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The Systematic Position, Morphology and Bionomics of *Acanthopsyche* (*Eumetisa*) *taiwana* Sonan, 1935, Newly Recorded from the Ryukyus, Japan (Lepidoptera: Psychidae)*

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Abstract. Oiketicinine species, *Acanthopsyche* (*Eumetisa*) *taiwana* Sonan, 1935, is first recorded from the Ryukyus, Japan. *Eumetisa* is synonymized with the genus *Manatha* Moore, 1877. Therefore scientific name of this species is changed to *Manatha taiwana* (Sonan, 1935), **comb. nov.** The generic characters of *Manatha* is revised. Morphology and some behaviours of the larvae, pupae and adults of both sexes are given in comparison with other oiketicinine species. The male last instar larva is unique to hang the swollen exuviae of the penultimate instar at the posterior opening of the pupation case.

Key words: Psychidae, *Acanthopsyche* (*Eumetisa*) *taiwana*, *Manatha*, systematics, behaviour.

Introduction

During our field surveys of the insect fauna in the Ryukyus in1997 and 1999, psychid larvae bearing a conical case were found at several localities in Okinawa-jima. We reared them in Fukuoka, Kyushu, and acquired male and female adults of a species of Psychidae. This species agrees with the original description of *Eumetisa taiwana* (Sonan, 1935) hitherto known from Taiwan. The Ryukyu specimens were found to be identical with the holotype of *E. taiwana*.

This species was first described as *Acanthopsyche* (*Eumetisa*) *taiwana*, designated originally as the type species of the subgenus *Eumetisa*, that was also proposed in the same paper (Sonan, 1935). The type series was from Taihoku (Taipei) and Jukilin (Shuhchiilin), Taiwan. Since then, no further record of the species has been published, and no species has been assigned to *Eumetisa*. In the original description of this species, Sonan treated only the male, and briefly described it as follows: body and antennae blackish brown; wings uniformly dark brown, shining copper brown; under surface similar to upper surface; tibiae white. Sonan (1935) stated that the subgenus *Eumetisa* is allied to the subgenus *Metisa* Walker, 1855, but the male of *Eumetisa* differs from the latter in several characters in wing venation.

Dierl (1971) was the first reviser of the subgenus *Eumetisa*, and concluded that it is extremely similar to *Brachycyttarus* Hampson, 1893, of the *Acanthopsyche* genus-group, and was distinguished from the latter in having 12 veins in the forewing. He also stated that there was no justification for separating *Eumetisa* from *Brachycyttarus* based only on this character.

Although Dierl (1971) suspected the validity of *Eumetisa*, he did not treat it as a synonym of *Brachycyttarus*, as he had no specimens of *A.* (*E.*) taiwana to be examined. He tentatively proposed the generic rank for *Eumetisa*, because many former subgenera of the genus *Acanthopsyche* Heylaerts, 1881, were currently raised to the generic status, and stated that further studies were needed for *Eumetisa*. Thus as the generic rank was given to *Eumetisa*, *Acanthopsyche* (*Eumetisa*) *taiwana* is currently treated as *Eumetisa taiwana*. However, its systematic position and detailed morphological characters including immature stages still remained to be clarified.

Our morphological study of this species, including the male genitalia and immature stages, as well as study on the bionomics based on the material from the

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Ryukyus, show that *Eumetisa* is distinct from *Brachycyttarus* and should be eventually synonymized with the genus *Manatha* Moore, 1877.

In this paper, we revised the generic characters of *Manatha*, provide detailed morphology of the adults, pupae and larvae of *E. taiwana*, record its bionomics, and discuss on synonymy of *Eumetisa*, and morphological and ecological characteristics of this species.

Materials and Methods

Materials

1) Larvae. The larvae of *Manatha taiwana* used in this paper were collected at the following localities in 1997 and 1999 in Okinawa-jima.

Hiji-gawa, Kunigami-son. 5 larvae on *Maesa tenara*, March 4, 1997 (M. Sugimoto); 1 larva on the same host, June 1, 1999 (T. Saigusa); 1 pupation case, March 1, 2001 (K. Araya).

Ishikawa-shi. Many larvae on *Quercus variabilis* and *Alpinia speciosa*, July 22, 1997 (M. Sugimoto); many larvae on *Quercus variabilis* and *Q. phillyraeoides*, December 22, 1997 (M. Sugimoto).

Sueyosi-kôen, Naha-shi. One larva and 2 old larval cases on fence, December 22, 1997 (M. Sugimoto).

Yona, Kunigami-son. One larva on wall of a hut in forest, April 1, 1999 (T. Saigusa).

2) Pupae. Five pupae of each sex reared from the above-mentioned field-collected larvae were used for external morphology.

3) Adults. More than 10 adults of each sex reared from the above-mentioned field-collected larvae were used for external morphology.

Methods

1) Rearing. Each of 5–20 field-collected larvae was reared with fresh leaves of *Quercus phillyraeoides* and/or *Alpinia speciosa* as food in a plastic box (22×16×8 cm) with a lid having a netted mesh (2×4 cm) at about 25°C of varying day length in the laboratory at Kyushu University in Fukuoka. Fresh leaves of *Maesa tenara* were also used for the Hijigawa larvae. Behaviours of larvae were observed both in the field and in the laboratory. Behaviour towards pupation was observed mainly in the laboratory.

2) Larval case. Structure of the larval case was observed on those of reared mature larvae and on the old fixed cases found in the field. They were examined under a binocular stereoscopic microscope (Olympus SZ60).

3) Immature stages. Mature larvae anesthetized with ethyl ether were used to observe coloration and shape and for photography. External structure of the larvae was observed on those preserved in 70% ethanol after being fixed with Carnoy's solution. To examine detailed structure and chaetotaxy, the larvae were treated with hot 15% KOH solution for 10–15 minutes, washed with distilled water, and observed in 70% ethanol under the binocular microscope or as a slide-mounted specimens with glycerol under a compound microscope (Olympus BX50).

Both living pupae and pupal exuviae were used for external morphology. Gross external structure was observed under the stereoscopic microscope. The compound microscope was used to observe detailed structure of the integument and chaetotaxy.

4) Adults. Coloration and size of body were observed and measured based on expanded dried specimens. Wing shape, size and venation were observed on slide-mounted wings which were cleared by removing scales from the wing surface with a minute cotton ball in 80% ethanol. For external morphology of male including the genitalia, dried specimens with the wings removed were placed in 10–15% KOH solution at 50°C for about 3 hours, then washed in distilled water, treated with 10% acetic acid, again washed in distilled water, and observed in 80% glycerol under the stereoscopic and the compound microscopes.

Immediately after emergence, adult females were removed from their pupal exuviae and photographed, and their coloration was observed. Then the females were fixed with Carnoy's solution for half a day, and preserved and observed in 80% ethanol under the stereoscopic microscope. Head structure was observed from a KOH-treated specimen under the compound microscope.

5) Drawing. Body structure of all stages was illustrated by using a section ocular micrometer and graph paper.

Results

Revised characterization of the genus Manatha

As stated in the introduction and discussed later, we consider *Eumetisa* as a synonym of *Manatha*. This genus was based only on *Manatha albipes* Moore, 1877 from Ceylon. Formerly many palaeotropical species were included in this genus (Hampson, 1892; Dalla Torre & Strand, 1929; Seitz & Gaede, 1932). However, according to Dierl (1971), in addition to the type species, only *M. scotopepla* Hampson, 1810 and *M. nigripes* Dierl, 1966 are assignable to this genus. Among the three species, *M. nigripes* from Nepal is considerably different from the other two, to the extent that it was separated from *Manatha*, and assigned to a new genus (Sugimoto & Saigusa, 2001). Below we revise the generic characters of the genus *Manatha* based on published descriptions and illustrations of *M. albipes* and *M. scotopepla* (Moore, 1882; Hampson, 1892, 1910; Dierl, 1966, 1971) and data of *M. taiwana* based on our specimens.

Genus *Manatha* Moore, 1877

Manatha Moore, 1877. Ann. Mag. Nat. Hist., **20**: 346. Type species: *Manatha albipes* Moore, 1877 (monobasic).

Manatha: Dierl, 1972. Mitt. Munch. Ent. Ges. (e.V.), **61**: 38–39.

Psyche (*Manatha*): Hampson, 1892. The Fauna of British India, Moths, **1**: 298.

Acanthopsyche (*Eumetisa*) Sonan, 1935. Trans. Nat. Hist. Soc. Formosa, **35**: 454. **Syn. nov.** Type species: *Acanthopsyche* (*Eumetisa*) *taiwana* Sonan, 1935 (monobasic).

Eumetisa: Dierl, 1971. Khumbu Himal, **4**(1): 66.

Male. Small to medium-sized psychids with rather slender body and broad wings 14–20 mm in expanse. Head small, narrower than mesonotum; compound eye small, its vertical diameter 4/5 as long as head height, longitudinal diameter 3/5 as long as head; eyes separated from each other by distance more than diameter of eye. Antenna 1/3 as long as forewing, consisting of about 20 segments; flagellum bipectinated to subapical flagellomere; pectinations very long; shaft and pectination covered with scales dorsally, the pectination with a style-like brush of several long hair-like scales at tip; ventral sides of shafts and of pectinations bearing long sensory hairs. Mouthparts, including labial palpus much reduced.

Forewing triangular in shape, 1.5–1.7 × as long as wide (length: distance between wing base and wing apex; width: shortest distance from tornus to costa), outer margin (termen) slightly shorter than inner margin (dorsum). Forewing entirely and densely covered with blackish scales, without markings. Forewing with 12 veins; discoidal cell slightly asymmetrical or symmetrical; 0.55–0.77 × as long as forewing, distinctly widened apically, with anterior margin arched (in *M. albipes* and *M. scotopepla*) or concave (in *M. taiwana*), and with anterior portion either somewhat longer than posterior portion (in *M. albipes*) or two portions almost subequal to each other (in *M. scotopepla* and *M. taiwana*); stem of M in discoidal cell simple, lacking posterior branch, so that cellula intrusa absent, but stem of M emitting median spur; Sc free from R_1 or partly anastomosed with it; R_3 and R_4 stalked for various lengths; R_5 arising from discoidal cell or short stalked with a common stem of R_3 and R_4; M_2 and M_3 connate or short stalked; CuP fused with middle of A_{1+2} at an acute angle; A_1 fused with A_2 at basal 1/3 of A_{1+2}, spur of A_1 arising at or a little proximad of the fusion of A_1 and A_2 (*M. scotopepla* and *M. taiwana*) or from A_{1+2} a little beyond the fusion (*M. albipes*).

Hindwing short oval, 3/4 as long as forewing, with costa more or less arched, termen rounded. Hindwing entirely covered with blackish scales. Hindwing with 8 veins; discoidal cell asymmetrical, 2/3 as long as hindwing, separated by simple stem of M, with anterior portion 2/3 as long as posterior portion, anterior discocellular (short basal section of M_1) weak, occasionally obsolete, then anterior portion of discoidal cell open; all veins free from discoidal cell; R_1 arising from middle of anterior margin of discoidal cell and soon fused with Sc; bases of Rs and M_1, and those of M_2 and M_3 closely approximate, respectively.

Legs rather slender; foreleg longest; fore tibia with a long epiphysis, which is almost as long as tibia, and arises from near base of tibia; mid and hind tibiae without spurs; 1st tarsomeres strongly elongated, much longer than 2nd tarsomeres. Legs with integument dark and clothed with blackish hair-scales on femora and tibiae, white in integument and clothed with white hair-scales on tarsi.

Abdomen slender, with apex slightly extending posteriorly beyond the level of tornus of hindwing; 8th tergum twice as long as wide, more or less widened anteriorly and laterally projecting into a short tapered anterolateral extensions; 8th sternum elongate, tapered posteriorly, and produced into a pair of long slender expansions from anterolateral corners.

Male genitalia extremely elongate; dorsum (tegumen+uncus) twice as long as wide, tapering posteriorly to apex which has a small notch; vinculum long, as high as dorsum, separated from dorsum by a long membranous incision from posterior margin; ventral portion of vinculum distinctly and evenly tapered anteriorly forming saccus, of which distal portion is extremely slender. Valva long and very slender for psychids, almost cylindrical as a whole; costa broad, as wide as anellifer; ampulla (cucullus of Davis, 1975; Dierl, 1964, 1972) rounded distally, extending posteriorly slightly beyond tip of dorsum; sacculus narrow; harpe (clasper of Dierl, 1964, 1972, sacculus of Davis, 1964, 1975) represented by a short projection apically furnished with 2 to several short spines; pulvillus (paired sclerites of anellus) well developed, as long as wide, rounded apically with a few spinules. Phallus long, slightly shorter than 0.8 times length of ring (measured between tips of dorsum and saccus), almost straight, with subapical dorsal protuberance on aedeagus.

Female

Vermiform and pupifug with very simple sclerites, head with simple eyespots and bud-like palpi. All other appendages completely obliterated. Ovipositor very short and simple (after Dierl, 1972).

The above description of the genus is partly incomplete because we have not examined specimens of the type species. The followings are believed to represent characters of generic significance within Psychidae, though they are based only on *M. taiwana*, but may also be applicable to other congeneric species.

Male: Head with vertex raised; one-segmented labial palpi arising from a large triangular labial sclerite. Thorax almost as deep as long; mesepimeron deeper than long, distinctly separated from mesomeron by a complete suture; meso- and metameron separated from their eucoxa; mesomeron longer than wide; metameron well developed.

Female: Vermiform, white with slightly brownish head and tergal regions of thorax and anterodorsal portion of 1st abdominal dorsum; head small and semicircular, with all appendages completely obliterated, eye-spots black; thoracic legs completely obliterated or each represented by a minute unsegmented process; 7th abdominal segment with anal hair-tuft (corethrogyne) consisting of longish yellowish white hairs; 8th abdominal tergum with short apophyses anteriores; papilla analis short, bearing apophysis posterioris slightly shorter than papilla proper.

Description of Manatha taiwana

The following includes the synonymy and morphological characters of adults, pupae and final instar larvae of both sexes.

Manatha taiwana **(Sonan, 1935), comb. nov.**

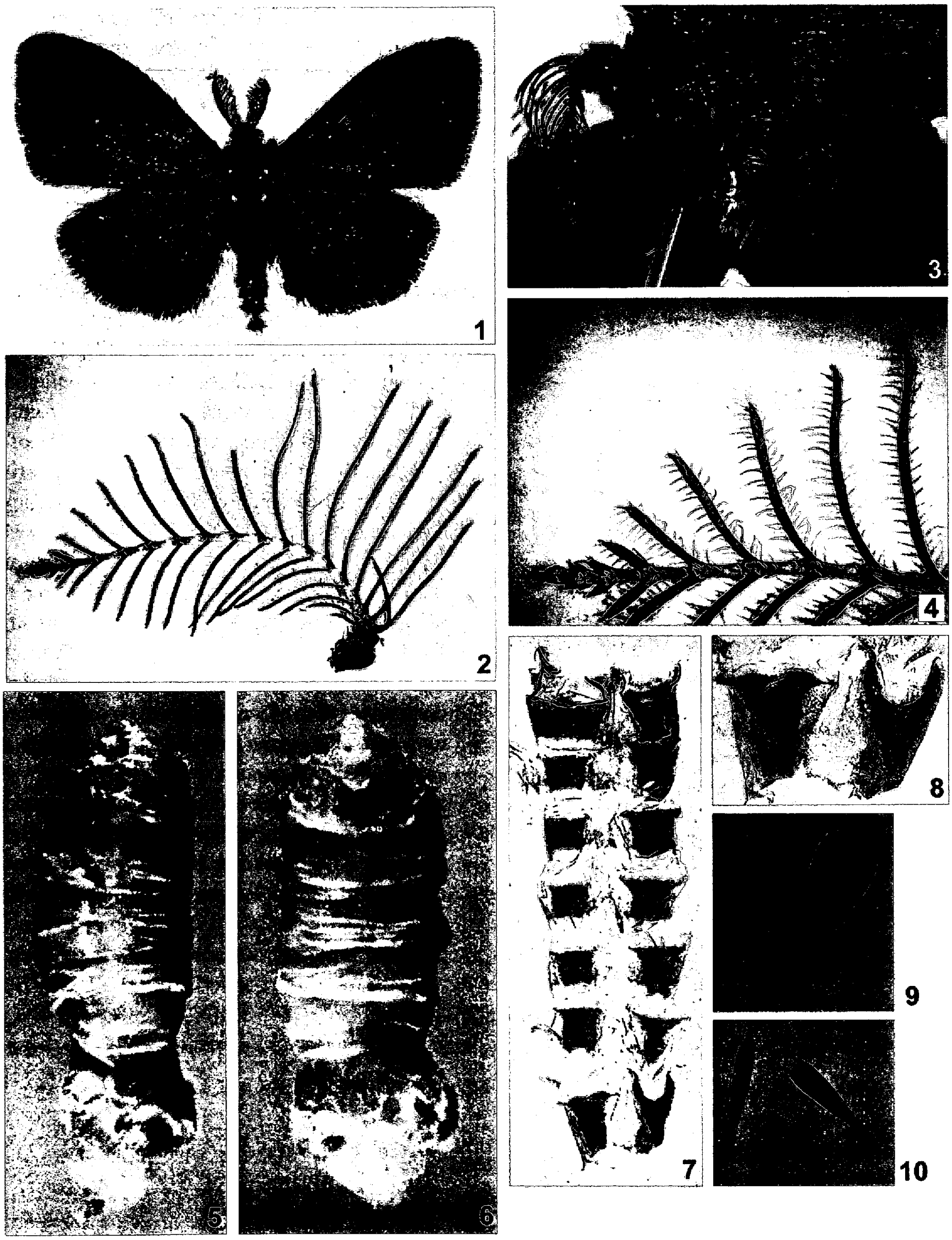
Acanthopsyche (*Eumetisa*) *taiwana* Sonan, 1935. Trans. Nat. Hist. Soc. Formosa, **25**: 454.

Eumetisa taiwana: Dierl, 1971. Khumbu Himal, **4** (1): 66.

1) Adults. Male (Fig. 1): Small-sized blackish species with broad wings, white-haired white tarsi and two longish spines at tip of harpe of genitalia.

Head (Figs. 11, 12): 0.85 the width of thorax; 0.8–0.87 × as long as high; cranium covered with long, brown hairs on vertical and occipital areas, long, pale hairs on anterior portion of vertex and below antennae, short dark scales on middle portion of face and pale ones along anterior margin of compound eye. Compound eye black, almost hemispherical, in lateral aspect 0.8 × as long as high, its vertical diameter 1/3 as long as head height; in frontal aspect eyes separated from each other by a distance slightly longer than 1/2 width of head. Antenna (Figs. 2, 4) 1/3 as long as forewing, scape globular, only slightly longer than wide; pedicel 1/2 as long as wide; flagellum consisting of 18 or 19 flagellomeres, long bipectinated; 2 basal flagellomeres short, the 3rd 1/30 as long as antenna, middle flagellomeres 0.07–0.08 × as long as antenna, and 3 × as long as wide; 1st flagellomere often with 2 anterior pectinations that are usually short stalked; anterior pectinations very long and nearly 1/2 as long as antenna on 3rd to 7th flagellomeres (longest on 5 th), then successively and gradually shortened on apical segments; posterior pectinations mostly shorter than anterior ones of the same flagellomeres, 1/4 as long as anterior one on 1st flagellomere, gradually longer towards 7th to 11th segments, of which the pectinations are 4 × as long as the flagellomeres, then shortened towards subapical segment which has a pair of short dentations; anterior and posterior pectinations are subequal in lengths on 13th to 17th flagellomeres. Sensory hairs of pectinations 3.5–4 × as long as thickness of pectination or slightly shorter than the longest flagellomere, arranged rather irregularly in two rows; the sensory hairs also present on apical portion of ventral surface of shaft of flagellomeres. Antenna including pectinations covered with blackish scales on dorsal surface, mixing pale ones on basal 1/4 of antenna, and pectinations bearing 2–3 very long hair-like scales (longer than the longest flagellomeres) at tips. Mouthparts extremely reduced; 2 minute irregular sclerites each representing mandibles and maxillae; labial sclerite large and triangular, bearing a pair of short one-segmented palpi which are 1/5 as long as head height, 3 × as long as wide, and basally approximated or united with each other, and fused with labial sclerite.

Thorax (Fig. 13) moderately developed, 1.1 × as long as deep; dorsal surface of thorax clothed with long dark brown hairs, on prothorax mixed with pale hairs. Prothoracic katapleurite completely fused with anapleurite, without trochantin. Mesothorax well developed, 6 × as long as metathorax measured along dorsomedian line. Mesepimeron 1/2 as long as its anterior margin including pleural wing process; mesomeron nearly as wide basally as long, demarcated from mesepimeron by a suture; trochantin represented

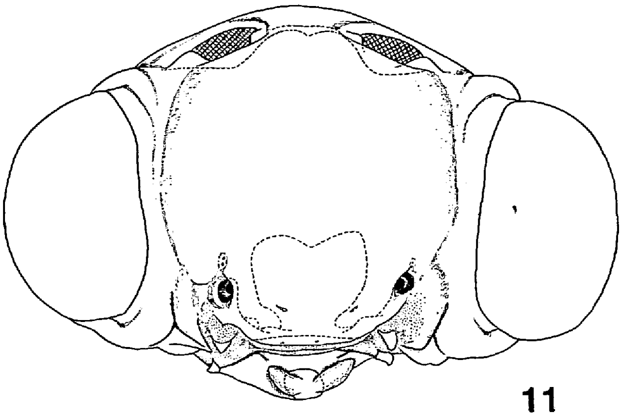


Figs. 1–10. *Manatha taiwana* (Sonan).——1, male adult; 2, male left antenna, ventral aspect; 3, male adult, ventrolateral aspect; 4, apical portion of male left antenna, ventral aspect; 5, female adult, lateral aspect; 6, ditto, dorsal aspect; 7, male abdominal sclerites excluding genitalia; 8, male 8th abdominal sclerites (left. tergum, right. sternum); 9, scales on upperside of forewing; 10, scales on upperside of hindwing.

by a minute sclerite in meso- and metathorax.

Wings. Shape: Forewing (Figs. 14, 16, 18, 19) short and broad, nearly right-angled isosceles triangle in shape with tornus of ca 110°, 1.64–1.75 × as long as wide; costa nearly straight for basal 2/3, then weakly curved towards apex, outer margin 0.82–0.85 × as long as hind margin, only slightly arched outwardly at cell m_2 to m_3. Hindwing (Figs. 15, 17) moderately broad, 1.06–1.31 × as long as wide, 0.70–0.75 × as long as forewing; costa moderately arched before the middle, apex rounded, outer margin roundly angulated at cell m_3; anal angle rounded.

Coloration: Forewing almost uniformly blackish brown with a slight brownish lustre; veins darker; upper surface densely covered with broad cover scales (Fig. 9) that are mostly 170 μ long, 60 μ wide, and have 3 (sometimes 4) apical teeth, mixing some hair-like scales at basal portion. Hindwing blackish brown, slightly paler on basal portion, upper surface covered with narrow cover scales (Fig. 10) that are mostly 170–230 μ long, 20–33 μ wide and have 1–2 (sometimes 3) apical teeth. Fringe of outer margins of wings elongate, 1.5 × as long as upper scale of forewing, with 3–4 sharp apical teeth.



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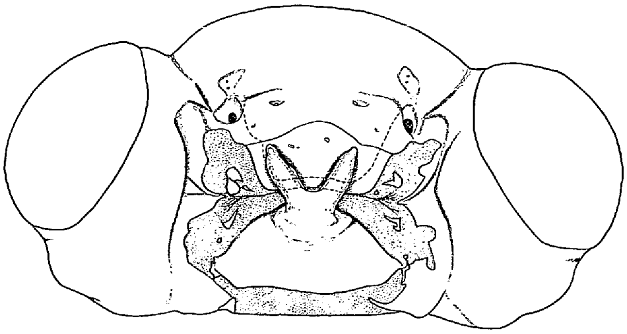

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Figs. 11–12. *Manatha taiwana* (Sonan).——11, male head, anterior aspect; 12, ditto, ventral aspect.

Venation: Forewing with 12 veins; Sc anastomosed with R_1 for length equal to 1–2.5 × of basal portion of R_1; then becoming free, but the free portion short and ending before costa; discoidal cell 0.55–0.60 × as long as forewing, very narrow and only slightly dilating apically on basal 1/2, then distinctly widening to base of R_1; median spur of M stem arising from 0.59–0.65 of M stem and united with posterior vein of discoidal cell well proximad of origin of CuA_2; R_1arising from apical 0.8 of discoidal cell; R_2 from subapical portion of discoidal cell; R_3 stalked with R_4, R_{3+4} (or R_{3+4+5}) 0.08–0.51 × as long as R_4; R_5 free or short stalked with R_{3+4}; M_2 and M_3 short stalked or free from each other; CuA_1 arising from close to base of M_3, base of CuA_2 opposite of that of R_1; CuP distinctly curved near apical portion, united with middle of A_1; A_2 connected with A_1 at its basal 1/4, emitting a fairly long spur that arises from subapical portion of A_2 and extends to near posterior margin of wing. Hindwing with 8 veins; basal section of R_1 short and oblique, arising from slightly beyond the middle of anterior margin of discoidal cell; posterior portion of discoidal cell 0.64–0.7 × as long as hindwing, anterior portion of discoidal cell 0.63–0.7 × as long as the posterior portion; anterior discocellular vein closing anterior

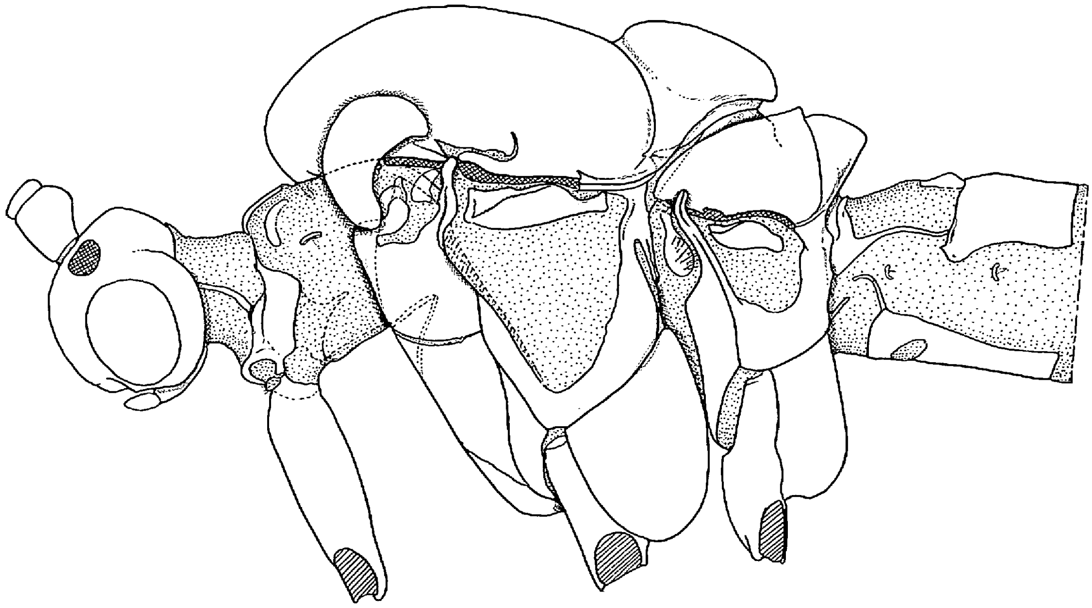
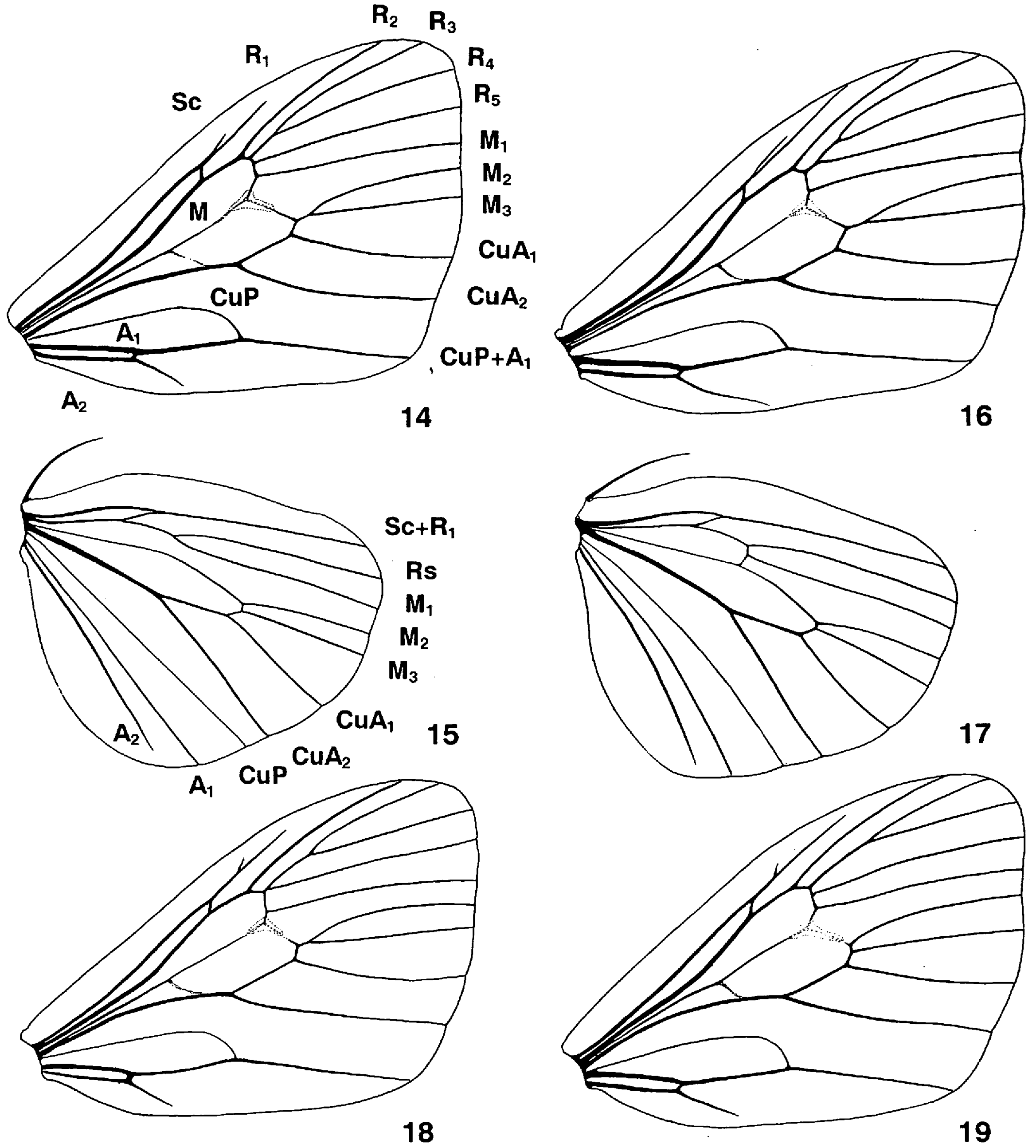


Fig. 13. *Manatha taiwana* (Sonan), male head and thorax, lateral aspect.

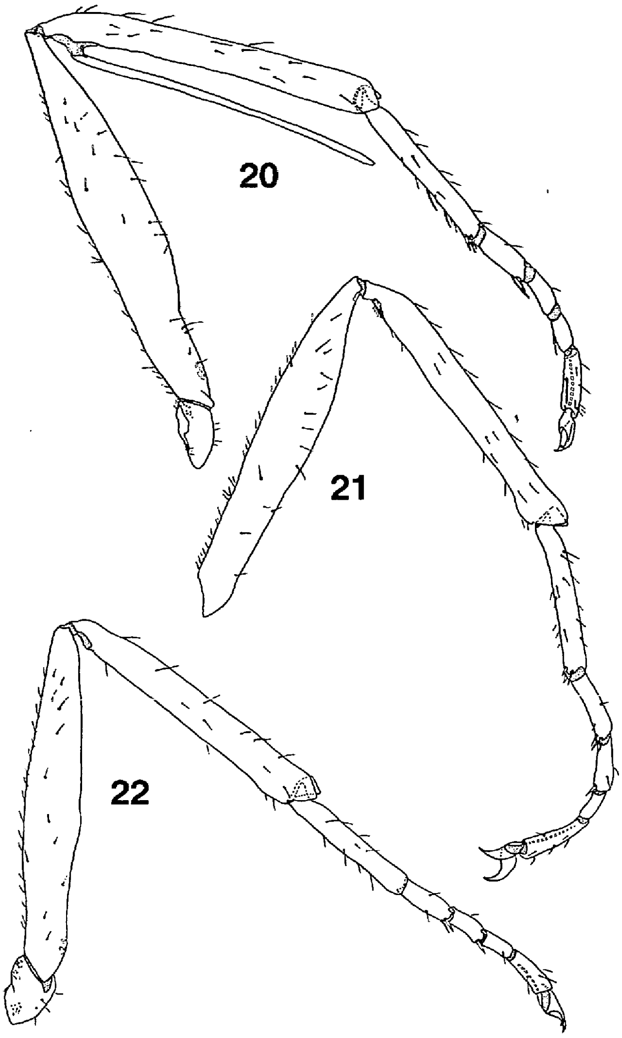


Figs. 14–19. *Manatha taiwana* (Sonan), male wings.——14, 16, 18, 19, forewings showing variation of venation; 15, 17, hindwings showing variation of venation.

portion of discoidal cell sometimes absent, so that the anterior portion open; M_2 and M_3 close to each other at apex of posterior portion of discoidal cell; base of CuA_2 slightly distad of the level of forking point of Rs and M_1; A_2 disappearing before wing margin.

Legs (Figs. 20–22) rather short and weak, pale brown on coxae, femora and tibiae, white on tarsi; coxae and femora clothed with brown long hairs; tibiae clothed with very long brown hairs as long as tibiae; tarsi clothed with long white hairs, which are longest on 1st tarsomere, gradually shorter towards apical tarsomere which bears a few dark scales mixed with white ones; claws brownish. Relative lengths of femur, tibia, tarsus (1st tarsomere): 120 : 100 : 105 (50) in foreleg; 108 : 88 : 105 (48) in midleg; 95 : 78 : 100 (40) in hindleg; epiphysis slightly shorter than fore tibia, arising from subbasal portion of the tibia; no spurs on mid and hind legs.

Abdomen slender, 2.7–3.0 × as long as thorax in macerated condition, usually slightly extending beyond posterior margin of hindwing in dried condition; abdomen densely clothed with dark brown hairs.



Figs. 20–22. *Manatha taiwana* (Sonan), male left legs. ——20, foreleg; 21, midleg; 22, hindleg.

Abdominal sclerites as in Fig. 7; 8th tergum (Fig. 8) 2 × as long as median width, gradually widened anteriorly, and expanded along anterior margin into narrow lateral expansions; 8th sternum 2.5 × as long as its medium width, deeply and widely incised anteriorly to its anterior 2/5, its posterior 3/5 distinctly tapered to pointed posterior tip.

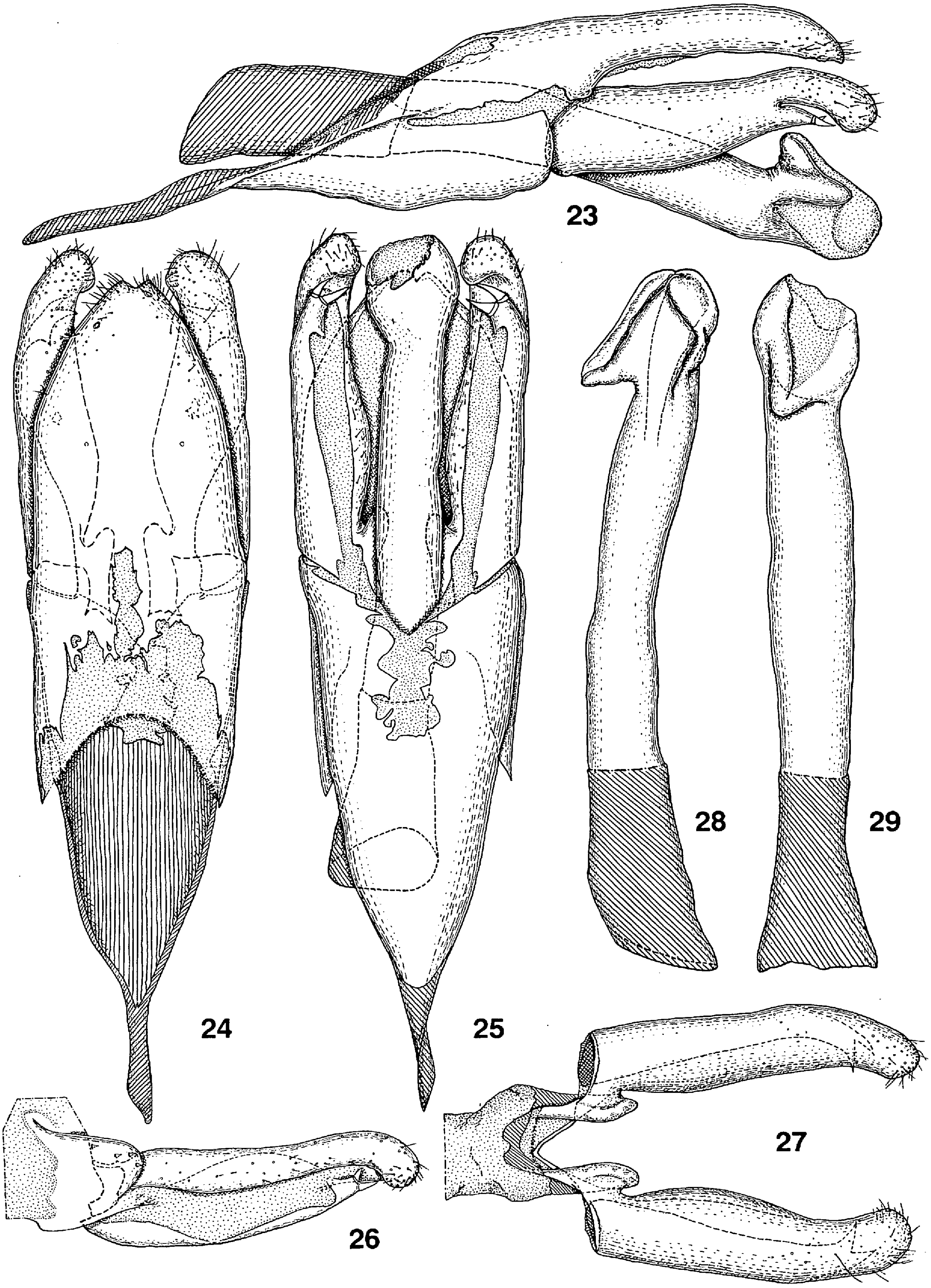
Male genitalia (Figs. 23–25): Extremely slender. Dorsum long and narrow, desclerotized on anterior portion, almost same width on anterior 2/3, then gently tapered to narrow weakly incised apex. Vinculum low and long, 0.63–0.69 × as long as entire genitalia, tapered anteroventrally, and gradually narrowing to slender saccus. Valva (Figs. 26, 27) long and slender, more or less cylindrical, about 0.4 × as long as entire genitalia, slightly deeper than wide, its inner surface sclerotized almost same width along dorsal margin as costa, and continuing to apically rounded ampulla that exceeds slightly beyond tip of dorsum and bears short setae; ventral portion of the inner surface narrowly sclerotized along ventral margin and produced into short harpe which bears two strong spines (the number of spines constant in five examined specimens); lateral lobe of anellus short, rounded apically, bearing a few spinules on inner surface. Phallus (Figs. 28, 29) long and rather thick, 0.85 × as long as genital ring, almost straight but slightly curved ventrally beyond the middle, subzonal portion 2/5 as long as suprazonal portion, apical portion of aedeagus slightly curved to left, and producing a subapical dorsal protuberance.

Length: Body 5.5–6.7 mm; forewing 5.9–7.2 mm; wing expanse 13.5–15 mm.

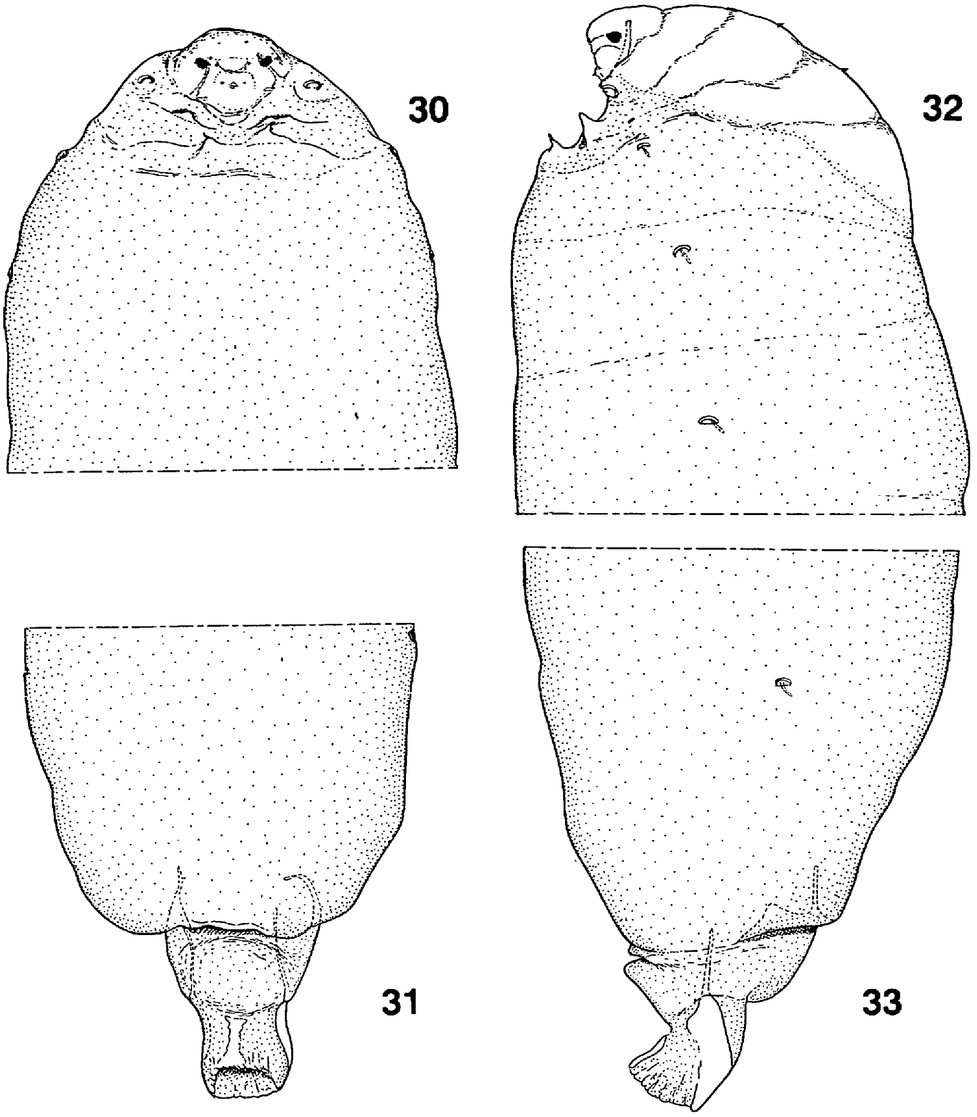
Female (Figs. 5, 6, 30–33): Vermiform, cylindrical, 3–3.5 × as long as wide or deep, roundly truncate anteriorly and posteriorly, and ending posteriorly in short papillae anales. Coloration white or pale yellowish white with a slight brownish tinge on head and tergal regions of thorax and anterodorsal portion of 1st abdominal dorsum. Head (Fig. 34) small and semispherical, evenly smooth on surface except for a minute protuberance behind mouth presumably representing spinneret, other appendages completely obliterated, eye-spots blackish. Thorax small, 0.15 × as long as body length, its dorsal margin weakly and evenly curved; tergal regions of three thoracic segments smooth on surface except for a pair of minute subdorsal spinules which may be reduced; prothoracic spiracle large; thoracic legs completely obliterated and represented by minute sclerites bearing a few sensilla, or in metathorax represented by a pair of minute unsegmented processes; a pair of small weak ridges in front of mid leg remnants. Abdomen almost membranous except for anterodorsal portion of 1st segment, and female terminalia; 7th abdominal segment densely clothed with anal hair-tuft consisting of longish yellowish white hairs about $250\,\mu$ long; 8th abdominal dorsum with short apophyses anteriores; papilla analis short, bearing apophysis posterioris slightly shorter than papilla proper.

Length: Body 6.1–8.7 mm; width 2.1–2.5 mm.

2) Pupae. Male (Figs. 35, 37): Blackish brown to dark brown on head and thorax, brown on legs and abdomen. Body cylindrical; in dorsal aspect weakly concave at vertex due to weak swellings of antennal bases, rather strongly widened to the middle of antennae, then slightly widened to subapical portions of forewings, widest there, then much constricted to 3rd to 4th abdominal segments, of which the 4th is 1/3 as wide as pupa at greatest width, then gradually tapered to posterior end; in lateral aspect dorsal margin of



Figs. 23–29. *Manatha taiwana* (Sonan), male genitalia.——23, whole genitalia, lateral aspect; 24, ditto, dorsal aspect excluding phallus; 25, ditto, ventral aspect; 26, right valva, inner aspect; 27, valvae with anellus, dorsal aspect; 28, phallus, lateral aspect; 29, ditto, dorsal aspect.



Figs. 30–33. *Manatha taiwana* (Sonan), adult female.——30, head, thorax and 3 abdominal segments, ventral aspect; 31, posterior portion, ventral aspect; 32, head, thorax and 3 abdominal segments, lateral aspect; 33, posterior portion, lateral aspect.

pronotum slightly arched, mesonotum evenly and rather strongly convex, pupa thickest from posterior portion of mesothorax to 2nd abdominal segment, then gradually tapered to posterior end. Compound eye roundly produced laterally; mandibles rather large, separated from each other by a distance equal to their width; maxilla short, extending to tip of labial palpus; labial palpus short, 1/2 as long as fore coxa, apical margin of combined labial palpi weakly incised medially. Antenna wide and moderately long, slightly swollen forward subbasally, widest at the level of mandible, then evenly tapered to tip, extending to the middle of distance between labial palpi and forewing apex. Front coxa with its apex ending a little anterior to tip of antenna; tips of fore- and midlegs extending to 2/3 and 4/5 of distance between labial palpi and forewing apex, respectively; apical portion of hind leg reaching near forewing apex, and exposed for a short distance. Forewing broad, both forewings touching along ventromedian line between tips of mid- and hindlegs 1/10 of distance between labial palpi and forewing tip. Hindwing narrowly exposed to posterior margin of 2nd abdominal segment. Prothorax rather small, more or less keeled dorsomedially; posterior margin of mesonotum in wide V-shape; dorsomedian length of metanotum slightly less than 1/5 of that of mesonotum. First to 7th abdominal segments with many transverse wrinkles on dorsum; 2nd to 5th abdominal dorsa with a transverse row of minute spinules directed cephalad along posterior submargin, the spinules most prominent on 5th segment; 7th and 8th abdominal dorsa with a transverse row of strong

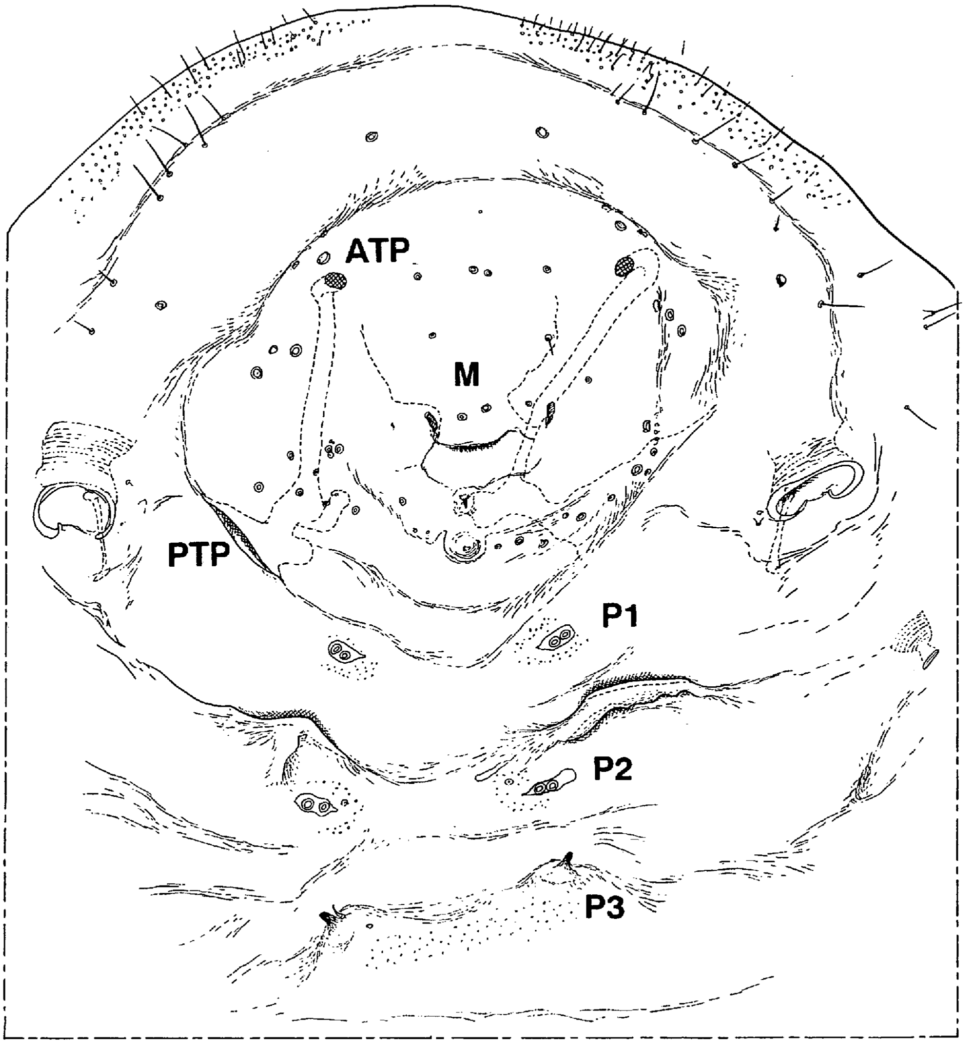
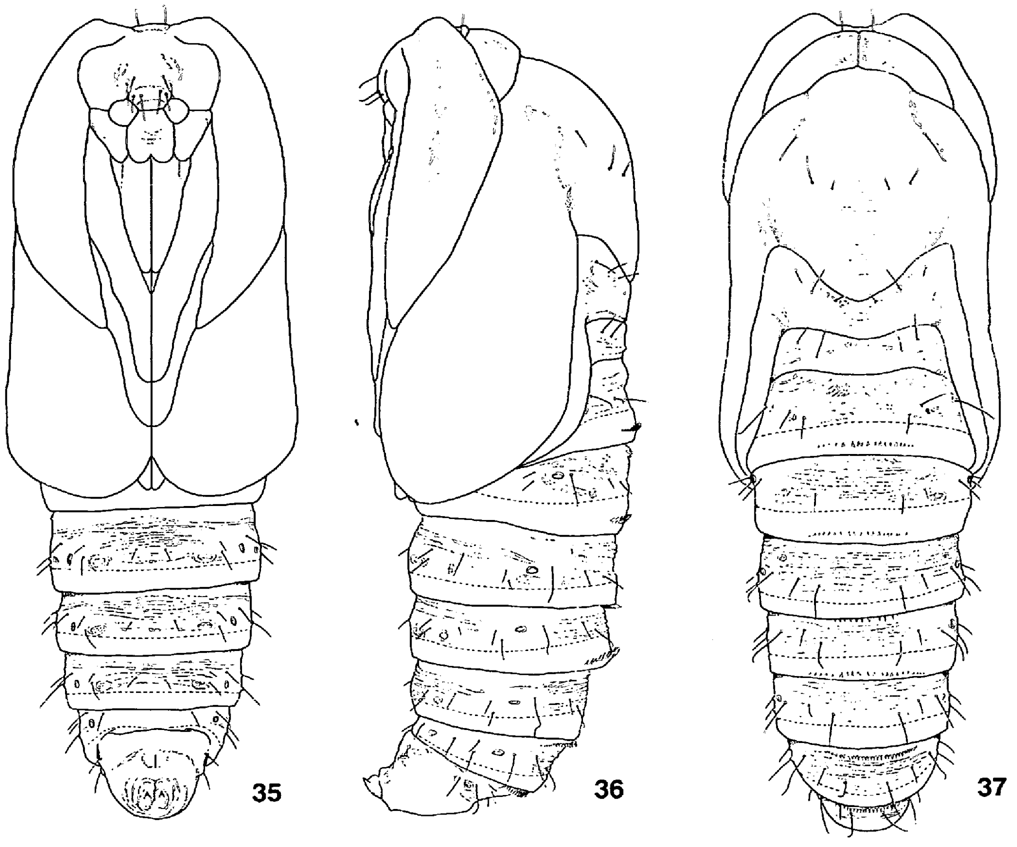


Fig. 34. *Manatha taiwana* (Sonan), female head and thorax (macerated, slide-mounted specimen), ventral aspect.

spines directed caudad near anterior margin, that of 8th abdominal dorsum not arranged on a distinct ridge; 4th to 6th abdominal dorsa with a narrow transverse ridge near anterior margin; dorsal outline of 8th segment even, not raised along posterior margin; that of 9th abdominal segment weakly rounded. Anal hook rather short.

Length: 5.5–6.5 mm.

Female (Figs. 38–40): Dark brown to blackish brown. Body cylindrical, almost same width and thickness as 6th abdominal segment, then gradually tapered to posterior tip; 3rd to 6th abdominal segments distinctly tapered on anterior half; anterior portion of body almost truncate in lateral aspect. Head (Figs. 41–43) small, and directed more or less ventral, rounded on posterior (dorsal) margin, slightly narrowed ventrally, with sublateral sutures separating antennae from smooth frontoclypeal area; mandible distinct and fairly large, maxillo-labial area elongate oval. Thorax (Figs. 41–43) strongly compressed anteriorly by abdomen, length less than 1/10 of entire pupa, three thoracic segments of almost the same length; lateral margins of thoracic segments extending to subventral portion; fore- and midlegs each represented by a pair of small tubercles which are separated by maxillo-labial sclerite; hindlegs represented by a small projection just posterior to maxillo-labial sclerite. Dorsomedian portion from mesothorax to 1st abdominal segment more or less raised as a weak keel. First and 2nd abdominal segments fused with each other leaving subventral transverse grooves anterior to 2nd abdominal spiracle; 1st abdominal spiracle close to anterior margin of the combined 1st and 2nd segments; posterior margin of 2nd abdominal segment raised as a ridge which bears some 20 spines directed cephalad and many minute granule-like projections more or less directed caudad. Third to 7th abdominal segments with many transverse wrinkles on firmly



Figs. 35–37. *Manatha taiwana* (Sonan), male pupa.——35, ventral aspect; 36, lateral aspect; 37, dorsal aspect.

sclerotized anterior area above and beneath; 5th abdominal segment with a transverse row of spines directed cephalad on flexibly sclerotized posterior submarginal area; 2–3 pairs of fine spinules on posteriormost portion of abdomen.

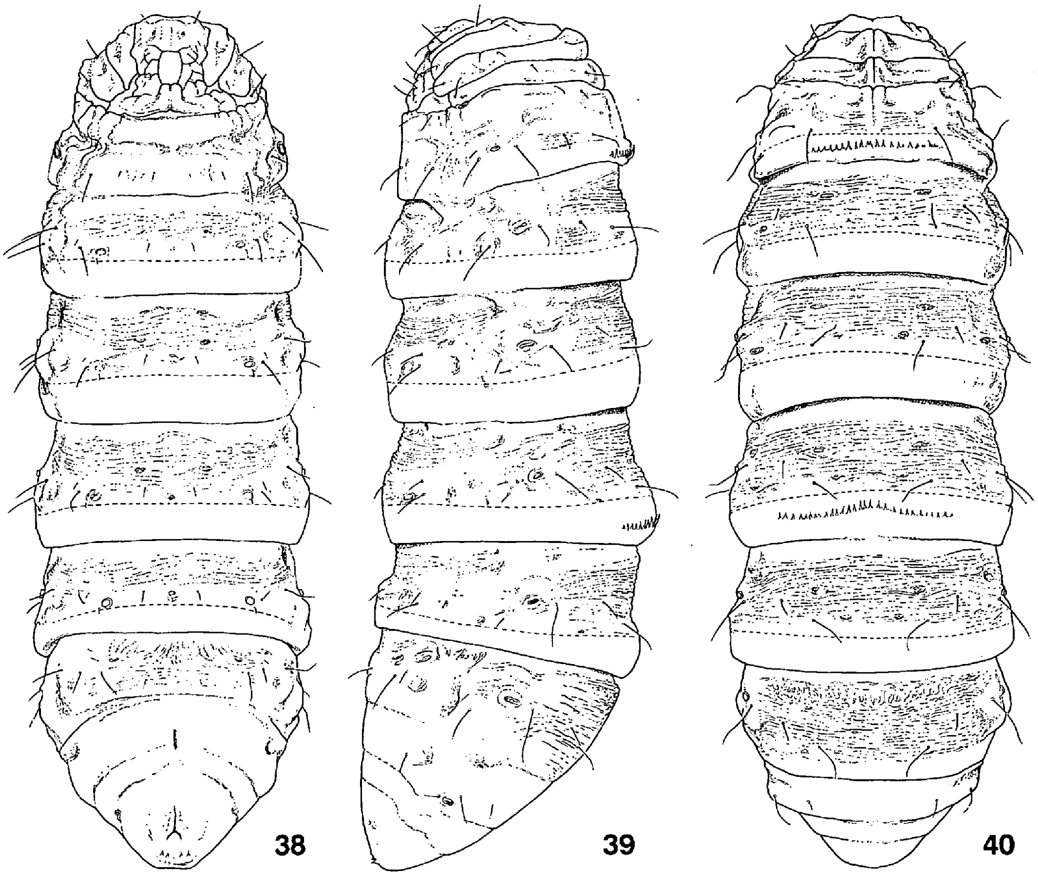
Length: 7.1–10.4 mm.

3) Larva. The last instar larvae as follows: Male and female penultimate instars are very similar to female last instar in coloration.

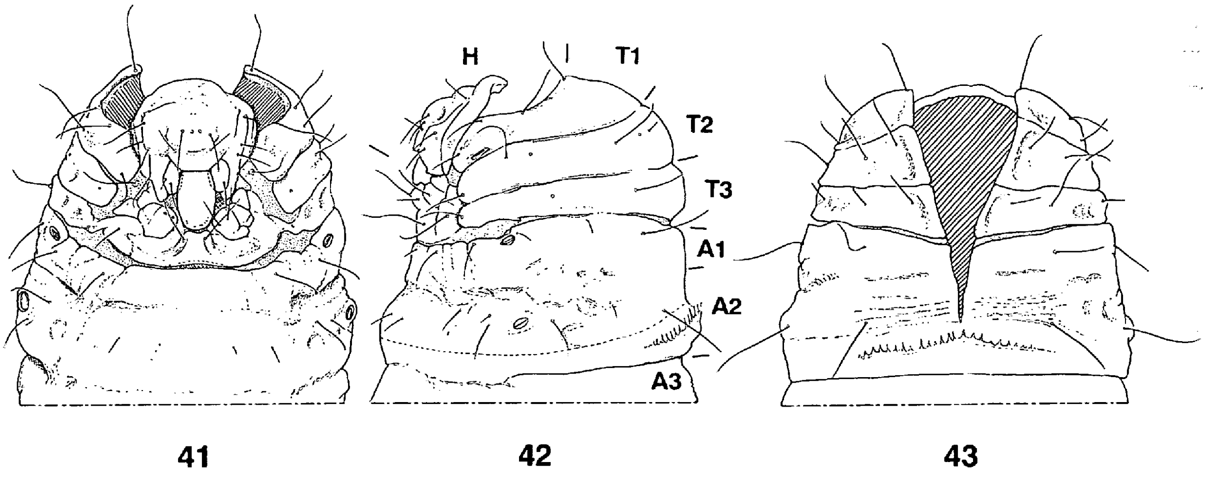
Final instar larvae. Coloration. Male (Figs. 46, 47): Head greyish brown, with coronal and epicranial sutures pale greyish brown, muscle attachments of cranium brown; dorsal half of clypeus and labrum chestnut brown, ventral half of clypeus white; ommatidia (ocelli) black. Body pale brownish grey, membranous parts and sclerites almost same in colour; thoracic notal sclerites a little darker than ground colour, with dark brown to black markings of muscle attachments; dorsomedian line of pro- and mesothoracic nota whitish. Abdomen paler than thorax, with sclerites slightly darker than membranous areas; sclerites surrounding D setae darker. Supra-anal plate a little darker, pale brown with minute black spots. Spiracles dark brown to black. Thoracic legs pale greyish brown with black markings. Body setae yellowish white to pale yellow.

Female (Figs. 48, 49): Head brown, frons and adfrontal area with darker marking surrounding bases of setae; coronal suture broadly bordered with dark brown; vertical area with blackish brown markings; ground colour of vertical area yellowish brown along adfrontal sutures and portions dorsolateral to ommatidia area. Membranous area of cervical area yellowish white. Thoracic nota (Fig. 56, T1–T2) brown; pronotal shield blackish around setae on anterior margin of subdorsal portion, darker on lateral portion of anterior marginal area, black from lateral margin to subdorsal area of posterior marginal area through spiracular area; mesonotum narrowly black along anterior margin, broadly darker along posterior margin from subdorsal to sublateral portions, and with an oblique dark line from anterolateral portion; metanotum similar to mesonotum in coloration. Thoracic legs chestnut brown on coxae, blackish brown from femora to middle of tibiae, chestnut brown beyond it. Abdomen grey with blackish tint on membranous area, blackish brown on sclerites; supra-anal plate dark brown, with browner lateral margins. Body setae all yellowish white.

Structure and chaetotaxy. Terminology of setae follows Hinton (1946). Cranium (Figs. 50–54) slight-

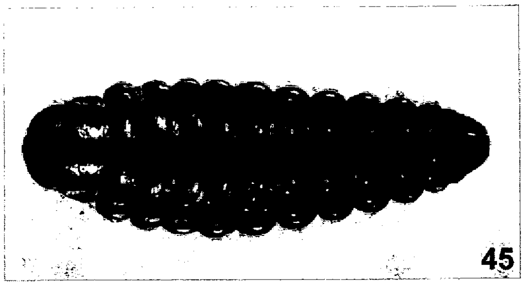


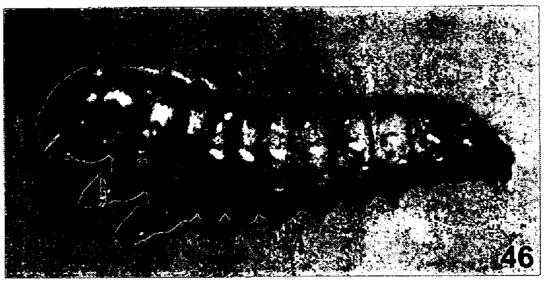
Figs. 38–40. *Manatha taiwana* (Sonan), female pupa.——38, ventral aspect; 39, lateral aspect; 40, dorsal aspect.

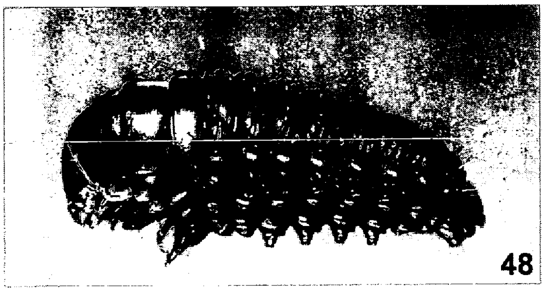


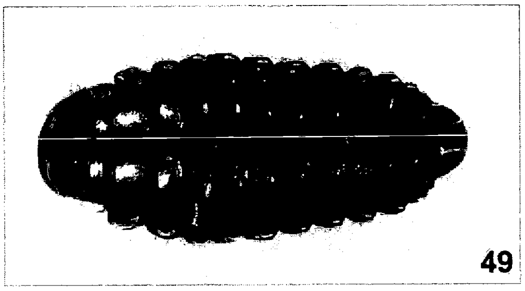
Figs. 41–43. *Manatha taiwana* (Sonan), anterior portion of female pupa showing detailed structure and fissure lines.——41, ventral aspect; 42, lateral aspect; 43, dorsal aspect.

ly wider than vertical thickness, slightly thicker than twice of longitudinal length; in frontal aspect almost circular with more or less straight vertical outline; coronal suture 2/3 as long as thickness of cranium; adfrontal suture indistinct; frontal suture weakly curved inwardly slightly below the middle. Chaetotaxy of cranium: F1 long, slightly ventrad to middle of frontoclypeal region, Fa at the same level of F1, C1 and C2 moderately long, C2 separated from opposite C2 by twice distance between C1 and C2; AF2 at the level of lowest portion of coronal suture, AF1 very short, at the level of midway of frontal suture; AFa at the level of AF2; V1, V2 and V3 arranged in a weakly outwardly curved line, Va lateral to V3; P1 very long, at the level of midway between AF1 and AF2, P2 represented by a minute setula a little below V1, Pa

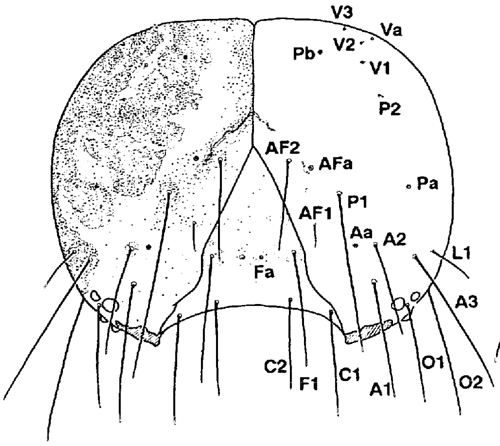








Figs. 44–49. *Manatha taiwana* (Sonan).——44, male penultimate instar larva, lateral aspect; 45, ditto, dorsal aspect; 46, male last instar larva, lateral aspect; 47, ditto, dorsal aspect; 48, female last instar larva, lateral aspect; 49, ditto, dorsal aspect.



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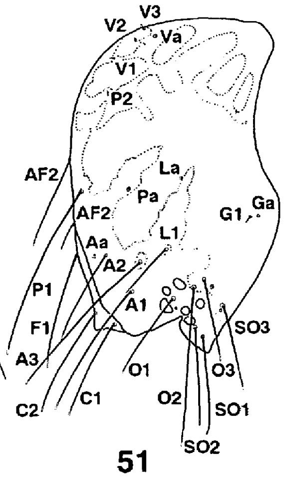

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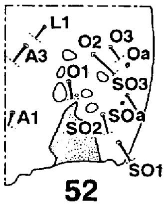

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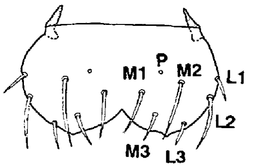

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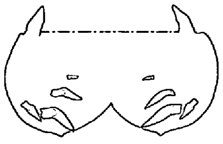

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Figs. 50–55. *Manatha taiwana* (Sonan), head of female final instar larva.——50, cranium, anterior aspect; 51, ditto, lateral aspect; 52, ditto, area surrounding ommatidia; 53, labrum, outer side; 54, ditto, inner side; 55, mandible, inner aspect.

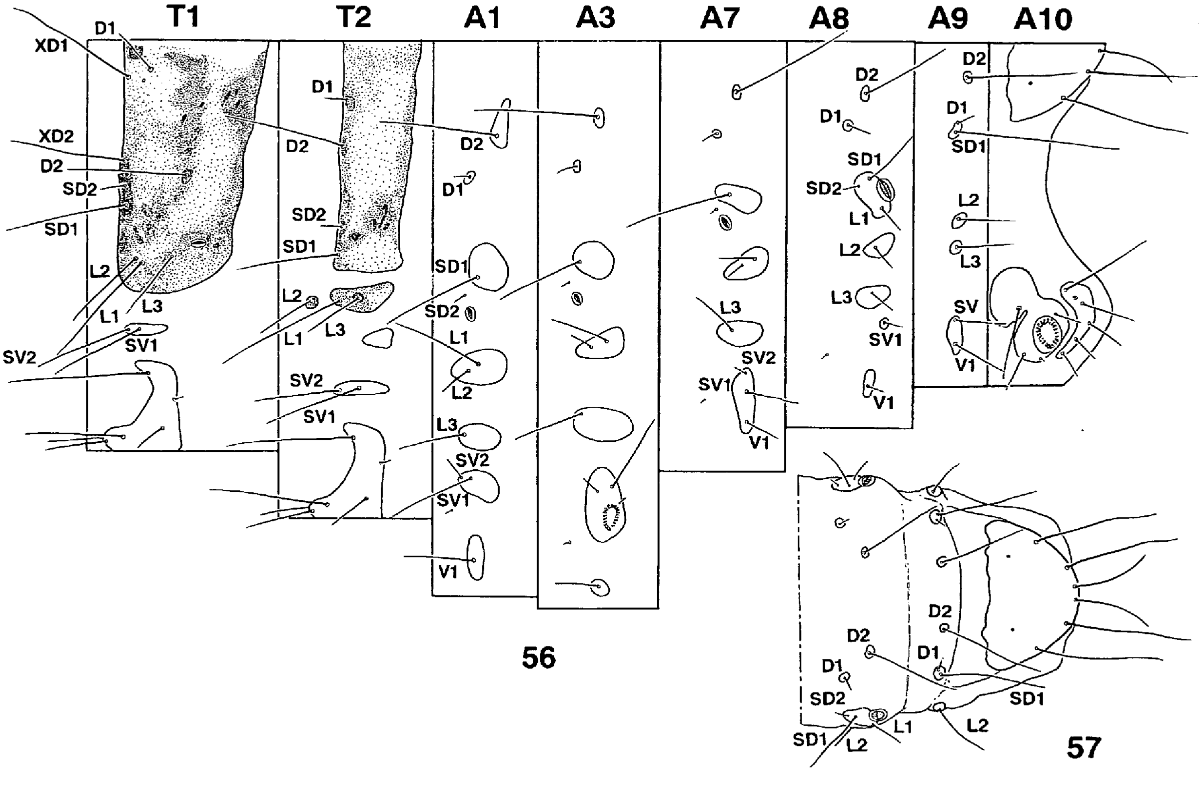
widely apart from P1 and at its level, Pb at the level of V1 or V2; A1 very long, A2 shorter than A1, A3 slightly below A2 level; L1 rather short, slightly posterior to A3, Aa proximad of A2 and at its level; G1 minute, Ga immediately posterior to G1; O1 moderately long, and situated between 2nd and 3rd ocelli, O2 very long, nearly at midway between 1st and 6th ocelli, O3 moderately long, immediately posterodorsal to O2, Oa posteroventral to O3; three SO setae moderately long, SO2 immediately below 5th ocellus, SO1 close to posterior mandibular condyle, SO3 posterodorsal to SO2 accompanying SOa anteroventral to it; 1st to 3rd ocelli arranged in a line, 3rd ocellus largest, 4th ocellus posterior to the 3rd, 5th ocellus slightly posteroventral to the 4th; 6th ocellus posterodorsal to the 5th. Labrum with M2 and L2 long, M1 moderately long, M3, L1 and L3 short, 3 L setae situated at lateral margin of labrum, L1–L2 distance 2/3 as long as L2–L3 distance; 4 ES setae, inner three arranged in an oblique straight line, most dorsal one smallest, most ventral one largest; 4th setae lateroproximal to and smaller than the largest. Labrum and mandibles as in Figs. 53 and 54, and Fig. 55, respectively.

Thorax and abdomen (Figs. 56, 57). Chaetotaxy: Prothorax: XD1 and D1 close to each other, the former very long, more than 2 × of the latter; D2 very long, a slightly ventrad to level of XD2; XD2 very long, situated far apart from XD1 and the distance between the two nearly 3 × of that between XD 2 and SD2; SD2 very short, situated at midway between XD2 and very long SD1; L2 moderately long, distance between this seta and SD1 more than 2 × of that between SD1 and SD2; L1 very long, close to L2; L3 long, at midway between L1 and spiracle; spiracle longitudinally longer; SV1 and SV2 long and close to each other.

Mesothorax: D1 very short; D2 very long, distance between D1 and D2 nearly 1/2 as long as distance between D2 and SD2; SD1 very long, distance between SD1 and SD2 shorter than that between D1 and D2; L1 very long, longer than L3, both on the same pinaculum; L2 subequal to L3, situated on a small pinaculum anterior to L1; SV1 and SV2 long, on a narrow pinaculum; a sclerite between pinnacula of L and SV setae group. Metathorax: Similar to mesothorax, but dorsal sclerite divided bilaterally by the dorsomedian membranization.

First abdominal segment: D2 very long, on a transversely long pinaculum; D1 very short, situated on a minute pinaculum widely and anteroventrally apart from D2 pinaculum; SD1 long, situated anterior margin of a rather large round pinaculum; SD2 minute, on membrane between SD1 and spiracle; very long L1 and short L2 on a large rounded pinaculum, L2 slightly anteroventral to L1; L3 on a pinaculum a little smaller than that of L1 and L2; SV1 and SV2 on a pinaculum similar to that of L3, SV1 very long, SV2 short; V1 moderately long, on a transversely elongate pinaculum; spiracle obliquely vertically longer.

Third abdominal segment: Similar to 1st abdominal



Figs. 56–57. *Manatha taiwana* (Sonan), chaetotaxy and marking of female last instar larva.——56, left side of body (T1, prothorax; T2, mesothorax; A1–A10, 1st to 10th abdominal segments); 57, 8th to 10th abdominal segments, dorsal aspect.

segment; pinaculum of D2 very small; proleg with about 20 crochets. Seventh abdominal segment: Similar to 1st abdominal segment, pinaculum of D2 as in 3rd abdominal segment, elongate SV1, minute SV2 and V1 on narrow transversely elongate pinaculum. Eight abdominal segment: Similar to preceding segments, spiracle large, 1.5 × as long as those of preceding segments with greater diameter, connate with oval pinaculum which bears long SD1 anterodorsal to spiracle, minute SD2 in front of spiracle, and short L1 below it; L2 and L3 rather short, each on a moderately large oval pinaculum; SV1 on a minute pinaculum; V 1 on a small pinaculum. Ninth abdominal segment: D 2 very long, on a minute pinaculum; D1 and SD1 close to each other, and on a small pinaculum; L2 and L3 each on a small pinaculum; V1 and SV1 on an elongate small pinaculum. Tenth abdominal segment: Anal plate slightly narrower than 2 × length, rather roundly produced posteriorly, with 3 pairs of setae

Length: Male 6.3–6.6 mm; female 7.5 mm.

Distinction between sexes in last instar larvae. In addition to the sexual colour differences in the last instars stated above, the following sexual differences are detected for both last and penultimate instars.

The male has a minute concavity on the ventromedian line close to the anterior margin of the 9th abdominal segment. In the female integument, this portion is lacking the concavity and is almost same as those in the preceding segments.

Habitat and phenology

The habitats where we found the larvae of this species are variou. At Hijigawa, we found the larvae on *Maesa tenera* growing along a trail in subtropical secondary forest. The habitat in Yona is similar to that in Hijigawa. In contrast, the habitats in Ishikawa-shi and Naha-shi are in urban parks.

Phenology of this species was not well studied, but it seems to be multivoltine, with various developmental stages found in spring and also in autumn. Development from the 1st to penultimate instars in spring to summer required about 3 months, 4 to 5 months in late summer to autumn, and about 1 month from the penultimate instar to emergence. So that total duration of the larval and pupal periods is 4 months in warm season, and 5 to 6 months in cooler season. Adults mostly appeared from late March to early June, and also from late August to late October.

Behaviour of larvae

1) Laval food plants

In the field in Okinawa-jima, we found larvae feeding on *Maesa tenera* (evergreen shrub of Myrsinaceae), *Quercus variabilis* (deciduous tree of Fagaceae), *Quercus phillyraeoides* (evergreen tree of Fagaceae) and *Alpinia speciosa* (evergreen herb of Zingiberaceae). The larvae collected in the field were fed with *Quercus phillyraeoides* and *Alpinia speciosa* in the rearing containers at Fukuoka.

2) Laval case (Figs. 58, 59)

The case of a full-grown larva consists of a conical main portion and a rather long collar (or neck)-like part surrounding the anterior opening of the case. The conical portion is 6.9–8.3 mm in length and 3.8–4.4 mm in diameter at the anterior part of the male case, and 7.7–9.3 mm in length and 4.1–4.4 mm in diameter in the female one. The conical portion is tough and its outer surface is covered with scale-like pieces of host plant leaves which were nibbled from the leaf surface and smoothly attached to the outer surface of the case with silk. The pieces of leaves covering the conical part are larger towards the anterior opening of case because older instar larvae attach larger pieces around the anterior portion of the conical part. In the male case, the smallest pieces of leaves are 0.7–0.9 mm across and the largest 2.2–2.5 mm, in the female case the smallest 0.7–1.1 mm and the largest 2.4–3.2 mm across. The collar of the case is as long as 1/4–1/3 of whole length of the case, *i.e.* 3.8–4.2 mm in the male case, 4.8–6.1 mm in the female one. The collar portion is tapered towards the anterior opening of the case like a turtleneck. It is spun with silk and is soft because no pieces of leaves are attached to it; but head capsules of younger instars are attached with silk.

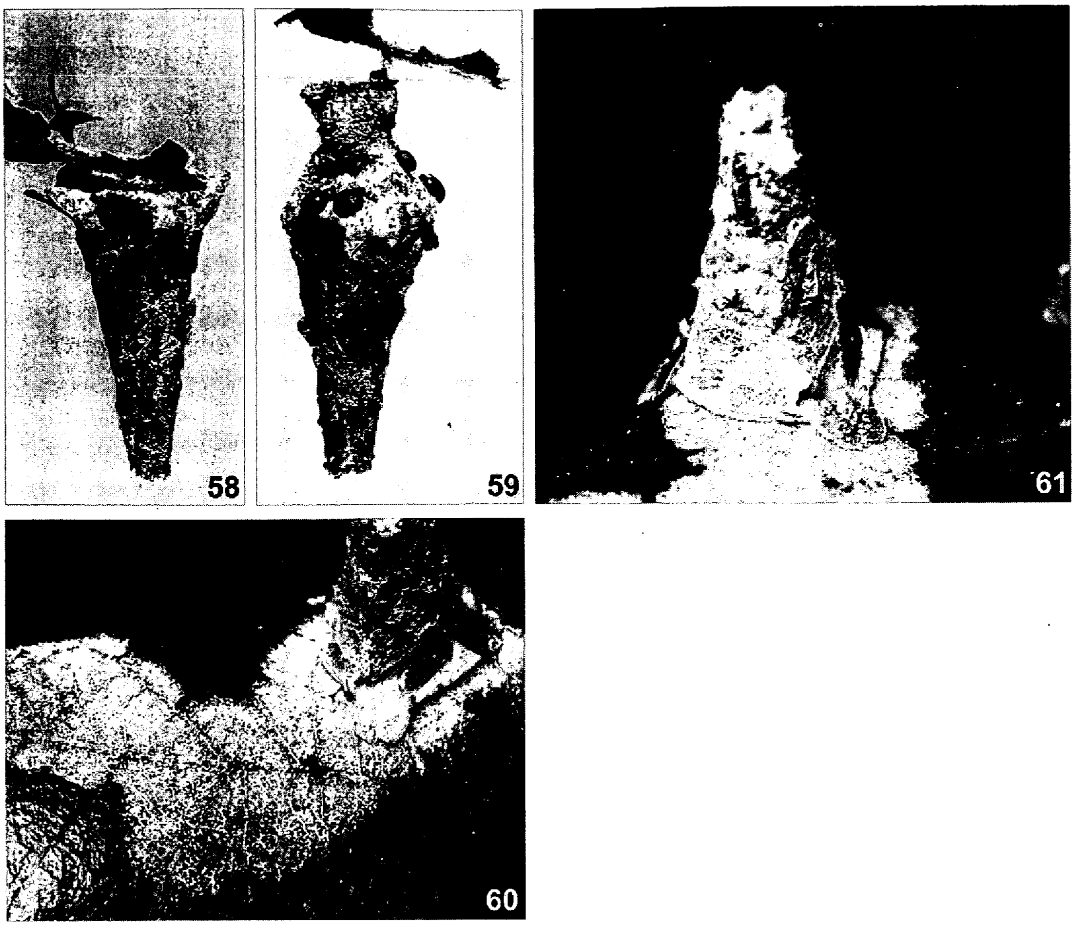
3) Feeding behaviour (Fig. 60)

The larvae feed exclusively on the leaves of the host. We did not observe even young larvae feeding on bark of twigs. The larvae skeletonize the mesophyll from one surface of a leaf leaving the epidermis of the other side. However, leaves were perforated by larvae feeding on the epidermis of the reverse side in some cases. Even mature larvae do not remove pieces of leaf from the margins.

4) Other behaviours involving the larval case (Fig. 61)

When the larva feeds or rests on a leaf, it loosely fastens its case to the leaf surface spinning some silk between a part of the anterior opening of case and the leaf surface, then pulls the anterior opening with its thoracic legs, so that anterior margin of the conical portion is tightly pressed to the leaf surface. Consequently, the larval case projects upright on the leaf surface.

Just before molting, the larva fastens the anterior



Figs. 58–61. *Manatha taiwana* (Sonan).——58, case of full grown larva, at rest; 59, ditto, in molting period; 60, a leaf of *Quercus phillyraeoides* eaten by full-grown larva; 61, full-grown larva feeding on a leaf of *Quercus phillyraeoides*.

opening of case to underside of a leaf with silk, and closes anterior margin of the neck part in a straight line. As the larva probably remains in the conical portion during molting, the collar portion is long extended.

When the larva walks, it trails the case slightly lifting the conical part, which is lined with the collar portion turned back to the inside of the conical portion.

5) Behaviour for pupation (Fig. 62)

In the male, the penultimate instar larva ceases to feed in its last stage, fastens the case to some support, then molts to the last instar and later pupates in the attached case (pupation case). Consequently, the last instar larva spends its entire stage in the attached case. When the penultimate instar larva fastens its case, it chooses a substratum from which the larva can suspend the case, then widely spins silk so that two fan-shaped portions are connected by a short narrow straight band. The larva closes the anterior opening of the case in a straight line, and fastens the closed margin to the straight band of the spun portion. So that the case is suspended, and its soft collar portion is extended. The pupation cases observed in field were on a fence and a signboard near the host, etc. In captivity, larvae fastened the case to the walls of the rearing box and under surface of the lid.

The exuviae of the penultimate instar without cranium hang on the posterior end of the attached male pupation case. The exuviae are rather unique, as they are not shriveled but inflated and nearly straight. As the thoracic legs of the exuviae are steadily directed forward, it appears as if the larva clings to the posterior end of the case; but the exuviae are loosely connected to the case with silk. This condition is characteristic and provides indication of molting in the last instar of the male.

The male last instar larva is light yellowish brown in body color, and its body integument is mostly soft. It remains in the attached case, and does not feed, and soon pupates. In the same way as in the female, the exuviae of male last instar become shriveled to a small mass and pressed to the furthest end inside the case.

The male pupa is enveloped within a fluffy cocoon-

Figs. 62–64. *Manatha taiwana* (Sonan).——62, pupation case of male, with swollen penultimate instar exuviae; 63, pupation case of male with exuviae of both pupa and penultimate instar larva; 64, male pupation case, showing an inner veil-like envelope.

like white silk veil inside the case (Fig. 64). The veil is cylindrical with both ends firmly attached to the inner surface of the case. Most part of the veil is separated from the inner surface of the case. The veil has some small pits. The function of this cocoon-like structure is unknown.

In the female, the larva feeds not only in the penultimate but also in the last instar, so that the last instar larva attaches the larval case and pupates after it is fully fed and developed. The behaviour to fasten the case is same as in the male penultimate instar. When the female larva attaches the case at the final stage of last instar, the exuviae of penultimate instar are not suspended from the end of posterior opening of the case. This difference in pupation behaviour easily distinguishes the female pupation case from the male. The female pupation case is not provided with the silken cocoon-like white veil that is found inside the male pupation case.

Behaviour of adults

1) Emergence

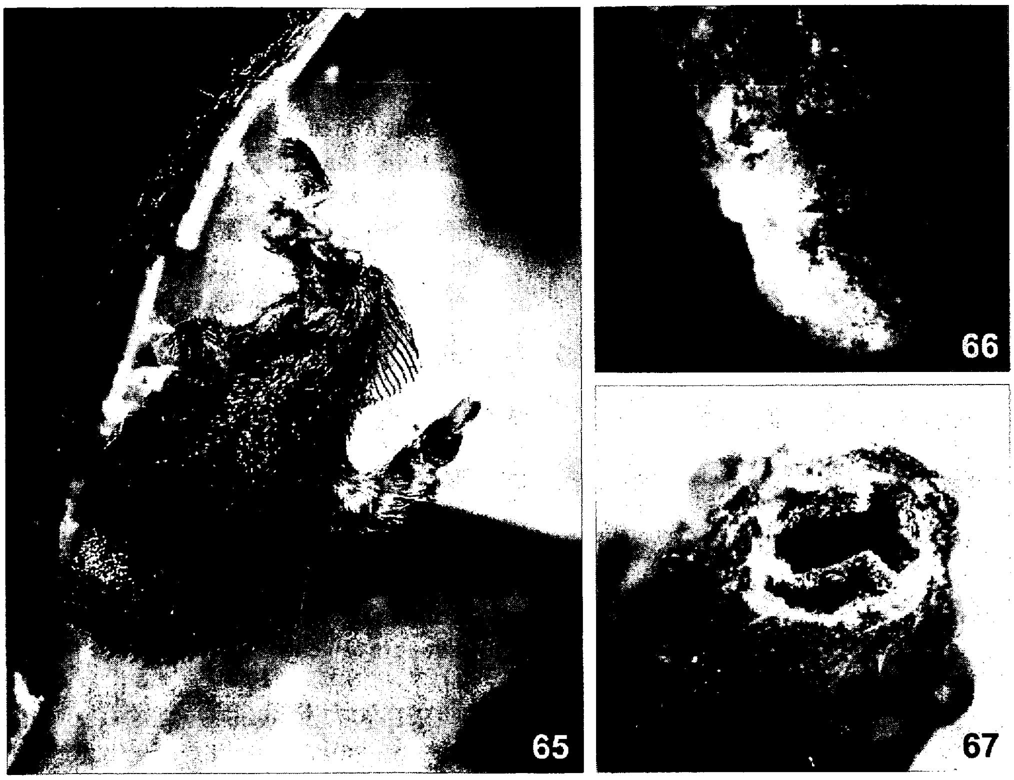
Prior to emergence, the male pupa (Fig. 63) moves to the posterior opening of the case and protrudes from the opening exposing its body anterior to the 5th or 6th abdominal segment.

The female pupa (Fig. 67) moves to the posterior opening of the case, but does not protrude its body from the posterior opening. The adult female emerges inside the case.

The rupture of the pupal cuticula at emergence is fundamentally the same in both sexes. The pupal cuticula ruptures along a T-shaped line consisting of the posterior margin of head inclusive of the antennae and the dorsomedian line through the pro- and mesothorax. The adult male emerges from the pupal cuticula pushing out the part of the head + legs. Clefts also appear along the anterior margin of the male antennae. The adult female remains in the pupal exuviae after emergence.

The pupal cuticula of the female is ruptured as in the male along a T-shaped line consisting of the posterior margin of head and the dorsomedian line of the pro- and mesothoracic dorsa. The female emerges from the pupal cuticula by pushing the anterior part of her body out of the cuticula. The lateral cleavage lines extend between the head + ventral part of thorax, and lateral portions of thoracic dorsum (corresponding to the anterior margins of forewings in male), so that the female exposes the anterior half of the body from the pupal cuticula.

After emergence of a male, the exuviae of the penultimate instar and the pupal exuviae are suspended from the posterior opening of the pupation case. However, in the female case its posterior opening is fully expanded as a round hole by movement of the adult female, and minute particles representing female scales are scattered around the posterior open-



Figs. 65–67. *Manatha taiwana* (Sonan).——65, male resting posture; 66, female adult protruding cephalothoracic region of her body to call males; 67, posterior opening of female-emerged case, showing pupal exuviae with Y-shaped fissure situated close to the opening.

ing.

2) Other behaviours of adults

Resting posture of male (Fig. 65). The adult male at rest often raises his body, and strongly curves his abdomen dorsally so that its tip almost reaches the same level of the thorax. His antennae are pressed against lateral portions of thoracic nota.

Calling posture of female (Fig. 66). The adult female sometimes moves to the posterior opening of case by vermicular movement and exposes the anterior portion of her body from the posterior opening. This behaviour is very similar to the calling posture of the female in *Eumeta variegata* Snellen, 1879 (Saigusa, 1981).

Discussion

Identification of the Ryukyu material with Acanthopsyche (Eumetisa) taiwana *Sonan.*

The present material from the Ryukyus well agrees with the original description of *Acanthopsyche* (*Eumetisa*) *taiwana* Sonan, 1935. However, there is an important difference between our specimens and the description in the leg coloration. In the original description, Sonan (1935) stated male "tibiae white". In all the specimens examined from the Ryukyus, the femora and tibiae are almost entirely black, and clothed with blackish scales and hairs, except for a few white ones at apices of tibiae. In contrast, the tarsi of our specimens are entirely white and densely clothed with white hairs. We examined the holotype of *Acanthopsyche* (*Eumetisa*) *taiwana* (Fig. 68) preserved in the collection of the Entomological Laboratory of the National Taiwan University, Taipei, and found that the integumental coloration and leg vestiture, together with other external characters of the holotype are quite identical with those of the Ryukyu specimens, *i.e.* the tibiae are black and the tarsi white. Thus the Ryukyu specimens were correctly identified with *Acanthopsyche* (*Eumetisa*) *taiwana*, and the original description should be amended in leg coloration as "tarsi white".

Systematic position of Eumetisa

Sonan (1935) stated that *Eumetisa* is allied to *Metisa* Walker, 1855, but differs from the latter in having a bar between the vein 12 (Sc) and the discoidal cell in the forewing, and the lower (posterior) part of the discoidal cell very long, about twice as long as the upper (anterior) part, and a bar connecting the veins 7(R_5) and 8(R_4) in the hindwings.

In addition to the differences pointed out by Sonan,

Fig. 68. *Holotype of Acanthopsyche* (*Eumetisa*) *taiwana* Sonan, 1935.

we found the following differences between them: In the forewing discoidal cell, the stem of M does not branched, but emits a short median spur that reaches the posterior margin of the cell proximal to the base of CuA$_2$ (according to Dierl (1969); in *Metisa* the stem of M branches, but lacks in the median spur); in the hindwing discoidal cell, the stem of M is simple, not branched (branched in *Metisa*); in the hindwing, Sc is connected with the anterior margin of discoidal cell only by a short bar of R$_1$ (in *Metisa* Sc, R$_1$ and the anterior margin are united with each other for a long distance); in the male genitalia the saccus is extremely long (in *Metisa* the saccus is almost undeveloped). In addition, the larval cases of *Metisa plana* Walker, 1855, the type species of the genus, and of *Metisa carnifrons* Dierl, 1971, are not conical but almost cylindrical, and the larvae attach the pupation case differently (Dierl, 1971; Kamarudin *et al*., 1984). Based on the foregoing differences, we consider that *Eumetisa* is distinct from *Metisa* as stated by Sonan (1935).

Based on Sonan's original illustration of wing venation, Dierl (1971) stated that *Eumetisa* is closely related to *Brachycyttarus* Hampson, 1893, and is distinguished from the latter by the presence of 12 veins of the forewings (11 veins in *Brachycyttarus*). This difference alone does not justify separating them as distinct genus. Our study on the venation and male genitalia of *Eumetisa taiwana* revealed the following differences between the two taxa.

In *E. taiwana*, the forewing discoidal cell has the spur of the stem of M ending at the middle of the posterior marginal vein of the discoidal cell proximad to the origin of CuA$_2$ (the M stem is simple and without a median spur in the cell in *Brachycyttarus*); the vein Sc and R$_1$ of the forewing are partly united for a short distance or connected by a short bar (the two veins are free from each other in *Brachycyttarus*); the forewing discoidal cell is shorter than half the length of the forewing (the cell is nearly half the length of the wing in *Brachycyttarus*); the saccus of male genitalia is extremely long and slender (the saccus is almost undeveloped in *Brachycyttarus*). In addition to the above-mentioned morphological differences, *Brachycyttarus* is quite different from *E. taiwana* in the structure of the larval case, the attachment behaviour of the pupation case, and molting behaviour of the male penultimate instar as stated below. These morphological and behavioural differences are too extreme to include *E. taiwana* in *Brachycyttarus*.

Dierl (1972) discussed the systematic position of the genus *Manatha* in his paper on the African macropsychids. As already stated, most of the morphological characters of adult male including the genitalia of *Manatha albipes* mentioned by Dierl (1972) are almost identical with those of *E. taiwana*. Distinctive differences between the two species are found only in a few specific instances as discussed in the following section. Thus, *M. albipes* and *E. taiwana* are extremely closely related to each other, and should be treated as congeneric. Furthermore, *Eumetisa* should be treated as a junior synonym of *Manatha*.

The systematic position of the genus *Manatha* is not clear. The genus *Manatha* was originally described as a full genus. Later it was erroneously treated as a subgenus of *Psyche* Schrank, 1801 (Hampson, 1892) notwithstanding the presence of epiphysis on the fore tibia. Many Oriental oiketicinine genera with an epiphysis are treated as subgenera of the genus *Acanthopsyche* (Hampson, 1892). These are *Oiketicoides* Heylaerts, 1881, *Dasaratha* Moore, 1881, *Pteroma* Hampson, 1892, *Brachycyttarus* Hampson, 1892, *Metisa* Walker, 1855, *Amicta* Heylaerts, 1881, etc. Although they are treated under the genus *Acanthopsyche* by reason of the presence of the epiphysis, they are not assigned to a monophyletic group based only on this plesiomorphic character. The phylogenetic relationships among oiketicinine genera are unclear at the present. Slight differences in the male genitalia and extensive differentiation of wing venation appear to be due to convergence among the genera (Dierl, 1971; Mathew, 1986). Consequently the systematic position of the genus *Manatha* remains uncertain. However, the extremely elongate male genitalia with almost cylindrical valvae are unique among the genera hitherto treated as subgenera of *Acanthopsyche*.

Intrageneric relationship in the genus Manatha

As already stated above, *Acanthopsyche* (*Eumetisa*) *taiwana* belongs to the genus *Manatha*. The male genitalia of *Manatha scotopepla* from Cachar that Dierl (1972) included in this genus are not illustrated. Because the venation illustrated by him is very similar to those of *M. albipes* and *M. taiwana*, it is believed that *M. scotopepla* almost certainly belongs to 'Manatha. The illustrations of wing venation of *M. albipes* and *M. scotopepla* are different from *M. taiwana* in possessing a longer forewing discoidal cell that is more than 0.6 × the forewing length. *M. albipes* differs also from *M. taiwana* in having veins R_1 and Sc of forewing are free from each other. According to Dierl's illustrations, *M. scotopepla* is similar in this respect as *M. albipes*. However, Seitz & Gaede (1933) described "(vein) 11 anastomoses with vein 12 at one place" in *M. scotopepla* as in *M. taiwana*. Further study will be required to clarify phylogenetic relationships among these three species.

According to Dierl (1972), *Manatha nigripes* described from Nepal should be excluded from *Manatha* on the basis of the number of veins (10 in forewing and 6 in hindwing), the long needle-like saccus and the broad valvae of male genitalia and the different structure of pupation case. For these reasons we proposed a new genus for it and its close ally in the Ryukyus (Sugimoto & Saigusa, 2001).

Morphological characters

The male genitalia of *M. taiwana* are characteristic in having very slender ring and valvae. These characters are peculiar to the subfamily Oiketicinae. They are shared also with *M. albipes*, and are considered to be autapomorphies of this genus. Similar genitalia are found in the Neotropical genus *Dendropsyche* Jones, 1926 (Davis, 1975b).

Development of the anterior and posterior rows of spines on the male pupal abdominal segments is variable among oiketicinine species (Yano, 1958; Davis, 1990). In the Japanese species, *Eumeta variegata*, *E. minuscula* (Butler, 1881) and *Nipponopsyche fuscescens* Yazaki, 1926, several segments have therowsbut in *Bambalina* species (treated as *Canephora asiatica* (Staudinger, 1887)) the rows are confined to a few segments (Yano, 1958). In *Brachycyttarus griseus* De Joannis, 1929, the male pupa has anterior rows only on the 6th to 8th segments and completely lacks the posterior row of spines (Davis, 1990). In *M. taiwana*, the development of the rows is similar to *Bambalina*, with the posterior rows confined to the 2nd to 5th segments and the anterior rows present only on the 7 th and 8th segments.

The rows of spines on the pupal abdominal segments of the female are usually more reduced than in the male pupa, but development of the rows is also variable among oiketicinine species as in the male (Yano, 1958; Davis, 1990). Davis (1990) reported an unusual development in *B. griseus* with no abdominal segment possesses a full complement of both anterior and posterior rows, and the 5th abdominal segment totally lacking spines. In *M. taiwana*, the spines are much more reduced than in *B. griseus*, and the only rows of spines are the posterior rows on the 3rd and 6 th abdominal segments.

The final instar larva of *M. taiwana* is unique in having the greatly reduced adfrontal suture of the head. This suture is almost always well developed not only in the primitive genera like *Taleporia* Hübner, [1825], but in higher psychids (Kozhanchikov, 1969; Davis, 1975a, 1975b, 1990). The enlargement of the spiracle on the 8th abdominal segment is also a unique feature of *M. taiwana*.

Structure of larval case

The larvae of most psychid species close the anterior opening of larval case at rest or disturbance, or before molting. The anterior marginal portion is soft and collar (or neck)-like in shape. In most species the collar is short, and the border between it and the main part of case is indistinct, (*e.g.*, it is as long as 1/6–1/13 length of the main body of the case in *Eumeta variegata* and *Eumeta minuscula*). In *Manatha taiwana*, the main part of case is conical and the diameter of its anterior margin is large, so that the collar part is long, consists only of silk, and gradually tapers towards the anterior opening. The collar is turned back to the inside of the conical part of case when the larva moves. As a result, the wall of anterior part of the case is doubled, which is peculiar to this species. The case of *Manatha nigripes* illustrated in Dierl (1966) seems to have a long collar similar to that of *M. taiwana*. But in this species the collar is adorned with fragments of lichen and bark.

In *M. taiwana*, head capsules of previous instars are attached to the collar with silk. This behaviour is unusual in the Psychidae, and it is neither found in *E. variegata*, *E. minuscula*, or *Acanthopsyche nigraplaga* (Wileman, 1911), nor in any Japanese species, except for *Mahasena aurea* (Butler, 1881) (Sugawara *et al.*, 1963; Inoue, 1982; Saigusa, 1972). In the latter, the head capsules of previous instars are attached near the anterior part of case, but as the collar is short (as long as 1/10 length of the case), the head capsules are sometimes attached on the main body of the case.

Manatha taiwana and *Mahasena aurea* are morphologically much different from each other and share no close phylogenetic relationship, so that the habit to attach head capsules to the larval case seems to be evolved independently. As stated above, the structure of the larval case and the habit to attach head capsules only to the collar of case are unique characters of *M. taiwana*.

Behaviour involving attachment of larval case for pupation

The habit to attach the case before pupation is various in species of Psychidae has been reported frequently (*e.g.*, Dierl, 1971; Davis, 1964; Herrmann, 1994; Davis & Robinson, 1999). Among Japanese species of Oiketicinae, mature larvae of *Eumeta variegata* spin silk around a twig forming a ring-shaped belt, then narrowly constricts the anterior part of case, and ties it with the belt. Consequently, the fixed case is spindle-shaped and fastened perpendicularly to the twig (Saigusa, 1981). In *Eumeta minuscula*, the mature larva extends the dorsal portion of anterior margin of the case into a narrow ribbon. The apex of this ribbon is tightly attached to a narrow straight silk base spun on the twig or main vein of underside of a leaf, then fixed most part of the anterior margin in a small oval shape. The case-angle (an equivalent for Sackwinkel of Dierl, 1971: the angle of the long axis of pupation case to the substratum) is nearly 45°, and its long axis projects at various angles. In *Acanthopsyche nigraplaga*, the mature larva spins silk on a flat substratum forming a circular silk base and tightly attaches the circular anterior margin of case to the base. The case-angle is about 30° (Sugimoto & Saigusa, unpublished data). In *Brachycyttarus* and *Pteroma*, the mature larva makes a string on the undersurface of a substratum unraveling the collar of larval case, and fastens the constricted anterior margin of the case to tip of the string (Kamarudin *et al.*, 1944; Dierl, 1971; Saigusa, 1972; Inoue, 1982).

The behaviour of forming a silken base consisting of two fan-shaped patterns connected by a straight line is unique to *Manatha taiwana*. This species is somewhat similar to *E. minuscula* in closing the anterior opening of case in a straight line, and also similar to *E. variegata* in fastening the case perpendicularly. But *M. taiwana* differs from these species in case-attachment behaviour. It is not phylogenetically closely related to *Eumeta*, so that some similarities of attachment behaviour between them seem to have evolved independently.

In *Manatha nigripes*, the female pupation case is suspended at the tip of a slender cord that is shorter in comparison with the cases of other *Brachycyttarus* species (Dierl, 1966; Davis, 1990). Consequently, the case-fastening behaviour of *M. nigripes* is quite different from that of *M. taiwana*.

The treatment of exuviae of penultimate instar larva

As the male penultimate instar of *Manatha taiwana* fastens the case for pupation, it molts into the final instar within the fastened case. The last instar pupates without feeding. This process cannot be directly observed, because it proceeds mostly inside the attached case. However, the process was indirectly confirmed based on the evidences that the exuviae of penultimate instar were attached to outside of the case and the remarkable colour difference was found between the penultimate and last instars. This peculiar behaviour of nonfeeding male last instar is also observed in *Eumeta variegata* and *Chalioides kondonis* Kondo, 1922 (Saigusa, 1981; Inoue, 1982; Sugimoto & Saigusa, unpublished data). In *E. variegata*, the colour and size of cranium are markedly different between the penultimate and final instars in the male (Nishida, 1983). Because no exuviae of penultimate instar were found both inside and outside of the case, we conclude that the final instar larva either ate or discarded the exuviae. In *C. kondonis*, exuviae of penultimate instar are attached near the posterior opening of the case with silk. They are not inflated but shriveled, and include head capsule. In *M. taiwana*, the headless exuviae of penultimate instar are inflated and hang from the posterior end of the case as mentioned previously. This inflated condition of exuviae is unique and, as far as we know, it is unknown in other psychids, and rarely found in other Lepidoptera (similar exuviae are found at least in early instars in some Lycaenidae (*e.g.*, *Artopoetes pryeri* (Murray, 1873), Saigusa's observation). The process from molting to attaching the exuviae of the penultimate instar and behavioral significance of this behaviour are unknown.

Emergence of female

The pattern of rupture of female pupal cuticula at emergence differs among species of Psychidae. In *Manatha taiwana*, the female pupal cuticula is ruptured as in the male, along the T-shaped line. *Mahasena* *aurea*, representing the delta grade (Saigusa, 1962) as *M. taiwana*, molts as in this species. In *Eumeta variegata*, the cephalothoracic region of the pupal cuticula is broken in pieces by movement of the female and detached from the main part of the exuviae, so that the main portion of the pupal cuticula has the circular anterior edge along the anterior margin of the 1st abdominal segment (Saigusa, 1981). In *Acanthopsyche nigraplaga*, the condition of female pupal rupture is intermediate between *E. variegata* and *M. taiwana* (Sugimoto & Saigusa, unpublished). The ruptured condition of pupal cuticula in the females of *M. taiwana* and *Mahasena aurea* resembles that widely seen not only in both sexes of primitive Psychidae but in the males of higher Psychidae. Therefore, it seems to be the primitive condition in this family.

Feeding behaviour of the larva

In *Eumeta variegata* and *Mahasena aurea*, young larvae superficially gnaw bark of twigs and leaf surfaces, feeding only the mesophyll (Sugawara *et al*., 1963; Saigusa, 1981). As the larvae grow up, they eat pieces of leaves cut from a leaf margin or from the margin of a hole of a leaf previously made by them (Sugimoto & Saigusa, unpublished data). In *Manatha taiwana*, larvae feed only on the mesophyll skeletonized from the surface of a leaf throughout their entire larval stage. In connection with this feeding behaviour, the larva of *M. taiwana* is characteristic in that the larval case projects upright on the leaf surface even at the final larval stage. *Pteroma* sp. from Japan shows behaviour similar to *M. taiwana* (Sugimoto & Saigusa, unpublished data). This behaviour may be widely found in psychids making conical larval cases or in early instars of other oiketicinine psychids.

Host plant variability

The larval food habit of Psychidae varies by species or even in one species (Tutt, 1990; Kozhanchikov, 1969). Many of the primitive species feed on fungi, lichens, mosses and even dead insects in captivity. In contrast, many species of Oiketicinae with vermiform females feed on higher plants, though most of them are polyphagous. *Bambalina* sp. from Japan is omnivorous, feeding on leaves and bark of twigs of higher plants, lichens, fungi, mosses, and even male pupae of *Ericerus pela* Chavannes (Chinese white-wax scale), including their wax (Saigusa, unpublished data). Yano (1958) reported that *Eumeta variegata* (as *Clania variegata*) fed on 34 plant species belonging to 18 families including Pinaceae. Sugawara *et al*. (1963) listed 43 plant species belonging to 23 families as food plants of *Mahasena aurea*. In contrast, the larvae of *Nipponopsyche fuscescens* Yazaki, 1926 are restricted to Poaceae and Cyperaceae (Seino, 1976). As far as we observed, the larva of *Manatha taiwana* feeds on leaves of 4 flowering plant species belonging to 3 families in the field. Sonan (1935) recorded that the larvae of this species fed on *Camellia sinensis* (=*Thea sinensis*, family Theaceae) in Taiwan. Thus, the larvae of *M. taiwana* are polyphagous like other oiketicinine species, with a broad host range, including both herbaceous and woody plants.

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