap penguins (*Pygoscelis antarctica*) from three localities in the Antarctic Peninsula and a review of their parasitic fauna

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Abstract

Studies of parasitism in chinstrap penguins (*Pygoscelis antarctica*) are infrequent and mainly refer to the identification and description of its parasites, with little ecological data. In an attempt to address that lack of knowledge, we collected endo- and ecto-parasites from 326 live and four dead of chinstrap penguins, in three different localities of Antarctica not studied before. Three species of endoparasites and two of ectoparasites were found parasitizing birds: two tapeworms, *Tetrabothrius pauliani* (Cestoda: Tetrabothriidae) and *Parorchites zederi* (Cestoda: Dilepididae); one roundworm, *Stegophorus macronectes* (Nematoda: Acuariidae), and one feather louse: *Austrogoniodes gressitti* (Insecta: Phthiraptera: Philopteridae). Ticks (*Ixodes uriae*—Acari: Ixodidae) were collected from the ground near the penguin nesting colonies at two localities, Shirreff Cape and Narebsky Point. New ecological data are given for the two species of ectoparasites. No parasites were found in the blood collected from 300 live penguins.

Keywords Chinstrap penguins · Antarctica · Endoparasites · Ectoparasites · Worms · Ticks · Lice

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Introduction

High parasite burdens can be detrimental to the health and fitness of penguins (Fraser and Patterson 1997), but most studies of parasites from the chinstrap penguin—*Pygoscelis antarctica* (Forster, 1781)—are fragmented and mainly deal with the identification and description of endoparasites (e.g., Zdzitowiecki and Drózdz 1980; Ippen et al. 1981; Andersen and Lysfjord 1982; Hoberg 1983; Zdzitowiecki 1991; Cielecka et al. 1992; Dimitrova et al. 1996; Georgiev et al. 1996; Vidal et al. 2012), and/or with very few reports on ectoparasites (e.g., Clay 1967; Barbosa et al. 2011). With a few exceptions (e.g., Hoberg 1986; Vidal et al. 2012), most studies include little or no information about ecological parameters and no comparison of data among different locations. Chinstrap penguins are an important part of the Antarctic fauna, and it is concerning that populations of these birds are decreasing (Sander et al. 2007; Barbosa et al. 2012; Naveen et al. 2012). However, assessments of the impact of parasitism and disease have been generally overlooked. In this paper, we report the endo- and ecto-parasites of chinstrap penguins collected from three different localities of Antarctica, including some ecological data for the tick

Ixodes uriae White, 1852, found only under rocks in two localities, as summarized on Table 1.

Materials and methods

With the previous authorization from the Chilean Antarctic Institute (INACH), parasite samples from live and dead chinstrap penguins were collected from three localities in the Antarctic Peninsula, as follows: Base Guillermo Mann in Shirreff Cape, Livingston Island [SC] (62°27′00″S; 64°47′00″W); Narebsky Point, Kind George Island [NP] (62°13′60″S; 58°46′25″W); and Kopaitic Island, Antarctic Peninsula [KI] (63°19′15″S; 57°51′01″W), from January 20 to February 17, 2012 (Fig. 1).

Live penguins were captured using a bird net, trying not to disrupt their breeding activities. Animal handling followed standard methods described in the CCAMLR Ecosystem Monitoring Program (Agnew 2004), with the methodology described by Wilson (1997).

Three hundred and twenty-six clinically healthy birds (SC $n=100$; KI $n=100$; NP $n=126$) were captured alive and each examined during 3 min to collect ectoparasites, which were placed in individual vials with 70% ethanol. The lice collected from the birds' plumage were slide-mounted following the technique described by Palma (1978) to allow their identification to species. Voucher specimens were deposited in the collection of "Parásitos y Enfermedades de Fauna Silvestre" in the Faculty of Veterinary Sciences, Universidad de Concepción, Chillán, Chile, and in the collection of the Museum of New Zealand, Wellington, New Zealand.

Ticks were collected from the ground near the penguin colonies and placed in vials of 70% ethanol, labeled, and kept for identification to species and permanent storage. Estimates of tick abundance are most often generated by the collection of ticks from under stones. Therefore, the ground beneath many stones was examined over a three-hour period at SC and at KI and over one hour in NP, totaling 420 min of sampling effort (Frenot et al. 2001). To compare the density of ticks among the different localities, the tick abundance index (TAI) was calculated, being the number of collected ticks divided by the sampling effort and expressed in tick numbers collected in 100 sampling minutes. ($TAI = TR \times 100/t$, with $TR =$ number of collected ticks, and $t =$ sampling period in minutes). The tick abundance indices were subjected to logarithmic transformation [ln (TAI + 1)] for statistical analyses. To compare abundance among the three localities studied, we used the program Quantitative Parasitology, version 2.0 (Reiczigel and Rózsa 2001).

In addition, a total of four frozen, well-preserved adult penguin carcases were collected in the three localities (SC $n=1$; KI $n=1$; NP $n=2$). They were fixed and stored in 70% ethanol until autopsies were performed to extract endoparasites. Nematodes were cleared in temporary mounts of lactophenol, identified, and then returned to the ethanol. Cestodes were stained with Semichon's carmine and mounted in Canada balsam (Oyarzún-Ruiz and González-Acuña 2020).

Blood smears were made from 300 of the penguins captured. A drop of blood was collected from each penguin from the external metatarsal or brachial vein (Ash and Orihel 1987; Bennett 1970). The blood smears were air-dried and fixed in 100% ethanol immediately after obtaining the sample and then were stained with 3% Giemsa for 20 min.

Results

From 29 (8.9%) of the live penguins examined, 51 lice (14♂, 36♀ and 1 nymph) belonging to the species *Austrogoniodes gressitti* Clay, 1967 (Phthiraptera: Philopteridae) were collected from the head and neck of the birds. Numbers of lice collected and number of louse-positive penguins in each locality were as follows: 40 lice on 19 birds from SC, 8 lice on 7 birds from KI, and 3 lice on 3 birds from NP. These quantities of lice were not significant to calculate other parasitological parameters.

No ticks were found on the bodies of the 326 live penguins examined. However, 1198 ticks of the species *Ixodes uriae* (Acari: Ixodidae) were collected from the ground near the penguin nesting colonies in two locations. See Table 1 for statistical data. We found no significant differences between the values of TAI from both tick-positive localities ($p > 0.05$). No ticks were found in KI, despite searching under more than 500 stones during a three-hour period.

Three species of endoparasites were found in the two autopsied penguins from NP. One bird had three specimens of *Parorchites zederi* (Baird, 1853) (Cestoda: Dilepididae) in the small intestine and four specimens of *Stegophorus macronectes* (Johnston and Mawson,

Table 1 Statistics relating to the ticks collected in two of the localities studied

Location	Total number of stones	Number of tick-positive stones	Average number of ticks per stone (all stones)	Average number of ticks per stone (tick-positive stones)	Total number of ticks	TAI
Shirreff Cape (SC)	478	33	2.1	30.7	1014	563.3
Narebsky Point (NP)	32	4	5.8	46	184	306.6

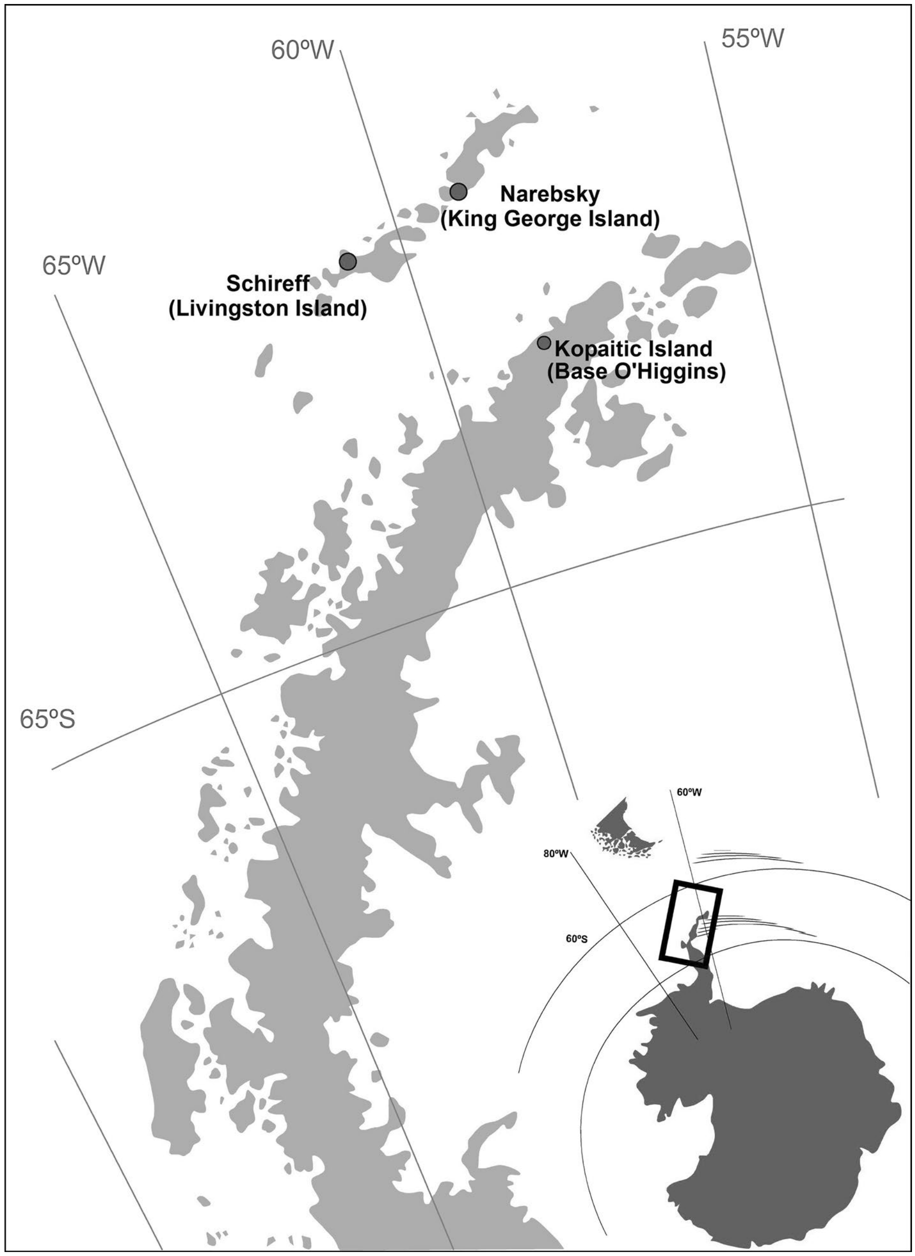

Fig. 1 Map of the Antarctic Peninsula showing the location of the three study areas

1942) (Nematoda: Acuariidae) in the gizzard, while the other bird had one *Tetrabothrius pauliani* Joyeux and Baer, 1954 (Cestoda: Tetrabothriidae) in the small intestine. Neither spiny-headed worms (Acanthocephala) nor flukes (Trematoda) were found, most likely due to the small number of dead penguins examined as well as their poor state of conservation when they were collected. Furthermore, flukes have not been recorded from chinstrap penguins yet. All blood samples taken tested negative for blood parasites.

Discussion

Although there has been a considerable number of reports on the diversity and burden of parasites from Antarctic penguins, taking into account the implications of climate change, it is necessary to continue monitoring their effect. A total of three species of arthropod ectoparasites (two lice and one tick) and six species of helminth endoparasites (three tapeworms, one spiny-headed worm, one

Table 2 Parasites recorded from chinstrap penguins

Higher parasite taxon (English names)	Parasite species	References
Cestoda (tapeworms)	*Parorchites zederi*	Ippen et al. (1981)
		Cielecka et al. (1992)
		Vidal et al. (2012)
		Present study
	Tetrabothrius pauliani	Andersen and Lysfjord (1982)
		Cielecka et al. (1992)
		Georgiev et al. (1996)
		Vidal et al. (2012)
		Present study
	Tetrabothrius joubini	Ippen et al. (1981)
		Cielecka et al. (1992)
		Georgiev et al. (1996)
Acanthocephala (spiny-headed worms)	*Corynosoma pseudohamanni*	Dimitrova et al. (1996)
	Corynosoma sp.	Vidal et al. (2012)
Nematoda (roundworms)	*Stegophorus macronectes*	Vidal et al. (2012, 2016)
		Present study
Trematoda (flukes)	*Renicola sloanei*	Wright (1954)
Ixodoidea (hard ticks)	*Ixodes uriae*	Barbosa et al. (2011)
		Present study
Phthiraptera (lice)	*Austrogoniodes gressitti*	Clay (1967)
		Clay and Moreby (1967, 1970)
		Banks and Paterson (2004)
		Present study
	Austrogoniodes macquariensis (straggler or contaminant, see text)	Clay (1967)
		Clay and Moreby (1970)
		Price et al. (2003)

roundworm, one fluke) have previously been recorded from chinstrap penguins as listed on Table 2. In our survey of this penguin, we recorded two species of ectoparasites and three of endoparasites, which is a similar parasitic burden to those previously reported for this species and other Antarctic penguins.

Ectoparasites: lice

The chewing or feather louse *Austrogoniodes gressitti* was originally reported from chinstrap penguins in Anvers Island and from gentoo penguins (*Pygoscelis papua* (Forster, 1781)) in South Georgia (Clay 1967). It was later recorded from gentoo penguins by Banks et al. (2006) in the Falkland Islands and by González-Acuña et al. (2013) in the Antarctic Peninsula and South Shetland Islands. Our record of *A. gressitti* from chinstrap penguins is from a new locality, enlarging its geographical distribution.

The percentage of chinstrap penguins infested with lice (8.9%) was low and similar to that recorded by González-Acuña et al. (2013) in gentoo penguins (2.2%). A low prevalence of louse infestation on emperor penguins was also noted by Palma (2017). This pattern of low louse prevalence on Antarctic penguins may be related to the extreme cold conditions they live in, which would make difficult for the lice to move from one host to another horizontally. Therefore, most of the louse dispersal would be vertical, from parents to chicks during brooding, and, consequently, the number of infested birds would be reduced. Furthermore, the fact that all the lice collected during this study were found on the head and neck of the birds would indicate that the birds were unable to preen the feathers of those body parts, an activity which otherwise would have reduced the number of lice (Clayton et al. 2010).

Although *Austrogoniodes macquariensis* Harrison, 1937 has also been cited as a parasite of chinstrap penguins by Clay (1967), Clay and Moreby (1970), Price et al. (2003) and Brandao et al. (2014), the original record was the result of straggling or contamination from other species of penguins (Pilgrim and Palma 1982). As expected, our examination of 326 chinstrap penguins failed to find any specimen of *A. macquariensis*.

Ectoparasites: ticks

The tick *Ixodes uriae* has a bipolar distribution, parasitizing more than 90 host species, mostly seabirds (Heath 1977; Muñoz-Leal and González-Acuña 2015). Woods et al. (2009) regard *I. uriae* as the most important of all ectoparasites of seabirds in terms of its impact on host health. Gauthier-Clerc et al. (1998) reported a hyper-infestation of *I. uriae* as a possible cause of death in adult king penguins (*Aptenodytes patagonicus* Miller, 1778). *Ixodes uriae* is a vector for *Borrelia* spirochetes affecting seabirds (Olsen et al. 1995), and antibodies of *Borrelia burgdorferi* were detected in 14% of tick-infested adult king penguins by Gauthier-Clerc et al. (1998). So far, three strains of *B. burgdorferi* sensu lato, a species of *Coxiella*, and a *Rickettsia*-like organism have been detected in *I. uriae* (Muñoz-Leal and González-Acuña 2015).

As in the present study, Barbosa et al. (2011) did not find ticks on the body of penguins from various localities in the Antarctic Peninsula, but found them in the birds' nesting sites. However, González-Acuña et al. (2013) found *I. uriae* on five (1.6%) of the 300 gentoo penguins examined in two of the same localities. The absence of ticks on the 326 chinstrap penguins examined during this study may be due to the sampling done toward the end of the host breeding season (20 January to 17 February), considering that ticks usually attach to the penguins at the beginning of the season, when the birds return to their nesting site (Benoit et al. 2008).

Ixodes uriae forms large aggregations on the ground around nesting sites, especially under stones with good drainage, and free of flooding during the spring ice melt and summer rains (Lee and Baust 1987; Frenot et al. 2001; Benoit et al. 2007). It would appear that, for the ticks to survive, the micro-environment must produce a high ambient humidity, around 93% (Benoit et al. 2007). In addition, Benoit et al. (2008) reported large aggregations of ticks under rocks, using the uric acid in penguin guano as a kairomone and guanine in tick feces as an assembly pheromone. Lee and Baust (1987) suggested that *I. uriae* is found under large stones only. However, in our study, ticks were found in large groups, in high humidity areas under stones of variable sizes, located close to nests.

We believe that our failure to find ticks in Kopaitic Island, despite our thorough search, was due to the lack of suitable under-stone microenvironments for ticks. At this locality, we found that the ground was muddy and too wet under the stones, unlike the other two localities where we collected ticks. We think that we can discount ambient temperature as a factor for the absence of ticks, considering that *I. uriae* is one of the arthropod species with the widest thermal tolerance, from minus 30 °C to 40 °C above zero (Lee and Baust 1987).

Endoparasites

All species of helminths found in this study have been previously reported from chinstrap penguins in Antarctica (Table 2). In addition to the chinstrap penguin, the tapeworm *Parorchites zederi* has been recorded from other species of the genus *Pygoscelis* (Adélie and gentoo penguins) and from the emperor penguin (*Aptenodytes forsteri* Gray, 1844), as well as in other seabird species (Ippen et al. 1981; Cielecka et al. 1992; González-Acuña et al. 2013). The tapeworm *Tetrabothrius pauliani* has been frequently recorded in chinstrap penguins (Table 2). The third tapeworm, *Tetrabothrius joubini*, has been reported in chinstrap penguins by several authors (Table 2). Our sample of four penguins examined may have been too small to detect the latter species of tapeworm.

The roundworm *Stegophorus macronectes* is a gastrointestinal parasite found in several species of Australian, Subantarctic, and Antarctic seabirds, including chinstrap penguins (Zdzitowiecki and Drózdz 1980; Barbosa and Palacios 2009; Vidal et al. 2012, 2016). Our sample of *S. macronectes* represents the second report of this endoparasite from chinstrap penguins, enlarging its geographical distribution.

Spiny-headed worms are rarely reported from marine birds (Ranum and Wharton 1996), and only four species have been so far recorded parasitizing Antarctic marine birds, including the species *Corynosoma pseudohamanni* Zdzitowiecki, 1991, the only spiny-headed worm recorded from chinstrap penguins (Dimitrova et al 1996). Vidal et al. (2012) reported *Corynosoma* from chinstrap penguins but without a species identification.

The fluke *Renicola sloanei* was described by Wright (1954) from a number of bird species held in British zoos, including chinstrap penguins, and has been found primarily in kidneys (Brandao et al. 2014).

Blood parasites

Several studies dealing with the health of Antarctic penguins have searched for blood parasites but, so far, all results have been negative (Jones 1988; Merino et al. 1997; Jones and Shellam 1999; González-Acuña et al. 2013). The main reason for the absence of these type of parasites is the lack of suitable vectors, usually mosquitoes, which do not live in Antarctica (Merino et al. 1997). Nevertheless, future global warming may enable invertebrate vectors to increase their geographic ranges toward the poles and consequently expand the range of malarial disease (Jones and Shellam 1999).

Conclusion

Knowledge of parasites of Antarctic penguins is relevant to their long-term survival in view of increased human activity in the Antarctic continent. Climate change is also of great concern as it is likely to change the shape of Antarctica and may result in the transmission of novel diseases to the Antarctic fauna, changing the dynamics of current host–parasite relationships. At present, we are unable to understand whether Antarctic penguin–parasite relationships have changed, as we have no previous long-term records of parasite diversity and/or infestation parameters from Antarctic penguins. Further studies of parasites from the Antarctic fauna, including viruses and bacteria, are warranted.

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Author contributions DAGA conceived and designed the project and collected specimens in Antarctica. LM conducted laboratory analysis. MW and BH conducted field work. MJK identified the three species of endoparasites. RLP identified the lice and took over as corresponding author after the death of DAGA, while this paper was in the process of publication. All authors contributed to writing and reviewing the paper.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest or personal relationships that could have influenced this paper.

Ethical approval Approval to conduct sampling from penguins in Antarctica was provided by the Universidad de Concepción, Facultad de Ciencias Veterinarias, Chillán, Chile (application number CE-3-2010).

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