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Two new species of nasal mites of the genus *Rhinonyssus* (Acari, Mesostigmata, Rhinonyssidae) from shearwaters

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Abstract

Nasal mites of the family Rhinonyssidae are parasites living in the respiratory system of birds. To date there were no record of these mites from representatives of the order Procellariiformes, a numerous grouping of exclusively marine birds that includes albatrosses, petrels, storm-petrels and shearwaters. The paper describes two new species of the genus *Rhinonyssus* from shearwaters (Procellariidae) found on various shores of Brazil: *Rhinonyssus borealis* **sp. nov.** from *Calonectris borealis* (Cory's shearwater) and *R. procellaricus* **sp. nov.** from *Puffinus puffinus* (Manx shearwater) and *Ardenna gravis* (Great shearwater). Both described mites are characterized by a large elliptical body and a relatively large and strongly sclerotized with the well-developed caudal extension. *Rhinonyssus borealis* **sp. nov.** and *R. procellaricus* **sp. nov.** are similar in their general appearance to each other but differ in the size of idiosoma, shape of podosomal and sternal shields and leg chaetotaxy.

Key words: *Ardenna*, *Calonectris*, *Puffinus*, parasites, systematics

Introduction

Over 2500 species of astigmatan mites from 40 families are closely associated with birds, occupying various habitats on the bodies and in nests of their hosts (Proctor & Owens 2000; Walter & Proctor 2013). Parasitism by mites in a respiratory system of hosts, occurs in several groups of vertebrates, affecting many bird species. These parasites are found on the lining of nasal turbinates, nose, larynx, trachea, lungs, and air and conjunctival sacs of birds (Amaral & Rebouças 1974; Fain 1994). The family Rhinonyssidae (Mesostigmata: Dermanyssoidea) currently includes about 600 described species arranged in eleven genera: *Larinyssus* Strandtmann, 1948; *Locustellonyssus* Bregetova, 1965*; Mesonyssus* Fain, 1960; *Ptilonyssoides* Vitzthum, 1935; *Ptilonyssus* Berlese & Trouessart, 1889; *Rallinyssus* Strandtmann, 1948; *Rhinoecius* Cooreman, 1946; *Rhinonyssus* Trouessart, 1894; *Sternostoma* Berlese & Trouessart, 1889; *Tinaminyssus* Strandtmann & Wharton, 1958 and *Vitznyssus* Castro, 1948 (Dimov 2018; De Rojas *et al*. 2020).

Rhinonyssid mites feed mainly on blood and occupy the anterior portion of the nasal cavity, usually in small numbers (Philips 2000). These parasites appear to be transmitted directly from host to host when infected adult birds feed the chicks, or during courtship behavior (Bell 1996).

Approximately 40 species of the genus *Rhinonyssus* Trouessart, 1894 have been described from various orders of aquatic (marine and freshwater) birds, including Anseriformes (geese, swans, and ducks) (Mascarenhas *et al*. 2009; Knee & Proctor 2010; Sinkoc *et al*. 2016), Charadriiformes (gulls, terns, plovers and sandpipers) (Knee & Proctor 2010; Silva *et al*. 2018), Pelecaniformes (pelicans, herons, ibises) (Pence 1975), Podicipediformes (grebes) (Pence 1973) and Sphenisciformes (penguins) (Gastal *et al*. 2018; Vanstreels *et al*. 2018).

Procellariiformes is a large order of exclusively marine birds approaching to the land only for breeding and includes albatrosses, petrels, prions, storm-petrels, diving petrels and shearwaters (Schreiber & Burger 2001). They occur in all oceans and seas, from the equator to polar regions and are among the most abundant seabirds globally (Chown *et al*. 1998). Several species make extensive trans-hemispheric migrations (Shaffer *et al*. 2006; Guilford *et al.* 2009). These birds are frequently found stranded on the beaches, dead or weakened (Faria *et al*. 2014). The potential causes of the stranding are most often difficult to determine, but most commonly are related to bad weather conditions (Ryan *et al*. 1989), negative interactions with fisheries (Bugoni *et al*. 2008), starvation (Haman *et al*. 2013), pollution (Colabuono *et al*. 2009), diseases and parasitosis (Cox 1976), among other factors.

Brazilian waters are recognized as important feeding areas to many procellariiform species, and the presence of these birds during the nonbreeding season is common (Olmos 2002). Despite being abundant, there are still no studies on nasal mites in birds of this order, in this region or globally. While analyzing marine birds found dead on the beaches or during rehabilitation, two undescribed species of rhinonyssid mites were found in shearwaters (Procellariidae) collected on coasts of Brazil. Herein, we describe these species and provide data on infection rates.

Materials and methods

Seventy-one shearwaters belonging to *Ardenna gravis* (O'Reilly, 1818) (n=14), *A. grisea* (Gmelin, 1789) (n=3), *Calonectris borealis* (Cory, 1881) (n=18) and *Puffinus puffinus* (Brünnich, 1764) (n=36) were collected in Praia Grande (São Paulo state), Florianópolis (Santa Catarina state), and Rio Grande (Rio Grande do Sul state), Brazil, and examined between 2017 and 2020. The animals were found dead during routine beach surveys or died under care in rehabilitation centers. All carcasses were collected with animal death estimated within the last 24 h. Fifteen animals were processed shortly after death and 56 were frozen for later analysis.

Samples were collected during necropsy, and mites were extracted by dissecting the nasal cavities of hosts: bird heads were placed in a glass dish, dissected through transverse sections dividing the maxilla into three portions to facilitate visualization and examined under a stereomicroscope (Figures 1–3). Then, the nasal cavity was washed in a running water on a 150-µm mesh sieve. The resulting content was inspected under a stereomicroscope and mites were collected with a brush (number 0) and stored in 70% ethanol. For microscopic analysis, some specimens were cleared in lactophenol and mounted in Hoyer's medium (Walter & Krantz 2009).

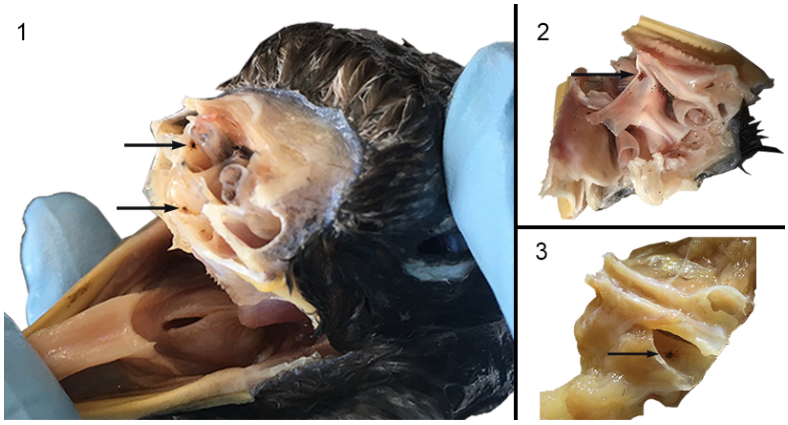
Photomicrographs were taken by using an Olympus® BX 41 microscope connected to a digital camera, and figures were prepared using Adobe's Photoshop® CS6. To perform the scanning microscopy, selected mites were prepared according to Gross *et al*. (2014). Photographs were taken using a Scanning Electron Microscope, in high- and low-vacuum mode, Jeol®, JSM - 6610LV, with EDS microprobe.

Nasal mites were identified with keys provided by Knee & Proctor (2006). Descriptions are based on the holotype and paratypes, following the standard format for rhinonyssid mites (Pence 1972; Knee 2008). Measurements were taken with an ocular having a calibrated ruler and are given

in micrometres (μm); the mean value is followed by the range in parentheses. All structures were measured in the longest or widest portion. The length of gnathosoma were taken in a ventral view including palps. Leg measurements were taken including coxa but excluding ambulacrum. The leg chaetotaxy formulae are based on the system established by Evans (1963).

The holotypes and paratypes were deposited in the *Coleção de Artrópodes do Laboratório de Parasitologia de Animais Silvestres* (CALAPASIL) of the Universidade Federal de Pelotas, Brazil, and the paratypes were deposited at *Coleção Acarológica do Instituto Butantan* (IBSP), Brazil.

The parasitological indices, prevalence (P %), mean abundance (MA), and mean intensity (MI), were estimated according to Bush *et al*. (1997).



FIGURES 1–3. Dissection of the nasal cavity of *Calonectris borealis* using cross-sections. 1. Frontal view of the proximal portion; 2. Ventral view of the medial portion; 3. Dorsal view of the medial portion. Mites are pointed by arrows.

Results

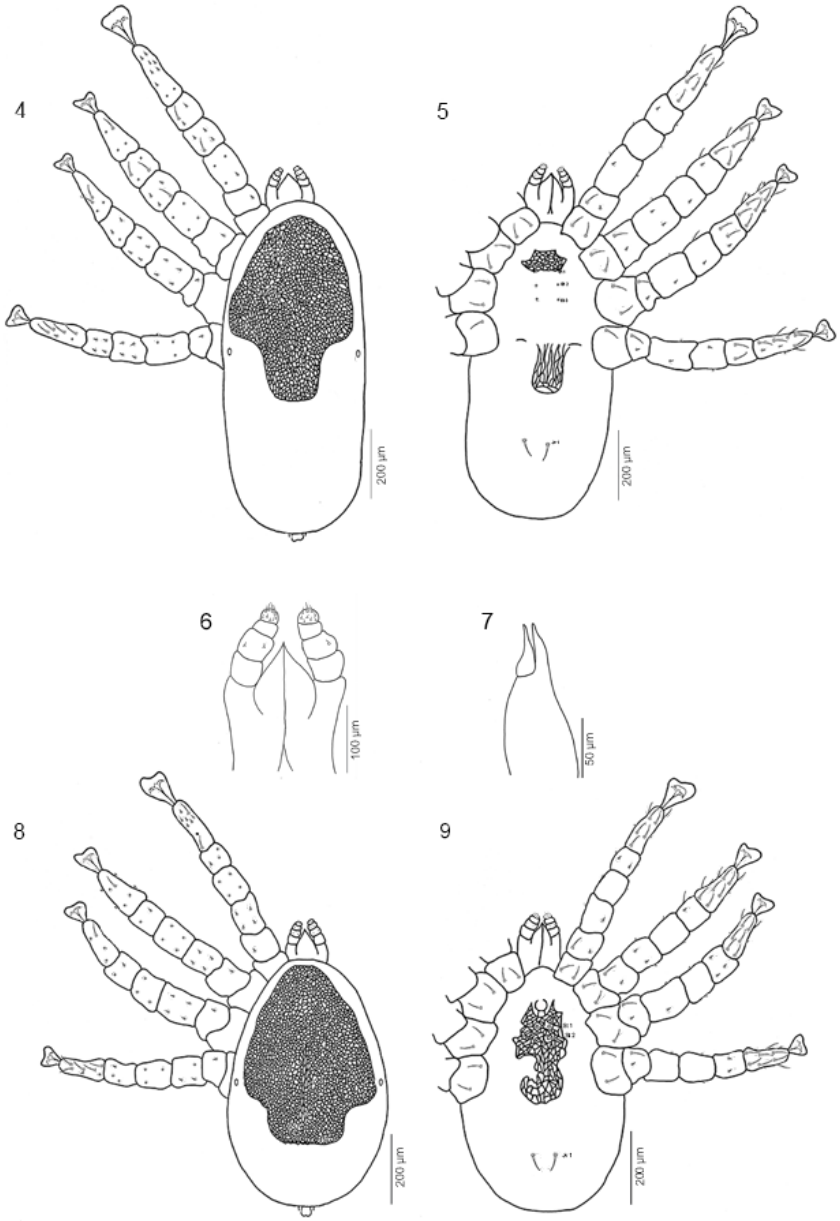
Twenty-four (33.7%) of the 71 shearwaters were parasitized by *Rhinonyssus* mites. *Ardenna gravis* (4.2%) and *Puffinus puffinus* (19.7%) were infected by *Rhinonyssus procellaricus* **sp. nov.** while *Calonectris borealis* (9.8%) was infected by *Rhinonyssus borealis* **sp. nov.** Nasal mites were not found parasitizing specimens of *Ardenna grisea*. Both new species described herein are the first records of nasal mites for procellariiform birds.

Family Rhinonyssidae Trouessart, 1895
Genus *Rhinonyssus* Trouessart, 1894

***Rhinonyssus borealis* sp. nov.**
(Figures 4–14)

Material examined

Type host. Calonectris borealis (Cory, 1881) (Aves: Procellariiformes: Procellariidae) the Cory's shearwater.



FIGURES 4–9. *Rhinonyssus borealis* **sp. nov.** parasite of *Calonectris borealis*. 4. Dorsal view of female; 5. Ventral view of female; 6. Gnathosoma of female; 7. Ventral view of left chaelicera; 8. Dorsal view of male; 9. Ventral view of male.

Type locality and collection dates. Holotype, allotype and paratypes (7 females, 2 males) from two *C. borealis*, Cassino Beach, Rio Grande, Rio Grande do Sul, Brazil, on 24 May 2019; coll. G. Oliveira, J.V. Gaiotto, S.B. Gastal, V. Muraro; other paratypes: 6 females, 2 males, same hosts (3 individuals) and locality, on 25 May 2019, coll. F.A. Faria.

Depository. Females—holotype CALAPASIL No. 574, paratypes CALAPASIL No. 575–583, IBSP 16539–16541. Males—allotype CALAPASIL No. 584, paratypes CALAPASIL 585–587.

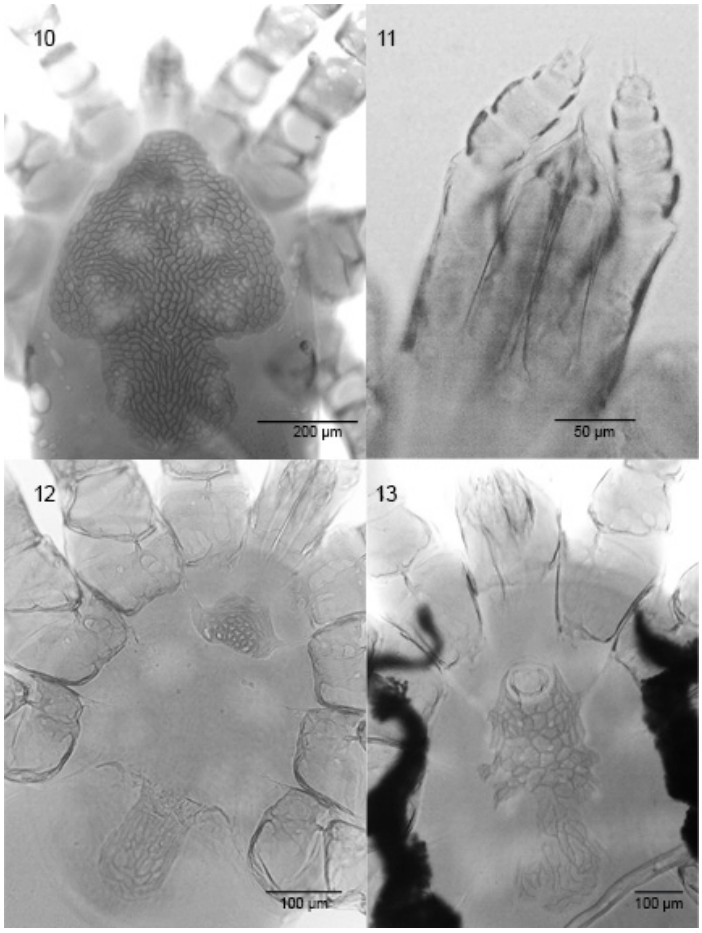
Description

Diagnosis. Large oval form with strongly sclerotized podosomal shield covering anterior half of idiosoma; podosomal shield with conspicuous caudal extension of roughly quadrangular shape; sclerotized sternal shield, roughly trapezoidal in shape; ventral opisthosoma with one pair of setae.

Female (n=13)

Measurements. Length of body including palps 1175 (925–1425); width of idiosoma 612 (500–775); length of podosomal shield 673 (640–700); width of podosomal shield 498 (470–520); length of gnathosoma 236 (210–260); width of gnathosoma 143 (125–158); length of palps 93 (85–100); length of chelicerae 135 (125–145); width of chelicerae 39 (33–40); length of chelicera mobile digit 37 (28–40); length of genital shield 189 (150–230); width of genital shield 165 (143–195); length of sternal shield 98 (83–143); width of sternal shield 163 (145–188); length of legs: leg I 817 (750–860); leg II 779 (760–820); leg III 765 (720–800); leg IV 783 (740–800).

Dorsal idiosoma. Elliptical, with podosomal shield covering anterior half of idiosoma. Podosomal shield strongly sclerotized, devoid of setae, with conspicuous caudal extension of roughly quadrangular shape (Figures 4, 10 and 14). Mesosomal platelets absent. Dorsal idiosoma without setae. Stigmata without peritremes located dorsolaterally at level of coxae IV. Anus situated dorsoterminally, flanked by a pair of paranal setae. Anal shield and cribrum absent.



FIGURES 10–13. *Rhinonyssus borealis* **sp. nov.** parasite of *Calonectris borealis*. 10. Podosomal shield of female; 11. Gnathosoma of female; 12. Sternal and genital shields of female; 13. Sternogenital shield of male.

Ventral idiosoma. Sternal shield sclerotized, roughly trapezoidal in shape, with the posterior angles slightly extending laterally. Sternal setae (*St1–St3*) strongly reduced and represented by alveoli, anterior pair (*St1*) situated on sternal shield, two other pairs (*St2–St3*) on soft cuticle posterior to sternal shield. Genital shield slightly longer than wide, rounded posteriorly, with reticulate pattern, and without genital setae. Ventral opisthosoma with one pair of setae (*Jv1*) (Figures 5 and 12).

Gnathosoma. Hypostomal setae and deutosternal denticles absent. Palps four-segmented, chaetotaxy of palp segments 0-4-2-10. Two apical setae much longer than other setae of apical palpal segment (Figures 6 and 11). Chelicerae widest proximally, tapering slightly to digits (Figure 7).

Legs (Figures 4, 5 and 14). Chaetotaxy of legs I–IV (based on 6 females): coxae 2-2-2-1; trochanters 2-3-3-3; femurs 7-7-6-5; genua 6-6-6-6; tibiae 5-6-5-6; tarsi 18-12-16-16. Leg segments with three types of setae: short and thickened, medium-sized and sharply tipped, and longer filamentous. Longer filamentous setae occur on ventrolateral portion of coxae, trochanters, tibiae, and in apical portion of tarsi. All tarsi with ambulacra; tarsi of legs I longer than on remaining legs. Tarsal claws common bow-shaped hooks. Empodium covers claws.

Male (n=4)

Measurements. Length of body including palps 750 (700–825); width of idiosoma 506 (475–525); length of podosomal shield 527 (500–550); width of podosomal shield 455 (410–450); length of gnathosoma 190 (180–200); width of gnathosoma 130 (123–135); length of palps 76 (73–78); length of chelicerae 150 (128–173); width of chelicerae 40 (38–40); length of chelicera mobile digit 38 (35–40); length of sternogenital shield 520 (480–560); width of sternogenital shield 260 (240–290); length of legs: leg I 582 (560–600); leg II 590 (570–610); leg III 590 (580–610); leg IV 595 (580–620).

Dorsal idiosoma. Dorsal surface resembling that of female; however, podosomal shield larger, covering more than a half of idiosoma, and caudal extension of this shield shaped as wide rectangle, twice as wide as in females (Figure 8).

Ventral idiosoma. Sternogenital shield elongated, strongly irregular in shape, with anterior end almost surrounding genital pore, surface of shield with reticulate pattern and two pairs of strongly reduced sternal setae (*St1–St2*) represented by alveoli. Opisthosoma has a pair of long pair of setae (*Jv1*) (Figures 9 and 13).

Gnathosoma. As in female.

Legs. All legs six-segmented (Figures 8 and 9). Chaetotaxy of legs I–IV: coxae 2-2-2-2; trochanter 3-3-3-3; femur 6-8-6-5; genua 6-6-6-6; tibia 7-6-6-6; tarsus 18-16-14-17. Setae and ambulacra identical to female.

Nymphs and larvae. Unknown.

Etymology. The specific epithet is directly taken from the name of the type host, *Calonectris borealis.*

Parasitological indices. Seven (38.8%) *C. borealis* were parasitized by *R. borealis* **sp. nov.** Mean abundance was 5.83 and the mean intensity was 15 mites/host.

Differential diagnosis. *Rhinonyssus borealis* **sp. nov.** resembles *R. caledonicus* Hirst, 1921 and *R. dobromiri* Dimov & Spicer, 2013. *Rhinonyssus caledonicus* is associated with auks (Charadriiformes: Alcidae) and was first described from *Cepphus grylle* (Linnaeus, 1758) and later, with more details, from *Cerorhinca monocerata* (Pallas, 1811) (Hirst 1921; Strandtmann 1956), and *Rhinonyssus dobromiri* was described from *Vanellus vanellus* (Linnaeus, 1758) (Charadriiformes: Charadriidae).

The new species, *R. borealis* **sp. nov.**, and *R. caledonicus* are similar in having a very large size of the body (at least 925 μm long) and the podosomal shield entire and longer than wide. In females

of the new species, the podosomal shield is longer (Table 1) and has a conspicuous caudal extension of roughly quadrangular shape. Besides, *R. borealis* differs by the absence of shieldlets next to it. In addition, *R. borealis* **sp. nov.** has the sternal shield, while in *R. caledonicus* it is absent. The number of sternal setae and anus position also differ between the species.

Rhinonyssus borealis **sp. nov.** is also similar to *R. dobromiri* but differs from by the body size, the shape and size of the podosomal shield, and by the size and shape of the sternal and genital shields. The number of setae in the ventral opisthosoma is also quite different: the new species has only two bristles, while *R. dobromiri* own between 50 and 53 bristles.

Other differential characteristics and measures separating *R. borealis* **sp. nov.** from *R. caledonicus* and *R. dobromiri* are shown in Table 1.

***Rhinonyssus procellaricus* sp. nov.**
(Figures 15–25)

Material examined

Type host. Puffinus puffinus (Brünnich, 1764) (Aves: Procellariiformes: Procellariidae), the Manx shearwater.

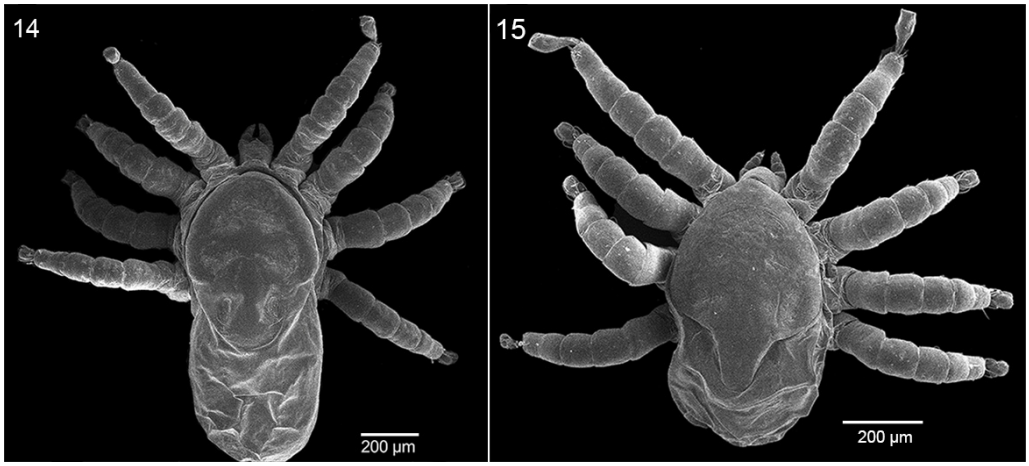
Type locality and collection date. Holotype, allotype and paratypes (1 female, 2 males) from two *P. puffinus*, Boqueirão Beach, Praia Grande, São Paulo state, 30 October 2016; other paratypes: 1 female, same host and locality, 31 October 2016, coll. D.S. Santos; 1 female, same host and locality, 02 November 2016, and 1 female, same host and locality, 19 November 2016; 2 females, same host (2 individuals) and locality, 25 July 2019; 1 female, same host, Cassino Beach, Rio Grande, Rio Grande do Sul, Brazil, 11 November 2017, and 2 females and 1 male, same host and locality, 06 October 2019, coll. S.B. Gastal.

Depository. Females—holotype CALAPASIL No. 588, paratypes CALAPASIL No. 589–593, IBSP 16542–16544. Males—allotype CALAPASIL No. 594, paratypes CALAPASIL No. 595–596.

Other host. Ardenna gravis (O'Reilly, 1818) (Aves: Procellariiformes: Procellariidae), the Great shearwater.

Locality and collection date. Cassino Beach, Rio Grande, Rio Grande do Sul state, Brazil, 24 May 2019, coll. G. Oliveira, J.V. Gaiotto, S.B. Gastal and V. Muraro.

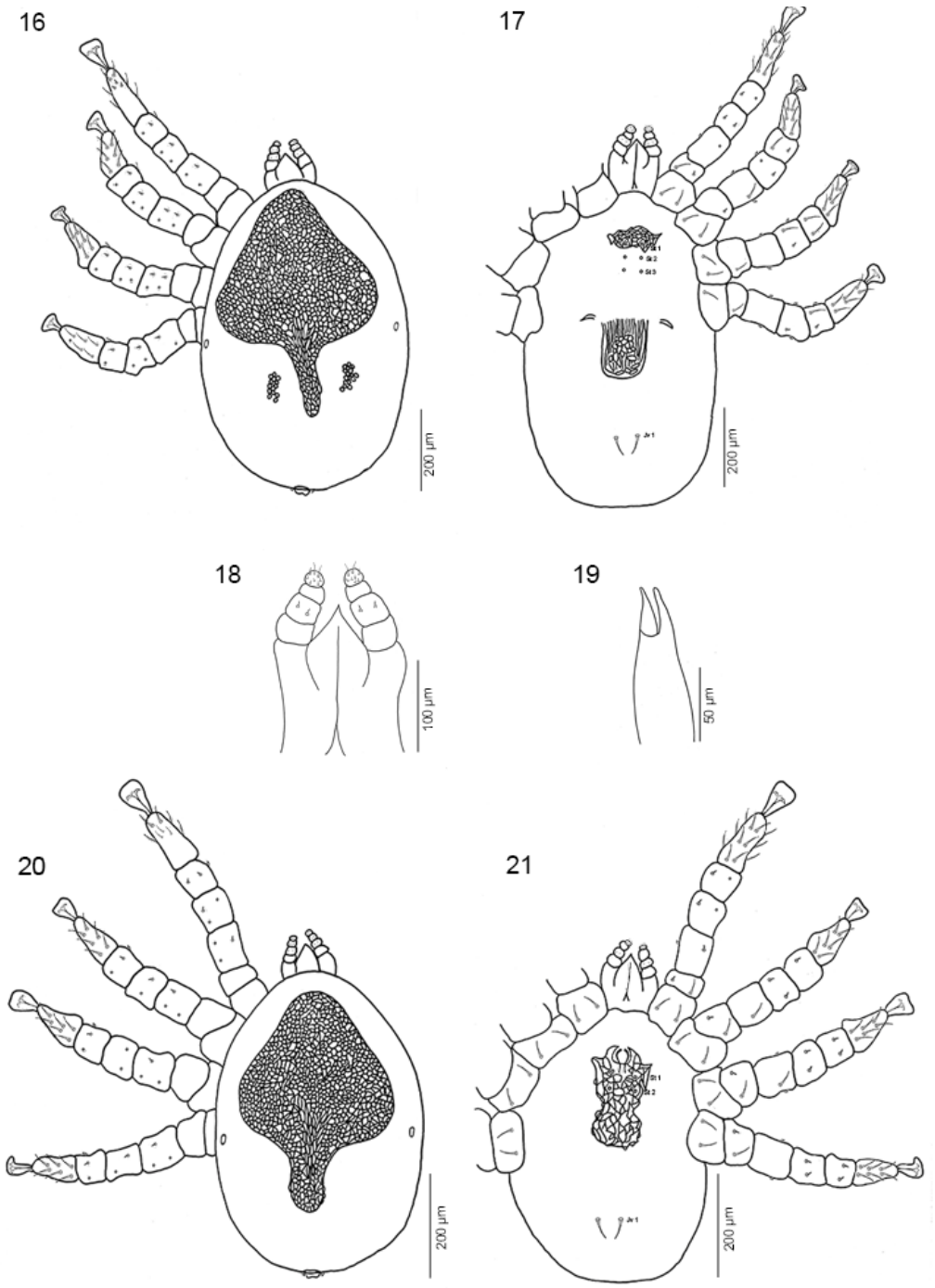
Depository. CALAPASIL No. 597–600.



FIGURES 14–15. New species scanning microscopy images. 14. Female dorsal view of *Rhinonyssus borealis* **sp. nov.**; 15. Female dorsal view of *Rhinonyssus procellaricus* **sp. nov.**

Description

Diagnosis. Oval form with a strongly sclerotized podosomal shield covering more than a half of idiosoma; caudal extension of podosomal shield shaped as narrow and almost parallel-sided band; sternal shield sclerotized, roughly trapezoidal in shape; ventral opisthosoma with one pair of setae.



FIGURES 16–21. *Rhinonyssus procellaricus* **sp. nov.** parasite of *Puffinus puffinus*. 16. Dorsal view of female; 17. Ventral view of female; 18. Gnathosoma of female; 19. Ventral view of left chaelicera; 20. Dorsal view of male; 21. Ventral view of male.

Female (n=9)

Measurements. Length of body including palps 820 (650–975); width of idiosoma 537 (450–625); length of podosomal shield 560 (550–570); width of podosomal shield 423 (400–430); length of gnathosoma 198 (185–205); width of gnathosoma 124 (120–128); length of palps 80 (72–88); length of chelicerae 118 (115–125); width of chelicerae 113 (110–120); length of chelicera mobile digit 29 (27–30); length of genital shield 161 (157–165); width of genital shield 150 (127–167); length of sternal shield 90 (70–100); width of sternal shield 156 (150–162); length of legs: leg I 691 (650–720); leg II 571 (540–610); leg III 558 (510–600); leg IV 573 (540–600).

Dorsal idiosoma. Idiosoma elliptical, podosomal shield covering more than a half of anterior idiosoma. Podosomal shield strongly sclerotized, devoid of setae, with caudal extension shaped as narrow and almost parallel-sided band. Two sclerotized areas of strongly irregular shape (shieldlets) situated lateral to caudal extension of podosomal shield. Mesosomal shieldlets absent. Dorsal idiosoma without setae. Stigmata without peritremes, located dorsolaterally at level of coxae IV. Anus situated dorsoterminally, flanked by a pair of paranal setae. Anal shield and cribrum absent (Figures 15, 16 and 22).

Ventral idiosoma. Sternal shield sclerotized, roughly trapezoidal in shape, variable in size, with anterior angles slightly extended. Sternal setae strongly reduced and represented by alveoli, anterior pair (*St1*) situated on sternal shield; two other pairs (*St2–St3*) situated posterior to it on soft cuticle. Genital shield approximately as long as wide, rounded posteriorly, surface reticulate and devoid of setae (Figures 17 and 24). Ventral opisthosoma with one pair of setae (*Jv1*).

Gnathosoma. Ventral in position. Hypostomal setae and deutosternal dents absent. Palps four-segmented, chaetotaxy of palps 0-4-2-8. Two apical pairs of setae noticeably longer than other setae of apical palpal segment (Figures 18 and 23). Chelicerae widest proximally, tapering distally (Figure 19).

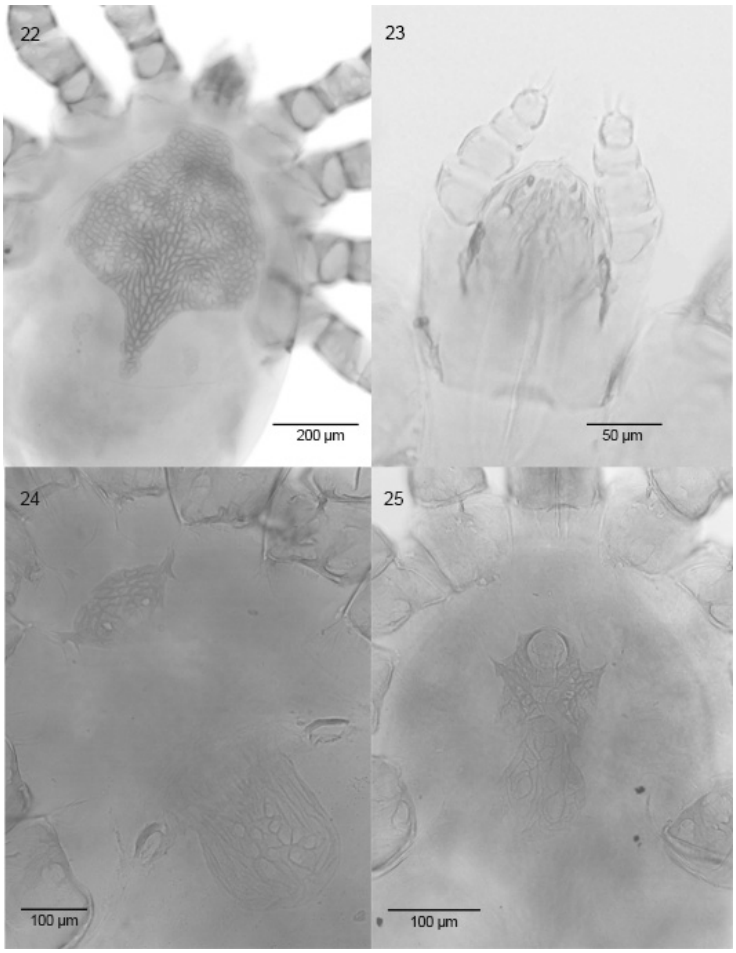
Legs (Figures 16 and 17). Chaetotaxy of legs I–IV: coxae 2-2-2-1; trochanters 2-2-2-2; femurs 5-7-6-4; genua 6-6-6-6; tibiae 5-5-5-5; tarsi 21-12-12-12. Leg segments with three types of setae: short and thickened, medium sized and sharply tipped, and longer filamentous. Longer filamentous setae situated on ventrolateral portion of coxae, trochanters, tibiae and in apical portion of the tarsi. Ambulacrum present in all tarsi, noticeably elongated on leg I. Claws of all legs simply curved, hook-like. Empodium covers bases of claws.

Male (n=3)

Measurements. Length of body including palps 641 (600–675); width of idiosoma 458 (450–475); length of podosomal shield 495 (480–510); width of podosomal shield 373 (360–390); length of gnathosoma 176 (175–177); width of gnathosoma 114 (112–117); length of palps 70 (67–75); length of chelicerae 104 (100–112); width of chelicerae 99 (95–108); length of chelicera mobile digit 25 (25–27); length of sternogenital shield 227 (222–230); width of sternogenital shield 125 (122–130); length of legs: leg I 510 (500–520); leg II 465 (450–480); leg III 465 (450–480); leg IV 480 (450–500).

Dorsal idiosoma. Dorsal surface similar to that of female. Caudal extension of podosomal shield slightly wider than in female, sclerotized areas lateral to this extension absent (Figure 20).

Ventral idiosoma. Similar to that of female, except for common sexual differences. Sternogenital shield of irregular shape, anterior end almost completely surrounding genital pore, surface with reticulate pattern and two pairs of reduced setae (*St1–St2*) represented by alveoli (Figures 21 and 25). Opisthosoma has a pair of long pair of setae (*Jv1*).



FIGURES 22–25. *Rhinonyssus procellaricus* **sp. nov.** parasite of *Puffinus puffinus*. 22. Podosomal shield of female; 23. Gnathosoma of male; 24. Sternal and genital shield of female; 25. Sternogenital shield of male.

Gnathosoma. As in female.

Legs: (Figures 20 and 21). Chaetotaxy of legs I–IV: coxae 2-2-2-1; trochanters 2-2-2-2; femurs 5-5-6-5; genua 5-4-4-4; tibiae 5-5-5-5; tarsi 20-12-12-12. Setae and ambulacrum equal to those in female.

Nymphs and larvae. Unknown.

Etymology. From Latin *procella*, which means storm. Refers to the host order: Procellariiformes.

Parasitological indices. Seventeen (38.8%) *Puffinus puffinus* and 3 (21.4%) *Ardenna gravis* were parasitised by *R. procellaricus* **sp. nov.** The mean abundance was 2.51 and 3.21, and the mean intensity was 6.28 and 15 mites/host, respectively.

Differential diagnosis. *Rhinonyssus procellaricus* **sp. nov.** resembles to *R. pluvialis* Fain & Johnston, 1966 and *R. dobromiri*. The body sizes of *R. procellaricus* and *R. pluvialis* are similar but in *R. dobromiri* is smaller (Table 1). Females of these three species differ from each other in the shape of sternal shield: it is trapezoidal in *R. procellaricus*, quadrangular in *R. pluvialis* and rectangular in *R. dobromiri*. Only one pair of setae is present on the ventral opisthosoma of *R. procellaricus* and *R. pluvialis*, while *R. dobromiri* bears from 50 to 53 setae in the same body region.

The podosomal shield of *R. procellaricus* is longer than in *R. pluvialis* and much longer than in *R. dobromiri*. The sternal shield of *R. pluvialis* is longer than in the two other species and the genital plate is the smallest in *R. dobromiri*. The anus is situated dorsoterminally in *R. procellaricus*, dorsally in *R. dobromiri* and ventrally in *R. pluvialis*.

TABLE 1. Differential characteristics and measurements separating *Rhinonyssus borealis* **sp. nov.**, *R. procellaricus* **sp. nov.**, *R. caledonicus*, *R. pluvialis* and *R. dobromiri*. Measures provided in micrometres (μm). Measures and setae based on females.

Character	*R. borealis* sp. nov.	*R. procellaricus* sp. nov.	*R. caledonicus*	*R. pluvialis*	*R. dobromiri*
Length of body	925–1425	650–975	1500 *	804–900	545–564
Width of idiosoma	500–775	450–625	No information	530–600	319–321
Length of podosomal shield	640–700	550–570	587 *	432–450	270–284
Width of podosomal shield	470–520	400–430	450 *	354–360	242–248
Sternal shield shape	trapezoidal	trapezoidal	absent	quadrangular	rectangular
Number of sternal setae	6	6	4	4	4
Number of setae on ventral opisthosoma	2	2	2	2	50–53
Host	*Calonectris borealis*	*Ardenna gravis*, *Puffinus puffinus*	*Cerorhinca monocerata*	*Pluvialis dominica*	*Vanellus vanellus*
Locality	Rio Grande do Sul state, Brazil	Rio Grande do Sul, Santa Catarina and São Paulo states, Brazil	Washington, USA	Ohio, USA	Leningrad, Russia
References	This study	This study	Strandtmann (1956)	Fain & Johnston (1966)	Dimov & Spicer (2013)

* Study does not provide the number of specimens examined.

Rhinonyssus procellaricus **sp. nov.** and *R. borealis* **sp. nov.** are similar in general appearance to each other but differ in the following characteristics: in both sexes of *R. borealis* **sp. nov.**, the idiosoma is slightly larger and wider and the caudal extension of podosomal shield is distinctly wider (Figures 4 and 8) than these features in corresponding sexes of *R. procellaricus* **sp. nov.** (Figures 16 and 20). The sternal shield in males of *R. procellaricus* **sp. nov.** is quite stable in its shape and almost symmetrical, while in males of *R. borealis* **sp. nov.**, it is asymmetrical and variable in shape.

Other differential characteristics and measures separating *R. procellaricus* **sp. nov.**, *R. pluvialis*, *R. dobromiri* and *R. borealis* **sp. nov.** are shown in Table 1, comparatively.

Discussion

Rhinonyssid mites are permanent haematophagous endoparasites of birds inhabiting their respiratory tracts (Fain 1994). Despite their presumed relevance, these mites are largely unstudied due to the difficulty in sampling them and, therefore, the majority of mite-host associations and species-prevalence data are unknown (De Rojas *et al*. 2020). Parasite host-specificity and prevalence parameters are informative of relevant processes such as parasite degree of specialization, population dynamics or transmission efficiency (Poulin 2007).

Host specificity of rhinonyssid mites varies among genera (Pence 1973). Some genera have been found to be constrained to a single host family, while others can occur on hosts from different orders (Pence 1975; Knee & Galloway 2017). There is a lack of specificity in some aquatic birds that might be explained by the gregarious behavior of these animals that creates favorable conditions for

the transfer of mites (Strandtmann 1958). In the current study, we found *R. procellaricus* **sp. nov.** in two distinct host species, which shows that at least one of the new mites does not have a monoxenous specificity.

Rhinonyssid mites generally show a relatively low prevalence in their hosts. The prevalence values found herein appeared higher than the prevalence values found by previous studies with another bird orders (*e.g.*, 33.7% in this study vs. 17.17% in Gastal *et al.* 2018; 17% in Spicer 1987; and 4.41% in De Rojas *et al.* 2020).

Blood-sucking mites can harm hosts by causing irritation, blood loss, anaemia, allergic reactions, transmission of pathogens and death (Proctor & Owens 2000). Studies of pathological influence of rhinonyssids on birds were carried out only on some mite species, for example on *Sternostoma tracheacolum* Lawrence, 1948 (Murray 1966; Tidemann *et al*. 1992), and its host, the Gouldian finch *Erythrura gouldiae* (Gould, 1844) (Passeriformes: Estrildidae). In a recent study by Dimov (2011), 100% of hosts from the orders Columbiformes and Passeriformes examined were found infected by rhinonyssid mites of the genera *Mesonyssus*, *Ptilonyssus* or *Sternostoma*. Cachexia, shortness of breath, sneezing, sputum, among other clinical signs, were observed in these birds that has led the author to name the disease caused by these mites as rhinonyssidosis (Dimov 2011).

Most reports on *Rhinonyssus* nasal mites were focused on taxonomy, while clinical and pathological analyses of the effect of these mites on seabirds are absent. Thus, finding of new mites, recording of new hosts and exploring them are important to understand the parasite-host relationships of these mites and procellariforms.

Spicer (1987) showed that the prevalence of rhinonyssid nasal mites in their hosts seems to vary significantly among geographic regions. The three species of seabirds analyzed in this study are long-distance migratory species, so we suggest that both new mite species could occur throughout the Atlantic Ocean, from the Falkland Islands and South Africa to Canada and the United Kingdom. Therefore, additional studies of the avian species included in this work should be carried out to verify whether the pattern of differences between geographical regions also occurs in oceanic migratory birds.

This is the first record of nasal mites parasitizing Procellariiformes. The number of published studies on these mites in seabirds is limited, given that approximately 350 avian species are entirely dependent on marine habitats (Croxall *et al*. 2012). Since Acari is a hyperdiverse group, the bulk of acarine diversity must reside in little or unexplored places (Walter & Proctor 2013). Therefore, considering the diversity of birds, it is probable that many additional hosts, including seabirds, are likely to be found if are examined thoroughly. Then, we encourage taxonomic and ecological studies on nasal mites of Procellariiformes and other seabirds.

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