Captive individuals of endangered Philippine raptors maintain native feather mites (Acariformes: Pterolichoidea) species

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**A R T I C L E   I N F O**

Keywords: Parasites of endangered species Ectoparasites Birds of prey Feather mites Pterolichoidea Pseudogabucinia nisaeti Nisaetus pinskeri Mindanao hawk-eagle Molecular phylogeny

**A B S T R A C T**

Endangered species of hosts are coupled with endangered species of parasites, which share the risk of co-extinction. Conservation efforts sometimes include breeding of rare species in captivity. Data on parasites of captive populations of endangered species is scarce and the ability of small numbers of captive host individuals to support the biodiversity of native parasites is limited. Examination of ectosymbionts of the critically endangered Philippine eagles and the endangered Mindanao Hawk-Eagle kept at the Philippine Eagle Center, Philippines, revealed three feather mite species despite regular treatment with insecticide powder. No other ectosymbiont taxa were detected. Studies in morphology and molecular phylogeny of these feather mites based on mitochondrial and nuclear DNA markers indicate that species found were typical for Accipitridae. Three new pterolichoid feather mite species (Acari: Pterolichoidea) were described from two species of eagles (Accipitriformes: Accipitridae) endemic to the Philippines: *Hieracolichus philippinus* sp. n. (Gabuciniidae) and *Pseudolopipus pithecophaga* sp. n. (Pterolichoidea) from the Great Philippine Eagle *Pithecophaga jefferyi* Ogilvie-Grant, 1896, and *Pseudogabucinia nisaeti* sp. n. (Kramerellidae) from the Mindanao Hawk-Eagle *Nisaetus pinskeri* Gould, 1863. The presence of *H. philippinus* on *P. jefferyi* supports the recent finding that the Great Philippine Eagle belongs to the lineage of serpent eagles (Circaetinae) rather than to the Harpy and other eagles.

**1. Introduction**

Parasites represent an important component of the ecosystem (Hudson et al., 2006) and support the diversity of the host populations by exerting selective pressure upon their hosts (Dawkins, 1990; Rózsa, 1992). Parasites of endangered species encounter a dual problem. On the one hand, parasites may negatively affect the natural and captive populations of their hosts threatened with extinction (De Castro and Bolker, 2005; McCallum and Dobson, 1995), and on another hand, these parasites often represent endangered species by themselves (Gomez and Nichols, 2013; Rózsa and Vas, 2014). The latter is especially relevant for host-specific parasites (symbionts), such as many ectosymbionts of birds and mammals that often face co-extinction with their host (Buckley et al., 2012).

Host populations of small size harbor reduced diversity of symbiont species due to the parasite loss (Altizer et al., 2007; Lloyd-Smith et al., 2005). The case of the Great Philippine Eagle *Pithecophaga jefferyi* Ogilvie-Grant, 1896 represents an extreme of minimal population size, both because of being a naturally uncommon apex predator in the islands and of current environmental change and habitat fragmentation, with an estimated 250-750 individuals in total (IUCN, 2017). The extremely low number of Philippine eagles increases the probability of loss for their parasites. Moreover keeping and breeding of rare bird species in captivity for the conservation purposes is also accompanied by the loss of their ectosymbionts mostly due to the antiparasitic treatment (Dunn et al., 2009). Therefore, the survival of the ectosymbionts on the captive group of Philippine eagles was under the question. Besides, its position as apex predator in the ecosystem could...
facilitate Philippine eagles to adopt alien parasite species from its prey. We tested whether the captive individuals of the Philippine raptors maintained the ectosymbionts and if the ectosymbionts found represented the native fauna of the Philippine eagles studied.

No data on parasites for critically endangered Philippine eagles was available so far; therefore, the study of biodiversity of ectosymbionts in these birds represents an essential need. During ectosymbiont examination of captive Philippine eagles in the Philippine Eagle Center, feather mites were found in spite of the annual antiparasitic treatment (dusting the body, wings and the tail with the powder containing carbamates, Gamma powder, a local producer).

Diurnal birds of prey (Accipitriformes and Falconiformes), a group containing the Philippine eagles, are of the most explored major groups of recent birds in relation to their specific feather mite fauna (Astigmata: Analgoidea and Pterolichoidea). Most collections of feather mites from raptors, especially rare species, have been made from museum skins (Gaud, 1983a; b; Gaud and Atyeo, 1996). Nowadays most species of raptors are endangered and highly protected; therefore, they are not easily accessible for parasitological examinations. All data on parasite-host associations of feather mites and raptors published before the end of 20th century were summarized by Philips (2000). After that, just a few papers on mites from raptors have been published (Dabert and Mironov, 2015; Hernandez, 2017; Mironov et al., 2007; Mironov and Galloway, 2003, 2014; Pedroso et al., 2015; Proctor et al., 2006).

In the present work, we studied the fauna of feather mites found on two eagles endemic to Philippines based on both morphology and molecular phylogenetic analysis (genes COI, EF-1α, 18S, 28S). We provided descriptions of three species of pterolichoidea feather mites and investigated whether these feather mite species likely represent native fauna of Philippine eagles as opposed to species recently acquired through prey-to-host transmission.

2. Material and methods

The mite material used in the present study was collected in the Philippine Eagle Center (Davao City, Malagos, The Philippines, 7°11.629°N, 125°24.5517°E) from two species of endemic raptors, the Great Philippine Eagle Pithecophaga jefferyi Ogilvie-Grant, 1896 and the Philippine Hawk-Eagle Nisaetus pinskeri Gould, 1863, during annual medical examination of birds by OOT in 2016. Parts of the feathers bearing mites were removed using forceps and a magnifying glass, placed in the tube with 96% ethanol and kept at 4 °C for subsequent studies.

2.1. Taxonomic study

Some of the collected mites were mounted on microslides in Hoyer’s medium according to the standard techniques used for many groups of small acariform mites (Krantz et al., 2009). Investigation of mite specimens and drawings were made by SM using a Leica DM 2500 light microscope with differential interference contrast (DIC) and equipped with a camera lucida. Descriptions of new species and measurement methods follow the formats elaborated for corresponding taxonomic groups of mites (Hernandes, 2017; Hernandes and Mironov 2015; Mironov et al., 2007, 2015; Pedroso et al., 2015). General morphological terms and leg chaetotaxy follow Gaud and Atyeo (1996); idiosomal chaetotaxy also follows these authors with corrections for coxal setation by Norton (1998). Descriptions provide the measurements for a male holotype with a range for paratype males in parentheses, and a range for female paratypes. All measurements are in micrometres (μm). Collection data indicate the places of origin and dates of taking of bird individual from nature.

2.2. Molecular study

DNA was isolated from specimens fixed in 96% ethanol using Holterman’s method (Holterman et al., 2006) with addition of proteinase K and mercaptoethanol in the lysing solution. Sequences of cytochrome oxidase subunit I (COI), elongation factor 1 alpha gene (EF1), partial sequences of 18S and 28S ribosomal DNA subunits 18S and 28S molecular markers were amplified using an EncycloPlus PCR Kit (Evrogen, Russia) with the parameters recommended by the producer on a Biocare T100 amplifier (United States). The sequences of primers used are given in Table 1. Polymerase chain reaction (PCR) products were visualized in gel, cut out, and cleaned using the SV Gel and PCR Clean-Up System Kit (Evrogen, Russia). They were then precipitated by ethanol in the presence of ammonium acetate to increase the efficiency of DNA precipitation. DNA sequencing was performed at the Genome Center for Collective Using (Genome, Russia). Molecular markers used and GenBank accession numbers for the sequences of the species studied are presented in Table 2. The sequences were combined and aligned using the ClustalX program after the addition of sequences from the GenBank (Thompson et al., 1997). Subsequently, the sequences were edited using the Genedoc 2.7 program (Nicholas et al., 1997). The phylogenetic trees were reconstructed in the Mr. Bayes 3.1.2 program (Huelsenbeck and Ronquist, 2001) and RaxML (Stamatakis, 2014) in the CIPRES server (Miller et. al., 2010) with the evolutionary model which was selected based on the results of the analysis in jModelTest2 program (Darriba et al., 2015). Sequences of the Amevorderes turdinus (GenBank accession number KU203310) and Amevorderes sp. (GenBank accession numbers KU202819 and KU202968) were used as outgroups for phylogenetic reconstructions. The genus Amevorderes (Analogidae: Proctophyllodidae) was selected as an outgroup for the Pterolichoidea feather mites studied because this genus is well defined morphologically and represents another superfamily, Analogidae, a sister lineage to all pterolichoidean mites used in our analysis. Taxa of feather mites used for phylogenetic analysis, their systematics and hosts are summarized in Table 3.

We tested the congruence of operational taxonomic units (OTUs) by the application of two analytical methods: Generalized Mixed Yule Coalescent (GMHC) (Pons et al., 2006) and Automatic Barcode Gap Discovery (ABGD) (Puillandre et al., 2012). GMHC represents a model-based approach, aiming to discover the maximum likelihood solution for the threshold between the branching rates of speciation, while ABGD detects the statistically inferred barcode gap - difference between the greatest intraspecific distance and the smallest interspecific distance - and uses it to partition the data.

Depositories of type material and voucher specimens used for molecular study are as follows: UMICHZ — Museum of Zoology of the University of Michigan, Ann Arbor, USA; ZISP — Zoological Institute of the Russian Academy of Sciences, Saint Petersburg, Russia.
Table 2
Molecular markers used and GenBank accession numbers for the sequences of the species studied.

| Species                      | Voucher numbers | EF1 sequences numbers | COI sequences numbers | 18S sequences numbers | 28S sequences numbers |
|------------------------------|-----------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Pseudallopinus pithecoptagae | ZISP 7411        | MF967007              | MG003448              | MG001907              | MG001914              |
| Hieracolichus philippinensis | ZISP 7454        | MF967008              | MG003449              | MG001908              | MG001915              |
| Pseudallopinus pithecoptagae | ZISP 7391        | MF967009              | MG003450              | MG001909              | MG001916              |
| Hieracolichus philippinensis | ZISP 7434        | MF967010              | MG003451              | MG001910              | MG001917              |
| Pseudallopinus pithecoptagae | ZISP 7401        | MF967011              | MG003452              | MG001911              | MG001918              |
| Pseudogabucinia nisaeti      | ZISP 7312        | MF967012              | MG003453              | MG001912              | MG001919              |
| Pseudallopinus pithecoptagae | ZISP 7371        | MF967013              | MG003454              | MG001913              | MG001920              |

3. Results

3.1. Systematics

Superfamily Pterolichoidae Trouessart et Mégnin, 1984
Family Gabuciniidae Gaud and Atyeo, 1975
Genus Hieracolichus Gaud and Atyeo, 1975
Type species: Pterolichus nisi Canestrini, 1878, by original designation.

Representatives of the genus Hieracolichus, currently including nine species, are restricted to birds of the order Accipitriformes (Gaud, 1989a). Although the genus Hieracolichus is not species-rich, taxonomic limits and species content of this genus need a revision (Mironov et al., 2007). This genus is very close to the genus Aetacarus Gaud and Atyeo, 1975, which has 10 of 12 known species associated with Accipitriformes. The genera Aetacarus and Hieracolichus differ from each other based only on a single feature of females: in Hieracolichus, coxal setae 4a are situated slightly anterior to the genital papillae and close to genital setae g, while in Aetacarus, these setae are situated posterior to the genital papillae, in some species even posterior to coxae IV. Because of a weak morphological boundary between two genera, Gaud (1989b) was unable to create separate keys to them and provided a single key where species of these genera were mixed together. Position of some species currently referred to the genus Hieracolichus is questionable. Thus, Hieracolichus hirundo (Mégnin and Trouessart, 1884) placed in this genus by Gaud and Atyeo (1975) and recently redescribed by Hernandes (2017) should be formally referred to the genus Aetacarus. The redescription of this species clearly shows that in females, setae g are closer to setae 4b than 4a, and the genital papillae are situated anterior to setae 4a. These are the two main diagnostic features of Aetacarus distinguishing it from Hieracolichus. Referring of H. ostudus Gaud, 1978 to Hieracolichus, being the only species of this genus having inflated bases of epimerites I and II and lacking solenidion on genu III, is also doubtful.

Type material. Male holotype (ZISP 7412), 13 male and 9 female paratypes from Pithicophagha jefferyi Ogilvie-Grant, 1896 (Accipitriformes), THE PHILIPPINES, Agusan del Norte, Santiago, Mt. Mamajao near Lake Mainit, caught on April 1974, mite collector O.O. Tolstenkov. The bird was at least 42 years old in 2016 when the mites were sampled. Voucher specimen: paratype female ZISP 7434.

Depository: holotype, 8 male and 5 female paratypes, including voucher – ZISP, remaining paratypes – UMICHZ.

Additional material. 3 males, 1 females from P. jefferyi, THE PHILIPPINES, Lanao del Sur, Wao, wild-caught on 25 April 2015, mite collector O.O. Tolstenkov. Voucher specimen: female ZISP 7454.

3.2. Description

MALE (Figs. 1 and 3A-D). (Holotype, range for nine paratypes in parentheses). Gnathosoma roughly trapezoidal, length including palps 80 (75–83), greatest width at base 78 (75–78). Idiosoma length from anterior end to bases of setae h3 on lobar apices 475 (465–490), greatest width at level of humeral setae 290 (270–290); length of hysterosoma 340 (330–350), Prodrossal shield: occupying almost entire prodorsum, Prodorsal shield: antero-lateral extensions protruding to margins of propodosoma between trochanters I and II and fused with epimerites Ia, antero-lateral margins heavily sclerotized, lateral margins with narrow and deep incisions encircling bases of setae ce, posterior margin slightly sinuous, greatest length 135 (120–135), width at posterior margin 180 (170–180). Setae vi spiculiform, 70 (67–73) long, extending slightly beyond tips of palps. Setae si spiculiform, 57 (55–60) long. Distance between bases of scopular setae: scse 87 (78–85), si:si 37 (28–35). Submural setae c3 filiform, with lanceolate enlargement in basal 1/3, 100 (95–105) long. Hysteronotal shield: greatest length from anterior margins to bases of setae h3 330 (320–345), length along midline 230 (225–240), width at anterior margin 155 (150–160), anterior margin slightly concave, surface of anterior half with sparse transverse striaion. Lateral bands distinct. Lobar areas of hysteronotal shield not separated from main body of hysteronotal shield. Supralanal concavity small triangular. Setae c2 thin spiculiform, 70 (70–70) long, situated in anterior angles of hysteronotal shield, cupules ia immediately postero-mesal to their bases. Setae ei situated at level of hysteronotal gland openings gl or slightly anterior to them. Length of terminal cleft from anterior end to lobar apices (setae h3) 93 (90–100), greatest width at level of setae h1 67 (65–75). Margin of anterior one third of terminal cleft heavily sclerotized, margin of remaining part membranous; this membranous margin strongly convex anterior to bases of setae h1, posterior ends of opisthosomal lobes with small semi-ovate extensions. Setae c2 spiculiform 52 (50–58) long, with apices extending slightly beyond level of setae h2; setae fj2 narrowly lanceolate, 27 (27–32) long, situated at level of setae h2, setae hf lanceolate with rounded apex, 23 (22–25) long, 3.5 (3.5–5) wide, situated posterior to level of setae h2. Distances between bases of dorsal setae and gland openings: c2:d2 120 (100–115), d2:e2 140 (140–150), e2:h3 60 (60–68), d2:gl 32 (29–35), h3:h3 95 (95–105), h2:h2 108 (100–115), d1:d2 37 (25–37), e1:e2 110 (105–115).

Epimerites I, II without inflated bases. Epimerites I with tips simple, not extending to bases of coxal setae 1a. Epimerites II slightly curved. Genital apparatus at level of trochanters IV, 23 (22–25) × 25 (25–30), aedeagus not extending to its base. Bases of setae 4a separated. Setae 4b are slightly posterior to level of setae 3a. Setae c at level of anterior pair of genital papillae. Distances between ventral setae: 4b:4b 37 (35–42), g4a 75 (67–75), 4acps3 37 (37–42), ps3:h3 93 (87–98), 4a:4a 15 (13–16). Anal suckers 25 (22–25) in diameter, corolla with 18–19 rounded denticles.

Femora I, II without ventral crest. Seta cG of genu I spiculiform, 90 (85–90) long, slightly exceeding entire length of genu and tribe. Solenidion ei of genu I (8–11) long, much longer than solenidion e2. Solenidion o of genu III situated in basal part of this segment. Solenidion q of triba IV shorter than corresponding tarsus. Tarsus IV with seta d button like and seta e of minute spine-like. Legs IV with distal half of tarsus extending beyond level of lobar apices. Length of tarsi: I 22 (22–24), III, IV 24 (22–25). Ambulacral disc of tarsus I ovate and in longitudinal diameter noticeably longer than the more circular-shaped ambulacral discs of tarsi II–IV. Length of tarsi: I 45 (45–50), II 58 (56–59), III 62 (60–63), IV 68 (65–68). Length of...
| Feather mite species | GenBank accession number(s) | Superfamily | Family | Host species |
|----------------------|----------------------------|-------------|--------|--------------|
| Amerodeces sp.       | KU202819, KU202968         | Analgoidea | Trouessart and Megnin, 1884 | Vireo hypochryseus Schaller, 1863 |
| Ameodectes tardinus (Berla, 1959) | KU203310 | Analgoidea | Trouessart and Megnin, 1884 | Catharus fuscescens Stephens, 1817 |
| Acouracarus sp.       | JQ000778, JQ000475, JQ000167 | Pterolichoidea | Trouessart and Megnin, 1884 | Asciurus cristatus Gmelin, 1789 |
| Cystoidosoma sp.      | JQ000777, JQ000474, JQ000166 | Pterolichoidea | Trouessart and Megnin, 1884 | Melanippe aurifrons Wagler, 1829 |
| Mesosathes sp.        | JQ000753, JQ000448         | Pterolichoidea | Trouessart and Megnin, 1884 | Crypturellus boucardi Schaller, 1860 |
| Freyana sp.           | JQ000744, JQ000439         | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Abecurus sp.          | JQ000769, EU152516, JQ000465 | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Capitolichus sp.      | JQ000774, JQ000470         | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Capitolichus sp.      | JQ000161                   | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Coraciacarus sp.      | EU152770, JQ000165, JQ00047 | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Gabucinia delbata (Robin, 1877) | JQ000770, JQ000158, JQ000466 | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Gabucinia sp.         | JQ000771                   | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Hieracolichus nitidus (Canestrini, 1878) | JQ000776, JQ000164, JQ000472 | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Hieracolichus philippinus | MP967008, MP967010, MG001908, MG001910, MG001915, MG001917 | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Pickformia sp.        | JQ000775, JQ000163, JQ000471 | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Dermonoton sp.        | JQ000742, JQ000437, JQ000129 | Pterolichoidea | Trouessart and Megnin, 1884 | Freyana dubini, 1951 |
| Kramerella ast (Lönstorf, 1937) | JQ000740, JQ000435 | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Kramerella hirae       | JQ000128, JQ000436         | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Pseudogabuncina nitidus | MP967012, MG001912, MG001919 | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Geranolichus canadensis Atyeo and Windingstad, 1979 | JQ000755, JQ000142, JQ0004501 | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Grallolichus fulicaceae (Trouessart, 1885) | JQ000757 | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Grallolichus sp.       | JQ000756                   | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Grallolichus sp.       | JQ000758, JQ000145, JQ000453 | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Kakolphus sp.         | JQ000759, JQ000454         | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Pseudodolopytus pithecophage | MP967007, MP967009, MP9670011, MP9670013, MG0019120, MG0019194, MG001999, MG001918 | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Pterolichus obtusus Robin, 1877 | JQ000754, EU152513, JQ000449 | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |
| Antacarus mexicanus Gaud and Atyeo, 1990 | JQ000762, JQ000457 | Pterolichoidea | Trouessart and Megnin, 1884 | Kramerellidae Gaud and Megnin, 1888 |

(continued on next page)
| Feather mite species | GenBank accession number | Superfamily | Family | Host species |
|----------------------|--------------------------|-------------|--------|--------------|
| Chelomatolichus sp.  | JQ000761, JQ000456, JQ000148 | Pterolichoidea Trouessart and Mégnin, 1884 | Pterolichidae Trouessart and Mégnin, 1884 | Linnaeus, 1758 Amazona autumnalis |
| Scolaralichus sp.    | JQ000760, JQ000455, JQ000147 | Pterolichoidea Trouessart and Mégnin, 1884 | Pterolichidae Trouessart and Mégnin, 1884 | Linnaeus, 1758 Amazona autumnalis (Trouessart, 1885) JQ000144 |
| Rectijanua sp.      | EU152767, JQ000459 | Pterolichoidea Trouessart and Megnin, 1884 | Rectijanuidae Gaud, 1961 | Linnaeus, 1758 Aix sponsa |
| Phyllochaeta tenuiseta | JQ000768, JQ000464, JQ000156 | Pterolichoidea Trouessart and Megnin, 1884 | Syringobiidae Trouessart, 1896 | Linnaeus, 1758 Charadrius vociferus |
| Syringobiidae sp.  | JQ000766, JQ000464 | Pterolichoidea Trouessart and Megnin, 1884 | Syringobiidae Trouessart, 1896 | Leisler, 1812 Plutarchusia chelopus |

*situated on epigynum, close to its tips. Setae 4b 35 anterior to genital papillae. Copulatory opening immediately posterior 1a long, barely reaching tips of palps. Setae 1a shaped as in male, 155 – 157. Epigynum horseshoe-shaped, 72 – 100 long, setae ps2:ps3:ps1 25, 78, 100. Hysteronotal shield: main body with almost straight anterior margin, anterior angles acute, posterior end extending to midlevel between hysteronotal gland openings gl and setae e2, posterior margin with blunt-angular median extension and pair of shallow concavities, greatest length 360–370, width at anterior margin 270–280, surface with faint transverse striation. Setae c2 spiculiform, 92–105 long, situated o 83. Prodorsal shield: main body with rounded median extension and pair of shallow concavities, greatest length 430–445, width at anterior margin 20–20, surface with faint transverse striation. Procoxae spiculiform, 75–125 long, situated o 83. Subhumeral setae 13 hysteronotal shield; cupules ia posteromesi to them and also off this shield. Setae d2 short filiform, about 20 long. Setae e1 approximately at level of hysteronotal gland openings gl. Lateral bands well developed, longer than main body of hysteronotal shield, with posterior ends almost extending to cupules ip and slightly curved medially. Posterior one of opisthosoma poorly sclerotized, with fine striation and, in some specimens, with barely distinct punctuation. Setae e2 spiculiform, 115–125 long, setae f2 filiform 30–40 long, setae h1 short filiform, 10 long; both pair situated on poorly sclerotized area of opisthosoma. Posterior end of opisthosoma with wide and rounded median extension bearing setae h2, h3 and ps1 and with strongly sclerotized margin. Distances between dorsal setae and gland openings: c2:d2 135–155, d2:e2 155–170, e2:h3 78–83, d2:gl 72–78, h1:h3 62–70, h2:h2 75–80, h3:h3 45–48. Epimerites I, II without basal inflation. Epimerites I not extending to setae 1a. Epigynum horseshoe-shaped, 72–88 long, 92–100 wide. Setae 4b situated on epigynum, close to its tips. Setae 4es situated slightly anterior to genital papillae. Copulatory opening immediately posterior to anal opening. Distances between ventral setae: 4bg 75–80, 4bsa 35–50, g:4a 13–25, ps2:ps3 27–32, ps2:ps2 67–72. Femora I, II with ventral crest. Setae cG of long spiculiform, 22–28 long, approximately subequal to entire length of genu and tibia I. Legs IV with tarsus and distal part of tibia extending beyond posterior end of opisthosoma. Length of tarsi: I 53–58, II 72–78, III 75–80, IV 93–100. Length of solenidia: αII 23–28, αII 8–12, αII 17–25, αII 16–18, αIII 22–24. Differential diagnosis. Among previously described species, Hieracolichus philippensis sp. n. is more similar to H. dobyi Gaud and Mouchet, 1959 described from Stephanozetes coronatus (Linnaeus, 1766) in Africa (Gaud and Mouchet, 1959; Gaud, 1983b) in having, in males, setae c2 extending to the level of setae h2 and f2, and relatively short and narrowly lanceolate setae h1. Hieracolichus philippensis differs from this species by the following features: in both sexes, setae c3 are long, filiform and exceed 100 μm in length, and genual solenidion σ is situated at the base of genu III; in males, setae g are situated almost at the level of anterior genital papillae; setae h1 are short (22–25 μm), and the inner margins of opisthosomal lobes have a pair of noticeably convex membranes in the anterior part of the terminal cleft; in females, the hysteronotal shield is shaped as an inverted trapezium and the posterior one third of the opisthosoma is devoid of sclerotization except the posterior margin, and tarsus IV completely extends beyond the posterior margin of the opisthosoma. In both sexes of H. dobyi, setae c3 are narrowly lanceolate at base with filiform apex (80–90 μm long), and genual solenidion μ is situated at the midlength of genu III; in males, setae g are situated anterior to the level of genital papillae; setae h1 are narrowly lanceolate, curved and 30–35 μm long, and the inner margins of opisthosomal lobes are almost straight; in females, the hysteronotal shield is shaped as an inverted trapezium and the posterior one third of the opisthosoma is devoid of sclerotization except for the posterior margin, and tarsus IV slightly (by ¼ the length) extends beyond the posterior margin of the opisthosoma. Etymology. The specific epithet is derived from the country, where
the mite was found.

Family Pterolichidae Trouessart et Méggin, 1884
Subfamily Pterolichinae Trouessart et Méggin, 1884
Genus Pseudalloptinus Dubinin, 1956

Type species: Pterolichus (Pseudalloptes) aquilinus var. milvulinus Trouessart, 1884, by original designation.

The genus Pseudalloptinus originally included pterolichine mites associated with birds from the orders Accipitriformes, Falconiformes, Gruiformes, Ciconiiformes and Psittaciformes (Dubinin, 1956; Gaud and Mouchet, 1959). After a revision (Gaud, 1988), the content of this genus was reduced to five species associated exclusively with birds of the order Accipitriformes. The genus Pseudalloptinus is readily distinguishable from other pterolichine genera in having, in most species, a unique structure in males: the postgenital sclerite [ = fossette post-genitale of Gaud (1988)]. This sclerite, being apparently a derivative of adanal apodemes, is situated between the genital apparatus and anal field and usually is stirrup-shaped or roughly ovate.

Type material. Male holotype (ZISP 7330), 20 male and 20 female paratypes from Pithecophaga jefferyi Ogilvie-Grant, 1896 (Accipitridae), THE PHILIPPINES, Lanao del Sur, Wao, 25 April 2015, mite collector O.O. Tolstenkov. Voucher specimen: female paratype ZISP 7371.

Depository. Holotype, 15 male and 15 female paratypes – ZISP, remaining paratypes – UMICHZ.

Fig. 1. Hieracolichus philippinensis sp. n. male. A – dorsal view, B – ventral view.
Additional material. 20 males, 20 females from 3 *P. jefferyi* individuals originated from the following locations: 10 males, 10 females – THE PHILIPPINES, Agusan del Norte, Santiago, Mt. Mamajao near Lake Mainit, caught on April 1974; 5 males, 5 females, THE PHILIPPINES, Davao Oriental, Mati, Don Salvador, South Biasong, caught on 13 January 2011; 5 males, 5 females, THE PHILIPPINES, Davao City, Malagos, Philippine Eagle Center, 4 February 2002 (captive breed), mite collector O.O. Tolstenkov. Voucher specimens: female paratypes ZISP 7391, 7411.

**MALE (Fig. 4, 6A–C).** (Holotype, range for eight paratypes in parentheses). Gnathosoma: length including palps 62 (60–65), greatest width at base 47 (46–50). Idiosoma length from anterior end to lobar apices (bases of setae h3) 25 (325–350), greatest width at level of humeral setae 180 (180–195). Length of hysterosoma 215 (210–225). Prodorsal shield: occupying most part of prodorsum, antero-lateral extensions acute, lateral margins with deep and narrow extensions encircling bases of scapular setae se, posterior margin slightly concave, length along midline 98 (95–105), greatest width 102 (100–110). Setae vi filiform, 38 (28–38) long, not extending to palpal apices. Setae se separated by 65 (65–68). Setae si minute filiform, close to bases of corresponding setae se. Scapular and humeral shields present. Setae c2 filiform, 15 (12–15) long, situated on anterior margin of humeral shields. Subhumeral setae c3 inceolate 20 (18–20) long, 4 (3.7–5) wide.

Hysteronotal shield: greatest length from anterior margins to bases of setae h3 212 (210–215), width at anterior margin 145 (140–150), anterior margin slightly concave, surface without ornamentation. Lateral bands distinct, narrow. Hysteronotal gland opening gl situated at level of trochanters IV. Setae d2 minute filiform about 10 (10–12) long; setae e2 filiform, 16 (15–18) long, situated at level of anterior end of supranal concavity, not extending to lobar apices. Opisthosomal lobes roughly triangular, at base slightly wider than long, rounded posteriorly. Terminal cleft roughly semi-ovate, 28 (25–30) long, 35 (34–38) in width at level of setae ps1. Supranal concavity open posteriorly into terminal cleft. Terminal cleft with narrow entire membrane forming semi-ovate terminal extensions on lobar apices, length of these extensions 10 (10–15) long, wide at base 18 (17–20). Setae ps2 long

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**Fig. 2. Hieracolichus philippinensis** sp. n. female. A – dorsal view, B – ventral view.
filiform, extending far beyond level of lobar apices; setae ps1 minute filiform, about 15 long, situated near bases of setae h2. Distances between dorsal setae: c2:d2 87 (80–88), d2:e2 75 (72–80), e2:h3 42 (40–45), ps1:ps1 40 (38–42), h2:h2 60 (60–65), h3:h3 50 (50–55), ps2:ps2 70 (70–75).

Epimerites I fused into a Y with short stem. Epimerites IIa present. Genital apparatus situated at level of anterior margin of trochanters IV, 14 (14–15) long, 14 (13–17) wide. Setae g4b slightly posterior to level of setae 3a. Setae g equidistant from genital arch apex and level of setae 4b. Anterior genital papillae at level of genital arch apex. Epimerites IVa long, bearing bases of setae 4a near tips and flanking base of genital arch. Adanal apodemes with L-shaped inner ends flanking median area with bases of setae ps3 but not forming separate postegenital sclerite. Anal suckers 13 (13–15) in diameter, corolla without indentation, surrounding membrane very wide and extending laterally over lateral margins of opisthosoma. Distances between ventral setae: 4b:g 23 (22–25), g4a 40 (40–47); 4aps3 30 (30–32), ps3:h3 67 (65–68).

Setae of tarsi I, II filiform. Solenidion σ1 situated at its midlevel of

Fig. 3. Hieracolichus philippinensis sp. n. details. A – opisthosoma of male, dorsal view B–D – genua and tibiae and tarsi I–III of male, respectively, E – tibia and tarsus IV of male, G – tibia and tarsus IV of female, H – spermatheca and spermaducts.
genus I and 1.3–1.5 times longer than this segment. Genual setae cGL, cGII, mGII and mGII filiform, shorter than corresponding segments. Solenidion σ of genus III in distal part of segment. Legs IV with distal half of tarsus extending beyond level of lobar apices. Tarsus IV with claw-like apical extension, setae d and e minute are absent. Solenidion ψ of tibia IV about 1.5 times longer than tarsus IV. Length of tarsi: I 35 (35–37), II 35 (35–38), III 38 (37–40), IV 33 (32–34). Length of solenidia: αII 40 (40–45), αII 8 (7.5–8), αIII 8 (8–10), αIII 11 (10–03), αIII 18 (16–18).

FEMALE (Figs. 5 and 6 G,H). Gnathosoma, length × width, 82–85 × 67–72. Idiosoma, length × width, 510 × 550. Length of hysteronotal shield 3235–365. Prodorsal shield: shaped as in male, but lateral margins without deep incisions, 135–145 long, 135–140 wide. Setae se separated by 80–85; setae si minute filiform, situated closely to corresponding setae se. Scapular and humeral shields present. Setae c2 short filiform, 20 (18–20) long, situated in anterior margin of humeral shields. Subhumeral setae c3 lanceolate, 26–30 long, almost half the length of humeral setae cp. Hysteronotal shield: entire, extending to posterior end of opisthosoma, anterior margin concave, 300–340 long, 210–220 wide at anterior margin surface without ornamentation, posterior end with declerotized transverse area bearing setae c2. Setae c1 on hysteronotal shield near its anterior margin. Setae d2 situated approximately at midlevel between cupules ϕ and hysteronotal gland openings gl. Setae e2 filiform, about 10–12 long. Lateral bands present, poorly distinct. Posterior margin of opisthosoma with relatively wide, distinctly round terminal external extension bearing setae h2, h3 and ps1. External copulatory tube minute, situated terminally about 2–3 long. Spermatheca and spermatoducts as in Fig. 6H, length of secondary spermatoducts 10–12. Length of opisthosomal setae: c2 18–20, f2 8–10, ps1 5–6, ps2 15–18. Distances between dorsal setae and openings: c2:g2 175–190, d2:e2 80–95, d2:g2 34–36, h2:h3 40–52, h2:h3 35–38, h2:h3 17–18. 

Epimerites I as in male. Epimerites IVA present. Epignymum semi-circular, thin, 42–48 long, 65–80 wide, with tips extending to level of setae 4b. Apomorph of oviporus narrow, barely sclerotized. Setae e1 situated approximately equidistant from levels of setae 4b and g. Distances between ventral setae: 4bs 50–58, 4bs: 52–65, g:4a 38–52.

Legs I–III as in male. Solenidion σ of genus III in distal part of segment. Solenidion ψ of tibia III slightly longer than corresponding tarsus; solenidion ψ of tibia IV about 1/5 the corresponding tarsus. Legs IV with tarsus and distal half of tibia extending beyond posterior end of opisthosoma. Legs I, as in male. Length of tarsi: I 50–53, II 50–55, III 57–60, IV 78–80. Length of solenidia: αII 68–80, αII 10–15, αIII 10–18, αIII 12–14, αIII 26–28.

Diagnostic differentiation. The new species, Pseudallopitus pithecophagae sp. n. is most similar to P. africanaus Gaud, 1988 and P. milvulinus (Trouessart,1884) in having the following features: in both sexes, setae c3 are lanceolate; in males, opisthosomal lobes are well developed, with semi-ovate terminal membranes; and in females, the striated sejugal area is large and constitutes about 1/5th of the total length of the idiosoma. Pseudallopitus pithecophagae sp. n. differs from these species by the following features: in males, the genital apparatus is situated at the level of the anterior margin of trochanters IV, epimerites IVA are long and almost extending to the genital arch, and setae e2 are filiform, situated at the level of the anterior end of supranal concavity and not do not extend to lobar apices; in females, the hysteronotal shield is entire, the epignymum is semicircular and extends to the level of setae 4b, setae c1 is situated on the hysteronotal shield, external copulatory tube is minute (only 2–3 μm long), and setae g are situated at the level of setae 3a. In males of P. africanaus and P. milvulinus, the genital apparatus is situated at the level of the posterior margin of trochanters III, epimerites IVA are poorly developed, and setae e2 are spiculiform, situated posterior to the supranal concavity and extend beyond the lobar apices; in females, the hysteronotal shield is split into a large anterior piece and a small pygidial fragment covering the very posterior end of the opisthosoma, the epignymum is bow-shaped and does not extend to the level of setae 4b, setae c1 are situated on striated tegument near the anterior margin of the hysteronotal shield, the external copulatory tube is about 15 μm long and curved ventrally, and setae g are situated posterior to the level of setae 3a.

The unique feature of P. pithecophagae males, easily discriminating this species from all previously known Pseudallopitus species, is the absence of the entire postgenital sclerite well separated from the analad apodemes. In this species, 1-shaped tips of analad apodemes turned anteriorly and flank small median area with setae ps3, apparently corresponding to the lateral pieces of the postgenital sclerite of other species of this genus.

Etyymology. The specific epithet is derived from the generic name of the type host and is a noun in the genitive case.

Family Kramererellidae Gaud et Mouchet, 1961
Genus Pseudogubucnia Cerny, 1961
Type species: Pterolicius ciconiae Canestrini et Berlese, 1881, by monotypy.

Up to now, the feather mite genus Pseudogubucnia has included only five species with hosts erratically distributed among non-passerine orders: Accipitriformes, Ciconiformes, Falconiformes, Gruiformes, and Otidiformes (Table 4) (Atyeo and Windstingd, 1979; Canestrini and Berlese, 1881; Dubinin, 1956; Gaud, 1968, 1983a; Gaud and Mouchet, 1961; Mégnin and Trouessart, 1884). This type of distribution is in surprising contrast to other six genera of Kramerellidae, each of which is associated with a particular bird order (Gaud and Atyeo, 1996).

Among previously known Pseudogubucnia species, Pseudogubucnia intermedia (Mégnin et Trouessart, 1884) has been recorded from raptor birds of two orders: from falcons Falco (Falconiformes: Falconidae), harriers Circus (Accipitriformes: Accipitridae) and buzzards Buteo (Gaud, 1988). Association of one species on hosts from different orders is quite rare among feather mites; therefore, it cannot be excluded that P. intermedia from these hosts (Table 4) could represent separate species. In the differential diagnosis below, the new species is compared with the specimens of P. intermedia from falcons.

Type material. Male holotype (ZISP 7307), 4 male and 1 female paratypes from Nisaetus pinckeri (Gould, 1863). (Accipitriformes), THE PHILIPPINES, Salayas, Davao City, caught in 2005, mite collector O.O. Tolstenkov. Voucher specimen: female paratype ZISP 7312.

Depository. Holotype, 3 male and 1 female paratypes – ZISP, 1 male paratype UMICHZ.

MALE (Fig. 7, 9A-E). (Holotype, range for three paratypes in parentheses). Gnathosoma: length including palps 43 (42–45), greatest width at base 50 (48–52). Idiosoma length from anterior end to lobar apices (bases of setae h3) 270 (265–280), greatest width at level of humeral setae 175 (170–180); length of hysterosoma 195 (190–195). Prodorsal shield: occupying anterior part of prodorsum, roughly trapezoidal in shape, with slightly convex posterior margin and posterior angles slightly extending laterally, not extending to bases of scapular setae, length along midline 45 (45–48), greatest width 47 (45–50) (Fig. 7). Setae se separated by 57 (55–58), Setae s1 spiculiform, 35 (35–47) long, separated by 23 (22–25), approximately equidistant from midline and corresponding setae se. Scapular and humeral shields absent. Setae c2 spiculiform, 30 (27–32) long, situated in striated tegument. Subhumeral setae long filiform, nearly half the length of macrorsetae cp. Hysteronotal shield: greatest length from anterior margins to bases of setae h3 185 (180–190), width at anterior margin 125 (115–125), anterior margin slightly concave, lateral margins almost straight, surface with fine longitudinal striae between levels of setae e1 and e2. Supranal concavity narrowed anteriorly and extending to level of setae e1. Hysteronotal gland opening gl situated approximately equidistant from levels of setae d2 and e2. Lateral bands poorly demarcated. Seta d2 minute filiform, about 5 long, setae e2 filiform 32 (27–33). Opisthosomal lobes roughly triangular, with rounded posterior ends, approximately as long as wide at base; apical and inner margins of lobes membranous. Terminal cleft wide triangular, with blunt anterior very end, 52 (52–55) long, 52 (50–55) in width at level of setae h3. Setae f2 narrowly lanceolate with short filiform apex 40
setae $h_1$ narrowly triangular, 15 (15–18) long thin, setae ps1 filiform, about 10 long, situated posterior to level of setae h1. Distances between dorsal setae: $c_2:d_2$ 77 (70–80), $d_2:e_2$ 57 (55–60), $e_2:h_3$ 63 (57–63), $d_1:d_2$ 37 (35–40), $e_1:e_2$ 25 (22–28), $f_2:f_2$ 112 (110–120), ps1:ps1 85 (82–88), $h_3:h_3$ 72 (70–75), $h_2:h_2$ 105 (100–105).

Epimerites I free, slightly converging. Epimerites IIa present, barely distinct. Genital apparatus 15 (14–15) in length, 13 (13–17) in width, its base situated at midlevels of trochanters IV (Fig. 7B). Setae $3a$ and $4b$ situated at the same level. Setae g at level of apex of genital arch. Genital papillae situated lateral to anterior half of genital arch. Distances between ventral setae: $4b:g$ 17 (16–18), $g:4a$ 23 (20–23); $4a:ps3$ 62 (60–64), $ps3:h_3$ 47 (47–50). Anal suckers 13 (12–14) in diameter, corolla with two rounded denticles. Small adanal sclerites presents between setae ps3 and anal suckers.

Solenidion $\sigma_1$ of genu I approximately half the length of this segment. Setae mG of genu II much longer than of genu I. Setae cG of genua I and III filiform, slightly longer than corresponding segments. Solenidion $\varphi$ of tibia IV slightly shorter than tarsus IV. Setae d and e of tarsi IV minute spine-like. Legs IV with ambulacral disc slightly extending beyond level of lobar apices. Length of tarsi: I 33 (32–34), II 42 (40–43), III 40 (37–40), IV 43 (40–43). Length of solenidia: $\sigma II$ 5 (5–6), $\omega I$ 12 (12–14), $\omega II$ 20 (18–20).

FEMALE (Fig. 8). Gnathosoma, length × width, 55 × 63. Idiosoma, length × width, 310 × 200, length of hysterosoma 230. Prodorsal shield: shaped as in male, 55 × 58. Setae se separated by 68; setae si spiculiform, 45 long, separated by 30, situated approximately equidistant from midline and corresponding setae se. Scapular and humeral shields absent. Setae c2 thin spiculiform, 35 long, situated in anterior angles of humeral shields. Subhumeral setae c3 long filiform 37 long,
about half the length of setae cp. Hysteronotal shield: length 180, width 125, anterior margin nearly straight, not extending to level of setae c2, surface without ornamentation, posterior margin with pair of narrow incision almost extending to level of setae c1 and wide semi-rounded extension between them. Setae d2 off hysteronotal shield. Lateral bands present, poorly demarcated. Spermatheca and spermaducts as in Fig. 3H, secondary spermaducts heavily sclerotized. Length of opisthosomal setae: e2 38, f2 125, ps1 40, ps2 155, h1 10. Distances between dorsal setae: c2:d2 87, d2:e2 83, e1:e2 20, h1:h1 50, h2:h2 83, h3:h3 55, ps1:ps1 32.

Epimerites I as in male. Epigynum bow-shaped, situated between tips of epimerites II, 15 long, 40 wide. Apodemes of oviporus barely sclerotized. Setae g and 3a situated approximately at same level of setae. Distances between ventral setae: 4b:g 12, 4b:3a 15, g:4a 32. Legs I–III as in male. Solenidion φ of tibia III slightly longer than corresponding tarsus; solenidion φ of tibia IV about one third the corresponding tarsus. Legs IV with ambulacral disc extending beyond posterior end of the opisthosoma.

Length of tarsi: I 35, II 50, III 45, IV 50. Length of solenidia: aII 10, aII 9, aII 6, aIII 12, aIII 20.

**Differential diagnosis.** The new species, *Pseudogabucinia nisaeti* sp. n. is close to *P. intermedia* (Mégnin et Trouessart, 1884) known from falcons by in having, in both sexes, ambulacral discs of tarsi IV extending to or slightly beyond the posterior margin of the body, and
Fig. 6. *Pseudalloptinus pithecophagae* sp. n. details. A – opisthosoma of male, ventral view, B–D – legs I–III of male, respectively, E – tibia and tarsus IV of male, G – tibia and tarsus IV of female, H – spermatheca and spermatoducts.

Table 4
Host associations of *Pseudogabucinia* species (PW – present work, * – type host).

| Mite                        | Host         | Host family   | Host order | Reference                  |
|-----------------------------|--------------|---------------|------------|---------------------------|
| *Pseudogabucinia ciconiae*  | *Ciconia alba* | Ciconiidae    | Ciconiiformes | Canestrini and Berlese, 1881; Cerny, 1961 |
| *P. intermedia*             | *Falco biarmicus* | Falconidae    | Falconiformes | Gaud, 1983a             |
| *P. microdisca*             | *Falco eleonorae* | Falconidae    | Falconiformes | Gaud and Mouchet, 1961     |
| *P. moucheti*               | *Falco peregrinus* | Falconidae    | Falconiformes | Gaud, 1983a             |
| *P. nisaeti* sp. n.         | *Falco eleonorae* | Falconidae    | Falconiformes | Gaud, 1983a             |
| *P. reticulata*             | *Falco eleonorae* | Falconidae    | Falconiformes | Gaud, 1983a             |
| *P. reticulata*             | *Falco eleonorae* | Falconidae    | Falconiformes | Gaud, 1983a             |
| *P. reticulata*             | *Circus aeruginosus* | Accipitridae  | Accipitriformes | Dubinin, 1956         |
| *P. reticulata*             | *C. cyanus* (± *C. pallescens*) | Accipitridae  | Accipitriformes | Dubinin, 1956         |
| *P. reticulata*             | *C. pygargus* (± *C. cineraceus*) | Accipitridae  | Accipitriformes | Dubinin, 1956         |
| *P. reticulata*             | *Lophoetus occipitalis* | Accipitridae  | Accipitriformes | Dubinin, 1956         |
| *P. reticulata*             | *Ardeotis arabs stibieri* | Otididae    | Otidiformes | Gaud and Mouchet, 1961     |
| *P. reticulata*             | *Lissotis melanogaster* | Otididae    | Otidiformes | Gaud and Mouchet, 1961     |
| *P. reticulata*             | *Balatorka pavonica* | Gruvidae    | Gruiformes | Atyeo and Windingstad, 1979 |
| *P. reticulata*             | *Grus canadensis tabida* | Gruvidae    | Gruiformes | Atyeo and Windingstad, 1979 |
setae c2 exceeding the distance between internal scapular setae si, and, in females, setae f2 and ps2 being equal to or exceeding the distance between their bases. *Pseudogabucinia nisaeti* sp. n. differs from that species by the following features: in both sexes, subhumeral setae c3 are long filiform and approximately half as long and humeral setae cp, solenidion ω1 of tarsus II does not extend to the apex of this segment; in males, the supranal concavity does not extend beyond the level of setae e1, setae 4a are situated posterior to the base of the genital arch; in females, the genital papillae are situated distinctly anterior to the level of setae g. In both sexes of *P. intermedia*, subhumeral setae c3 are about 1/3 the length of setae cp, solenidion ω1 of tarsus II extends to the apex of this segment; in males, the supranal concavity extend far beyond the level of setae e1, setae 4a are situated posterior at the of the level of genital arch base; in females, the genital papillae are situated at the level of setae g.

**Etymology.** The specific epithet is derived from the generic name of the type host and is a noun in the genitive case.

### 3.3. Molecular phylogenetics

We obtained sequences for the genes COI, EF-1α, 18S, 28S from four specimens of *P. pithecophagae*, two specimens of *H. philippinensis* and one specimen of *P. nisaeti* (Table 2). Data on different molecular markers studied for feather mites of superfamily Pterolichidae in GenBank are both sparse and variable in coverage (Klimov and O'Connor, 2008). Therefore, we did not provide the resulting phylogenetic tree for COI because there were very few sequences for pterolichoid feather mites available in GenBank. Phylogenetic trees for EF-1α, 18S and 28S molecular markers placed the sequences of the Philippine raptor feather mites studied among the other pterolichoid feather mites (Fig. 10, Figure S1, Figure S2). Although only the phylogenetic tree for elongation factor 1 alpha sequences showed congruent topologies between Bayesian and maximum likelihood analyses (Fig. 10). Operational taxon unit testing analysis by both GMYC and ABGD algorithms supported delimitation of OTU hypothesized by morphological studies.

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Fig. 7. *Pseudogabucinia nisaeti* sp. n. male. A – dorsal view, B – ventral view.
for feather mites *P. pithecophagae* and *H. philippinensis* from *Pithecophaga jefferyi* while for *P. nisaeti* only the ABGD delimitation was significant, which can be explained by the presence of single specimen of the latter species available for analysis.

4. Discussion

Most of the birds species host several groups of ectosymbionts, including obligatory feather mites and chewing lice species (Mironov, 2016; Price et al., 2003). However, our examination of captive Philippines Eagles revealed feather mites species and no chewing lice were detected. Although we sampled only three individuals of the Great Philippine Eagles, the fact that we found no chewing lice suggests that these insects are much more susceptible to the antiparasite treatment, and endemic lice will likely not survive on captive birds in the Philippine Eagle Center. Loss of chewing lice is not unusual for small populations of endangered species of birds conserved and bred in captivity (Dunn et al., 2009). The feather mites according to results of our examination are capable of surviving annual antiparasitic treatments for a long time. For example, one of the examined birds, named Thor, was captured in the wild in 1974 and at the day of examination in 2016 hosted a viable population of *H. philippinensis*. This fact, assuming this population of mites is endemic, suggests that these ectosymbionts have been able to survive 43 years in captivity.

We describe for the first time feather mites of two endangered Philippine eagles, which, if they prove to be species-specific, are endangered species too. Based on the phylogenetic position of the species described herein and known reference data on associations of their genera and families, it is possible to drawn out very preliminary hypotheses on the origin of the examined feather mite species from eagles of the Philippines. Of 16 genera of the family Gabuciniidae, eight genera, including the genus Hieracolichus, are restricted to birds of the order Accipitriformes (Gaud, 1983b; Gaud and Atyeo, 1974; Mironov et al., 2007). Most representatives of the genus Aetacarus, with

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**Fig. 8.** *Pseudogabucinia nisaeti* sp. n. female. A – dorsal view, B – ventral view.
exception of a few species, are associated with raptors. Although
the primary origin of the family Gabuciniidae as developing on Accipi-
triformes is not completely proven, gabuciniids have a maximum of
diversity in genera and species on Accipitriformes compared to its other
host orders, like Coraciiformes, Caprimulgiformes, and Otidiformes. In
any case, it is possible to state that the core of the family Gabuciniidae
likely arose on the ancestors of the order Accipitriformes and ex-
tensively evolved on these birds. In this light, it is possible to suggest
that *Hieracolichus philippinensis* represents the original feather mite
fauna on the Great Philippine Eagle rather than a recently acquired
feather mite species.

Currently the suprageneric system of the family Pterolichidae is not
fully developed (Mironov, 2016). Our attempts to study the molecular
phylogeny of the family showed a lack of available sequences in Gen-
Bank for many molecular markers, which make it difficult to build a
reasonable concatenated tree. Nevertheless, based on the distribution
of the genus *Pseudalloptinus* exclusively inhabiting Accipitriformes
(Dubinin, 1956; Gaud, 1988), we could conclude that this genus was
probably formed on the ancestors of this order and successfully evolved
on these birds. In this case, like *H. philippinensis*, *Pseudalloptinus
pithecophagae* also represents rather ancient and most likely the primary
fauna on the Great Philippine Eagle.

Wide and mosaic distribution of the kramerellid genus *Pseudogabucinia*
among birds orders and within Accipitriformes and Falconiformes (Table 4)
strongly contrasts with other genera of the family Kramerellidae that are each restricted to a particular host order
(Gaud and Atyeo, 1996). Distribution of *Pseudogabucinia* represents on phylogenetically distant genera of raptors of two or-
ders allows us to hypothesize that species associated with accipitriforms
could represents some remnants of formerly rich fauna of *Pseudoga-
bucinia* on these birds. On the other hand, mites of this genus could
represent invading fauna transferred from other unknown host groups
or rather, a transferrable mite grouping between accipitriform and even
falconiform hosts.

The Great Philippine Eagles were historically placed in the sub-
family Harpiinae related to other eagles but were recently moved to the
family Circaetinae based on molecular studies (Lerner and Mindell,
2005; Ong et al., 2011). Although the host distribution of the genus
Hieracolichus is not yet well explored, its preferential occurrence on
rather basal lineages (see Lerner and Mindell, 2005) of accipitriforms,
such as Aegypiinae, Circarctinae, Polyboroidinae (Gaud, 1983b; Philips, 2000), can be considered as additional evidence that P. jefferyi indeed belongs to the lineage of serpent eagles Circaetinae, rather than derived lineages of typical eagles as Aquilinae and Harpiinae.

5. Conclusions

We showed that a small captive group of endangered birds could maintain viable populations of native feather mites, demonstrating the utility of ectosymbiont examination for host individuals even after decades in captivity. We provided the first record of feather mites from endemic raptors or diurnal birds-of-prey in the Philippines, with three new feather mite species described, and revealed the native origin of the feather mites studied. Our work facilitated an understanding of biodiversity in the understudied family of feather mites Pterolichidae, although many more species should be sequenced before the relations in the family can be resolved clearly by molecular phylogeny.

Acknowledgement

The authors thank Executive Director of Philippine Eagle Foundation Mr. Dennis Salvador - for access to the specimens, Dr. Alma...
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