

A MORPHOLOGICAL STUDY OF FIRST-STAGE NYMPHS
OF FIVE PERIPLANETA SPECIES (DICTYOPTERA: BLATTIDAE)

by

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INTRODUCTION

The cockroach genus Periplaneta is a large one, with approximately 41 described species (Princis, 1966). The majority of its members are endemic to Africa, Asia, and the Orient. However, several species, P. americana, P. australasiae, P. brunnea, and P. fuliginosa, have been introduced into North and South America (Rehn, 1945). These four species are among the best known in the genus due to the fact that they are common pests of man (Cornwell, 1968). There are no non-domiciliary Periplaneta species in North America (Rehn, 1945).

Adults of the four North American Periplaneta species are well known and have been well studied with respect to their identification, biology, reproduction, and behavior. However, little work, particularly systematic work, has been conducted on the immature stages. There are very few descriptions of the nymphs of any Periplaneta species, and those available are rather brief and not completely accurate. Burmeister (1838), in his paper establishing the genus Periplaneta and describing P. brunnea as a new species, gave a brief and misleading description of the nymph of P. americana.

Periplaneta japonica is a pest in Japan (Asahina, 1961). It has not yet been reported from the United

States. However, its potential for becoming established in this country is very great considering the vast amount of trade between the United States and Japan.

The first-stage nymph is important from a morphological standpoint. Identification of this stage could be useful from a practical standpoint also. Oothecae of closely related cockroach species are often difficult to distinguish, and development to the adult stage may require up to a year or more. Therefore, the development of a method for the identification of small nymphs could prove to be very valuable.

The objectives of the research reported here were 1) to examine the external morphology and prepare detailed descriptions of the first-stage nymphs of P. americana, P. australasiae, P. brunnea, P. fuliginosa, and P. japonica; 2) to devise both prose and pictorial keys to the first-stage nymphs; and 3) to examine closely any unique features of external morphology.

REVIEW OF THE LITERATURE

The biology and life history of several species of Periplaneta have been well documented. The significant works concerning the biology and life history of P. americana include studies by Klein (1933), Nigam (1933), Gould and Deay (1938), Rau (1940), Griffiths and Tauber (1942), and Gier (1947).

Periplaneta fuliginosa and P. brunnea have also received some attention concerning their biology and life history. Gould and Deay (1940) published the biology of six domiciliary species of cockroaches, including both P. fuliginosa and P. americana. Rau (1945) and Wright (1979) presented life histories of P. fuliginosa, the former including a short description of the first-stage nymph. Edmunds (1957) and Wright (1973) published life histories of P. brunnea, the former including a brief description of the first-stage nymph. Willis, et al. (1958) reviewed the nymphal development of the four Nearctic Periplaneta species.

Modern workers have tended more toward studying the effects of the environment on growth and development, as seen in the 1967 and 1968 papers by Wharton, et al. on survival and growth rates of P. americana nymphs as related to population density. Solomon and Griffin (1974),

Sandler and Solomon (1976), and Solomon, et al. (1977) reported on the relationship between illumination of oothecae and nymphs during development and resulting nymphal body weight. Fleet, et al. (1978) studied age distribution and seasonal activity in outdoor populations of P. fuliginosa.

Recently many works have been published in Japan concerning the ecology and life history of several Periplaneta species. Takagi (1974, 1978) examined population age structure and nymphal development in P. fuliginosa. Tabaru and Kobayashi (1971) reported on winter hibernation of P. japonica, and Tsuji and Tabaru (1974) studied the age distribution in these overwintering populations. Tsuji and Mizuno (1972, 1973a) published studies on the effects of autumn and winter conditions on the survival, development, and reproduction of P. americana, P. fuliginosa, and P. japonica.

Brunner de Wattenwyl (1865), Ragge (1965), and Harz and Kaltenbach (1976) described accurately but briefly the nymphs of P. americana and P. australasiae. Hebard (1917) gave brief descriptions of the nymphs of P. americana, P. australasiae, and P. fuliginosa. Cornwell (1968) described the nymphs of P. americana, P. brunnea, and P. australasiae. Lawson and Lawson (1965) figured the terminalia of P. americana and P. brunnea first-stage nymphs and discussed determination of the

sexes. Saito and Hayashi (1973) gave characters for sexing P. fuliginosa nymphs. Huber (1974) subjected to analysis by methods of numerical taxonomy the first-stage and last-stage nymphs of four Nearctic Periplaneta species.

In recent years, some aspects of behavior of both nymphs and adults of several Periplaneta species have been studied. Provine (1976, 1977) discussed eclosion and hatching behavior in P. americana. Reingold and Camhi (1978) published a study of grooming behavior in nymphs and adults of P. americana. Oloman, et al. (1976) studied aggressive behavior in nymphs and adults of P. americana. Tsuji (1965) studied the feeding behavior of first-stage and older nymphs, as well as adults, of P. americana and P. fuliginosa. Tsuji and Mizuno (1973b) and Mizuno and Tsuji (1974) discussed the harboring behavior of P. fuliginosa, P. americana, and P. japonica. Ono and Tsuji (1974) studied the effects of temperature on the harboring behavior in these three species.

Some work has also been done on pheromone-directed behavior in Periplaneta species. Bell, et al. (1972, 1973) reported on the species specificity of the aggregation pheromone in first-stage and second-stage nymphs of P. americana and the maze and trail following directed by this pheromone. Burk and Bell (1973) discussed inhibition of locomotion as a result of the aggregation pheromone. Roth and Cohen (1973) reported

interspecific, pheromone-directed aggregation by first-stage nymphs of P. americana, P. brunnea, and P. japonica; and Piper (1977) noted this phenomenon in P. americana and P. fuliginosa.

MATERIALS AND METHODS

This paper is based on the study of over 800 specimens of first-stage nymphs. Specimens of P. americana, P. australasiae, P. brunnea, P. fuliginosa, and P. japonica were obtained from laboratory colonies maintained at the Cockroach Genetic Stock Center at VPI and SU. Some of the P. americana were obtained from a laboratory colony of adult females collected in Roanoke, Virginia.

Unhatched oothecae were removed from the laboratory rearing containers and placed in petri dishes which contained 2 x 3 cm pieces of moist plastic sponge. When the first stage had tanned fully, they were killed and preserved in 70% ethanol to which a small amount of glycerin was added. Observations made on live nymphs, freshly preserved nymphs, and nymphs that had been preserved for six months or more indicated that storage in ethanol did not affect the color to a noticeable degree. To obtain second-stage nymphs, first-stage nymphs were kept in petri dishes until a molt had occurred and then preserved.

Specimens used for study with the scanning electron microscope were first preserved in formalin for 24 hours,

then placed in 30% ethanol for 24 hours, and finally stored in 70% ethanol.

Ten first-stage nymphs (five males, five females) of each of the five species were used in the descriptions. Nymphs were selected at random from as many different hatch dates as possible.

Specimens were cleared in cold potassium hydroxide overnight and mounted in glycerin on microscope slides.

Adult and nymphal specimens were studied with the aid of a stereoscopic microscope with magnifications of 15 to 90X. A compound microscope with magnifications of 40 and 100X was used for accurate counting and placement of setae. Setae on the pronotum were counted with the aid of an ocular drawing grid. Measurements were made with an ocular micrometer.

Figures of the thoracic regions of the five species were each drawn from a single specimen, different from the 10 from which the means and standard deviations were obtained, by use of an ocular drawing grid.

A scanning electron microscope was used to examine certain setae more closely. Specimens were coated with a 60:40 mixture of gold-palladium. The coated specimens were examined with an Advanced Metals Research Scanning Electron Microscope (Model 900-52) equipped with EDAX (Energy Dispersive X-ray Analysis; Model 707A). Specimens

of all five species were examined. Photographs were taken at magnifications of 50 to 5000X.

COMMENTS ON DESCRIPTIONS AND KEYS

The description of each of the five species includes an adult diagnosis drawn from the literature, a diagnosis of the first-stage nymph, a detailed description of the first-stage nymph, a brief statement of the distribution of the species, also drawn from the literature, and a list of the material examined. Measurement ratios and setal numbers have been reported as a range followed by $\bar{X} \pm \text{SD}$, hence 64-84 (71.4 ± 5.5). Synonymies given include the original description and the one placing the insect in the genus Periplaneta. An annotated list of the important literature pertaining to nymphs has been given, omitting literature dealing with medical importance, chemical control, physiology, reproduction, adult behavior, and adult taxonomy. Cornwell (1968) has also been omitted because of the numerous references to Periplaneta species in this text.

Since the prose key relies primarily on setal types, numbers, and patterns which are difficult to observe on unmounted specimens, it is necessary to clear and mount the specimens on slides after the general body color has been determined. Setae that are approximately 0.20 mm in length are considered long, those about 0.12 mm are moderately long, and those 0.02-0.06 mm are considered

short. The pictorial key (page 31) is primarily designed for use with whole, unmounted specimens.

SPECIES DESCRIPTIONS

PERIPLANETA AMERICANA (LINNAEUS)

(Figs. 1, 2, 3, 5)

Blatta americana Linnaeus, 1758:424.

Periplaneta americana; Burmeister, 1838:503.

Klein, 1933:102-122 (biology)

Nigam, 1933:530-543 (biology)

Gould and Deay, 1938:489-498; 1940:4-11 (biology)

Rau, 1940:121-124, 186-189, 223-227, 273-278
(biology)

Griffiths and Tauber, 1942:263-272 (biology)

Gier, 1947:303-317 (biology)

Willis, et al., 1958:53-69 (biology)

Lawson and Lawson, 1965:408-410 (nymphs)

Tsuji, 1965:255-262 (behavior)

Wharton, et al., 1967:699-716; 1968:637-653
(biology)

Bell, et al., 1972:414-421; 1973:251-255
(behavior)

Tsuji and Mizuno, 1972:101-111; 1973a:185-194
(biology)

Burk and Bell, 1973:36-41 (behavior)

Roth and Cohen, 1973:1315-1323 (behavior)

Ono and Tsuji, 1974:95-98 (behavior)

- Mizuno and Tsuji, 1974:237-240 (behavior)
Solomon and Griffin, 1974:140-142 (biology)
Olomon, et al., 1976:243-248 (behavior)
Sandler and Solomon, 1976:889-890 (biology)
Provine, 1976:127-131; 1977:213-220 (behavior)
Piper, 1977:88-93 (behavior)
Solomon, et al., 1977:409-413 (biology)
Reingold and Camhi, 1978:101-110 (behavior)

Adult Diagnosis. This species can be distinguished from other Nearctic Periplaneta by the following character combination: color above chestnut brown; tegmina unicolorous; last segment of male and female cercus twice as long as wide; male first abdominal segment unmodified; male supraanal plate translucent, apically rounded and deeply notched, produced considerably beyond the subgenital plate.

First-Stage Nymph Diagnosis. This species can be distinguished from other Nearctic Periplaneta by the following character combination: antenna, head, thorax, and abdomen unicolorous pale brown; majority of nonmarginal setae on thoracic nota short to moderately long (0.02-0.12 mm); pronotum with 50-82 nonmarginal setae; mesonotum with 24-38 nonmarginal setae; metanotum with 22-32 nonmarginal setae.

First-Stage Nymph Description (N=10). Head pale brown dorsally and ventrally; ocelliform spot distinct, white; apical tips of maxillary and labial palps white; interocular ratio 1.92-2.34 (2.03 ± 0.12). Antenna as long as body, pale brown.

Thoracic nota pale brown, sparsely setose. Majority of nonmarginal setae short to moderately long (0.02-0.12 mm). Pronotum: length-width ratio 0.66-0.72 (0.70 ± 0.02), 64-84 (71.4 ± 5.5) marginal setae, 50-82 (64.8 ± 8.4) nonmarginal setae, 10-14 (10.4 ± 1.3) short, robust setae with tubular sockets along underside of posterior margin. Mesonotum: 38-52 (45.0 ± 4.1) marginal setae, 24-38 (33.2 ± 4.1) nonmarginal setae, 10-12 (10.4 ± 0.8) short, robust setae with tubular sockets along underside of posterior margin. Metanotum: 48-48 (43.6 ± 3.0) marginal setae, 22-32 (25.8 ± 3.1) nonmarginal setae, 10-12 (10.4 ± 0.8) short, robust setae with tubular sockets along underside of posterior margin.

Abdominal terga pale brown, sparsely setose, segments II-VIII dorsally with a strong seta at posterolateral corner. Segments I-VIII pale brown ventrally, glabrous. Cercus pale brown, three segmented.

Legs pale brown to white. Coxae with scattered small setae. Tarsi slightly longer than tibiae, each tarsomere with 3 strong setae ventrally. Foreleg: femur with curved row of 15-19 (17.1 ± 1.3) stout setae on

antero-ventral margin, apical seta 1/7 length of femur; tibia with 8-10 (9.3 ± 0.7) strong setae on apical 2/3, apical setae 1/3 length of tibia. Midleg: femur with curved row of 9 (9.0 ± 0.0) stout setae on antero-ventral margin, apical seta 1/5 length of femur; tibia with 12-15 (13.6 ± 1.0) strong setae on apical 2/3, apical setae 1/3 length of tibia. Hindleg: femur with curved row of 9 (9.0 ± 0.0) stout setae on antero-ventral margin, apical seta 1/6 length of femur; tibia with 19-24 (22.5 ± 1.6) strong setae on apical 2/3, apical setae 1/5 length of tibia.

Known Distribution. Africa, Europe, India, Japan, Australia, North America, South America.

Material Examined. Five first-stage nymphs from the Cockroach Genetic Stock Center at VPI and SU, one from each of the following hatch dates: April 24, 1978; June 29, 1978; July 23, 1978; August 3, 1978; August 6, 1978; and five first-stage nymphs from the Roanoke, Virginia colony, one from each of the following hatch dates: February 28, 1978; March 27, 1978; April 7, 1978; May 27, 1978; June 6, 1978.

PERIPLANETA AUSTRALASIAE (FABRICIUS)

(Figs. 6, 10, 11, 12, 14)

Blatta australasiae Fabricius, 1775:271.

Periplaneta australasiae; Burmeister, 1838:503.

Willis, et al., 1958:53-69 (biology)

Adult Diagnosis. This species can be distinguished from other Nearctic Periplaneta by the following character combination: color above chestnut brown; tegmina with yellow sub-marginal stripe along basal third; male first abdominal segment with broad, shallow median depression bearing tuft of setae; male supraanal plate sclerotized, opaque, apically truncate and not deeply notched, not or scarcely produced beyond the subgenital plate; ventral surface of male supraanal plate not specialized.

First-Stage Nymph Diagnosis. This species can be distinguished from other Nearctic Periplaneta by the following character combination: antenna with 2 pale bands at basal and distal ends; mesonotum lighter in color than pronotum; metanotum dark brown with 2 white spots near anterior margin (rarely absent); abdominal segments I and II white ventrally; majority of nonmarginal setae on thoracic nota moderately long to long (0.12-0.20 mm); pronotum with 102-122 nonmarginal setae; mesonotum with 36-56 nonmarginal setae; metanotum with 30-38 nonmarginal setae.

First-Stage Nymph Description (N=10). Head dark brown dorsally and ventrally; ocelliform spot distinct, pale brown; apical tips of maxillary and labial palps white; interocular ratio 1.91-2.32 (2.02 ± 0.13). Antenna as long as body, first 5-6 segments all or partly pale brown, last 4-5 segments pale brown to white, intermediate segments dark brown.

Thoracic nota dark brown to brownish-white, setose. Majority of nonmarginal setae moderately long to long (0.12-0.20 mm). Pronotum: dark brown, length-width ratio 0.66-0.72 (0.69 ± 0.02), 90-102 (96.0 ± 3.9) marginal setae, 102-122 (112.6 ± 7.3) nonmarginal setae, 8 (8.0 ± 0.0) short, robust setae with tubular sockets along underside of posterior margin. Mesonotum: white, translucent medially, bordered anteriorly and posteriorly by dark brown bands, 48-58 (53.0 ± 3.0) marginal setae, 36-56 (46.8 ± 5.4) nonmarginal setae, 6-10 (8.0 ± 1.3) short, robust setae with tubular sockets along underside of posterior margin. Metanotum: dark brown medially, pale brown laterally, with 2 pale brown to white spots near anterior margin, 46-56 (49.8 ± 2.7) marginal setae, 30-38 (33.8 ± 2.4) nonmarginal setae, 6-10 (8.0 ± 0.9) short, robust setae with tubular sockets along underside of posterior margin.

Abdominal terga dark brown, setose, segment II dark brown medially, white laterally, segments II-VIII

dorsally with a strong seta at postero-lateral corner. Segments I and II white ventrally, segments III-VIII dark brown ventrally, glabrous. Cerci dark brown, three segmented.

Legs dark brown to brownish-white. Coxae with scattered small setae. Tarsi slightly longer than tibiae, each tarsomere with 3 strong setae ventrally. Foreleg: femur with curved row of 14-17 (15.4 ± 0.8) stout setae on antero-ventral margin, apical seta $1/5$ length of femur; tibia with 9-11 (10.1 ± 0.6) strong setae on apical $2/3$, apical seta $1/3$ length of tibia. Midleg: femur with curved row of 9 (9.0 ± 0.0) stout setae on antero-ventral margin, apical seta $1/4$ length of femur; tibia with 15-17 (15.6 ± 0.7) strong setae on apical $2/3$, apical setae $1/3$ length of tibia. Hindleg: femur with curved row of 9 (9.0 ± 0.0) stout setae on antero-ventral margin, apical seta $1/5$ length of femur; tibia with 21-23 (22.0 ± 0.8) strong setae on apical $2/3$, apical setae $1/4$ length of tibia.

Known Distribution. Africa, Australia, Europe, Japan, North America, South America, the West Indies.

Material Examined. Ten first-stage nymphs from the Cockroach Genetic Stock Center at VPI and SU, one one from each of the following hatch dates: November 15, 1977; March 8, 1978; April 1, 1978; April 12, 1978; April

20, 1978; April 26, 1978; May 9, 1978; May 17, 1978; May 19, 1978; June 7, 1978.

Remarks. Approximately 5-6% of 147 specimens did not have two white spots on the mesonotum. Nine of the 10 specimens used for the description had two spots; the tenth specimen had only one spot.

PERIPLANETA BRUNNEA BURMEISTER

(Fig. 7)

Periplaneta brunnea Burmeister, 1838:503.

Edmunds, 1957:283-286 (biology)

Willis, et al., 1958:53-69 (biology)

Lawson and Lawson, 1965:408-410 (nymphs)

Roth and Cohen, 1973:1315-1323 (behavior)

Wright, 1973:274-277 (biology)

Adult Diagnosis. This species can be distinguished from other Nearctic Periplaneta by the following character combination: color above chestnut brown; tegmina unicolorous; last segment of male and female cercus not twice as long as wide; male first abdominal segment with broad, shallow median depression bearing tuft of setae; male supraanal plate sclerotized, opaque, apically truncate

and not deeply notched, not or scarcely produced beyond the subgenital plate; ventral surface of male supraanal plate not specialized.

First-Stage Nymph Diagnosis. This species can be distinguished from other Nearctic Periplaneta by the following character combination: antenna with 2 pale bands at basal and distal ends; mesonotum lighter in color than pronotum; abdominal dorsum lighter in color than head or pronotum; abdominal segments I and II ventromedially pale brown, dark brown laterally; majority of nonmarginal setae on thoracic nota moderately long to long (0.12-0.20 mm).

First-Stage Nymph Description (N=10). Head dark brown dorsally, pale brown ventrally; ocelliform spot distinct, pale brown; apical tips of maxillary and labial palps white; interocular ratio 1.74-1.97 (1.89 ± 0.07). Antenna as long as body, first 8-9 segments pale brown, last 5-6 segments white, intermediate segments brown.

Thoracic nota brown to brownish-white, setose. Majority of nonmarginal setae moderately long to long (0.12-0.20 mm). Pronotum: dark brown medially, pale brown laterally, length-width ratio 0.64-0.72 (0.67 ± 0.03); 80-98 (86.6 ± 5.4) marginal setae, 60-72 (65.8 ± 5.1) nonmarginal setae, 8 (8.0 ± 0.0) short, robust setae with tubular sockets along underside of posterior margin. Mesonotum: pale brown to whitish-brown, translucent

medially, bordered anteriorly and posteriorly by brown bands, 48-60 (52.6 ± 3.8) marginal setae, 22-30 (23.8 ± 2.6) nonmarginal setae, 8 (8.0 ± 0.0) short, robust setae with tubular sockets along underside of posterior margin.

Metanotum: dark brown medially, pale brown laterally, 44-54 (49.4 ± 3.7) marginal setae, 16-24 (19.2 ± 2.9) nonmarginal setae, 6-8 (7.8 ± 0.6) short, robust setae with tubular sockets along underside of posterior margin.

Abdominal terga pale brown medially, brown laterally, setose, segments I and II dorsally entirely pale brown, segments II-VIII dorsally with a strong seta at posterolateral corner. Segments I-VIII ventrally pale brown medially, dark brown laterally, glabrous. Cercus dark brown, three segmented.

Legs brown to brownish-white. Coxae with scattered small setae. Tarsi slightly longer than tibiae, each tarsomere with 3 strong setae ventrally. Foreleg: femur with curved row of 17-19 (18.1 ± 0.6) stout setae on antero-ventral margin, apical seta $1/5$ length of femur; tibia with 8-11 (9.6 ± 1.1) strong setae on apical $2/3$, apical setae $1/3$ length of tibia. Midleg: femur with curved row of 9-10 (9.2 ± 0.4) stout setae on antero-ventral margin, apical seta $1/4$ length of femur; tibia with 14-17 (15.9 ± 1.0) strong setae on apical $2/3$, apical setae $1/3$ length of tibia. Hindleg: femur with curved row of 9 (9.0 ± 0.0) stout setae on antero-ventral margin,

apical seta 1/5 length of femur; tibia with 21-26 (23.2 ± 1.5) strong setae on apical 2/3, apical setae 1/5 length of tibia.

Known Distribution. Africa, Australia, South China, Malaysia, Japan, North America, South America.

Material Examined. Ten first-stage nymphs from the Cockroach Genetic Stock Center at VPI and SU, two from the March 8, 1978 hatch date and one from each of the following hatch dates: November 8, 1977; May 15, 1978; May 17, 1978; May 30, 1978; June 4, 1978; June 15, 1978; June 18, 1978; June 20, 1978.

PERIPLANETA FULIGINOSA (SERVILLE)

(Figs. 8, 13, 15)

Kakerlac fuliginosa Serville, 1839:70.

Periplaneta fuliginosa; Brunner de Wattenwyl, 1865: 238.

Gould and Deay, 1940:26-28 (biology)

Rau, 1945:107-108 (biology)

Willis, et al., 1958:53-69 (biology)

Tsuji, 1965:255-262 (behavior)

Tsuji and Mizuno, 1972:101-111; 1973a:185-194;
(biology); 1973b:65-72 (behavior)

Saito and Hayashi, 1973:181-184 (nymphs)

Ono and Tsuji, 1974:95-98 (behavior)

Takage, 1974:27-34; 1978:85-92 (biology)

Adult Diagnosis. This species can be distinguished from other Nearctic Periplaneta by the following character combination: color above entirely blackish-brown; both sexes fully winged; male first abdominal segment with broad, shallow depression bearing tuft of setae; male supraanal plate sclerotized, opaque, apically truncate and not deeply notched, not or scarcely produced beyond the subgenital plate; ventral surface of male supraanal plate specialized, bearing two large callosities, the surfaces of which are covered with microscopic denticulations.

First-Stage Nymph Diagnosis. This species can be distinguished from other Nearctic Periplaneta by the following character combination: antenna with 2 pale bands at basal and distal ends; mesonotum lighter in color than pronotum; metanotum solid dark brown; abdominal segments I and II white ventrally; majority of nonmarginal setae on thoracic nota moderately long to long (0.12-0.20 mm); pronotum with 52-90 nonmarginal setae; mesonotum with 18-36 nonmarginal setae; metanotum with 16-24 nonmarginal setae.

First-Stage Nymph Description (N=10). Head dark brown dorsally and ventrally; ocelliform spot distinct, pale brown; apical tips of maxillary and labial palps

white; interocular ratio 1.79-2.09 (1.96 ± 0.08). Antenna as long as body, first 3-6 segments all or partly pale brown, last 4-5 segments pale brown to white, intermediate segments dark brown.

Thoracic nota dark brown to brownish-white, setose. Majority of nonmarginal setae moderately long to long (0.12-0.20 mm). Pronotum: dark brown, length-width ratio 0.62-0.69 (0.65 ± 0.02), 78-96 (87.6 ± 5.7) marginal setae, 52-90 (75.8 ± 11.2) nonmarginal setae, 6-8 (7.6 ± 0.8) short, robust setae with tubular sockets along underside of posterior margin. Mesonotum: pale brown to white, translucent medially, bordered anteriorly and posteriorly by dark brown bands, 40-56 (49.6 ± 5.2) marginal setae, 18-36 (29.8 ± 5.5) nonmarginal setae, 4-8 (7.2 ± 1.4) short, robust setae with tubular sockets along underside of posterior margin. Metanotum: dark brown medially, pale brown laterally, 40-52 (47.8 ± 3.7) marginal setae, 16-24 (22.0 ± 2.3) nonmarginal setae, 6-10 (8.0 ± 0.9) short, robust setae with tubular sockets along underside of posterior margin.

Abdominal terga dark brown, setose, segment II dark brown medially, white laterally, segments II-VIII dorsally with a strong seta at postero-lateral corner. Segments I and II white ventrally, segments III-VIII dark brown ventrally, glabrous. Cercus dark brown, three segmented.

Legs dark brown to brownish-white. Coxae with scattered small setae. Tarsi slightly longer than tibiae, each tarsomere with 3 strong setae ventrally. Foreleg: femur with curved row of 16-19 (18.1 ± 0.9) stout setae on antero-ventral margin, apical seta $1/5$ length of femur; tibia with 9-11 (9.6 ± 0.7) strong setae on apical $2/3$, apical setae $1/3$ length of tibia. Midleg: femur with curved row of 9-10 (9.1 ± 0.3) stout setae on antero-ventral margin, apical seta $1/4$ length of femur; tibia with 13-17 (15.2 ± 1.4) strong setae on apical $2/3$, apical setae $1/3$ length of tibia. Hindleg: femur with curved row of 9-10 (9.2 ± 0.4) stout setae on antero-ventral margin, apical seta $1/5$ length of femur; tibia with 23-27 (25.6 ± 1.2) strong setae on apical $2/3$, apical setae $1/4$ length of tibia.

Known Distribution. Japan, China, North America, South America.

Material Examined. Ten first-stage nymphs from the Cockroach Genetic Stock Center at VPI and SU, two from the May 12, 1978 hatch date and one from each of the following hatch dates: November 18, 1977; February 7, 1978; May 30, 1978; June 4, 1978; June 11, 1978; June 14, 1978; December 4, 1978; December 8, 1978.

PERIPLANETA JAPONICA KARNY

(Fig. 9)

Periplaneta japonica Karny, 1908:18.

Tabaru and Kobayashi, 1971:76-77 (biology)

Tsuji and Mizuno, 1972:101-111; 1973a:185-194

(biology)

Roth and Cohen, 1973:1315-1323 (behavior)

Ono and Tsuji, 1974:95-98 (behavior)

Tsuji and Tabaru, 1974:215-218 (biology)

Mizuno and Tsuji, 1974:237-240 (behavior)

Adult Diagnosis. This species can be distinguished from Nearctic Periplaneta by the following character combination: color above entirely blackish-brown; female brachypterous; male first abdominal segment with broad, shallow depression bearing tuft of setae; male supraanal plate sclerotized, opaque, not or scarcely produced beyond the subgenital plate, with parallel sides and an acute emargination of the posterior margin, lateral angles acute and projecting in the form of sharp spines; ventral surface of male supraanal plate not specialized.

First-Stage Nymph Diagnosis. This species can be distinguished from Nearctic Periplaneta by the following character combination: antenna, head, thorax, and abdomen unicolorous dark brown; majority of nonmarginal setae on thoracic nota short to moderately long (0.02-0.12 mm);

pronotum with 36-44 nonmarginal setae; mesonotum with 16-22 nonmarginal setae; metanotum with 12-16 nonmarginal setae.

First-Stage Nymph Description (N=10). Head dark brown dorsally and ventrally; ocelliform spot distinct, pale brown; apical tips of maxillary and labial palps white; interocular ratio 1.85-2.03 (1.94 ± 0.06). Antenna as long as body, dark brown.

Thoracic nota dark brown medially, pale brown laterally, sparsely setose. Majority of nonmarginal setae short to moderately long (0.02-0.12 mm). Pronotum: length-width ratio 0.59-0.68 (0.63 ± 0.03), 60-76 (68.4 ± 5.2) marginal setae, 36-44 (39.2 ± 2.5) nonmarginal setae, 6-10 (8.0 ± 0.9) short, robust setae with tubular sockets along underside of posterior margin. Mesonotum: 38-46 (41.0 ± 3.0) marginal setae, 16-22 (19.0 ± 1.7) nonmarginal setae, 8-10 (8.4 ± 0.8) short, robust setae with tubular sockets along underside of posterior margin. Metanotum: 36-44 (39.2 ± 2.9) marginal setae, 12-16 (13.8 ± 1.5) nonmarginal setae, 8-10 (8.8 ± 1.0) short, robust setae with tubular sockets along underside of posterior margin.

Abdominal terga dark brown medially, pale brown laterally, sparsely setose, segments II-VIII dorsally with a strong seta at postero-lateral corner. Segments I-VIII dark brown ventrally, glabrous. Cercus pale brown, three segmented.

Legs dark brown to brownish-white. Coxae with scattered small setae. Tarsi slightly longer than tibiae, each tarsomere with 3 strong setae ventrally. Foreleg: femur with curved row of 16-18 (17.1 ± 0.7) stout setae on antero-ventral margin, apical seta $1/6$ length of femur; tibia with 7-10 (8.5 ± 1.0) strong setae on apical $2/3$, apical setae $1/3$ length of tibia. Midleg: femur with curved row of 9-10 (9.2 ± 0.4) stout setae on antero-ventral margin, apical seta $1/4$ length of femur; tibia with 15-18 (16.1 ± 0.9) strong setae on apical $2/3$, apical setae $1/3$ length of tibia. Hindleg: femur with curved row of 9-10 (9.4 ± 0.5) stout setae on antero-ventral margin, apical seta $1/4$ length of femur; tibia with 24-30 (26.8 ± 1.8) strong setae on apical $2/3$, apical setae $1/5$ length of tibia.

Known Distribution. Japan, China, the Soviet Union.

Material Examined. Ten first-stage nymphs from the Cockroach Genetic Stock Center at VPI and SU: two from the June 16, 1978 hatch date, five from the July 15, 1978 hatch date, and three from the July 23, 1978 hatch date.

KEY TO FIRST-STAGE NYMPHS OF PERIPLANETA AMERICANA,
P. AUSTRALASIAE, P. BRUNNEA, P. FULIGINOSA,
AND P. JAPONICA

1. Antenna, head, thorax, and abdomen unicolorous pale brown to dark brown; majority of nonmarginal setae on thoracic nota short to moderately long (0.02-0.12 mm) 2
Antenna with 2 pale bands at basal and distal ends; mesonotum lighter in color than pronotum; majority of nonmarginal setae on thoracic nota moderately long to long (0.12-0.20 mm) 3
2. Entire body dark brown; pronotum with 36-44 nonmarginal setae; mesonotum with 16-22 nonmarginal setae; metanotum with 12-16 nonmarginal setae.
. P. japonica (p. 26)
- Entire body pale brown; pronotum with 50-82 nonmarginal setae; mesonotum with 24-38 nonmarginal setae; metanotum with 22-32 nonmarginal setae.
. P. americana (p. 12)
3. Abdominal dorsum lighter in color than head or pronotum; abdominal segments I and II ventromedially pale brown,

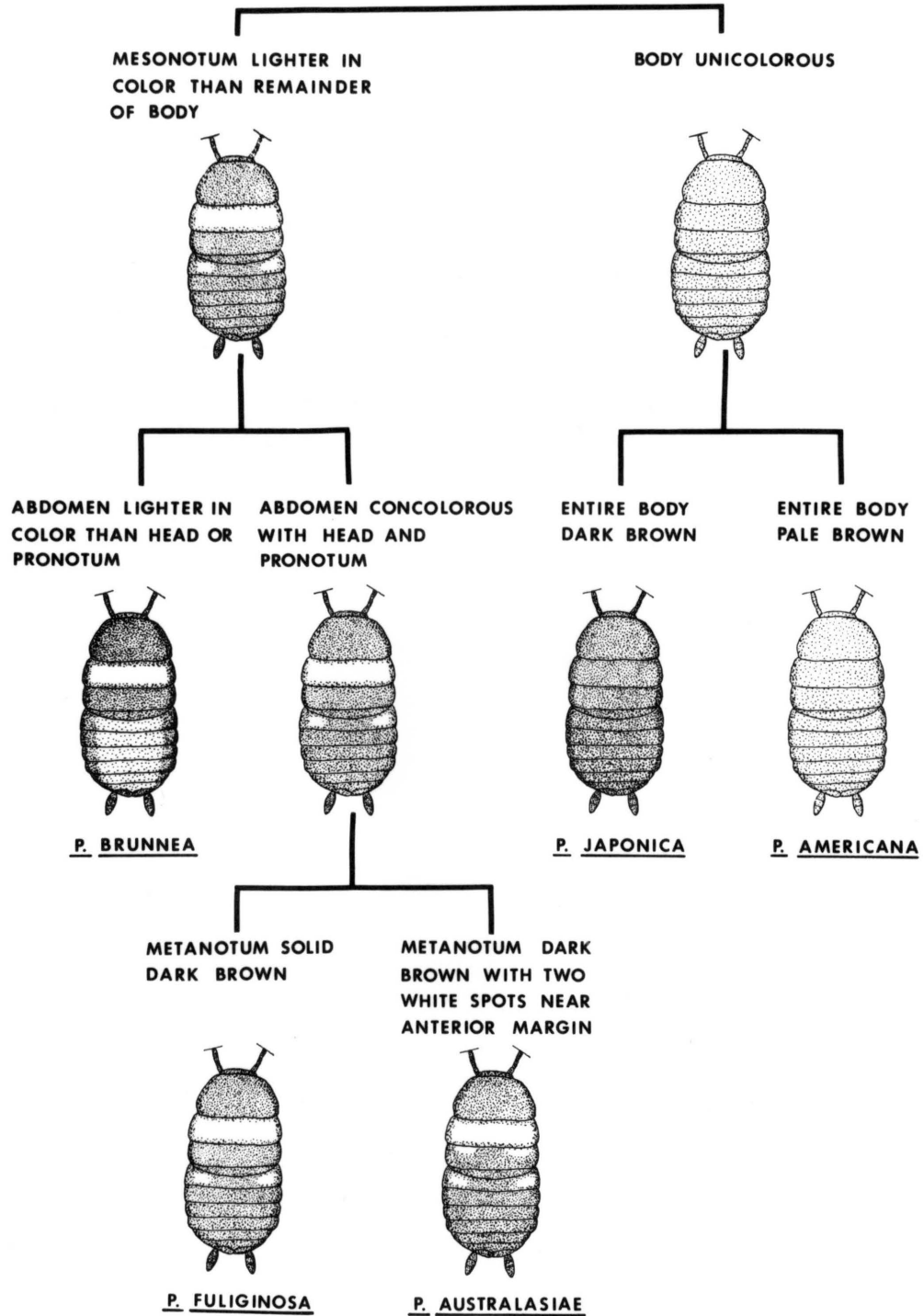
dark brown laterally; antennal segments 1-9 pale
brown P. brunnea (p. 19)

Abdominal dorsum concolorous with head and pronotum;
abdominal segments I and II entirely white ventrally
. 4

4. Metanotum dark brown; pronotum with 52-90 non-
marginal setae; mesonotum with 18-36 nonmarginal setae;
metanotum with 16-24 nonmarginal setae.
. P. fuliginosa (p. 22)

Metanotum dark brown with 2 white spots near anterior
margin (rarely absent); pronotum with 102-122 non-
marginal setae; mesonotum with 36-56 nonmarginal setae;
metanotum with 30-38 nonmarginal setae.
. P. australasiae (p. 16)

PICTORIAL KEY TO FIRST-STAGE NYMPHS
OF FIVE PERIPLANETA SPECIES



DISCUSSION

Close observations of the external morphology of the first-stage nymphs of the five Periplaneta species revealed the presence of at least five types of thoracic setae (Figs. 10-15). These are classified on the basis of length and shape and include 1) long (0.20 mm) and 2) short to moderately long (0.02-0.12 mm) thoracic macrosetae; 3) tiny, whiplike nonmarginal setae, visible at magnifications of 2000 and 5000X; 4) short, robust setae with hooked tips and tubular sockets, approximately 0.014-0.023 mm in length, along the underside of the posterior margins of the three thoracic segments; and 5) smaller, robust marginal setae located dorsally on the thoracic segments and visible at magnifications of 2000 and 5000X. The short, robust setae with tubular sockets located along the underside of the posterior thoracic margins are found on first-stage nymphs and second-stage nymphs (and presumably also on other instars).

The short, robust setae are unique in that these cockroach species have no other setae similar to them located elsewhere on the body. Due to their position and proximity to the next posterior segment, they probably function as mechanoreceptors.

Periplaneta australasiae and P. fuliginosa have all five types of setae, but P. americana, P. brunnea, and P. japonica lack the tiny, whiplike nonmarginal setae. It is uncertain whether they have the small, robust dorsal marginal setae. All possess the short, robust setae with tubular sockets. Even among these five species there is a wide range of setal number, from the very setose P. australasiae to the much less setose P. japonica. Even greater variability of setal number probably exists among all the species in the genus.

The five species of Periplaneta seem to fall into two rather well-defined groups based on five criteria: 1) the number and length of nonmarginal thoracic setae, 2) the color pattern, 3) the size of the oothecae (Cornwell, 1968; Roth, 1968), 4) the chromosome number (Cohen and Roth, 1970), and 5) Huber's (1974) numerical taxonomy. Group I consists of P. americana and P. japonica, both solid in color, both having the majority of the non-marginal setae on the thoracic nota short to moderately long (0.02-0.12 mm), both having short (7-10 mm) oothecae, and both having a diploid chromosome number of 34. Group II contains P. brunnea, P. fuliginosa, and P. australasiae, which have banded color patterns, the majority of the non-marginal setae on the thoracic nota moderately long to long (0.12-0.20 mm), long (11-14 mm) oothecae, and a diploid chromosome number of 28. Huber (1974) subjected

the first-stage nymphs of P. americana, P. australasiae, P. brunnea, and P. fuliginosa to analysis by numerical taxonomy. He found that P. fuliginosa, P. australasiae, and P. brunnea formed a cluster, and P. americana was isolated from the rest, which is in agreement with the results presented here.

Although the primitive habitat in which the five species evolved is not known, the two groups of Periplaneta (Group I - P. americana, P. japonica; Group II - P. brunnea, P. fuliginosa, P. australasiae) probably evolved in different types of habitats. The possession of a banded color pattern and longer setae, as in Group II, might be advantageous in a more open situation, where the banding might allow the insect to be cryptic against a background surface and where long setae would not come into contact with the walls of a crack or crevice. In a tight-crevice habitat, in which P. americana and P. japonica may have evolved, evolution would tend to favor shorter setae, and a banded pattern would be unnecessary. A rather protected habitat could then have resulted in a solid color pattern and shorter setae.

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* - denotes literature not seen by the author.

- Fig. 1. P. americana first-stage nymph, dorsal view.
- Fig. 2. P. americana first-stage nymph, anterior view of left metathoracic leg.
- Fig. 3. P. americana first-stage nymph, head, anterior view, dashed lines show source of length-width ratio.
- Fig. 4. Periplaneta sp., first-stage nymph, thorax, longitudinal section, enlargement showing position of short, robust setae with tubular sockets; A (anterior), P (posterior).

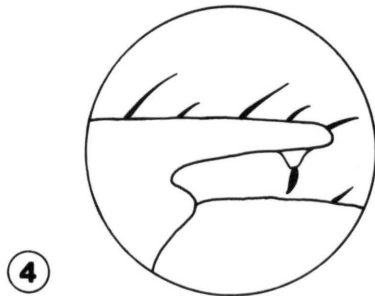
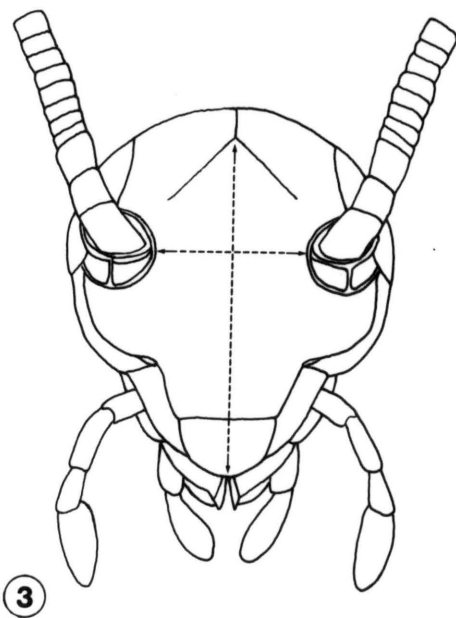
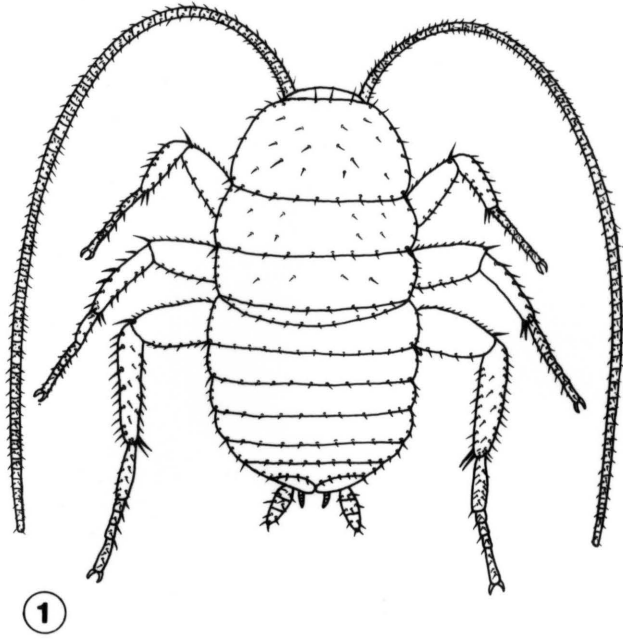


Fig. 5. P. americana first-stage nymph, thoracic nota;
dorsal view (left) showing macrosetae,
ventral view (right) showing position of
short, robust setae.

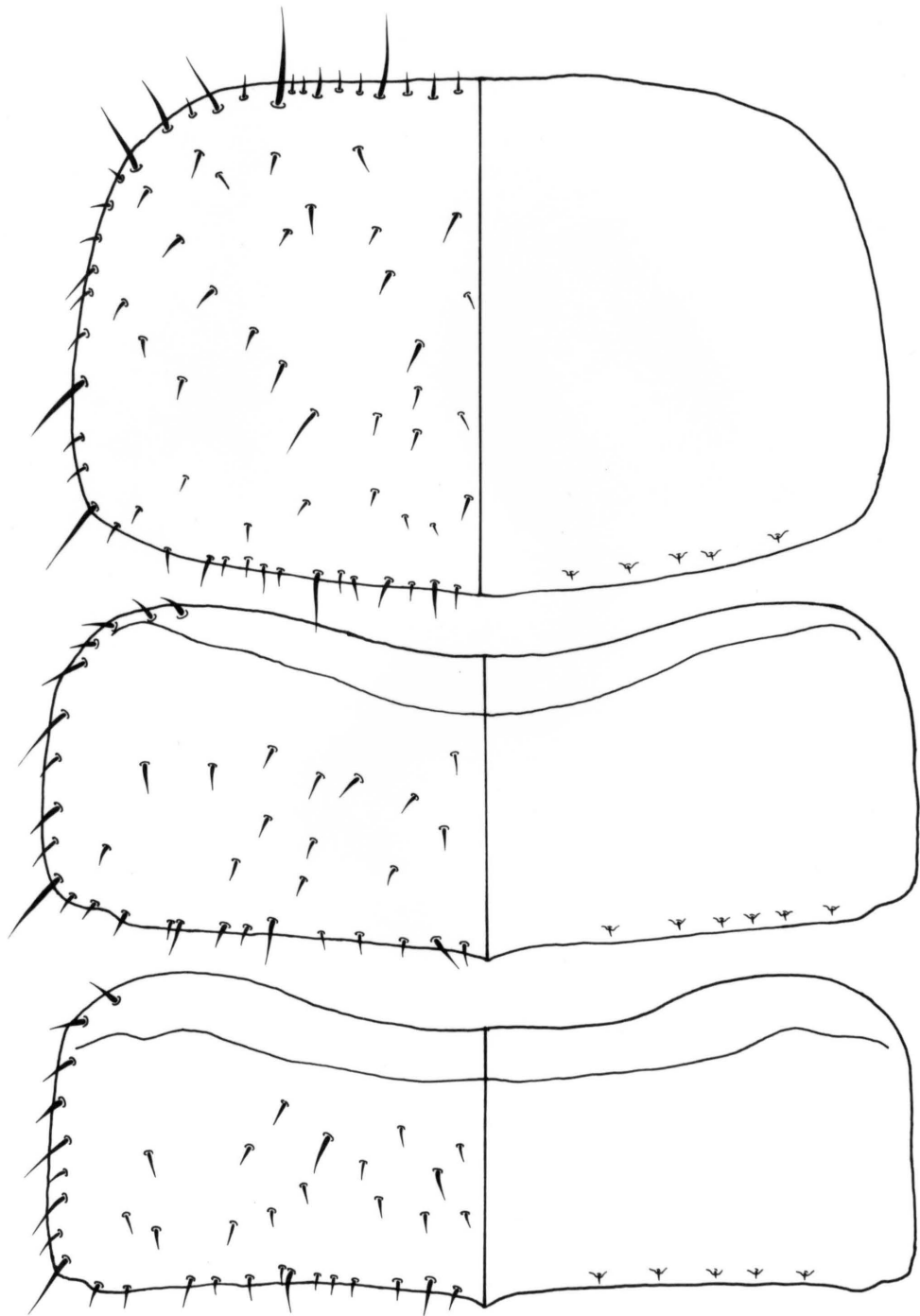


Fig. 6. P. australasiae first-stage nymph, thoracic nota;
dorsal view (left) showing macrosetae,
ventral view (right) showing position of
short, robust setae.

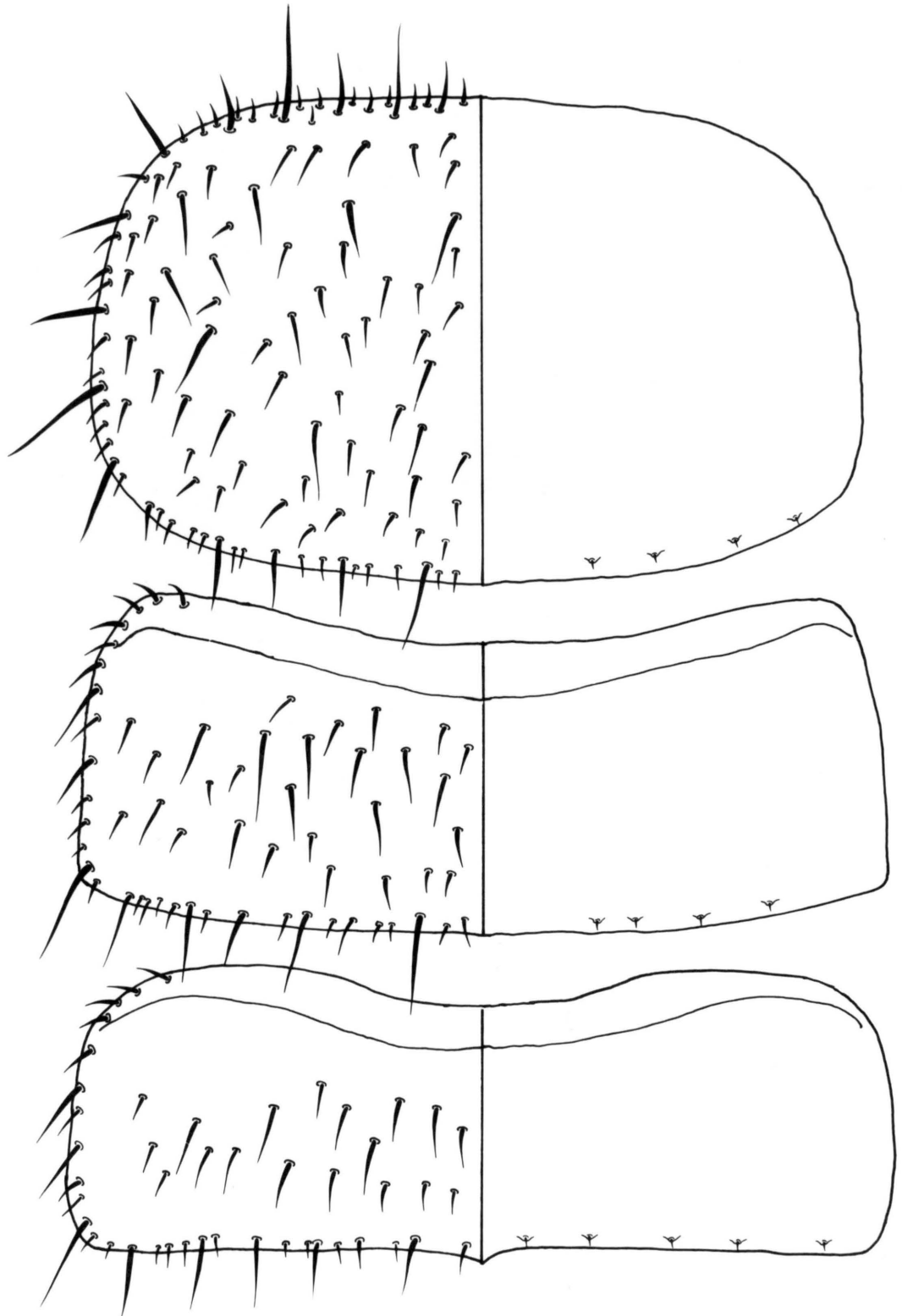


Fig. 7. P. brunnea first-stage nymph, thoracic nota;
dorsal view (left) showing macrosetae,
ventral view (right) showing position of
short, robust setae.

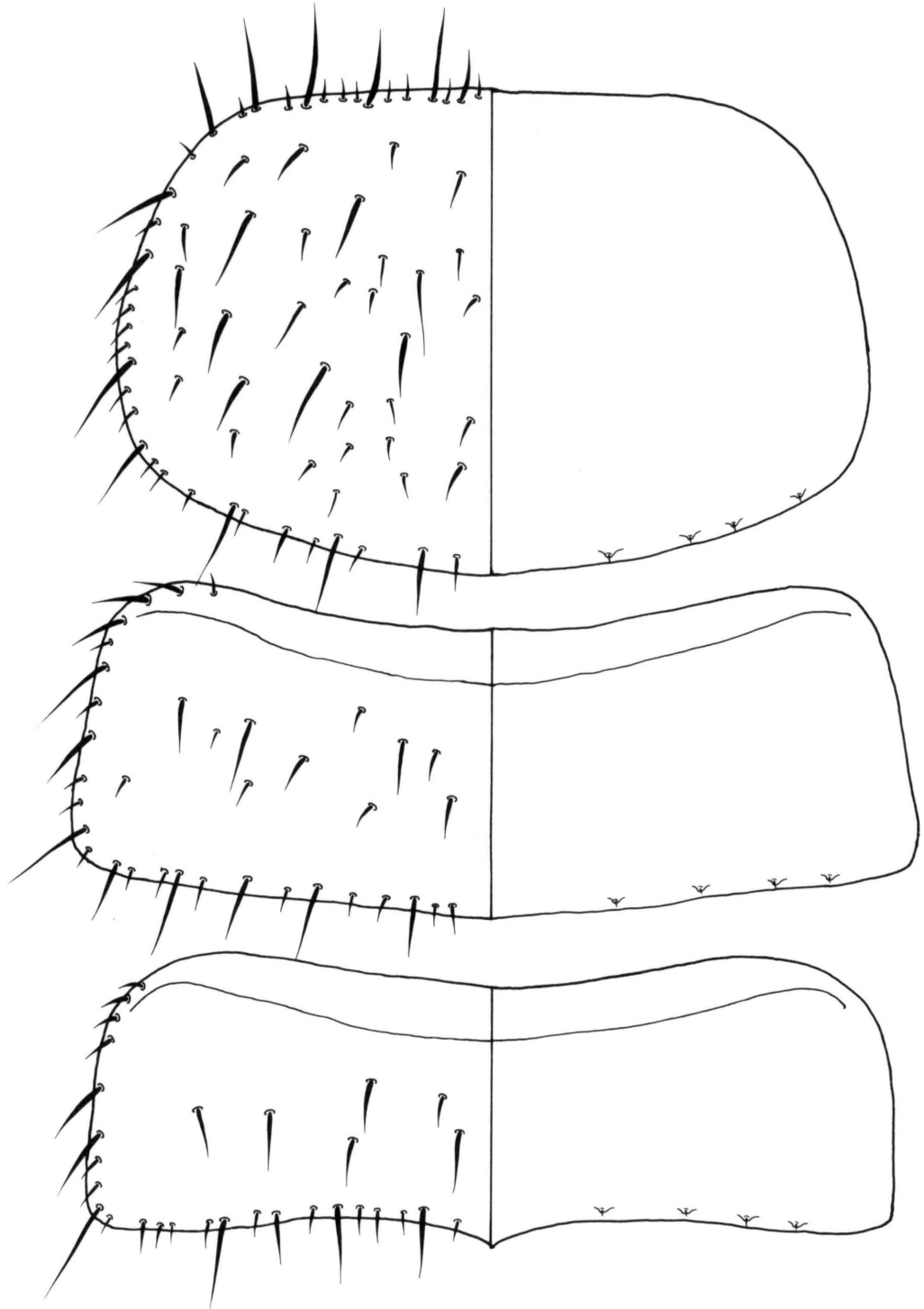


Fig. 8. P. fuliginosa first-stage nymph, thoracic nota;
dorsal view (left) showing macrosetae,
ventral view (right) showing position of
short, robust setae.

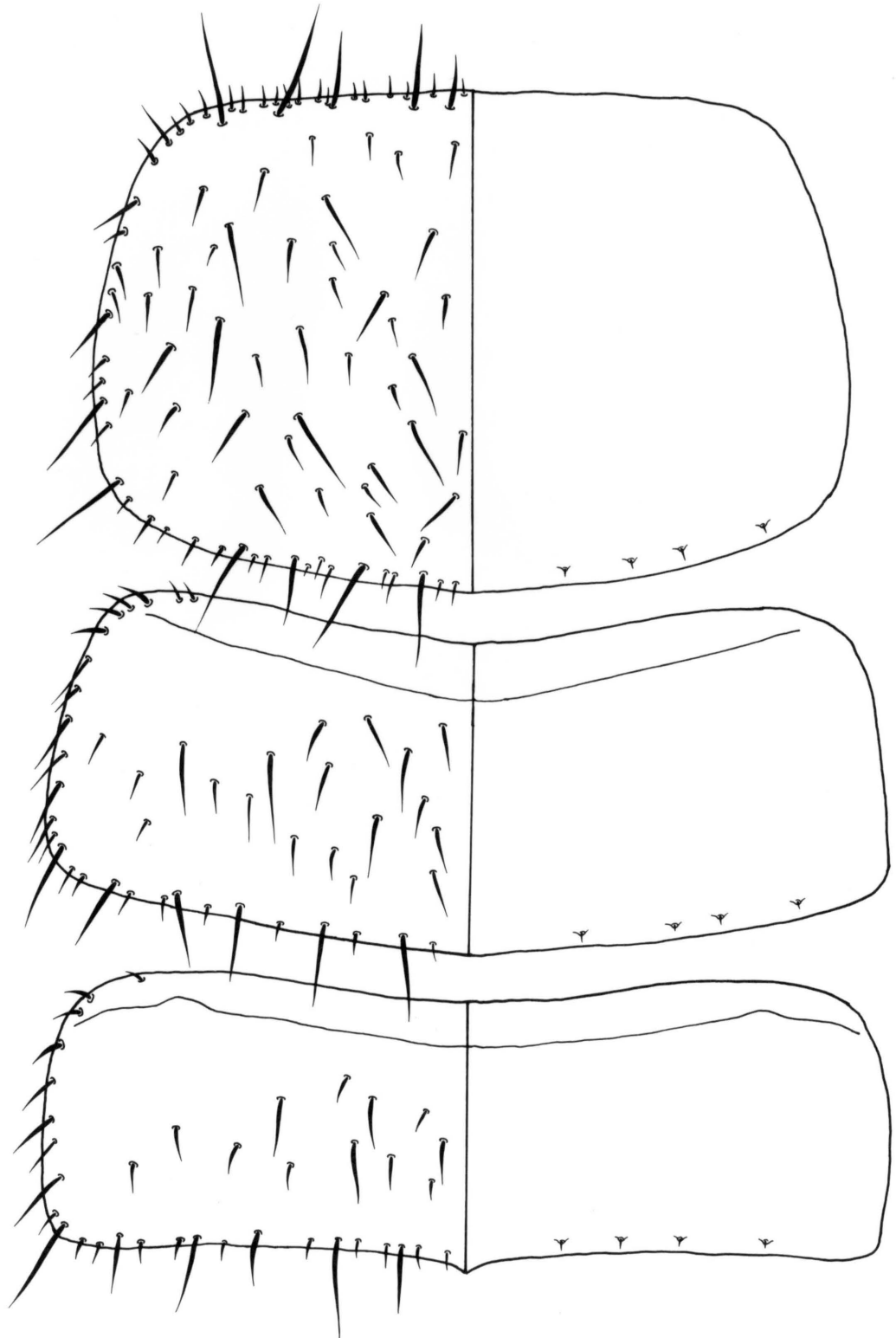
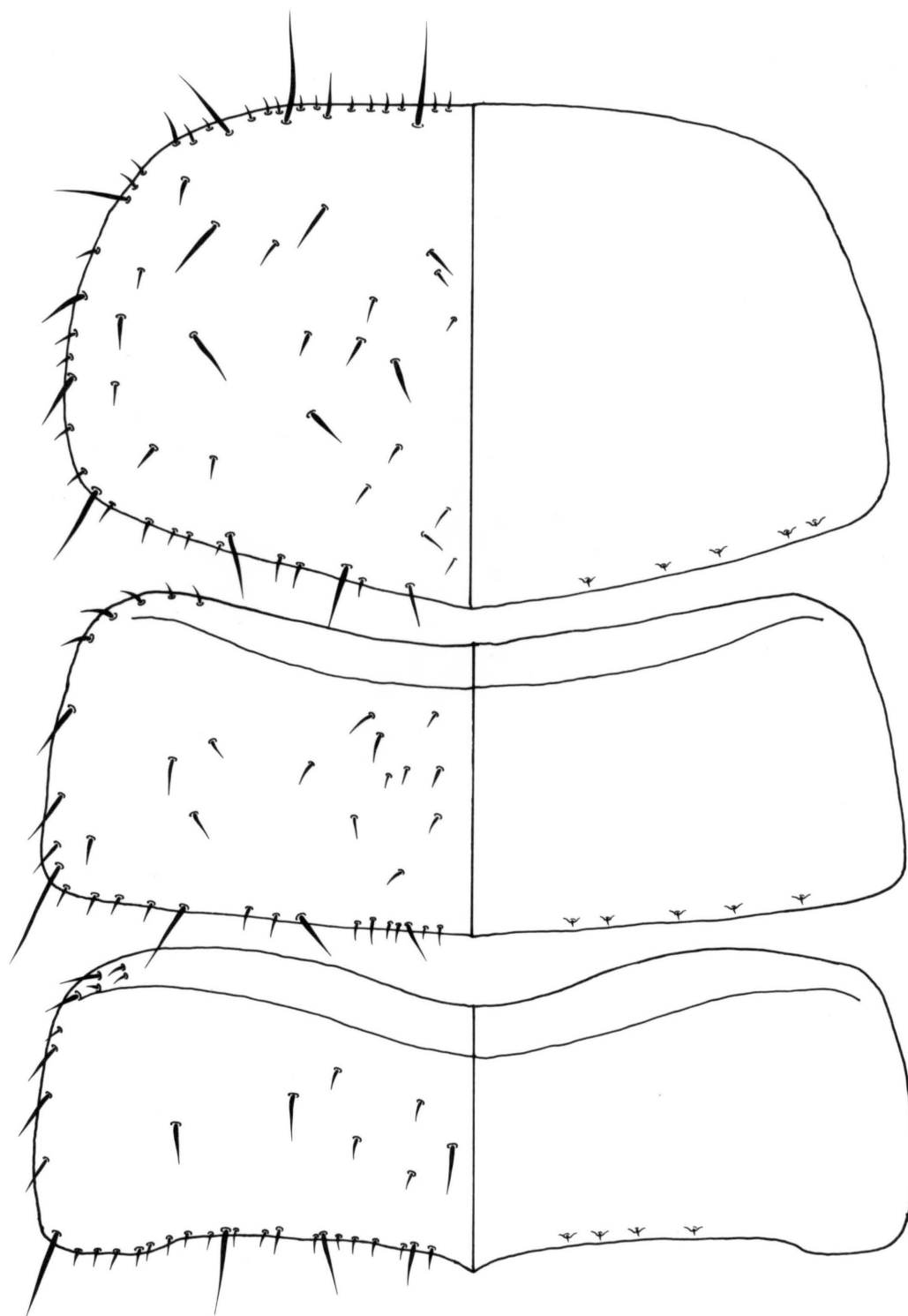
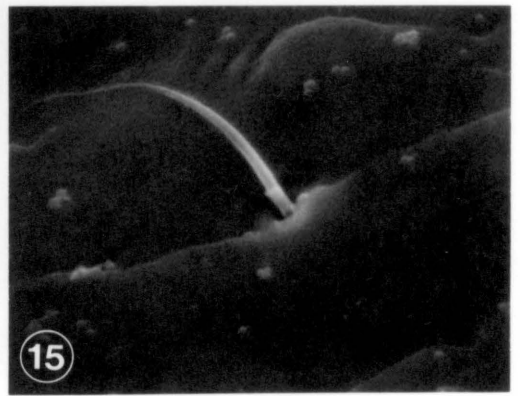
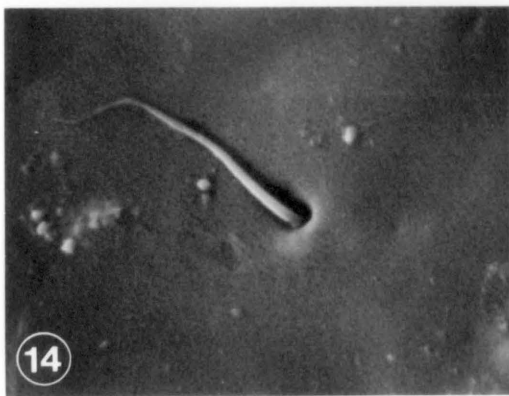
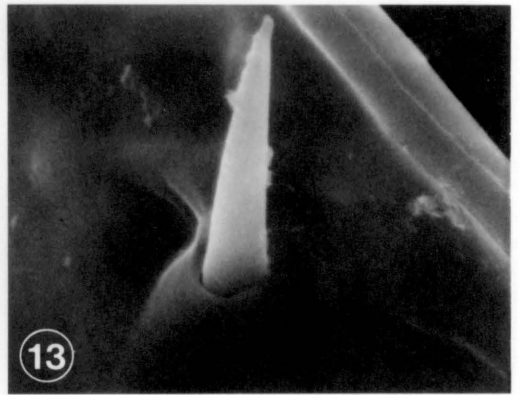
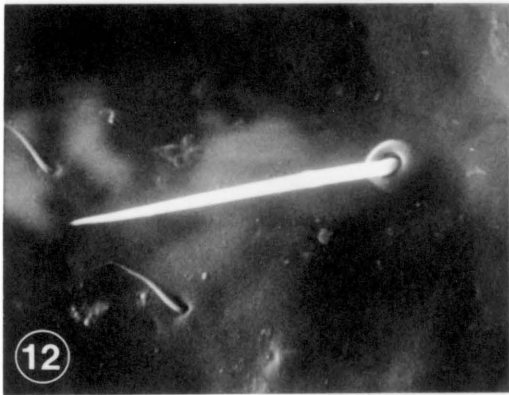
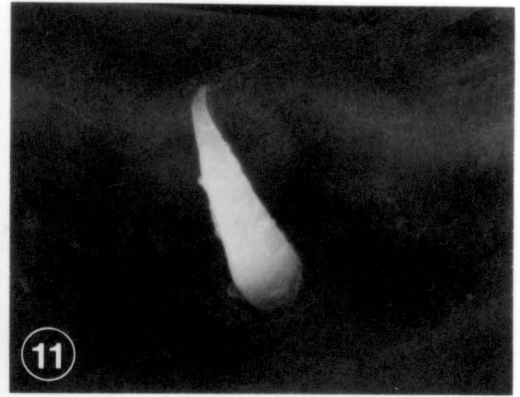
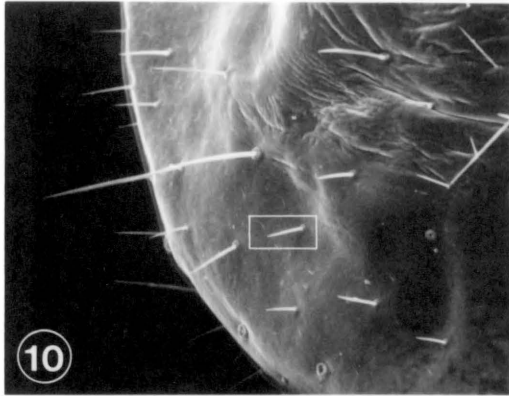


Fig. 9. P. japonica first-stage nymph, thoracic nota;
dorsal view (left) showing macrosetae,
ventral view (right) showing position of
short, robust setae.



- Fig. 10. P. australasiae first-stage nymph, pronotum
(200X)
- Fig. 11. P. australasiae first-stage nymph; short, robust
seta with tubular socket (5000X).
- Fig. 12. P. australasiae first-stage nymph, pronotum,
short macroseta (2000X).
- Fig. 13. P. fuliginosa first-stage nymph; short, robust
seta with tubular socket (5000X).
- Fig. 14. P. australasiae first-stage nymph, pronotum,
whiplike seta (5000X).
- Fig. 15. P. fuliginosa first-stage nymph, pronotum,
whiplike seta (5000X).



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A MORPHOLOGICAL STUDY OF FIRST-STAGE NYMPHS
OF FIVE PERIPLANETA SPECIES (DICTYOPTERA: BLATTIDAE)

by

Peggy K. Powell

(ABSTRACT)

Adults of Periplaneta americana, P. australasiae, P. brunnea, P. fuliginosa, and P. japonica are well known and have been well described. However, little systematic work has been conducted on the immature stages. There are very few descriptions of the nymphs of any Periplaneta species, and those that are available are rather brief and not completely accurate.

This paper presents detailed descriptions and keys to the first-stage nymphs of the above species. Five types of setae, including unique mechanoreceptive setae, were found on the thoracic segments.

P. australasiae, P. fuliginosa, and P. brunnea have very setose thoracic nota and a banded color pattern, while thoracic nota of P. americana and P. japonica are less setose and solid in color. Great variability of setal number and color pattern probably exists among all the species in the genus.