Bull. Natl. Mus. Nat. Sci., Ser. A, 38(4), pp. 159–172, November 22, 2012

A New Genus and Two New Species of Chigger Mites (Acari, Trombiculidae) Collected from Amphibious Sea Snakes of Japan

Mamoru Takahashi[1], Hitoko Misumi[1] and Yumi Takahashi[2]

[1] Department of Anesthesiology, Saitama Medical University,
Moroyama-machi, Iruma-gun, Saitama, 350–0495 Japan
[2] Faculty of Medicine, Saitama Medical University,
Moroyama-machi, Iruma-gun, Saitama, 350–0495 Japan
E-mail: m.takahashi @ wish.ocn.ne.jp

(Received 1 August 2012; accepted 26 September 2012)

Abstract One new genus and two new species of chigger mites are described and illustrated from amphibious sea snakes of the Nansei Islands in Japan. *Ancoracarus* gen. nov. is created for the unique species *Ancoracarus hayashii* sp. nov., collected from a Japanese sea krait *Laticauda semifasciata* (Reinwardt, 1837). This mite is characterized by having a palpal setal formula of BN/NNB/6B; more than 7 genualae on each of genu I, II, and III; 2, 2, and 1 tibiala on each of tibia I, II, and III; no mastisetae on legs; elongated tarsala I; unique anchor-like post-humeral setae in the central portion of the dorsal idiosoma; scutum roughly pentagonal with filamentous sensillae that are trifurcate; and anteromedian seta base on the line of the anterolateral seta bases. *A. hayashii* sp. nov. is also parasitic on the other Japanese sea kraits, *L. laticaudata* (Linnaeus, 1758) and *L. colubrina* (Schneider, 1799). *Schoutedenichia masunagai* sp. nov., found only on *L. laticaudata,* differs from the previously known species of the genus *Schoutedenichia* Jadin and Vercammen-Grandjean, 1954 by the shape and size of the scutum, form of sensillae and combination of characters mentioned in the diagnosis. Our description of a new species of *Schoutedenichia* increases the total number of species in this genus to 3 (*S. atollensis, S. nagasakiensis* and *S. masunagai* sp. nov.) in Japan and 10 in Asia.
Key words: Trombiculidae, chigger, new genus, *Ancoracarus hayashii* sp. nov., *Schoutedenichia masunagai* sp. nov., sea snake.

Introduction

Hayashi and Masunaga (2001) reported the results of intensive surveys of ectoparasites on amphibious sea snakes in the Ryukyu Islands in southern Japan. We had an opportunity to study the slide specimens of the many chiggers they collected. Among their samples, there were two previously undescribed species. One species had morphologically unique characteristics, including having many genualae on each of genu I, II and III and anchor-like post-humeral dorsal idiosomal setae, with the exception of the marginal setae. Hence, the study of this unique specimen led us to propose the new genus *Ancoracarus*.

Another rare and previously undescribed species belonged to the genus *Schoutedenichia* Jadin and Vercammen-Grandjean, 1954 in accordance with the classification of Vercammen-Grandjean, 1968. Subsequently, we investigated ectoparasitic chigger mites from more than 100 laticaudid sea snakes isolated from the Nansei Islands of Japan during the period 2007–2011. The chiggers collected were mounted in gum chloral solution and identified under a photomicroscope. We obtained specimens of the above two new species from the same sea snake host species listed in the collection records of Hayashi and Masun-

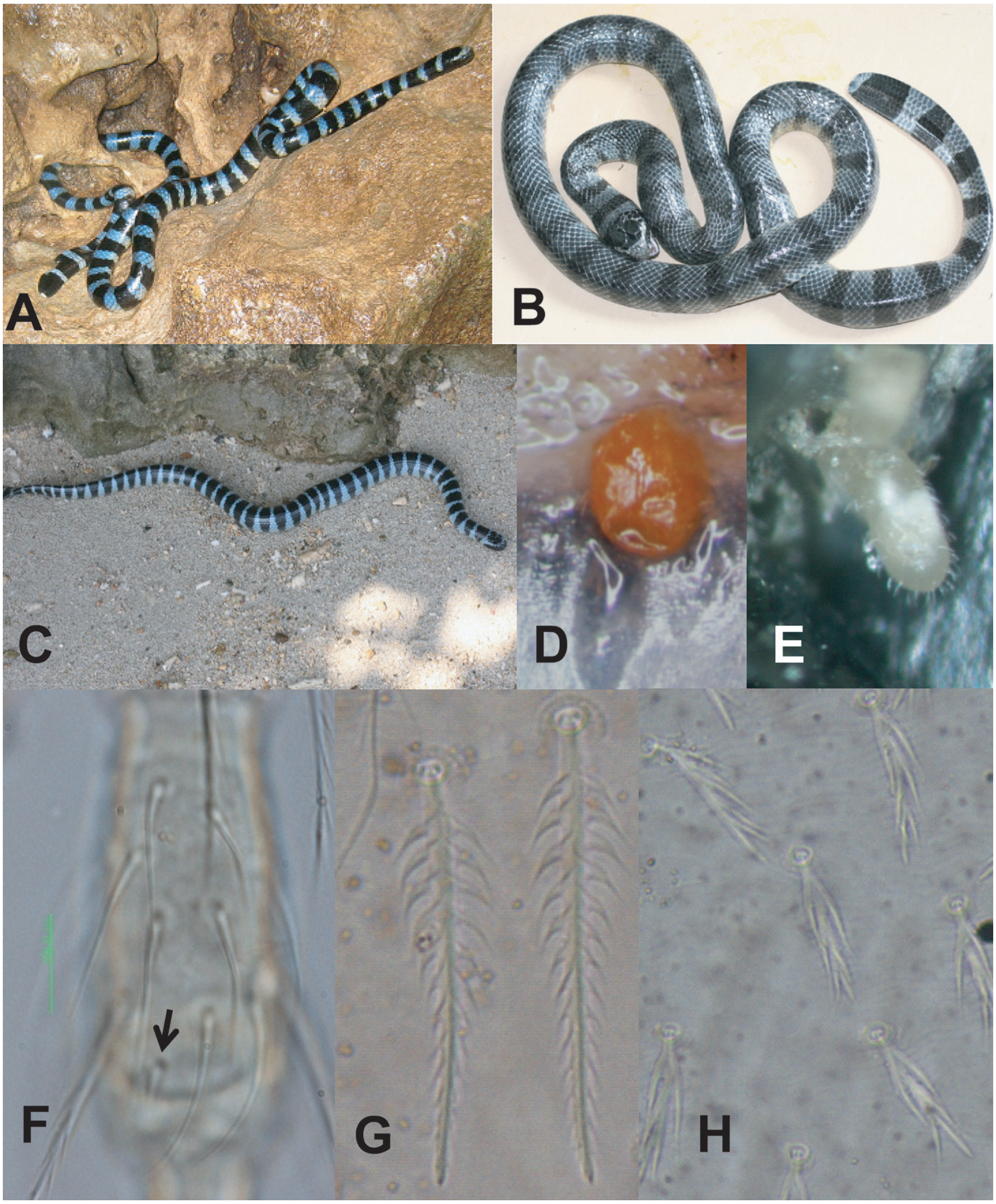


Fig. 1. Three Japanese sea kraits (unique hosts) and two new chigger species parasitic under their scales. A, *Laticauda laticaudata*, resting on the shore bed in a seashore cave in Ishigakijima Island; B, *L. colubrina*; C, *L. semifasciata*; D, living *Ancoracarus hayashii* sp. nov. (red in color) parasitic under the scale of *L. semifasciata*; E, living *Schoutedenichia masunagai* sp. nov. (white in color) parasitic under the scale of *L. laticaudata*. F–H: characteristic setae of *A. hayashii* sp. nov.; F, dorsal view of genuala I, having 10 genualae and long microgenuala (arrow) (holotype); G, dorsal medial setae of first post-humeral setal row (note anchor-like setules); H, ventral preanal setae, having stout and differentiated setules along their entire length.

aga (2001) (Fig. 1).

Abbreviations and terminology are those used by Goff *et al*. (1982), with some modifications: anterolateral seta (AL); anteromedian seta (AM); distance from anterolateral setal base to posterolateral setal base on one side (AP); distance from sensillary bases to extreme anterior margin (ASB); anterior width of scutum (AW); branched seta (B); postanal seta or caudal seta (CS); dorsal idiosomal seta (DS); dorsal setal formula (DSF); coxal setation formula (fCx); palpal setal formula (fPp); scutal formula (fSC); ventral setation formula (fV); humeral seta (H, HS); leg index (IP); nude seta (N); total number of idiosomal setae, excluding coxal setae (NDV); posterolateral seta (PL); distance from sensillary bases to extreme posterior margin (PSB); parasubterminala (pST); posterior width of scutum (PW); length of sensilla (S); distance between sensillary bases (SB); scutal depth (SD): SD = ASB + PSB; synthetic identification formula (SIF); sternal seta (StS); and true ventral seta or preanal seta (VS).

All measurements were obtained in micrometers, with those for the holotype followed in parentheses by the mean and extremes of the type series (holotype + 9 paratypes) in each new species. All specimens collected from sea snakes in the present study were insufficiently engorged larvae.

The specimens used for descriptions of the two new species are deposited in the collection of the Department of Zoology, National Museum of Nature and Science, Tokyo, Japan.

Results

Family **Trombiculidae**

Ancoracarus Takahashi, Misumi and Takahashi, gen. nov.

[Japanese name: Ikaritsutsugamushi-zoku]

Type species: *Ancoracarus hayashii* Takahashi, Misumi and Takahashi, sp. nov.

Diagnosis. Trombiculinae larvae with 7-segmented legs; palpal setation BN/NNB/6B; galeala N; 3 claws trifurcate, each of same length, arising from the distal end of the palpal tibia. Cheliceral blade with dorsal and ventral rows of small teeth; 9–11 genualae I and long microgenuala, 7 genualae II, 7 genualae III; subterminala, parasubterminala, and pretarsala I; microtarsala, stout and elongate tarsala I; tarsala II and microtarsala; no tarsala III; no mastisetae on legs; scutum punctate, roughly pentagonal with anterior margin concaved deeply twice and peculiarly pronounced anterolateral shoulders, posterior margin deeply convex with 5 setae barbs; filamentous sensillae with trifurcate; eyes 2/2, on ocular plate. Unique anchor-like post-humeral dorsal idiosomal setae except for the marginal setae.

Etymology. The specific epithets are a combination of Latin words, ancora (anchor) and acarus (mite), and refers to the morphologically unique anchor-like post-humeral setae in the central portion of the dorsal idiosoma.

Remarks. Vercammen-Grandjean (1960b) published an abbreviated pictorial key to the more than 100 genera and subgenera of the largest subfamily Trombiculinae in the world. Subsequently, Vercammen-Grandjean (1968) also published an illustrated key and a synopsis for 80 genera and subgenera of chigger mites of the Far East. Nadchatram and Dohany (1974) keyed 50 genera and subgenera of Southeast Asian chiggers.

Among genera belonging to the Trombiculinae having palpal tarsus 6B, palpotibial claw trifurcate, scutum punctate, roughly pentagonal with pronounced anterolateral shoulders and posterior angle, *Ancoracarus* gen. nov. is similar to the genus *Eltonella* Audy, 1956 (Vercammen-Grandjean, 1960b, 1965, 1968). However, *Ancoracarus* may be easily separated from *Eltonella* in having approximately 10, 7, and 7 genualae on each of genu I, II, and III (2 or 3, 1, 1 in all known *Eltonella)*, and unique anchor-like post-humeral setae in the central portion of the dorsal idiosoma (normally ciliated in *Eltonella*).

Ancoracarus hayashii Takahashi, Misumi and Takahashi, sp. nov.

[Japanese name: Hayashi-ikaritsutsugamushi]

(Fig. 2)

Trombiculidae sp. t: Hayashi and Masunaga, 2001: 6, 7, fig. 2.

Diagnosis of larva. SIF = 6B-B-3-(8–10) 771.0000; fPp = BN/NNB/6B; fCx = 1.1.1; IP = 1227 (1166, 1124–1227); pST = N; fSC = AM＞PL＞AL; 10–14 humeral setae; 122–142 dorsal setae (122 in holotype) arranged in irregular rows; fV = 130–148 (134 in holotype); NDV = 250–280 (256 in holotype).

Type specimens. Holotype (NSMT-Ac 13689): larva from *Laticauda laticaudata* (Linnaeus, 1758) collected from Hoshizuna-kaigan (24°26′16″N, 123°46′40″E), Iriomotejima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture, Japan, on 23-VII-2000 by F. Hayashi and G. Masunaga.

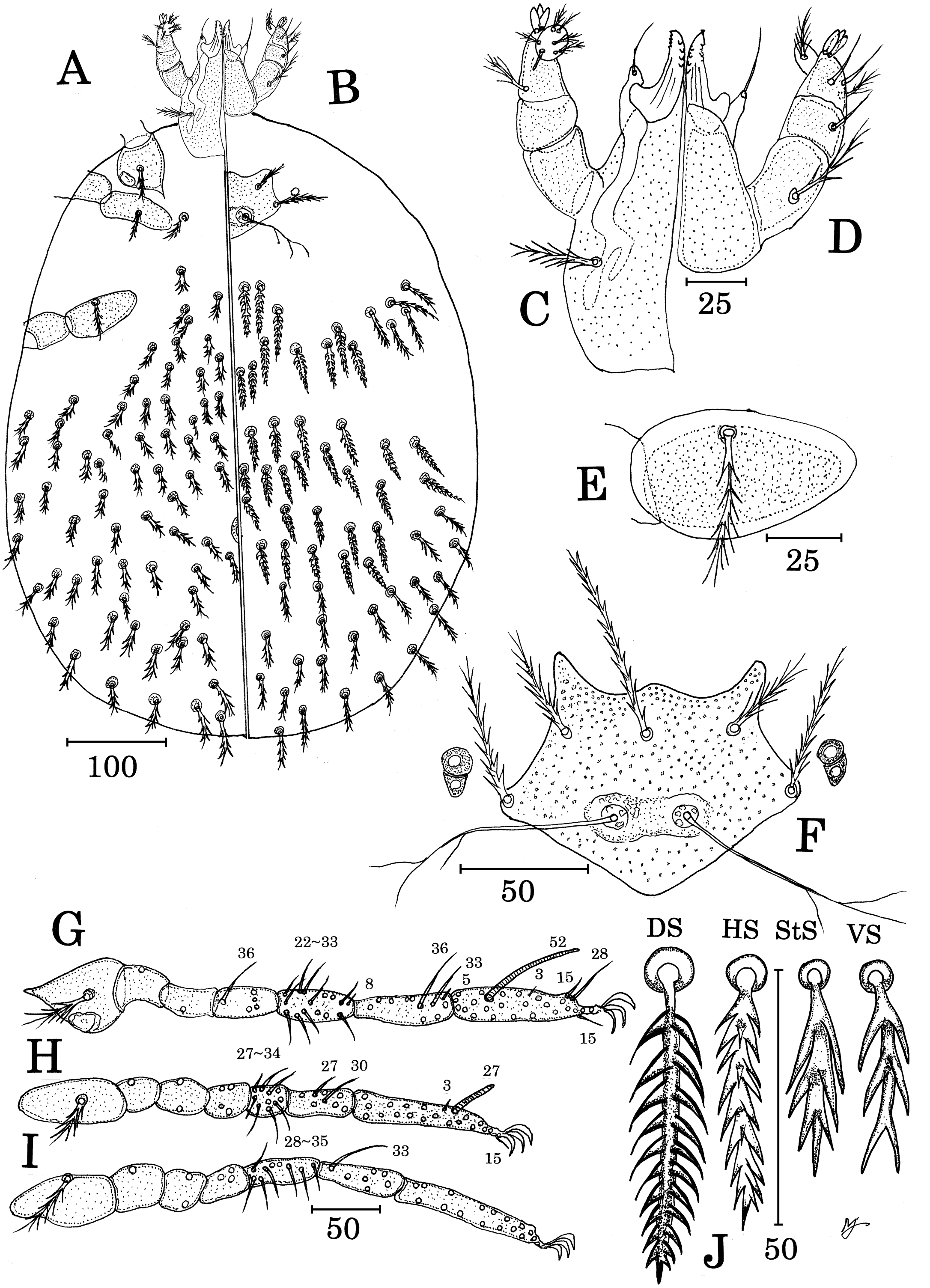
Paratypes: (NSMT-Ac 13690–13693), 4 larvae from the same host, location, and collection date as the holotype collected by F. Hayashi and G. Masunaga; (NSMT-Ac 13694), 1 larva from *L. semifasciata* (Reinwardt, 1837), Kodakarajima Island (29°13′33″N, 129°19′51″E), Kagoshima-gun Toshimamura, Kagoshima Prefecture, 5-X-2006, coll. M. Takahashi; (NSMT-Ac 13695), 1 larva from the same host, location and collection date as the holotype collected by F. Hayashi and G. Masunaga; (NSMT-Ac 13696–13698), 3 larvae from *L. colubrina* (Schneider, 1799), Kuroshima Island (24°14′57″N, 124°1′42″E), Taketomi-cho, Yaeyama-gun, Okinawa Prefecture, 16-XII-2010, coll. K. Kameda and M. Takahashi.

Other collection records. Kuroshima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture: 1 larva from *L. colubrina,* 7-VII-2010, coll. K. Kameda and M. Takahashi; 3 larvae from *L. colubrina*, 16-XII-2010, coll. K. Kameda and M. Takahashi; 3 larvae from *L. colubrina,* 7-V-2010, coll. K. Kameda and M. Takahashi. Hoshizuna kaigan, Iriomotejima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture:1 larva from *L. colubrina,* 10-VII-2010, coll. M. Toda and M. Takahashi; 4 larvae from 2 *L. laticaudata*, 21-VII-2008, coll. G. Masunaga, Y. Tahara, and M. Takahashi; 1 larva from *L. colubrina*, 23-VII-2008, coll. G. Masunaga, Y. Tahara, and M. Takahashi; 1 larva from *L. colubrina*, 2-X-2007, coll. Y. Tahara and M. Takahashi; 2 larvae from *L. laticaudata*, 2-X-2007, coll. Y. Tahara and M. Takahashi. Unarizaki, Iriomotejima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture; 7 larvae from 3 *L. laticaudata*, 20-VII-2008 coll. G. Masunaga, Y. Tahara, and M. Takahashi. Uganzaki, Ishigakijima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture: 3 larvae from 2 *L. laticaudata*, 25-VII-2008, coll. G. Masunaga and M. Takahashi; 1 larva from *L. laticaudata*, 24-VII-2008, coll. G. Masunaga and M. Takahashi. Kodakarajima Island, Kagoshima-gun Toshimamura, Kagoshima Prefecture: 2 larvae from *L. semifasciata*, 1-X-2006, coll. M. Takahashi.

Description of larva. Live insufficiently engorged larvae, red in color. Idiosoma: Body longer than wide, measuring 625 (675, 615–710) long and 446 (451, 446–457) wide. Two pairs of eyes on the ocular plate, located by scutum at the level of a slightly upper part of PL bases; diameter of anterior and posterior eyes 6 (6, 5–6) and 5 (5, 4–5), respectively.

Gnathosoma: Gnathosomal base moderately punctated, 87 (86, 84–87) wide at the level of the bases of a pair of branched setae; cheliceral bases triangular and posterior margin rounded, 57 (56, 54–60) long by 39 (39, 37–40) wide; cheliceral blade 45 (46, 44–48) long by 5 (4, 4–5) wide, with dorsal and ventral rows of small teeth; Galeal seta nude. fPp = B/N/NNB/6B; palpal

Fig. 2. *Ancoracarus hayashii* sp. nov., insufficiently engorged larva. A and B, ventral and dorsal aspects of larva; C and D, ventral and dorsal aspects of gnathosoma; E, coxa III; F, scutum and eyes on ocular plate; G, H, and I, legs I, II, and III; J, details of setae (abbreviations: DS, dorsal medial seta of first post-humeral row; HS, humeral seta; StS, anterior sternal seta; VS, ventral medial seta of first post-sternal row). The length of the scale bar for each structure is in micrometers.


A
B
C
D
25
E
25
100
F
50
G
36
22~33
36
33
52
28
8
5
3
15
15
H
27~34
27
30
3
27
15
I
28~35
33
50
DS
HS
StS
VS
J
50

claw stout, 3 pronged, each of same length, 11 long.

Scutum: Shape roughly pentagonal, sparsely punctate; slightly wider than long, PW/SD ratio 1.2 (1.2, 1.1–1.3) with anterior margin concaved deeply twice and peculiarly pronounced antero-lateral shoulders; lateral margins slanting outwards with slightly concavity, posterior margin convex, degree of convexity more marked medially between sensillary bases; posterior corners somewhat extended; width of scutum greatest at PL corners; AL seta situated on inner side of lateral margin, and on the half of ASB. PL seta on extended respective corners. AM seta situated on sub-anterior margin, on the half of ASB. AM base in line with AL seta bases; relative length of the scutal setae, AM＞PL＞AL; AL, AM, and PL setae barbed with stout and short setules, resembling humeral setae in appearance, but not anchor-like post-humeral setae; The sensillary bases are surrounded by upheaval of an elliptical form, and each base round with several small ridges. Sensillarly bases not so widely separated from each other, and slightly below portion in line with PL seta bases; tip of filamentous sensilla with trifurcate, proximal shaft finely nude; large punctations distinctly distributed on scutum, except around AM base. Scutal measurements: AW, 68 (63, 58–68); PW, 117 (115, 113–117); SB, 35 (33, 32–35); ASB, 68 (63, 60–68); PSB, 31 (32, 31–33); AP, 33 (34, 33–35); AM, 73 (72, 72–73); AL, 43 (42, 40–43); PL, 56 (55, 54–56); S, 102 (97, 93–102).

Idiosomal setae: 5–7 pairs HS, measuring 53 on average (55, 47–58); DS with well developed barbs; number of DS varies from 120–142 (122 in holotype), arranged in irregular rows; post-humeral and dorsal idiosomal setae in central portion peculiarly anchor-like, unique for the genus, while humeral and dorsal marginal setae are usually covered with a moderate number of thick, short setules for almost their entire length, similar to scutal setae. Length of dorsal setae as follows: medial seta of first post-humeral row 54 (59, 54–62); dorsal medial seta in central position 45 (46, 45–47); posterodorsal medial seta 44 (47, 44–48); dorsal terminal seta 45 (47, 45–49); two pairs of StS usually recognized, but one pair of sternal setae observed in several specimens, and posterior sternal setae undistinguishable from preanal setae. StS 2–2 [anterior 44 (44, 43–44), posterior 41 (41, 40–41)], covered with a moderate number of stout and differentiated setules on their entire length; 72–86 preanal setae and 56–66 postanal setae (72 and 58 setae in holotype, respectively) similar in nature to StS but shorter; length of medial seta in first preanal setal row 35 (34, 33–35); medial seta in first postanal setal row 30 (31, 30–32), different in nature from dorsal marginal setae, but shorter; total number of idiosomal setae, excluding coxal setae, 252–284 (256 in holotype).

Leg: IP = 1227 (mean 1166, range 1124–1227). All 7-segmented, terminating in a pair of claws and a slender claw-like empodium. Onychotriches lacking. Conspicuous small punctations on coxae and free leg segments. No modified leg segments.

Leg I: 413 (414, 410–419) long; tarsus + pretarsus 104 (106, 105–107) long by 23 (23, 22–23) wide; coxa with 1 B; trochanter 1B; basifemur 1B; telofemur 4B and one nude seta 36 (36, 33–37); genu 4B, 9–11 genualae, 28 on average (28, 26–30), long microgenuala 8 (7, 6–8); tibia 8B, 2 tibialae [proximal tibiala 36 (33, 31–36), distal tibiala 33 (33, 33–34)], slightly long microtibiala 5 (5, 4–5); tarsus 23B, stout and elongate tarsala 52 (50, 48–54) located on proximal 1/4 of segment, microtarsala 3 (3, 3), a nude subterminala 28 (26, 25–28), a short parasubterminala 15 (14, 13–15), a short pretarsala 15 (14, 13–15).

Leg II: 383 (348, 328–383) long; tarsus + pretarsus 102 (97, 92–105) long by 21 (21, 19–22) wide; coxa 1B; trochanter 1B; basifemur 2B; telofemur 4B; genu 3B, 7 genualae 31 on average (29, 27–31); tibia 6B, 2 tibialae [proximal tibiala 27 (29, 27–31), distal tibiala 30 (32, 30–34)]; tarsus 18B, tarsala stout and blunt 27 (33, 27–37), microtarsala 3 (3, 3), a short pretarsala 15 (14, 13–15).

Leg III: 431 (404, 386–434) long; tarsus +

pretarsus 108 (110, 108–111) long by 21 (20, 20–21) wide; coxa 1B situated on the anterior margin; trochanter 1B; basifemur 2B; telofemur 3B; genu 2B, 7 genualae 30 on average (29, 28–30); tibia 6B, stout and blunt tibiala 38 (35, 35–40), no microtibiala; tarsus 16B.

Etymology. This species is named in honor of Associate Professor Fumio Hayashi, Department of Biological Sciences, Tokyo Metropolitan University, in recognition of his substantial contribution to our knowledge of the ectoparasites of amphibious sea snakes in Japan.

Family **Trombiculidae**

Genus *Schoutedenichia* Jadin and Vercammen-Grandjean, 1954

Schoutedenichia masunagai Takahashi, Misumi and Takahashi, sp. nov.

[Japanese name: Masunaga-tamatsutsugamushi]

(Fig. 3)

Trombiculidae sp. b: Hayashi and Masunaga, 2001: 6, 7, fig. 2.

Notes. Jadin and Vercammen-Grandjean (1954) created the genus *Schoutedenichia* with *S. fulleri* Jadin and Vercammen-Grandjean, 1954 as the type specimen. Vercammen-Grandjean (1958) revised the genus and listed 41 species and subspecies. The chiggers of this genus are predominantly African with many records (Goff, 1983; Taufflieb, 1960, 1961, 1966; Vercammen-Grandjean, 1960a, 1963, 1964a, b; Vercammen-Grandjean and Yang, 1963, 1964; Vercammen-Grandjean and Watkins, 1965). However, several species in this genus have been recorded from non-African locations, including Southeast Asia (Audy, 1956; Domrow, 1962; Mitchell and Nadchatram, 1966; Mo *et al.*, 1959; Schluger *et al.*, 1960; Upham and Nadchatram, 1968; Wharton and Hardcastle, 1946; Womersley, 1952), Australia (Domrow and Lester, 1985), Europe, and Russia (Kudryashova, 1998; Stekolnikov and Daniel, 2012). In Japan, *Neoschoengastia atollensis* Wharton and Hardcastle, 1946 initially collected from wild birds at Okinawa, southern Japan, had been transferred into the genus *Schoutedenichia* (Vercammen-Grandjean, 1960b). Subsequently, Suzuki (1982) reported unfed *S. nagasakiensis* larvae collected from soil samples at Unzen, Nagasaki Prefecture. *S. masunagai* sp. nov. is the third species of this genus from Japan.

Diagnosis of larva. SIF = 4B-B(N)-3-2110.0000; fPp = B/B/NNB/4B; fCx = 1.1.1; IP = 715 (731, 715–757); pST = N; fSC = PL＞AL＞AM; DSF = 2H, 8–10, 6–8, 8, 8, 6, 4, 2; 2H, 8, 4–5, 10, 2, 6–8, 6, 2–4,4, 2; 2H, 8, 6, 8, 2, 8, 8, 6, 4, 2; DS = 44–54; fV = 59–68; NDV = 107–114.

Type specimens. Holotype (NSMT-Ac 13699): larva from *L. laticaudata* collected from a coral reef at Uganzaki (24°26′30″N, 124°4′53″E), Ishigakijima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture, Japan, on 24-VII-2008 by G. Masunaga and M. Takahashi. Paratypes: (NSMT-Ac 13700–13701), 2 larvae from the same host, location, and collection date as the holotype collected by G. Masunaga and M. Takahashi; (NSMT-Ac 13702–13703), 2 larvae from the same host and location as holotype, collected on 7-VII-1999 by F. Hayashi and G. Masunaga; (NSMT-Ac 13704–13705), 2 larvae from *L. laticaudata* collected from Hoshizuna-kaigan (24°26′16″N, 123°46′40″E), Iriomotejima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture, Japan, on 15～23-VII-1999 by F. Hayashi and G. Masunaga; (NSMT-Ac 13706–13708), 3 larvae from *L. laticaudata* collected from Unarizaki (24°25′44″N, 123°46′7″E), Iriomotejima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture, Japan, on 20-VII-2008 by G. Masunaga, Y. Tahara, and M. Takahashi.

Other collection records. Unarizaki, Iriomotejima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture: 1 larva from *L. laticaudata*, 20-VII-2008, coll. G. Masunaga, Y. Tahara, and M. Takahashi. Uganzaki, Ishigakijima Island, Taketomi-cho, Yaeyama-gun, Okinawa Prefecture: 30 larvae from *L. laticaudata*, 24-VII-2008, coll. G. Masunaga and M. Takahashi; 2 larvae from *L. laticaudata*, 25-VII-2008, coll. G. Masunaga and M. Takahashi; 40 larvae from 6 *L. laticaudata*, 28-VII-2009, coll. G. Masunaga and M.

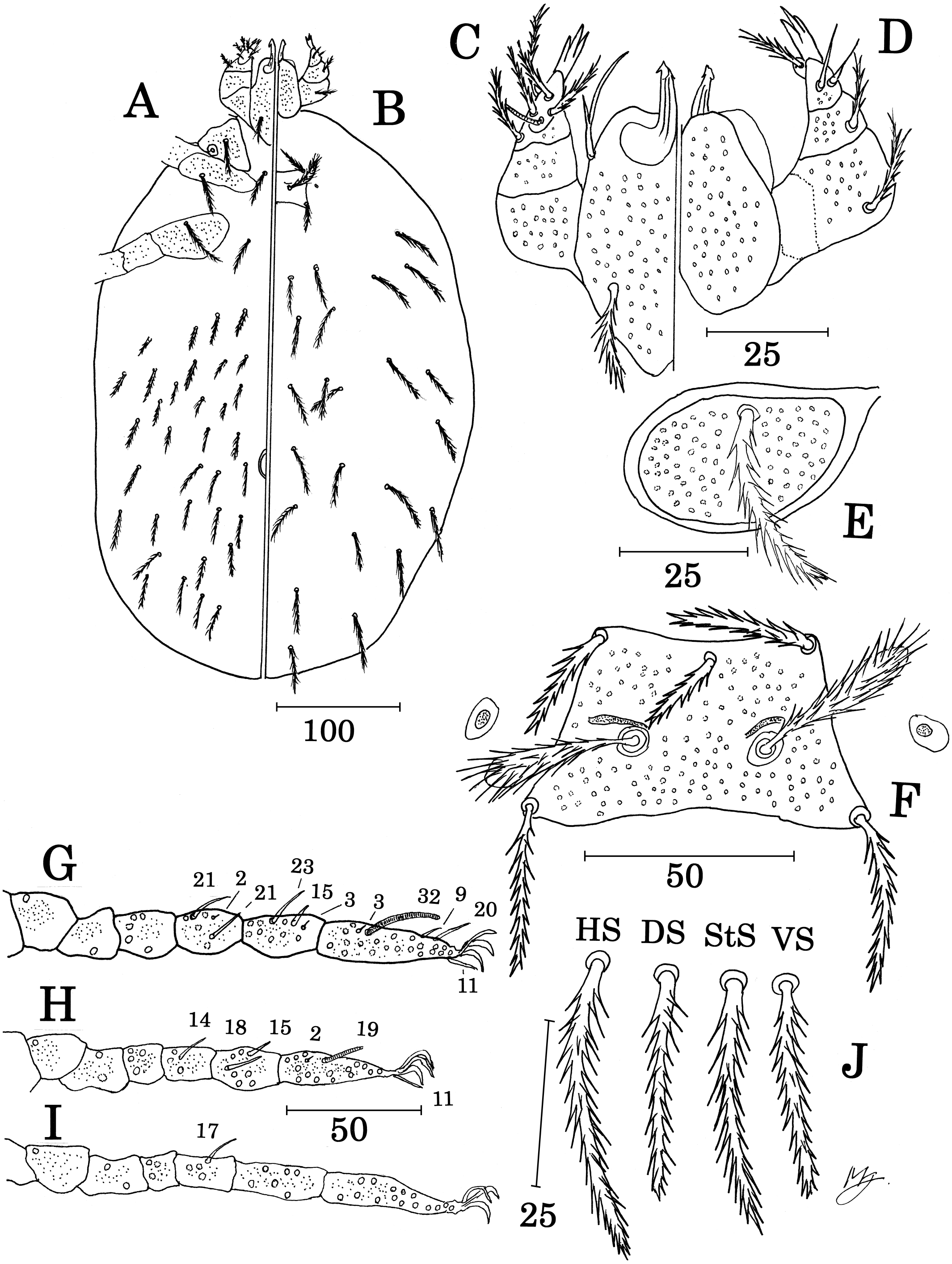


Fig. 3. *Schoutedenichia masunagai* sp. nov., insufficiently engorged larva. A and B, ventral and dorsal aspects of larva; C and D, ventral and dorsal aspects of gnathosoma; E, coxa III; F, scutum and eyes on ocular plate; G, H, and I, legs I, II, and III; J, details of setae (abbreviations: HS, humeral seta; DS, dorsal medial seta of first post-humeral row; StS, anterior sternal seta; VS, ventral medial seta of first post-sternal row). The length of the scale bar for each structure is in micrometers.

Takahashi.

Description of larva. Live insufficiently engorged larvae, white in color.

Idiosoma: Body longer than wide, measuring 415 (475, 404–606) long by 293 (352, 268–494) wide. One pair of eyes on the ocular plate, located by scutum at level of sensillary bases; diameter of eyes 7 (6, 4–7).

Gnathosoma: Gnathosomal base moderately punctated, 57 (59, 57–61) wide at level of the bases of a pair of branched setae; posterior margin of cheliceral bases rounded, 36 (36, 35–40) long by 19 (18, 17–23) wide; cheliceral blade 21 (19, 17–22) long by 4 (4, 4–5) wide, with one longer subapical dorsal tooth and one short ventral tooth (tricuspid cap). Galeal seta mainly nude, sometimes one branch (holotype). fPp = B/B/NNB/4B; palpal claw stout, 13 (13, 11–14) long, 3 pronged, with axial prong 7 (7, 7–8), 2 accessory prongs of unequal length and shorter than axial prong.

Scutum: Shape trapezoidal, large punctations distinctly distributed except around AM base and sensillary bases; wider than long, PW/SD ratio 1.7 (1.7, 1.7–1.9) with shallowly sinuous anterior margin and two slightly convex anterior corners; lateral margins slanting outwards with slightly concavity, posterior margin slightly concave, degree of concavity more marked medially, between sensillary bases; posterior corners somewhat extended; width of scutum greatest at PL corners. AL and PL setae in respective corners, AM seta submarginal and PL setae situated on extended PL margins. AM base slightly below portion in line with AL seta bases; AL, AM, and PL setae barbed with stout and short setules, resembling dorsal setae in appearance; Sensillary bases round and widely separated, anterior margins of sensillary bases with midline of lateral margins.

PL＞AL＞AM; sensillae lanceolate and covered with many long bristles, proximal shaft finely nude; an “eye-lid” ridge on anterior margins of sensillary bases. Other scutal setae with a moderate number of short, thick setules for almost their entire length. Scutal measurements: AW, 50 (51, 49–53); PW, 74 (77, 74–83); SB, 33 (32, 29–36); ASB, 27 (28, 27–29); PSB, 17 (17, 16–17); AP, 43 (43, 42–43); AM, 21 (19, 18–21); AL, 39 (37, 35–39); PL, 47 (44, 42–47); S, 47 (48, 47–49).

Idiosomal setae: One pair HS, measuring 47 (47, 46–47); DS with well-developed barbs; number of DS varied from 44–54 as follows: DSF = 2H, 8–10, 6–8, 8, 8, 6, 4, 2; 2H, 8, 4–5, 10, 2, 6–8, 6, 2–4, 4, 2; 2H, 8, 6, 8, 2, 8, 8, 6, 4, 2; DS in holotype arranged 2, 8, 8, 8, 8, 6, 4, 2; dorsal setae covered with a moderate number of thick and short setules for almost their entire length. HS and DS similar to scutal setae. Length of dorsal setae as follows: medial seta of first post-humeral row 36 (33, 30–36); dorsal medial seta in central position 36 (35, 34–36); posterodorsal medial seta 34 (35, 33–37); dorsal terminal seta 38 (38, 34–41); StS 2–2 [anterior 39 (38, 36–39), posterior 28 (29, 28–31)], covered with a moderate number of short setules on the surface of their entire length, more pliant than preanal setae; 24–36 VS (36 in holotype) similar in nature to StS but shorter; length of medial seta in first preanal setal row 20 (21, 20–23); 32–36 CS (32 in holotype) similar in nature to DS but shorter and more slender; length of medial seta in first postanal row 34 (35, 34–36). Total number of idiosomal setae, excluding coxal setae 107–114 (114 in holotype).

Leg: IP = 715 (mean, 731; range, 715–757). All 7-segmented, terminating in a pair of claws and a slender claw-like empodium. Onychotriches lacking. Conspicuous small punctations on coxae and free leg segments. No modified leg segments.

Leg I: 250 (260, 250–273) long; tarsus + pretarsus 61 (66, 61–70) long by 18 (18, 17–18) wide; coxa 1B; trochanter 1B; basifemur 1B; telofemur 5B; genu 4B, 2 genualae [dorsal genuala 21 (19, 18–21), distal genuala 21 (20, 19–21)], microgenuala 2 (3, 2–3); tibia 8B, 2 tibialae [proximal tibiala 23 (23, 22–23), distal tibiala 15 (17, 15–19)], microtibiala 3 (3, 3–4); tarsus 20B, tarsala stout and blunt 32 (31, 31–32), microtarsala immediately proximal to base of tarsala 3 (2, 2–3), a nude subterminala 20 (22, 20–25), a short parasubterminala 9 (11, 9–15), a short pretarsala 11 (11, 11–12).

Leg II: 218 (220, 216–227) long; tarsus + pretarsus 51 (50, 46–54) long by 15 (16, 15–17) wide; coxa 1B; trochanter 1B; basifemur 2B; telofemur 4B; genu 3B, genuala 14 (14, 14–15); tibia 6B, 2 tibialae [proximal tibiala 18 (16, 15–18), distal tibiala 15]; tarsus 15B, tarsala stout and blunt 19 (19, 18–20), microtarsala 2 (3, 2–3), a short pretarsala 11 (12, 11–12).

Leg III: 247 (250, 246–257) long; tarsus + pretarsus 63 (63, 60–67) long by 14 (14, 13–14) wide; coxa 1B; trochanter 1B; basifemur 2B; telofemur 3B; genu 3B, genuala 17 (18, 17–18); tibia 6B (tibiala absent); tarsus 15B.

Etymology. It is a pleasure to name the new species for Dr. Gen Masunaga, who not only collected chiggers from sea kraits that hosted this new species, but contributed much to our knowledge of the ecology of sea snakes in Japan.

Remarks. Although this new species is closely related to *S. centralkwangtunga* (Mo, Chen, Ho and Li, 1959), *S. trisetosa* Upham and Nadchatram, 1968 and *S. shalleri* Mitchell and Nadchatram, 1966, this species is separated from these species by the shape and size of the scutum, the form of the sensillae and the combination of characters mentioned in the diagnosis.

The trombiculine genus *Schoutedenichia* is predominantly African, but the newly identified species increases a total number of known *Schoutedenichia* species in Asia to 10: *S. atollensis* (Wharton and Hardcastle, 1946), *S. bisetosa* Domrow, 1962, *S. centralkwangtunga* (Mo, Chen, Ho and Li, 1959), *S. jubbulporensis* (Womersley, 1952), *S. nagasakiensis* Suzuki, 1982, *S. nausheraensis* (Womersley, 1952), *S. shalleri* Mitchell and Nadchatram, 1966, *S. trisetosa* Upham and Nadchatram, 1968, *S. vercammeni* Audy, 1956, and the present new species.

Discussion

Association with ectoparasites and unique hosts — sea snakes

There are 70 species of sea snakes in the world, found in 4 of the 15 living families of snakes. Two of the four families include venomous sea snakes, the Laticaudidae (4 species) and the Hydrophiidae (53 species), some species of which have venom toxicity more than 10 times that of the most lethal terrestrial elapid snake venom, making them among the most potentially dangerous of all animals (Broad *et al.*, 1979; Pickwell, 1994; Tamiya, 1975). These two families are closely related to each other and to the terrestrial cobras of the family Elapidae (Heatwole, 1999). However, the systematics of sea snakes has been variously classified at the familial and subfamilial level, and there is no universal agreement on the scheme to be used (Heatwole and Cogger, 1993). Following the review by Heatwole (1999), new species and re-classified species were added. Thus, eight species are currently recognized in the genus *Laticauda*: *L. semifasciata* (Reinwardt, 1837); *L. laticaudata* (Linnaeus, 1758); *L. colubrina* (Schneider, 1799); *L. frontalis* (De Vis, 1905); *L. shistorhynchus* (Guenther, 1874); *L. guineai* Heatwole, Busack et Cogger, 2005; *L. saintgironsi* Cogger et Heatwole, 2006; and *L. crockery* Slevin, 1934. These laticaudids are restricted to the tropical waters of the western Pacific and eastern Indian oceans (Heatwole and Guinea, 1993; Heatwole, 1999).

Laticaudids, such as the amphibious sea snakes (sea kraits), that live on land and water, have been reported to have evolved a marine mode of life independent of true sea snakes, or Hydrophiidae, which never leave the water (Cogger and Zweifel, 1998; Keogh, 1998). The common name of the sea krait comes from the resemblance of these snakes to land kraits, ringed terrestrial Asian venomous snakes of the genus *Bungarus*, family Elapidae. Sea kraits have developed flattened paddle-like tails, enabling them to swim rapidly, but have retained a cylindrical body shape similar to their terrestrial relatives. They also have enlarged specialized ventral scales for crawling on land, unlike Hydrophiidae species, which have belly scales that are either greatly reduced in size or absent (Easton, 2003). Ecological data suggest that the Laticaudidae evolutionarily departed from an elapid stem much later than other Hydrophiidae. This would explain their parasitic association with two tick species, *Amblyomma nitidum* Hirst and Hirst, 1910 and *Aponomma fimbriatum* (Koch, 1844), which are lacking in other Hydrophiidae (Easton, 2003; Hayashi and Masunaga, 2001; Takahashi *et al*., 2012a). *Amblyomma* is the only genus of acarine ectoparasites hosted by *Laticauda*, and the latter genus, *Aponomma*, is generally host specific to terrestrial snakes and varanid lizards (Wilson, 1970, 1975; Sonenshine, 1991).

Vercammen-Grandjean (1972) described a new species of chigger, *Eutrombicula poppi*, from *Laticauda* sp. It is well known that several representatives of the genus *Eutrombicula* parasitize terrestrial snakes. One of the species described here for the first time, *Ancoracarus hayashii* sp. nov., infests laticaudid snakes, but not other members of Hydrophiidae, and it provids further evidence for the later divergence of this genus of snakes than that of the true sea snakes (Hydrophiidae).

The new genus *Ancoracarus* is closely related to the genus *Eltonella* Audy, 1956, and many species of *Eltonella* are recorded from various terrestrial snakes (Vercammen-Grandjean, 1965). Further, Japanese laticaudid snakes have been found to have infestations of their trachea and longitudinal lung by 4 species of chigger mites (*Vatacarus ipoides* Southcott, 1957, *V. kuntzi* Nadchatram and Radovsky, 1971, *Iguanacarus alexfaini* Nadchatram, 1980 and *Iguanacarus* sp.) (Takahashi *et al*., 2012b), that are highly specific to laticaudid snakes. These chiggers are maggot-like endoparasites unlike the typical shape of ectoparasitic chiggers, lacking in other Hydrophiidae snakes (Nadchatram and Radovsky, 1971; Nadchatram, 2006; Takahashi *et al*., 2012b).

Timing of the infestation of chigger larvae on the sea snakes

Of the 70 species of marine snakes in the world, ecto- and endoparasitic chiggers are recorded only in laticaudid species (Hayashi and Masunaga, 2001; Nadchatram, 2006; Takahashi *et al*., 2012b). True sea snakes (family Hydrophiidae) are completely adapted to a marine way of life. They are livebearers and never come onto land, either voluntarily or to breed (Heatwole and Cogger, 1993). Thus, they have no opportunity to be infested with unfed terrestrial chiggers. In contrast, sea kraits (family Laticaudidae) are oviparous, and gather in shore-based aggregations to breed or to rest. They lay their eggs in rock crevices and/or on cave beds. It is during this period that the life histories of the ecto- and endoparasitic chiggers and sea kraits appear to overlap; the sea kraits are often infested with unfed terrestrial larval chiggers. Therefore, all chiggers that were found under the scales are considered insufficiently engorged larvae.

Host relationships between chiggers and sea kraits

Hayashi and Masunaga (2001) examined a total of 147 individuals of sea kraits, consisting of *L. semifasciata* (27), *L. laticaudata* (99) and *L. colubrina* (21), and 77 individuals of true sea snakes, consisting of *Emydocephalus ijimae* Stejneger, 1898 (58), *Hydrophis melanocephalus* Gray, 1849 (11) and *H. ornatus* Mittleman, 1947 (8), collected from Ishigakijima Island and Iriomotejima Island in the Nansei Islands of Japan. Ectoparasitic chiggers, especially *A. hayashii* sp. nov. and *S. masunagai* sp. nov. described here were collected only from the laticaudid sea snakes, and not from the true sea snakes. Subsequently, we also investigated ectoparasitic chigger mites from more than 100 laticaudid sea snakes collected from several of the Nansei Islands during 2007–2011. The above two new species were obtained from the same hosts listed by Hayashi and Masunaga (2001) (unpublished data).

Ancoracarus hayashii sp. nov. was collected from all three species of Japanese sea kraits (Laticaudidae) (*L. laticaudata, L. colubrina* and *L, semifasciata*). However, *S. masunagai* sp. nov. was collected only from *L. laticaudata.* Hayashi and Masunaga (2001) did not find either of these species on any of the 77 true sea snakes (Hydrophiidae) that they examined. Therefore, *A. hayashii* sp. nov. is considered to be restricted to parasitizing the genus *Laticauda*, but is not host species specific. Eight sea krait species are currently recognized in the world (Heatwole and Guinea, 1993; Heatwole, 1999; Takahashi *et al*., 2012b). It is possible that *A. hayashii* sp. nov. is parasitic on the remaining five sea krait species.

Almost all known species of *Schoutedenichia* parasitize either mammals (Prosimiens to Rongeurs) or birds and have a wide host range (Vercammen-Grandjean, 1958, 1968). The present study is the first record of a species of *Schoutedenichia* parasitic on a reptile, and it was found on only one species, *L. laticaudata*. Thus, *S. masunagai* sp. nov. is considered to have close host specificity to *L. laticaudata.*

Expansion of chigger distribution

Three laticaudid sea snakes (*L. semifasciata, L. laticaudata* and *L. colubrina*) are found in Japan, mainly around the Ryukyu Archipelago. The habitats of these species overlap, and they are non-territorial. If different species of laticaudid sea snakes interacted in a spawning ground or other place, unfed larval chiggers parasitizing one snake could expand its hosts domain and distribution leading to further opportunities for diffusion. Indeed, on Iriomotejima Island, all three species are often found on coral reefs and sometimes two species use the same rock crevice to rest or digest a meal. Notably, 20–30 *L. semifasciata* and almost the same number of *L. laticaudata* gather within a single cave from June to August (Takahashi *et al*., 2012b). As mentioned above, *A. hayashii* sp. nov. was collected from all Japanese sea krait species and from all localities (Iriomotejima Island, Ishigakijima Island and Kodakarajima Island).

Acknowledgments

We express our gratitude to Associate Professor Fumio Hayashi of the Department of Biological Sciences, Tokyo Metropolitan University, for his kindness in offering us the valuable chiggers collected from amphibious sea snakes. Our sincere appreciation goes out to Dr. Gen Masunaga and Mr. Yoshitaka Tahara, formerly of the Tropical Biosphere Research Center, University of the Ryukyus, Okinawa, for their dedicated cooperation in collecting chiggers from sea snakes during field surveys. Our thanks are also due to Professor Hidetoshi Ota of the Institute of Natural and Environmental Sciences, University of Hyogo, and Associate Professor Mamoru Toda of the Tropical Biosphere Research Center, University of the Ryukyus, Okinawa, for their kind help and arrangements in the field collection of sea snakes in the Ryukyu Archipelago. We sincerely thank Dr. Kimito Uchikawa, formerly of the Department of Parasitology, School of Medicine, Shinshu University, Matsumoto, Japan, for his kindness in reading the manuscript and providing valuable comments.

References

Audy, J. R. 1956. Malayan trombiculid mites. 1. *Shoutedenichia vercammeni* n. sp. with a note on the genus. Bulletin of the Raffles Museum, 28: 81–85.

Broad, A. J., S. K. Sutherland and A. R. Coulter 1979. The lethality in mice of dangerous Australian and other snake venom. Toxicon, 17: 661–664.

Cogger, H. G. and R. G. Zweifel 1998. Encyclopedia of Reptile & Amphibians. 240 pp. Academic Press, London.

Domrow, R. 1962. The genus *Schoutedenichia* in S. E. Asia (Acarina, Trombiculidae). Acarologia, 4: 358–361.

Domrow, R. and L. N. Lester 1985. Chiggers of Australia (Acari: Trombiculidae): an annotated checklist, keys and bibliography. Australian Journal of Zoology, Supplementary Series, (114): 1–111.

Easton, E. R. 2003. Ecology of ticks, including a new record of *Aponomma* (Ixodoidea: Ixodidae) from *Laticauda colubrina* on Loloata Island of Papua New Guinea. Hamadryad, 27: 256–259.

Goff, M. L., R. B. Loomis, W. C. Welbourn and W. J. Wrenn 1982. A glossary of chiggers terminology

(Acari: Trombiculidae). Journal of Medical Entomology, 19: 221–238.

Goff, M. L. 1983. Two new species of *Schoutedenichia* (Acari: Trombiculidae) from a shrew (Insectivora) in Tanzania, east Africa. International Journal of Entomology, 25: 74–78.

Hayashi, F. and G. Masunaga 2001. Ecological notes on the tick, *Amblyomma nitidum*, and trombiculid mites infesting sea snakes in Japan. The Acarological Society of Japan, 10: 1–17. (In Japanese with English summary.)

Heatwole, H. and H. Cogger 1993. Family Hydrophiidae, In Glasby, C. G., G. J .B. Ross and P. L. Beesley (eds.): Fauna of Australia Vol. 2A Amphibia and Reptilia, pp. 1–20. Australian Government Publishing Service, Canberra.

Heatwole, H. and M. L. Guinea 1993. Family Laticaudidae, In Glasby, C. G., G. J. B. Ross and P. L. Beesley (eds.): Fauna of Australia Vol. 2A Amphibia and Reptilia, pp. 1–8. Australian Government Publishing Service, Canberra.

Heatwole, H. 1999. Sea Snakes, 2nd edn. University of New South Wales Press Ltd and Krieger Publishing Company. 148 pp. Malabar, Florida.

Jadin, J. B. and P. H. Vercammen-Grandjean 1954. Cinq nouvelles especes de Trombiculides (Acarina), Trombidiidae du Ruanda-Urundi, et creation d'un genre nouveau: *Schoutedenichia*, Annales du Musee Royal du Congo Belge Sciences Zoologiques, 1: 194–206.

Keogh 1998. Molecular phylogeny of elapid snakes and a consideration of their biogeographic history. Biological Journal of the Linnean Society, 63: 177–203.

Kudryashova, N. I. 1998. Chigger Mites (Acariformes, Trombiculidae) of East Palearctics. 342 pp. KMK Scientific Press Ltd, Moscow. (In Russian.)

Mitchell, C. J. and M. Nadchatram 1966. Seven new species of chiggers from central India, with a redescription of *Leptotrombidium (L) pelta* (Womersley, 1953) (Acarina: Trombiculidae). Journal of Medical Entomology, 3: 61–77.

Mo, C. F., C. R. Chen, T. S. Ho and Y. L. Li 1959. Three new species of chigger mites (Acarina, Trombiculidae) from China. Acta Entomologica Sinica, 9: 253–263. (In Chinese with English summary.)

Nadchatram, M. and F. J. Radovsky 1971. A second species of *Vatacarus* (Prostigmata, Trombiculidae) infesting the tracheae of amphibious sea-snakes. Journal of Medical Entomology, 8: 37–40.

Nadchatram, M. and A. L. Dohany 1974. A pictorial key to the subfamilies, genera and subgenera of southeast Asian chiggers (Acari, Prostigmata, Trombiculidae). Bulletin Institute for Medical Research Kuala Lumpur, Malaysia, 16: 1–67.

Nadchatram, M. 2006. A review of endoparasitic acarines of Malaysia with special reference to novel endoparasitism of mites in amphibious sea snakes and supplementary notes on ecology of chiggers. Tropical Biomedicine, 23: 1–22.

Pickwell G. V. 1994. A review of contemporary sea snake toxinology: chemistry, pharmacology, immunology and clinic-pathological aspects. In Gopalakrishnakone (ed.): Sea Snake Toxinology, pp. 93–166. Singapore University Press, Singapore.

Schluger, E. G., I. M. Grochoyska, Dan Van Ngu, Nguyen Xuan Hoe and Do Kinh Tung 1960. Fauna of the chiggers (Acariformes, Trombiculidae) of North Vietnam. Parasitologieskii Sbornik, 19: 169–193. (In Russian with English summary.)

Sonenshine, D. E. 1991. Biology of Ticks. Volume 1. 447 pp. Oxford University Press, New York.

Stekolnikov, A. and M. Daniel 2012. Chigger mites (Acari: Trombiculidae) of Turkey. Zootaxa, 3216: 1–104.

Takahashi, M., H. Misumi, T. Kaito, T. Kuriyama and H. Fujita 2012a. First record of *Amblyomma geoemydae* tick on the snake *Dinodon semicarinatum,* with records of ticks on snakes in Japan. Annual Report of Ohara General Hospital, 51: 35–38.

Takahashi, M., H. Misumi, R. Yokomizo, G. Masunaga, Y. Tahara, K. Kameda, M. Toriba, Y. Takahashi, T. Kadasaka, H. Moriguchi, H. Takahashi, T. Kishimoto, N. Takada and H. Fujita 2012b. Reservoir hosts of endoparasitic chigger mites, sexual distinction in the engorged larvae of *Vatacarus ipoides* Southcott 1957 and *V. kuntzi* Nadchatram and Radovsky 1971, and lung structures of sea kraits isolated from the Nansei Islands of Japan. Annual Report of Ohara General Hospital, 51: 39–58.

Tamiya, N. 1975. Sea snake venoms and toxins. In Dunson, W. A. (ed.): The Biology of Sea Snakes, pp. 385–415. University Park Press, Baltimore.

Taufflieb, R. 1960. Etude d'une collection de Trombiculidae d'Afrique Occidentale. Acarologia, 2: 224–237.

Taufflieb, R. 1961. Notes sur les Trombiculidae (Acarina) de la region Brazzaville deux nouveaux *Schoutedenichia* et redescription de *Schongastiella taufflieb*i Lavoipierre, 1955. Acarologia, 3: 578–584.

Taufflieb, R. 1966. Quatre nouveaux *Schoutedenichia* de la Republique Centrafricaine. Acarologia, 8: 287–295.

Upham, R. W. and M. Nadchatram 1968. Three new species of trombiculid mites from Malaysia with a redescription and notes on *Leptotrombidium muridia* (Womersley) (Acarina, Trombiculidae). Journal of Medical Entomology, 5: 195–203.

Vercammen-Grandjean, P. H. 1958. Revision du genre *Schoutedenichia* Jad. et Verc. Annales du Musee Royal du Congo Belge Sciences Zoologiques, 65: 1–101.

Vercammen-Grandjean, P. H. 1960a. Trombiculidae larvaires de l'afrique septentrionale et centrale. Archives del Institut Pasteur d Algerie, 38: 50–69.

Vercammen-Grandjean, P. H. 1960b. Introduction a un essai de classification rationnelle des larves de *Trombiculinae* Ewing 1944 (Acarina-Trombiculidae). Acarologia, 2: 469–471.

Vercammen-Grandjean, P. H. 1963. Un *Schoutedenichia* parasite intranasal du lievre African (Trombiculidae-Acarina). Acarologia, 5: 249–251.

Vercammen-Grandjean, P. H. and Y. M. Yang 1963. Une nouvelle larve de *Schoutedenichia* parasite des oreilles d'une musaraigne africaine (Trombiculidae-Acarina). Acarologia, 5: 256–258.

Vercammen-Grandjean, P. H. 1964a. Deux *Schoutedenichia* parasites d'oiseuax (Trombiculidae-Acarina). Acarologia, 6: 118–122.

Vercammen-Grandjean, P. H. 1964b. *Ascoschoengastia annulata* Lawrence 1949 est un veritable *Schoutedenichia* (Trombiculidae). Acarologia, 6: 111–113.

Vercammen-Grandjean, P. H. and Y. M. Yang 1964. Un *Schoutedenichia* parasite de lemurien (Trombiculidae-Acarina). Acarologia, 6: 123–126.

Vercammen-Grandjean, P. H. 1965. Revision of the genera: *Eltonella* Audy, 1956 and *Microtrombicula* Ewing, 1950, with descriptions of fifty new species and transferal of subgenus *Chiroptella* to genus *Leptotrombidium* (Acarina, Trombiculidae). Acarologia, 7: 34–257.

Vercammen-Grandjean, P. H. and S. G. Watkins 1965. *Schoutedenichia gigantica* and *S. tiptoni*, two new and extraordinary species from Madagascar (Acarina: Trombiculidae). Acarologia, 7: 684–694.

Vercammen-Grandjean, P. H. 1968. The Chigger Mites of the Far East (Acarina: Trombiculidae and Leeuwenhoekiidae). Special Study. 135 pp. United States Army Medical Research and Development Command, Washington, D. C.

Vercammen-Grandjean, P. H. 1972. *Eutrombiculla (E.) poppi,* a new chigger from a sea snake (ACARINA, TROMBICULIDAE). Opuscula Zoologica, 114: 1–3.

Wharton, G. W. and A. B. Hardcastle 1946. The genus *Neoschoengastia* (Acarinida: Trombiculidae) in the western Pacific area. Journal of Parasitology, 32: 286–322.

Wilson, N. 1970. New distributional records of ticks from Southeast Asia and the Pacific (Metastigmata, Argasidae, Ixodidae). Oriental Insects, 4: 37–46.

Wilson, N. 1975. Fouling organisms and parasites associated with the skin of sea snakes. In Dunson, W. A. (ed.): The Biology of Sea Snakes, pp. 251–265. University Park Press, Baltimore.

Womersley, H. 1952. The scrub typhus and scrub-itch mites (Trombiculidae, Acarina) of the Asiatic-Pacific region. Records of the South Australian Museum, 10: 1–673.