

Description of feather mite *Proctophyllodes musicus* (Acariformes, Proctophyllodidae) obtained from *Turdus merula*

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Feather mites (Acariformes, Astigmata) are a large group of species in which mites of the genus *Proctophyllodes* Robin, 1868. Analgoidea are among the most common parasites of passerines. These mites are permanent obligate ectoparasites localized on the flight feathers, greater wing coverts, and on the tail. Most species of feather mites are characterized by high host specificity. The taxonomy and fauna of feather mites of the genus *Proctophyllodes*, and their morphological identification characters in different countries of the world are still a matter of research. The aim of our work was to describe the morphological features and metric parameters of feather mites of the species *P. musicus* Vitzthum, 1922, isolated from the common blackbird *Turdus merula* Linnaeus, 1758 in Ukraine. 32 parameters are determined in males and females of *P. musicus* mites, which characterize both their general structure of the body and sexual dimorphism. The structure and sizes of the body, gnathosoma, idiosoma, prodorsal and hysteronotal shields, epimerites I, setae cp and c3, and the distance between setae of the scapula se-se and si-si are described. In males, the sizes of adanal sucker discs, epigastric shields, genital arch, setae ps2, h3, h2, the distance between setae 4a-4a, g-g, ps3-ps3, ps1-ps1 are additionally described and determined. Lamellae in males are wide, tongue-shaped, do not overlap. The aedeagus is short, slightly extending beyond the posterior margin of the genital arch. In female mites, the dimensions of the lobar shield, terminal appendages, and terminal recess are additionally described and determined, taking into account the location of setae ps1, h2, the dimensions of setae cp, c3, h3, h2, the distance between setae h1-h1, the distance between hysteronotal and lobar shields. The mite eggs were measured in the body of the female and on the feathers of the birds. The scientific data obtained in this study expand the already existing data on morphological and metric characters of feather mites of the species *P. musicus* (Proctophyllodidae) isolated from the common blackbird.

Keywords: Analgoidea; ectoparasites; birds; identification; morphology; metric parameters.

Introduction

Feather mites (Acari, Astigmata) are a large and diverse group of persistent, highly specialized ectoparasites of birds. The mites live on the feather cover of their hosts, on the skin and in the cavity of the eyes and feather follicles. This group has a worldwide distribution, its representatives are known from birds of all modern orders except penguins (Gaud & Atyeo 1976; Dabert & Mironov 1999; Proctor, 2003; Doña et al., 2016).

One of the most common feather mites on passerine birds are mites of the genus *Proctophyllodes* Robin, 1868, most species of which are host species-specific. Parasites inhabit the flight feathers and greater wing coverts, as well as the tail (de Rojas et al., 1988; Burdejnaja & Kivganov, 2011; Doña et al., 2019; Pedrosa & Hernandes, 2021). Feather mites are permanent symbionts, spending their entire life cycle on the body of the host, and their prevalence can be quite high and reach 100% among different bird species (Behnke et al., 1995; Klimov et al., 2017a).

In particular, 13 species of *Proctophyllodes* (*P. anthi*, *P. ceratophyllus*, *P. garrula*, *P. canora*, *P. scleroticus*, *P. glandarinus*, *P. flexuosa*, *P. truncatus*, *P. sinensis*, *P. vegetans*, *P. brevis*, *P. weigoldi* and *P. micurus*) were collected from a number of passerine species in China (Sun et al., 2023). Among bird species of the families Fringillidae, Motacillidae, Prunellidae, Pycnonotidae and Turdidae, parasites of 8 species of mites of

the genus *Proctophyllodes* were found, 3 of which were new to science: *P. danieli* sp. n., *P. macrophallus* sp. n. and *P. puniceus* sp. n. Other known mite species were represented by *P. anthi*, *P. cotyledon*, *P. glandarinus*, *P. leucosticti* and *P. aff. poubiani* (Cerný, 1988). At the same time, in the north-central part of the USA, during the study of *Carpodacus mexicanus*, parasitism of two species of feather mites of the genus *Proctophyllodes* was found: *P. pinnatus* and *P. vegetans* (Hartup et al., 2004); and in Chile, one species of *Proctophyllodes* – *P. spini* – was found in *Spinus barbatus* (Fuentes-Castillo et al., 2016).

New species of this genus are frequently found. Thus, in Costa Rica new species of *Proctophyllodes* were found in Passeriformes birds: *P. arremoni* sp. n., *P. euphoniae* sp. n., *P. vesicularis* sp. n., *P. parkesiae* sp. n., *P. strictophyllus* sp. n. (Mironov et al., 2017). Moreover, *P. habiae* Atyeo and Braasch, 1966 was registered in Costa Rica for the first time in that study. A new species of feather mites, *Proctophyllodes pirangae* sp. n., was discovered in North America from two tanagers of the genus *Piranga* Vieillot, 1808 (Passeriformes, Cardinalidae). Moreover, the authors identified the discovered mites as *P. polyxenus* by the size and morphological structure of the aedeagus and genital sheath extending in males, which extended to or slightly beyond the level of setae g. The authors also took into account the shape and structure of the opistogastric shield. In females, both the lobar cleft and the transverse band of soft tegument at the level of setae

h1 are considerably narrower (Hernandes et al., 2017). Mites of the genus *Proctophyllodes* are regarded as a most “complex” and species-rich genus from both a taxonomic and morphological phylogenetic point of view. Traditionally, the taxonomy of these mites is based mainly on the morphological features of the sexual structures of males. The females are much more uniform and less variable morphologically (McPeck et al., 2008; Klimov et al., 2017b). Thus, when establishing the species *P. huiizilopochilii*, the researchers noted that the light microscopic evaluation of mites was sufficient to determine the genus and species (Yamasaki et al., 2018). The importance of studying the morphological structures of specialized copulatory structures, adanal discs in *Proctophyllodes* males, is reported by the authors who studied the peculiarities of the structure of these structures, involved in attachment during copulation between a male and a female, or between a male and a tritonymph (Atyeo & Braasch, 1966; Byers & Proctor, 2014).

When differentiating two new species of the genus *Proctophyllodes* (*P. markovetsi* sp. n., *P. loxiae* sp. n.) in passerine birds (*Anthus campestris*, *Loxia curvirostra*) in Europe, they were compared with closely related species – *P. tchagrae* and *P. fuchsi*. In particular, the males of *P. markovetsi* most clearly differ from *P. tchagrae* in that they have larger terminal lamellae, the tips of the genital arcs are bent medially, and the corolla of the anal sucker has 14–15 denticles. In females of this species the terminal appendages are distinctly longer than the lobar region width. Males of *P. loxiae* differed from *P. fuchsi* by smaller lamellae, the genital organ protruded beyond the posterior edge of the lamellae by half their length. Females of the new species were distinguished morphologically, taking into account the fact that the terminal cleft is noticeably wider than the length (Mironov, 2017).

Although mites of the genus *Proctophyllodes* are among the most common feather mites on passerine birds, this genus is not fully studied because a number of passerine birds have remained unexamined so far, and several species of mites of this genus can be localized simultaneously on certain species of birds (Kivganov et al., 2006).

The aim of the research was to describe the morphological features and metric parameters of mites of the species *Proctophyllodes musicus* Vitzthum, 1922, isolated from common blackbirds in Ukraine.

Materials and methods

The materials used in this study were collected from common blackbirds (*Turdus merula*) during 2023 in the Poltava and Kharkiv regions of Ukraine. The research protocol of the current study was approved by the Ethics Committee of the Poltava State Agrarian University. The protocol of handling wild birds was approved by the Ethics Committee of the NSC IECVM (No. 2-21, 24.11.2021).

Birds were caught in natural conditions during field expeditions with spider nets, using methods of safe handling of birds. After determining the species and carrying out other additional manipulations, each bird was carefully examined for the presence of feather mites. After all manipulations were completed, the birds were released into the natural environment. Mites were collected with a dissecting needle or tweezers and stored in tubes with 70% alcohol. In laboratory conditions, mites were mounted on glass slides in micropreparations. Identification was carried out according to the identifying key (Atyeo & Braasch, 1966).

The morphometric parameters of male and female mites (n = 15) were studied using ImageJ for Windows® software (version 2.00) in interactive mode. Microphotography was carried out using a Sigeta M3CMOS 14000 14.0 MP digital camera (China).

Statistical processing of the experimental results was carried out using Statistica 10 (StatSoft Inc., USA) software. Standard deviation (SD) and average values (x) were calculated.

Results

Proctophyllodes musicus feather mites at various stages of development were found in the vane of flight feathers both as single specimens and in colonies (Fig. 1). The male mites were oval in shape, the females were more elongated. Sexual dimorphism is well expressed, females are larger (Fig. 2a) than males (Fig. 2b). The gnathosoma is well defined, the chelicerae are laterally compressed. The prodorsal shield occupies almost the entire dorsal surface of the propodosoma, which has the shape of a trapezoid and carries legs I and II. The hysterosomal shield is rectangular in shape, occupies almost the entire part of the hysterosoma and carries legs III and IV.

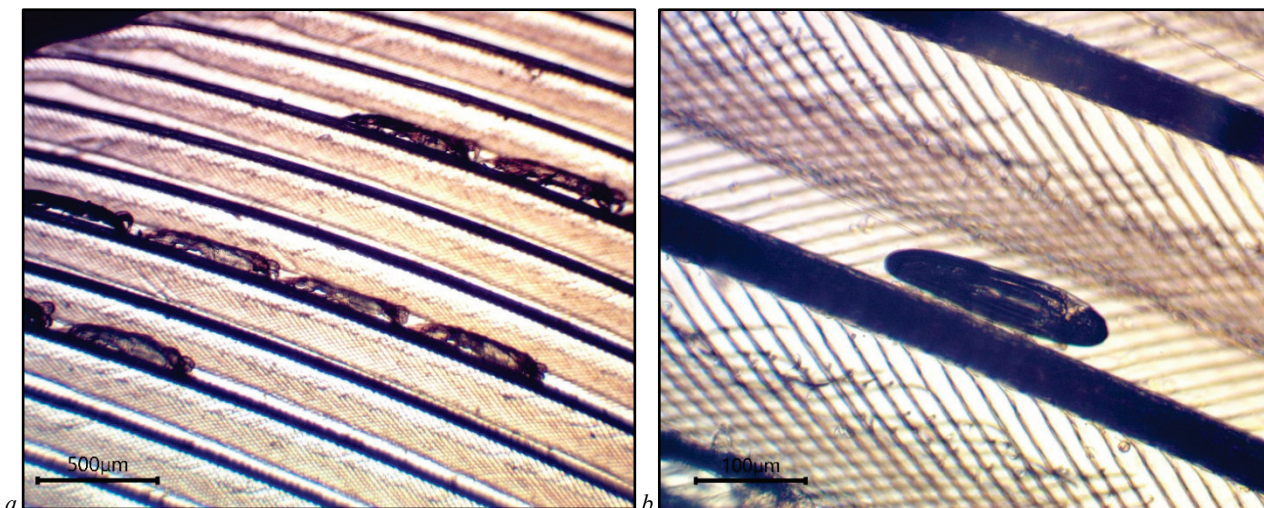


Fig. 1. Location of *Proctophyllodes musicus* mites along the barbs in the vane of flight feathers of a common blackbird: a – mites, b – egg

The length and width of body of *P. musicus* males are 283.7 and 141.6 µm, respectively, and their ratio is 2 : 1. The length and width of the gnathosoma is 44.6 and 37.1 µm, the length of the idiosoma is 239.1 µm, and the length of the hysterosoma is 161.9 µm (Table 1). The prodorsal shield contains setae se and si, its edges have depressions in front and behind the external setae of the scapulae, the posterior edge is wavy (Fig. 3a). Distance between scapular setae: se–se 57.8 µm, si–si 40.9 µm. Humeral shields are moderately developed and bear setae cp, their length is 135.8 µm, length and width of setae c3 19.6 × 3.9 µm. Hysteronotal shield 163.9 µm in length, 87.4 µm in width. Its front edge is slightly

concave (Fig. 3b). Apodemes well developed, epimerites I U-shaped, without lateral extensions. The genital arch reaches the level of legs IV. The aedeagus is short, slightly extending beyond the rear edge of the genital arch. Setae 4a are located above epimerites IVa. Epigastral shields are divided, trapezoidal and bear one pair of setae ps3 (Fig. 4a). Distance between setae: 4a–4a 33.4 µm, g–g 10.7 µm, ps3–ps3 24.5 µm, ps1–ps1 14.4 µm. The length of ps2 setae is 36.8 µm. The discs of adanal suckers are oval, each measuring 18.8 × 31.4 µm. Lamellae are wide, tongue-shaped, do not overlap (Fig. 4b); length 40.8 µm, width 31.4 µm. The length of setae h2 152.7 µm, h3 89.3 µm.

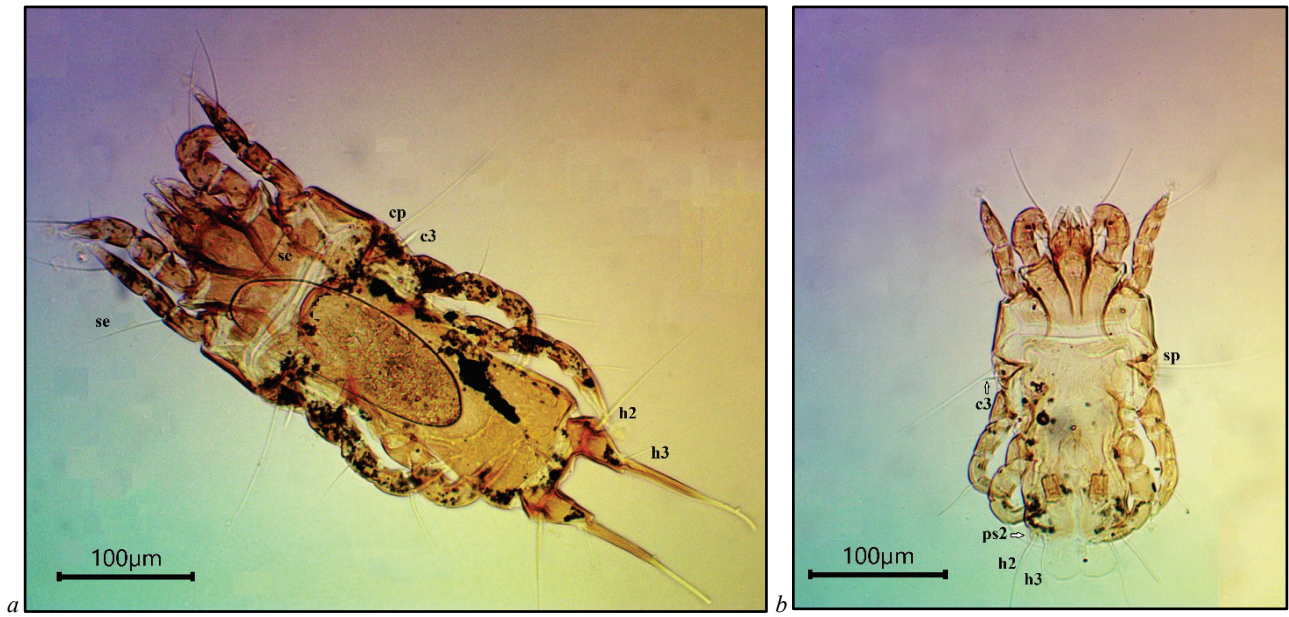


Fig. 2. *Proctophyllodes musicus*: a – female, b – male

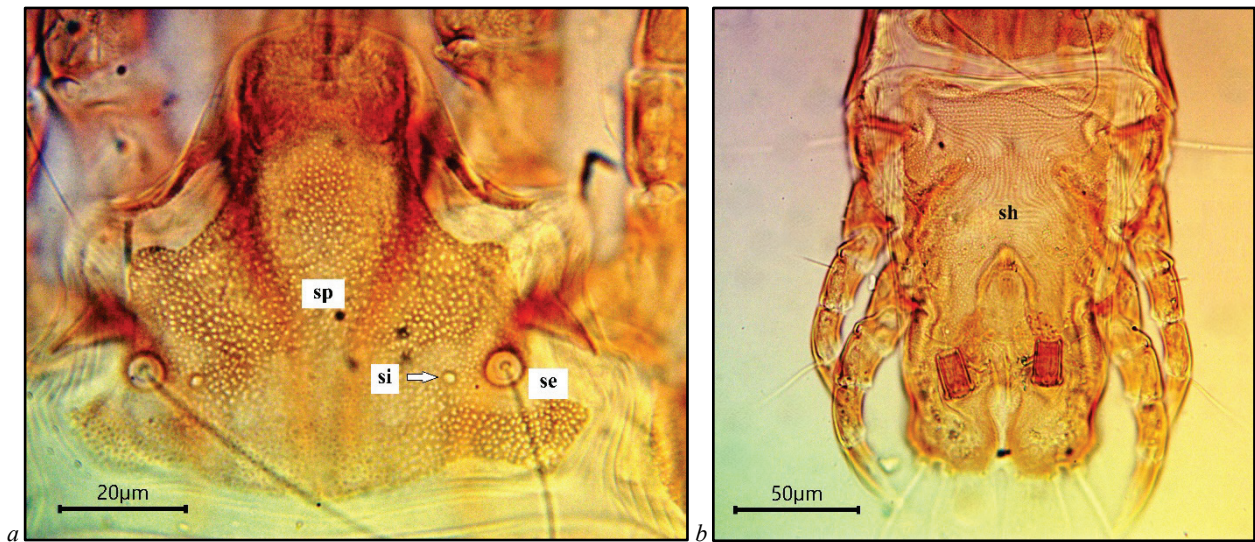


Fig. 3. *Proctophyllodes musicus* male, dorsal view: a – propodosomal shield (*sp*), scapular setae (*se*, *si*); b – hysteronotal shield (*sh*)

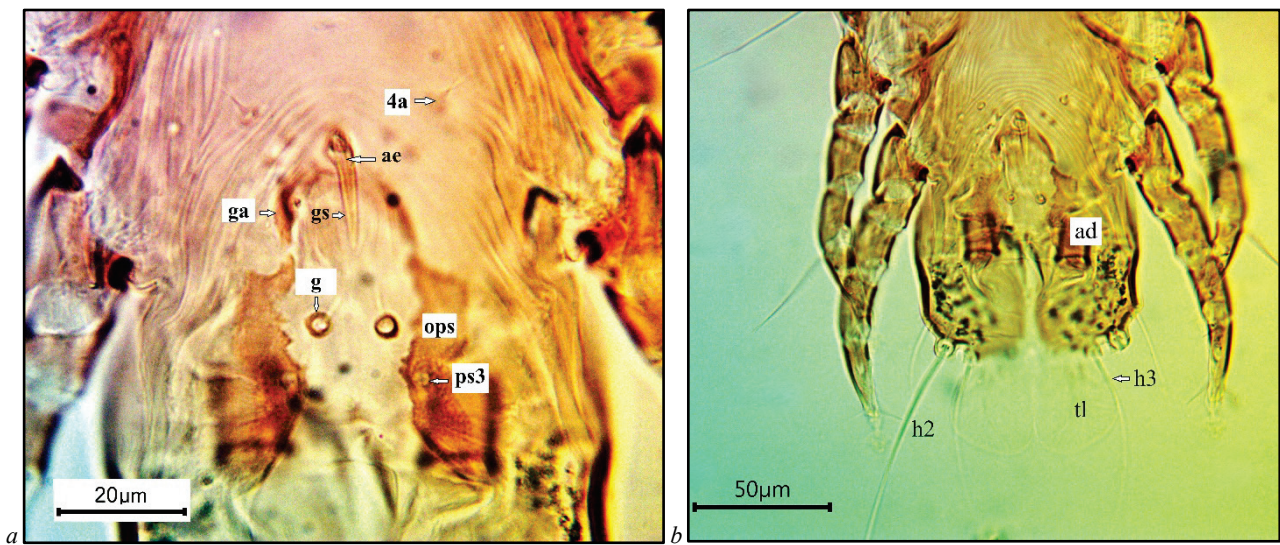


Fig. 4. *Proctophyllodes musicus* male, ventral view: a – aedeagus (*ae*), genital sheath (*gs*), opisthogastric shield (*ops*), genital arch (*ga*), setae (*4a*, *g*, *ps3*); b – adanal sucker (*ad*), terminal lamella (*tl*), setae (*h2*, *h3*)

Morphologically, the humeral shields of *P. musicus* females are moderately developed, the scapular shields are elongated. The length and width of the body is 411.8 and 166.7 μm , respectively, their ratio is 2.5 : 1. The length and width of the gnathosoma is 61.3 and 52.4 μm , the length of idiosoma is 350.4 μm , and the length of hysterosoma is 240.6 μm (Table 2). Setae *se* and *si* are located on the prodorsal shield. The lateral edges of the prodorsal shield are slightly indented anteriorly and behind the setae *se*, the posterior edge of prodorsal shield is slightly sinuous (Fig. 5a). Distance between scapular setae: *se*–*se* 75.6 μm , *si*–*si* 46.9 μm . The length of seta *cp* is 172.8 μm , the length and width of seta *c3* is 19.6 \times 3.9 μm . Epimerites I U-shaped. The epigynum is semicircular, well developed, without lateral extensions (Fig. 5b). The hysterosoma contains

the hysteronotal shield and the lobar region. The length of hysterosoma is 240.6 μm . The hysteronotal shield is approximately rectangular, its front edge is slightly concave (Fig. 6a), its length and width are 219.7 \times 99.6 μm . The lobar region is clearly separated from hysterosoma (Fig. 6b). Distance between hysteronotal and lobar shields is 5.9 μm . The length of lobar shield is 58.2 μm , its width at the level of setae *h2* is 95.4 μm . Terminal appendages are 123.3 μm long and 10.1 μm wide. The terminal cleft is wide, its lateral edges are almost parallel, slightly diverging towards the base, 40.7 μm long. The distance between the lateral margins of terminal cleft at the level of *ps1* is 38.9 μm , the width of the lateral margins of the terminal cleft at the level of *ps1* is 20.2 μm . Distance between setae *h1*–*h1* 46.2 μm , length of setae *h2* 184.1 μm , *h3* 68.9 μm .

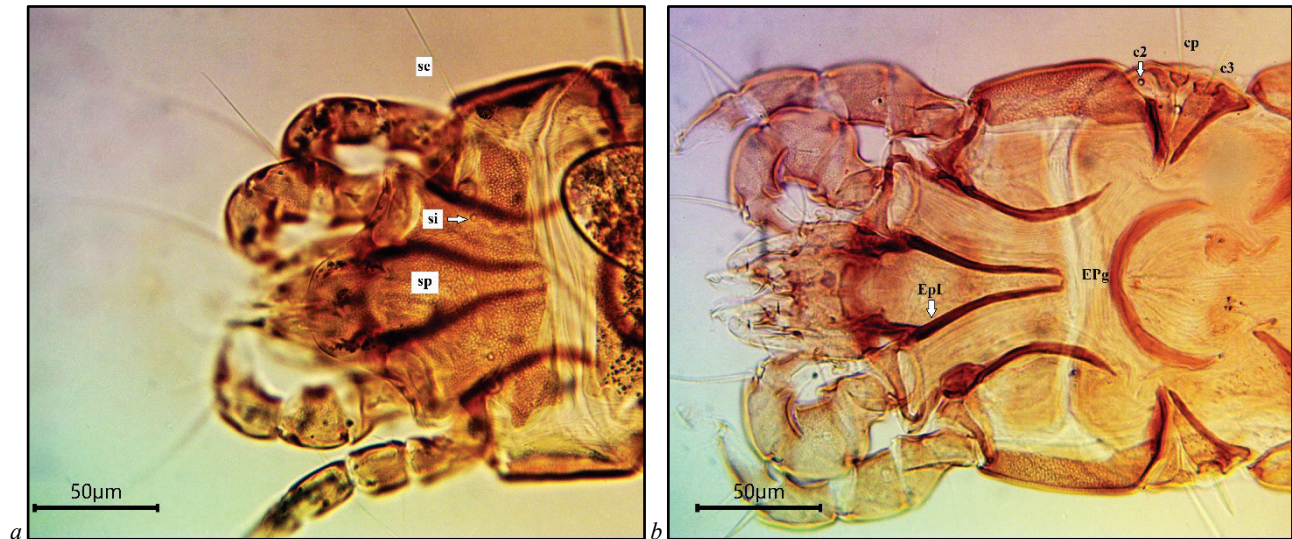


Fig. 5. *Proctophyllodes musicus* female: *a* – dorsal view, propodosomal shield (*sp*), scapular setae (*se*, *si*); *b* – ventral view, epigynum (*EPg*), setae (*c2*, *cp*, *c3*)

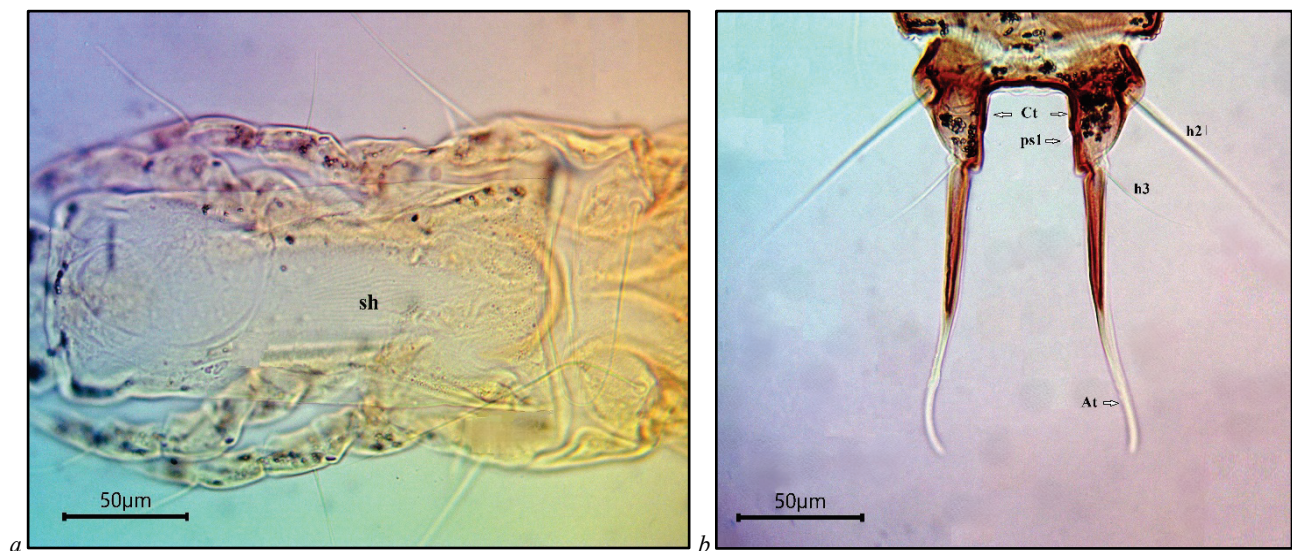


Fig. 6. *Proctophyllodes musicus* female, dorsal view: *a* – hysteronotal shield (*sh*); *b* – lobar region, terminal appendages (*At*), terminal cleft (*Ct*), setae (*h2*, *h3*, *ps1*)

The eggs in the body of female mites were 194.9 μm in length and 69.6 μm in width. Mite eggs found on bird feathers were longer, 223.7 μm , and narrower, 51.2 μm (65.7–74.8 μm) than eggs found in the body of the female.

Discussion

Feather mites are permanent ectosymbionts localized on the surface of the feather cover (mainly on the flight feathers, cover feathers of the wings and tail) of birds, among which passerine birds (Passeriformes) are

their most common hosts (Atyeo & Braasch, 1966; Dabert & Mironov 1999; Kivganov et al., 2006; Koshelev et al., 2020a, 2020b). The genus *Proctophyllodes* (Analgoidea, Proctophyllodidae) is the most species-rich among all feather mite genera. To date, the genus *Proctophyllodes* is constantly updated, revised and supplemented with new species (Mironov, 2012; Mironov & O'Connor, 2014; Mironov et al., 2017; Mironov, 2019). This is due to the fact that this genus is insufficiently studied for several reasons: a number of passerine bird species have not yet been studied; several species of mites of this genus can be localized simultaneously on certain species of birds (Kivganov et al., 2006).

Table 1
Metric parameters of male *Proctophylloides musicus* mites
(n = 15; x ± SD, min–max)

Parameters, μm	Present specimens	Atyeo & Braasch (1966)
Length of body	283.7 ± 8.7 (265.3–298.6)	287
Width of body	141.6 ± 2.5 (137.5–146.4)	143
Length to width of body ratio	2 : 1 (1.9 : 1; 2.1 : 1)	–
Length of gnathosoma	44.6 ± 3.5 (40.2–52.1)	–
Width of gnathosoma	37.1 ± 1.9 (33.8–40.1)	–
Length of idiosoma	239.1 ± 9.1 (218.6–255.1)	–
Length of podosoma	182.4 ± 4.9 (175.4–188.6)	–
Length of propodosoma	77.2 ± 3.8 (70.2–84.4)	–
Length of metapodosoma	105.2 ± 2.0 (102.8–109.1)	–
Length of hysterosoma	161.9 ± 9.5 (139.6–175.2)	–
Length of opisthosoma	56.7 ± 9.9 (32.5–71.8)	–
Length of proterosoma	227.0 ± 7.3 (215.6–238.3)	–
Length of prodorsal shield	78.2 ± 2.1 (75.0–81.3)	77
Width of prodorsal shield	86.3 ± 2.2 (82.2–89.6)	82
Distance between external setae of scapula (se)	57.8 ± 2.3 (53.7–61.8)	56
Distance between internal setae of scapula (si)	40.9 ± 1.6 (38.1–43.4)	–
Length of hysteronotal shield	163.9 ± 3.0 (158.7–168.9)	162
Width of hysteronotal shield	87.4 ± 2.4 (82.6–91.1)	86
Distance between setae 4a	33.4 ± 1.1 (31.5–35.3)	–
Distance between setae g	10.7 ± 0.8 (9.2–12.5)	–
Distance between setae ps3	24.5 ± 1.6 (21.9–27.0)	–
Distance between setae ps1	14.4 ± 0.7 (13.2–15.9)	–
Length of seta ps2	36.8 ± 2.7 (32.2–44.3)	–
Length of seta c3	15.2 ± 0.7 (13.8–16.0)	15.9
Width of seta c3	2.8 ± 0.3 (2.3–3.3)	2.8
Length of seta cp	135.8 ± 4.1 (128.9–141.1)	–
Length of seta h3	89.3 ± 4.8 (80.2–96.1)	–
Length of seta h2	152.7 ± 7.5 (139.7–162.5)	–
Length of lamellae	40.8 ± 1.3 (39.1–42.8)	40
Width of lamellae	31.4 ± 1.0 (30.2–33.6)	28
Length of disks of adanal suckers	18.8 ± 1.0 (17.1–20.2)	14 × 12
Width of disks of adanal suckers	12.3 ± 0.4 (11.5–12.9)	–

Note: “–” parameters were not defined.

We collected feather mites from the common blackbird. The mites were identified by morphological and metric parameters as *Proctophylloides musicus* Vitzthum, 1922. Parasitization of mites of this species on the common blackbird is also evidenced by other scientists who discovered this mite in other regions. In particular, *P. musicus* was isolated from a blackbird in Turkey (Labrador et al., 2022; Eren et al., 2023).

When studying the morphometric features of the collected male *P. musicus* mites, 32 indicators were determined that describe the general structure of the body, namely: total length, body width and their ratio, length and width of the gnathosoma, length of idiosoma, podosoma, propodosoma, metapodosoma, hysterosoma, opisthosoma, proterosoma, length and width of prodorsal shield, distance between scapular setae se–se and si–si, length of seta ps2 and width and length of seta c3. In males, the shape and location of the epigastric shields, genital arch, lamellae, and aedeagus were determined, as well as the sizes of the adanal suction discs, lamellae, setae ps2, h3, h2, the distance between setae 4a–4a, g–g, ps3–ps3, ps1–ps1. In the literature available to us, the authors determined in males of this species only 13 indicators characterizing the length and width of the body, the dimensions of the prodorsal and hysteronotal shields, setae c3, lamellae, discs of adanal suckers, the distance between setae se–se (Aty eo & Braasch, 1966). The sizes determined by the authors coincide with the intervals of minimum and maximum values obtained in our study.

The female mites that we found were larger in size, which was confirmed by their metric parameters. We also determined 32 indicators, which, like in males, describe the general structure of the body and its parts, the distance between the scapular setae se–se and si–si, the length of the seta ps2 and the width and length of the setae c3. In females, the measurements of the lobar shield, terminal appendages, and terminal cleft were also determined, taking into account the location of setae ps1, h2, the distance between the hysteronotal and lobar shield, the dimensions of setae cp, c3, h3, h2, the distance between setae h1–h1. According to scientific

data, 14 indicators were determined in female *P. musicus* mites, which characterize the length and width of the body, the sizes of the prodorsal, hysteronotal and lobar shields, the length of the lateral edges of the terminal cleft, the distance between them at the level of setae ps1, the sizes of setae c3, the distance between setae se–se and h1–h1 (Aty eo & Braasch, 1966).

Table 2
Metric parameters of female *Proctophylloides musicus* mites
(n = 15; x ± SD, min–max)

Parameters, μm	Present specimens	Atyeo & Braasch (1966)
Length of body	411.8 ± 17.6 (391.3–440.4)	463
Width of body	166.7 ± 5.5 (160.0–179.2)	179
Length to width of body ratio	2.5 : 1 (2.4 : 1–2.8 : 1)	–
Length of gnathosoma	61.3 ± 2.2 (56.6–64.3)	–
Width of gnathosoma	52.4 ± 1.2 (50.1–53.9)	–
Length of idiosoma	350.4 ± 16.9 (331.2–378.3)	–
Length of podosoma	214.2 ± 11.7 (193.6–230.2)	–
Length of propodosoma	109.8 ± 5.1 (100.9–118.5)	–
Length of metapodosoma	104.4 ± 7.6 (92.3–115.6)	–
Length of hysterosoma	240.6 ± 18.3 (213.0–268.3)	–
Length of opisthosoma	136.2 ± 21.2 (104.9–167.2)	–
Length of proterosoma	275.6 ± 12.0 (256.8–293.3)	–
Length of prodorsal shield	100.9 ± 2.9 (96.3–105.8)	99
Width of prodorsal shield	117.8 ± 2.7 (113.2–122.6)	114
Distance between external setae of scapula (se)	75.6 ± 3.3 (70.5–83.0)	81
Distance between internal setae of scapula (si)	46.9 ± 5.3 (40.4–59.0)	–
Length of hysteronotal shield	219.7 ± 2.2 (215.5–222.6)	235
Width of hysteronotal shield	99.6 ± 3.5 (94.8–105.1)	114
Distance between hysteronotal and lobar shields	5.9 ± 0.6 (5.2–7.2)	–
Length of lobar shield	58.2 ± 3.6 (51.3–63.8)	48
Width of lobar shield at the level of setae h2	95.4 ± 4.7 (86.0–101.6)	–
Length of lateral margins of terminal cleft	40.7 ± 3.7 (36.2–49.1)	31
Distance between lateral margins of terminal cleft at the level of ps1	38.9 ± 1.8 (36.4–41.6)	36
Width of lateral margins of terminal cleft at the level of ps1	20.2 ± 2.6 (16.7–26.1)	–
Length of seta cp	172.8 ± 11.5 (150.2–194.3)	–
Length of seta c3	19.6 ± 1.7 (17.1–23.3)	20.7
Width of seta c3	3.9 ± 0.4 (3.2–4.6)	4.1
Length of terminal appendages	123.3 ± 6.8 (112.3–133.7)	–
Width of terminal appendages	10.1 ± 1.0 (8.4–11.4)	–
Length of seta h3	68.9 ± 10.3 (50.3–87.2)	½ of terminal appendages
Length of seta h2	184.1 ± 11.0 (159.2–201.4)	–
Distance between setae h1	46.2 ± 3.9 (40.7–53.1)	46
Length of egg in female mite body	194.9 ± 7.1 (180.2–204.9)	–
Width of egg in female mite body	69.6 ± 1.9 (65.9–73.3)	–
Length of egg on feather	223.7 ± 4.2 (216.9–230.5)	–
Width of egg on feather	51.2 ± 2.9 (45.2–55.8)	–

Note: see Table 1.

The importance of the structure and sizes of the aedeagus, genital sheath, genital arch, lamellae, epigastric shields in males, and the lobar shield, terminal cleft in females, as well as determining their metric parameters for the identification of feather mites of the *Proctophylloides* genus, is reported in scientific papers (Badek et al., 2008; Zhang et al., 2021).

The scientific data obtained in this study extend the already existing data on morphological characters and metric parameters of feather mites of the species *P. musicus* (Astigmata, Proctophylloidae) isolated from the common blackbird.

Conclusion

Morphological and metrical studies of mites of the species *P. musicus*, isolated from common blackbirds in Ukraine, described and determined 32 indicators in male and female mites which characterize the structure and size of body, its parts, prodorsal and hysteronotal shields,

setae cp and c3, as well as the distance between the scapular setae (se–se, si–si). In male mites, the sizes of lamellae, discs of adanal suckers, hysteronotal setae (ps2, h3, h2), distance between setae 4a–4a, g–g, ps3–ps3, ps1–ps1 were also determined. In female mites, the distance between the hysteronotal and lobar shields, the sizes of the lobar shield and the terminal cleft, terminal appendages, setae h3 and h2, and the distance between dorsal setae (h1–h1) were determined.

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The authors declare that there is no conflict of interest.

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