

# THE PROBABLE ASSOCIATION OF FEATHER MITES OF THE GENUS *INGRASSIA* (ANALGOIDEA: XOLALGIDAE) WITH THE BLUE PENGUIN *EUDYPTULA MINOR* (AVES: SPHENISCIFORMES) IN AUSTRALIA

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**ABSTRACT:** A new feather mite species, *Ingrassia eudyptula* n. sp. (Xolalgidae: Ingrassiinae), is described from the blue penguin *Eudyptula minor* (J. B. Forster, 1781) in Australia. This is the first description of a feather mite species from representatives of the avian order Sphenisciformes, which had previously been considered free from feather mites due to their strongly modified plumage and highly aquatic lifestyle. We suggest that, most probably, this mite species or its ancestor moved onto penguins from a shearwater species (Procellariiformes: Procellariidae) via shared nesting burrows in seabird colonies. In support of this argument, we illustrate similarities between *I. eudyptula* n. sp. and the closely related *I. dubinini* Černy, 1967 from shearwaters (*Puffinus* spp.).

Feather mites are highly specialized astigmatan mites (Acari: Astigmata) that live permanently on the plumage and skin of birds. Currently, there are approximately 2,500 described species arranged in 34–38 families and 2–3 superfamilies within the cohort Psoroptidia (O'Connor, 1982; Gaud and Atyeo, 1996). Extensive exploration since the 1950s of feather mite diversity and host associations has produced definitive records from representatives of all recent avian orders except for penguins (Sphenisciformes). Indeed, for over 50 yr the literature has stated strongly that feather mites do not occur on these birds (Dubinin, 1951; Gaud and Atyeo, 1982, 1996; Dabert and Mironov, 1999; Proctor, 2003). Reasons for the absence of feather mites from penguins have never been discussed in detail, probably because they seem rather obvious, given certain aspects of spheniscid biology. For example, the plumage of penguins is strongly modified in comparison with other birds and is represented by dense, stiff coverts rather than by normal plumage (Martínez, 1992). It seems reasonable to suggest that feather mites were lost because they were unable to survive on these scale-like feathers. In addition, the subaquatic lifestyle of penguins would make their plumage an even more hostile habitat for feather mites. Supporting this hypothesis is the observation of reduced diversity of mite species on hosts that dive and swim under water, compared to that of closely related bird taxa that live mainly on shore (Dubinin, 1952a; Dabert and Mironov, 1999). For example, each auk species (Charadriiformes: Alciidae) bears only a single feather mite species of *Alloptes* Canestrini, 1879 (Alloptidae), while species of the much less aquatic waders (Charadriiformes: Scolopacidae) commonly bear 4–6 species in 4 families (Dubinin, 1952b; Gaud, 1972; Vasyukova and Mironov, 1991). Similarly, each loon species (Gaviiformes: Gaviidae) has only 1 species of *Brephosceles* Hull, 1934 (Alloptidae), while their close relatives, the albatrosses and petrels (Procellariiformes), commonly bear 5–7 mite species from up to 4 families (Dubinin, 1949; Atyeo and Peterson, 1967; Peterson, 1971). These examples strongly imply that a highly aquatic mode of life in avian hosts resulted in the loss of most groups of feather mites.

The present paper provides a description of a new feather

mite species belonging to the genus *Ingrassia* Oudemans, 1905 (Xolalgidae Dubinin, 1953; Ingrassiinae Gaud and Atyeo, 1981), collected from museum skins of the blue penguin, *Eudyptula minor* (Forster, 1781), deposited in museums in eastern and western Australia. Mites of this genus, as do most representatives of the Ingrassiinae, inhabit the down and basal downy parts of body covert feathers and most likely consume uropygial oil and small particles, such as fungal spores, that become trapped in the oil (Proctor, 2003). Identification keys to species of *Ingrassia* are available only for those associated with Charadriiformes from Africa (Gaud, 1972) and northern Eurasia (Vasyukova and Mironov, 1991). Until now, *Ingrassia* included 24 species (Gaud, 1972; Gaud and Atyeo, 1981; Dabert and Ehrnsberger, 1991; Mironov and Palma, 2006). Representatives of this genus have been previously described from 5 orders of aquatic birds, i.e., Anseriformes, Charadriiformes, Pelecaniformes, Podicipediformes, and Procellariiformes. The majority (18) of *Ingrassia* species are known from charadriiform hosts, and the true diversity of *Ingrassia* spp. on hosts other than Charadriiformes is still poorly known (Gaud and Atyeo, 1981). We argue that the observed association of this feather mite and blue penguins is natural, and we discuss its possible origin.

## MATERIALS AND METHODS

Material was collected by H.P. from dry skins in 2 museums in Australia, i.e., the Queensland Museum (Brisbane, Queensland; host specimens indicated with 'QMO' accession code) and the Western Australian Museum (Perth, Western Australia; host specimens indicated with 'A' accession code). Mite samples were extracted from bird skins by a feather-ruffling technique (Gaud and Atyeo, 1996) and mounted on microslides in PVA medium (BioQuip Products, Rancho Dominguez, California). Description of the new species follows the standard used for ingrassiine mites (Dabert and Ehrnsberger, 1991; Mironov and Palma, 2006). Measurements are presented in micrometers ( $\mu\text{m}$ ). The holotype and 1 paratype female are deposited in the Queensland Museum (QM; Brisbane, Australia); other paratypes are deposited in the following institutions: Western Australian Museum (WAM; Perth, Australia), E. H. Strickland Entomological Museum at the University of Alberta (UASM; Edmonton, Canada), and the Zoological Institute of the Russian Academy of Sciences (ZISP; Saint Petersburg, Russia).

## DESCRIPTION

*Ingrassia eudyptula* n. sp.  
(Figs. 1, 2, 3a, b)

*Male* (holotype, range of measurements for 4 paratypes in parentheses): Length of idiosoma from anterior end to bases of setae  $h_3$  284 (295–318), greatest width 193 (190–230), length of hysterosoma 140

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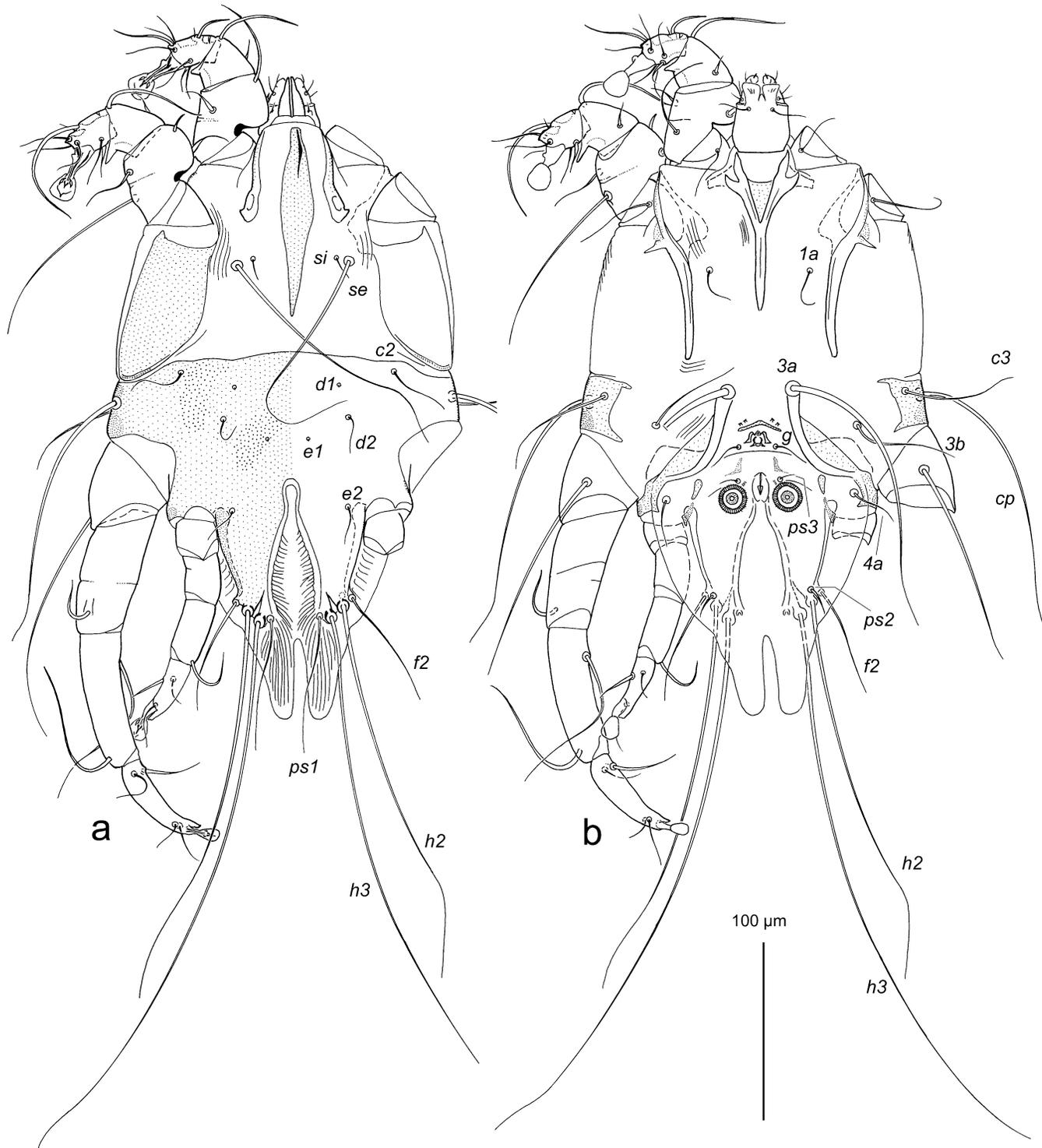


FIGURE 1. *Ingrassia eudyptula* n. sp., male. (a) dorsal view; (b) ventral view.

(145–165). Prodorsal shield: narrow longitudinal plate with strongly attenuate anterior and posterior ends, anterior part with longitudinal sclerotized ridge, length 102 (102–110), greatest width 20 (20–22), extending beyond level of scapular setae *se*, *si* by one quarter of total length (Fig. 1a). Setae *se* separated by 62 (62–82), situated on finely striated tegument. Scapular shields wide, inner margin smooth, posterior margin with short and flat suprattegumental extension. Hysteronotal shield: anterior margin slightly convex, rough, length of shield from

anterior end to bases of setae *h3* 153 (155–168). Supranal concavity ovate, open posteriorly into terminal cleft. Length of terminal cleft from anterior end of concavity to base of setae *h3* 82 (78–84), greatest width of terminal cleft (at level of setae *h2*) 27 (30–35). Terminal membranous extensions on lobar apices tongue-like, with longitudinal striation, length from base of setae *h3* to apices 50 (50–65), width at base 25 (22–28), length of incision between extensions 45 (40–55). Distance between dorsal setae: *c2*:*c2* 118 (112–140), *c2*:*d2* 25 (22–26), *d2*:*e2* 50

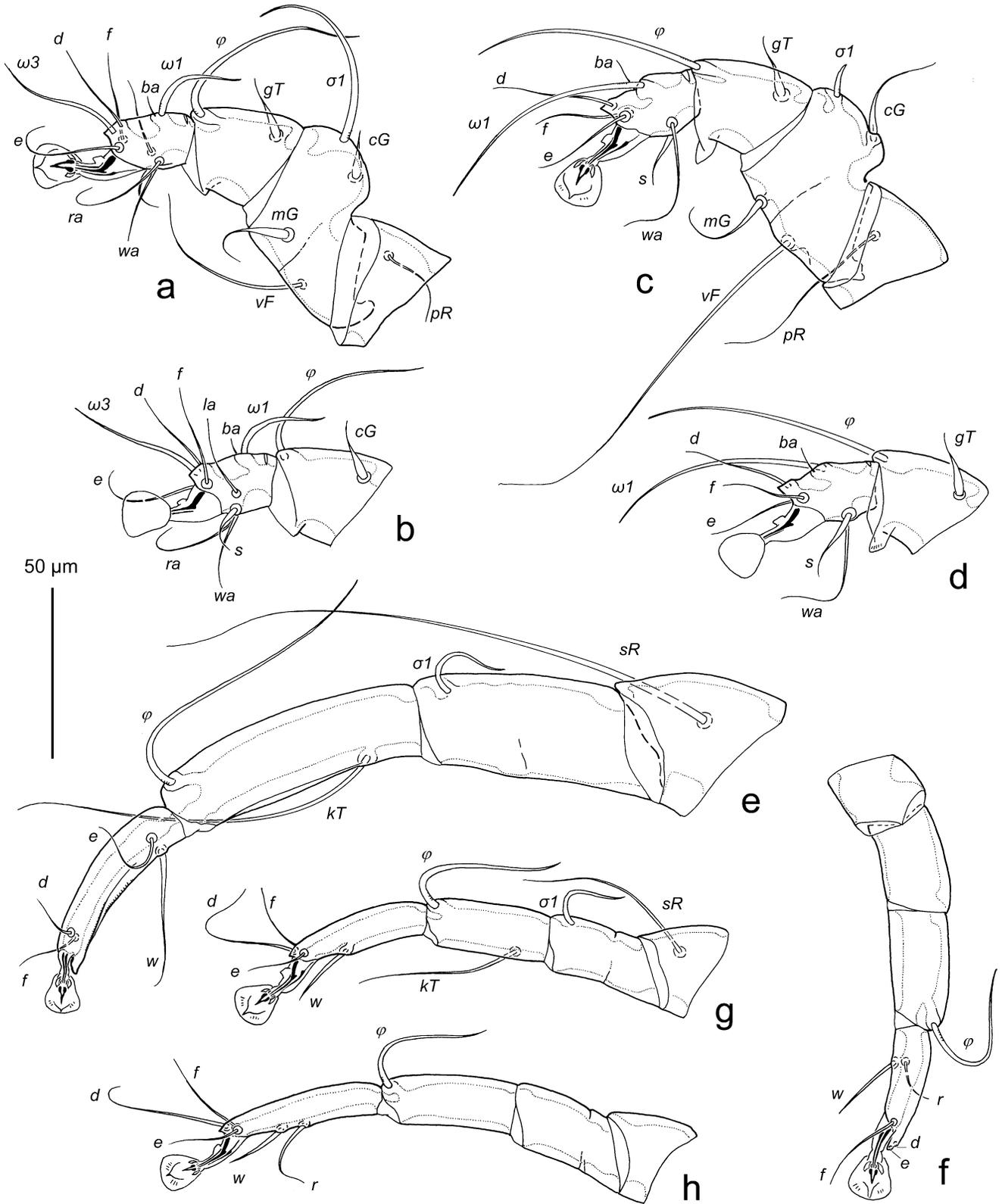


FIGURE 2. Legs of *Ingrassia eudyptula* n. sp. Male: (a) leg I, dorsal view; (b) tibia and tarsus I, ventral view; (c) leg II, dorsal view; (d) tibia and tarsus II, ventral view; (e) leg III, dorsal view; (f) leg IV, dorsal view. Female: (g) leg III, dorsal view; (h) leg IV, dorsal view.

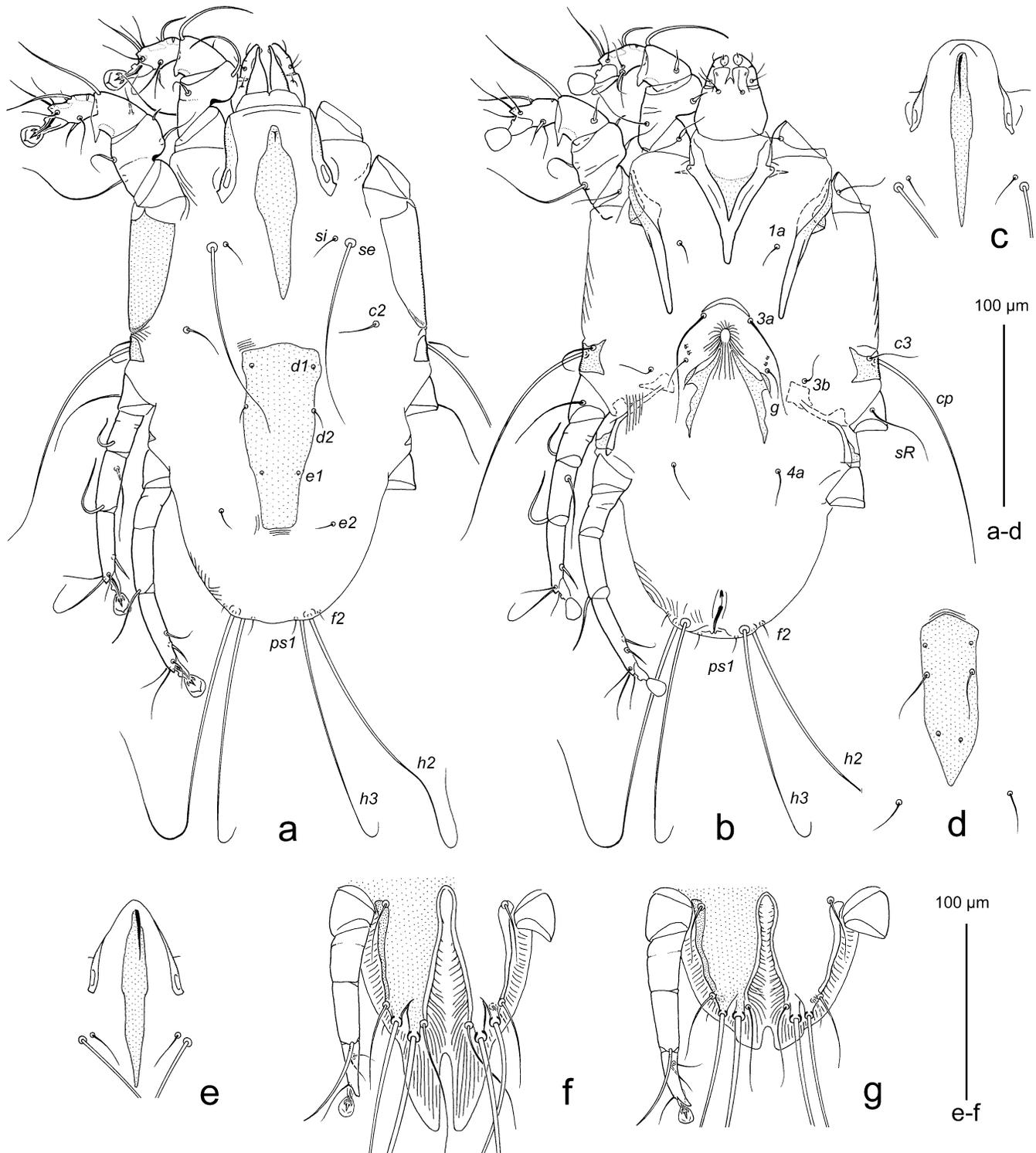


FIGURE 3. *Ingrassia* spp. Females: (a) *I. eudyptula* n. sp., dorsal view; (b) *I. eudyptula* n. sp., ventral view; (c) *I. dubinini* Černý, prodorsal shield; (d) *I. dubinini*, hysteronotal shield. Males: (e) *I. dubinini*, prodorsal shield; (f) *I. dubinini*, opisthosomal lobes of long-lobed form; (g) *I. dubinini*, opisthosomal lobes of short-lobed form.

(48–60),  $e2:h3$  62 (70–74),  $h3:h3$  40 (42–48),  $ps1:ps1$  28 (28–35). Setae *ps1*, situated approximately at level of setae *h3*. Setae *ps1* and *h3* situated at same transverse level, setae *h2* slightly anterior to this. Setae *c2* equal in length to trochanter III, setae *d2*, *e2* shorter than trochanter III.

Sternum about  $\frac{1}{2}$  of total length of epimerites I. Inner ends of epimerites IIIa free, setae *3a* situated on these ends strongly thickened in basal part, their tips extending beyond lobar apex. (Fig. 1b). Pregenital apodeme small, bow-shaped. Genital apparatus  $7 \times 18$  ( $7-8 \times 17-20$ ). Adanal sclerites present, represented by small L-shaped sclerites be-

tween levels of setae *g* and *ps3*. Coxal fields IV not sclerotized. Epimerites IVa present, represented by 2 small sclerites flanking coxal fields IV from inner margin. Diameter of anal suckers 18 (18–19). Distance between ventral setae: *3a:3a* 38 (38–44), *3a:3b* 20 (20–22), *3a:g* 32 (30–32), *g:ps3* 20 (22–30), *ps3:h3* 95 (88–90).

Tarsi I, II each with well-expressed apico-dorsal spine (Figs 2 a–d). Tibia I with short ventral process, tibia II with large spine-shaped ventral process. Femoragenu II without dorsobasal retrograde apophysis. Tibia III without crest or spine, solenidion (Phi) situated on rounded apico-dorsal end; tarsus III with small finger-like apical extension, length of tarsus III 55 (50–55) (Fig. 2e). Tarsus IV with finger-like apical extension, bearing setae *d*, *e* (Fig. 2f). Legs IV excluding pretarsus 115 (115–122), articulation of genu and tibia approximately at level of setae *h3*; tarsus IV slightly extending beyond the level of terminal membrane apices.

*Female (range of 8 paratypes):* Length of idiosoma 285–330, greatest width 165–215, length of hysterosoma 165–200. Prodorsal shield: general form as in male, but slightly larger and with small T-shaped ridge in anterior part (in some specimens this ridge indistinct); shield extending by posterior ½ beyond level of scapular setae; length 98–110, greatest width 22–32 (Fig. 3a). Setae *se* separated by 68–108, situated on finely striated tegument. Inner margin of scapular shields smooth, without extensions, posterior margin with short and flat suprategumental extension. Humeral shields small, without antero-mesal extension. Hysteronotal shield: longitudinal plate strongly narrowed towards posterior end and reaching from level of humeral setae *cp* to level of setae *e2*; anterior margin slightly convex; posterior end truncate; greatest length of the shield 98–110, width of anterior margin 42–52. Setae *d1*, *d2*, *e1* situated on lateral margins of hysteronotal shield. Setae *c2* approximately equal in length to trochanter III, setae *d2*, *e2* shorter than trochanter III. Distances between dorsal setae: *c2:d2* 43–60, *d2:e2* 60–70, *e2:h3* 50–62, *h3:h3* 30–38. Sternum about ½ of total length of epimerites I. Epigynum thin, bow-shaped, 8–12 long, 30–40 wide, tips extending to bases of setae *3a* (Fig. 3b). Apodemes of oviporus long and acute, posterior ends extending to midlevel of epimerites IV.

Legs I, II as in the male. Distal half of tarsus IV extending beyond posterior end of opisthosoma. Length of tarsi III and IV 38–43 and 42–48, respectively. Setae *sR* III approximately equal to total length of trochanter and femoragenu III.

### Taxonomic summary

*Type host:* *Eudyptula minor* (J. B. Forster, 1781), blue penguin.

*Symbiotype:* Deposited at the Queensland Museum, Brisbane, Queensland, accession code QMO 29839.

*Type locality:* Five km N of Eurong, Fraser Island, Queensland (25°28'S, 153°09'E).

*Specimens examined:* Male holotype, 1 male and 2 female paratypes (ex. QMO 29839), Queensland, Eurong, 5 km N, Fraser Island, 25°28'S, 153°09'E, 6 May 1992, col. unknown; 1 female paratype (ex QMO 31577), Queensland, Main Beach, Stradbroke Is., opp. Keyhole Lakes, 27°30'S, 153°31'E, 24 May 2001, col. unknown; 2 male and 6 female paratypes (ex A16370), Western Australia, Mondrain Island, Recherche Archipelago, 34°08'S, 122°14'E, 14 December 1979, col. unknown; 1 male paratype (ex A19508), Western Australia, Point Dempster, 33°37'S, 123°53'E, 25 January 1985, col. unknown.

*Specimens deposited:* QM: Holotype male (QMS 83455) and 1 female paratype (QMS 83456); WAM: 2 paratypes, 1 male (T85556) and 1 female (T85557); UASM: 6 paratypes, 1 male (UASM 80505) and 5 female paratypes (UASM 80506–80508); ZISP: 2 male and 2 female paratypes (a male and female on each of 2 slides, ZISP 4363–4364).

*Etymology:* The specific epithet derives from the generic name of the host and is a noun in apposition.

*Comparative material:* *Ingrassia dubinini* Černý, 1967: 1 male (ZISP 4370) ex *Puffinus tenuirostris* (Temminck, 1835), [Russia, Kamchatka], Koryatskaya Zemlya, Apuka, 17 August 1959, L. A. Portenko; 1 male (ZISP 4371) ex *P. newelli* Henshaw, 1900, Pacific Ocean, 10°15'N, 159°24'W, 17 July 1969, V. Shushibov; 4 males, 1 female (ZISP 17471) ex *P. lherminieri* Lesson, 1839, [Island] Reunion, 01.1981, coll. unknown. The original type material from Černý (1967) of *I. dubinini* ex *P. tenuirostris* from Wrangel Island, Russia, was not found within the ZISP collection.

### Remarks

The new species is most closely related to *I. dubinini* recorded from several species of *Puffinus* (Procellariiformes: Procellariidae), in that it has a narrow prodorsal shield with an acute posterior end and short filiform setae *c2* in both sexes and by the absence of an apico-dorsal spine on tibiae III in males. Males of *I. eudyptula* n. sp. differ from *I. dubinini* by having setae *ps1* and *h3* situated at the same transverse level and by the smooth anterior margin of the hysteronotal shield (Figs. 1a, b). The females differ by having a small, T-shaped ridge on the prodorsal shield, the hysteronotal shield with truncate posterior end, and setae *c2* approximately equal in length to trochanters III (Fig. 3a). In the males of *I. dubinini*, setae *ps1* are situated anterior to setae *h3*, at the level of setae *h2* or even anterior to it, and the anterior margin of the hysteronotal shield mesal to setae *c2* has short incisions; in the females, the prodorsal shield has a well-developed dorsal ridge as in the male (Figs. 3c, e), the hysteronotal shield has an acute posterior end (Fig. 3d), and setae *c2* are almost twice as long as trochanters III. We observed that males of *I. dubinini* display variability in the length of opisthosomal lobes and terminal membranes, particularly samples from *P. lherminieri*, which we designate as long-lobed and short-lobed forms (Figs. 3f, g). The only males in the comparative material from *P. tenuirostris* and *P. newelli* were of the short-lobed form.

We are confident that this association between *I. eudyptula* and *E. minor* is natural and not the result of accidental contamination in the course of preparing museum skins or in the collecting of feather mites from these skins. The penguin specimens in both the WAM and QM were isolated in species-specific museum drawers rather than being mixed with other bird specimens. Additional evidence is the report of an *Ingrassia* sp. from this host given in the checklist of mites associated with birds of New Zealand (Heath and Bishop, 1998). This information was previously dismissed by Proctor (2003), who had been told by the alleged collector of this mite (Bob Pilgrim, University of Canterbury, New Zealand) that he had no record of the specimen in question. We have not attempted to locate this material to determine whether it is conspecific with *I. eudyptula* n. sp.

### DISCUSSION

The finding of feather mites on blue penguins raises the question of how the association was formed. As mentioned previously, it has long been assumed that penguins had lost their feather mite fauna, fauna they might have potentially inherited from a common ancestor with procellariiforms (hypothesized to be the closest relatives of penguins [Caley, 2007]). The first potential hypothesis is that the ancestors of *Ingrassia eudyptula* n. sp. were indeed inherited from flying ancestors and were retained in spite of strong changes in penguin plumage. The statement by Martínez (1992) that “(t)he genus *Eudyptula* apparently represents a link between the penguins and Procellariiformes. . .” provides some support for this hypothesis. However, it is difficult to imagine that in the course of evolution, *Ingrassia* spp. were retained on penguins almost without any modification compared to species living on procellariiforms, birds with normally structured plumage. Indeed, differences in morphology among *Ingrassia* species from different families of procellariiforms, *I. antarctica* (Gaud, 1952) from Pelecanoididae (*Pelecanoides georgicus* Murphy and Harper), *I. dubinini* Černý, 1967 from Procellariidae, *I. oceanica* (Vitzthum, 1921), and *I. oceanodromae* (Černý, 1967) from Hydrobatidae (*Hydrobatas pelagicus* Linnaeus and *Oceanodroma leucorhoa* Vieillot, respectively) are of the same degree, or even greater, than between *I. eudyptula* and *I. dubinini*.

The second hypothesis, which is more likely correct in our opinion, is that the blue penguin has acquired its *Ingrassia* spp. from a recent procellariiform host. Considering that the new mite species is very close to *I. dubinini* known from the short-

tailed shearwater, *Puffinus tenuirostris*, it is reasonable to hypothesize that *I. eudyptula*, or its ancestral species, has been transferred relatively recently from some shearwater or petrel species. Additional evidence of the possibility of such a transfer is the observation that blue penguins and short-tailed shearwaters in southern Australia compete for occupancy of the same nesting burrows (Reilly and Balmford, 1975).

We cannot state with certainty that *I. eudyptula* is a monoxenous inhabitant of the blue penguin. Given the many procellariids that have not been examined for feather mites, *E. minor* may share this mite with a burrow-nesting shearwater species other than *P. tenuirostris*, e.g., *P. carneipes* Gould or *P. pacificus* Gmelin, which have breeding ranges that also overlap with that of *E. minor* (Carboneras 1992). Despite this uncertainty, it is possible to conclude that either *I. eudyptula* has successfully adapted to living on the blue penguin or that blue penguin individuals receive this mite species regularly, and in considerable numbers, from cohabitating shearwaters. As a final note, the 'received wisdom' that feather mites are absent from Sphenisciformes may have dissuaded researchers from rigorously searching for them; we hope that the records presented here will encourage others to carefully examine more species of penguins for these and other symbiotic mites.

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