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IMMATURE STAGES OF *SCAPHISOMA CASTANEUM* MOTSCHULSKY (COLEOPTERA: STAPHYLINIDAE: SCAPHIDIINAE), WITH OBSERVATIONS ON NATURAL HISTORY, FUNGAL HOSTS AND DEVELOPMENT

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Abstract.—Eggs, larvae, pupae and known aspects of the life history and habits of *Scaphisoma castaneum* Motschulsky are described based upon field collected and laboratory reared material. Immatures were collected and reared from the polypore fungus *Auriporia aurea* (Peck) Ryvarden found within a downed log of *Pinus ponderosa* Douglas. Approximate duration of the developmental stages at room temperature (22–24°C) in days were: egg 4–6; larvae, instar I, 1–2; instar II, 2–4; instar III, 4–6; prepupa, 1–2; pupa, 9–12. Complete developmental time of *S. castaneum* ranged from 21–25 days (mean 22). Second and third larval instars were observed to construct longitudinal, meshwork-like canopies from digested food excreted from the anus over occupied parts of the host fungus. Descriptive illustrations of the third larval instar and pupa are provided. Morphological and behavioral comparisons to *S. impunctatum* Reitter, the only other species of New World *Scaphisoma* with described immatures and habits, are made.

Key Words: Coleoptera, Staphylinidae, Scaphidiinae, *Scaphisoma castaneum, Auriporia aurea,* fungus feeding, immature stages, canopy-building behavior

Both larvae and adults of the genus *Scaphisoma* are known to occur in association with higher, fleshy fungi, wood debris and leaf litter (Hatch 1957, Lawrence and Newton 1980, Ashe 1984, Newton 1984, 1990, Leschen 1988, 1994, Leschen et al. 1990). Newton (1984) reported that fungal hyphae are probably the primary food source for most species of *Scaphisoma.* These hyphae are often, but not necessarily, from fruiting bodies of the host fungi, a feature which may explain the numerous specimens that are collected from wood debris and leaf litter.

North American species of *Scaphisoma* are known to feed on a wide variety of fungi, including coral fungi (Clavariaceae) (Newton 1984), gilled mushrooms (Agaricales) (Newton 1984, Leschen et al. 1990, pers. observ.), ground fan fungi (Thelophoraceae) (Leschen et al. 1990), jelly fungi (Heterobasidiomycetes) (Newton 1984, Leschen 1988, Leschen et al. 1990), polypore fungi (Polyporales) (Perris 1876, Weiss and West 1920, 1921, 1922, Newton 1984, Leschen 1988, pers. observ.), slime molds (Myxomycetes) (Newton 1984), white slime mold (Newton 1984), and mold (Moniliaceae) (Palm 1959).

Even with such numerous, diverse fungal hosts reported for species of *Scaphisoma,* little is known concerning natural histories, development and immature stages. Ashe (1984) comprehensively described the mature larva, pupa and natural history of *S. terminata* Melsheimer. However, in Les-

chen's (1988) description of the immatures and natural history of *S. impunctatum* Reitter, the specimens of *S. terminata* used in Ashe's study were revealed to be *Caryoscapha americanum* Löbl, a species described subsequent to Ashe's work. Additionally, no life histories of any species of *Scaphisoma* have been worked out in any detail.

The literature concerning immatures of *Scaphisoma* has been confused by misidentifications of larvae of *Sepedophilus* species as various species of *Scaphisoma* by numerous authors. Ashe (1984) and Newton (1984) reviewed the known misidentifications of larvae of *Scaphisoma* and possible implications to subsequent works dealing with immatures of the Scaphidiinae.

The objectives of this study are to describe the natural history, development, and immature stages of *S. castaneum* Motschulsky with patterns of evolutionary or taxonomic significance being noted. Adults of *S. castaneum* have been reported as common throughout Washington, Oregon, Idaho and British Columbia (Hatch 1957), however nothing is known concerning the immatures or habits of this species.

Material and Methods

To describe the life history, development and immature stages of *S. castaneum,* 52 eggs, 160 larvae, and 141 adults were collected from a mass of *Auriporia aurea* (Peck) Ryvarden (Polyporaceae). This fungus was found within a downed log of *Pinus ponderosa* Douglas at the Lyle Grove Biological Area, Whitman County, Washington.

Eggs, larvae and adults found on the fungus were brought alive into the laboratory and transferred to glass jars containing moist, sterile, potting soil. The jars were maintained at room temperature (22–24°C) and provided with pieces of the host fungus on wood bits as required (fragments of wood with the host fungus were kept refrigerated until needed). Behavioral and developmental observations were readily made under these conditions.

When full grown, larvae were allowed to pupate in the same containers. Samples of eggs, larval instars I, II, and III, prepupae, and pupae were killed and fixed in Kahle's solution and preserved in 80% ethyl alcohol. Specimens were prepared for structural examination by first clearing in cold 10% KOH for up to two days or until clear and then examining in glycerin. Specimens were examined with a stereo-dissecting microscope.

For the descriptions of the immature stages, 52 eggs, 28 larvae (3 instar I, 3 instar II and 22 instar III), 2 prepupae, and 27 pupae were studied. From the remaining immatures, 37 adult specimens of *S. castaneum* were successfully reared and preserved.

Results

Development. Three larval size groups are present in the preserved material, and these groups are interpreted as 3 larval instars. Male and female adults isolated in the laboratory readily mated, with the females depositing eggs in cracks and crevices on the host fungus within 36 hours after collection. Eclosion occurred approximately 12 hours after each egg was deposited, and within 36 hours all eggs had hatched.

Complete developmental time (eclosion to adult emergence) of *S. castaneum* averaged 22 days (range 21–25 days) at room temperature (Fig. 1). After feeding, the vast majority of full grown larvae burrowed from the fungus into the wood substrate forming small oval cavities lined with silk-like material secreted from the anus. Four of the larvae left the host fungus and buried themselves about 3 cm deep in the soil substrate forming similar chambers. The larvae remained non-feeding and inactive as prepupae in these cavities for 1–2 days before pupation. Pupation lasted between 9–12 days.

Host relationship. Gilbertson and Ryvarden (1986) and Breitenbach and Kränzlin

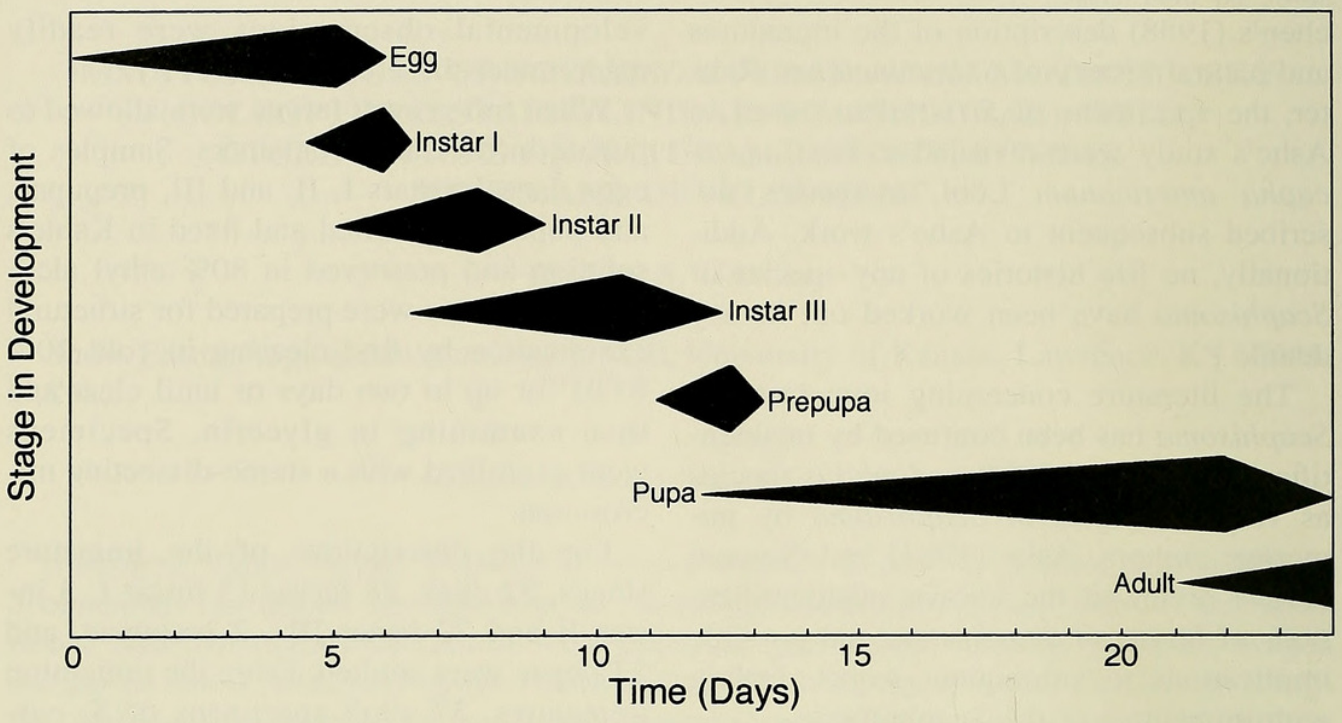


Fig. 1. Stages in the development of *Scaphisoma castaneum* Motschulsky with their duration and timing at room temperature (22–24°C). For each stage, the greatest width denotes all individuals have reached that stage. The apicies indicate first and last individuals found in that stage.

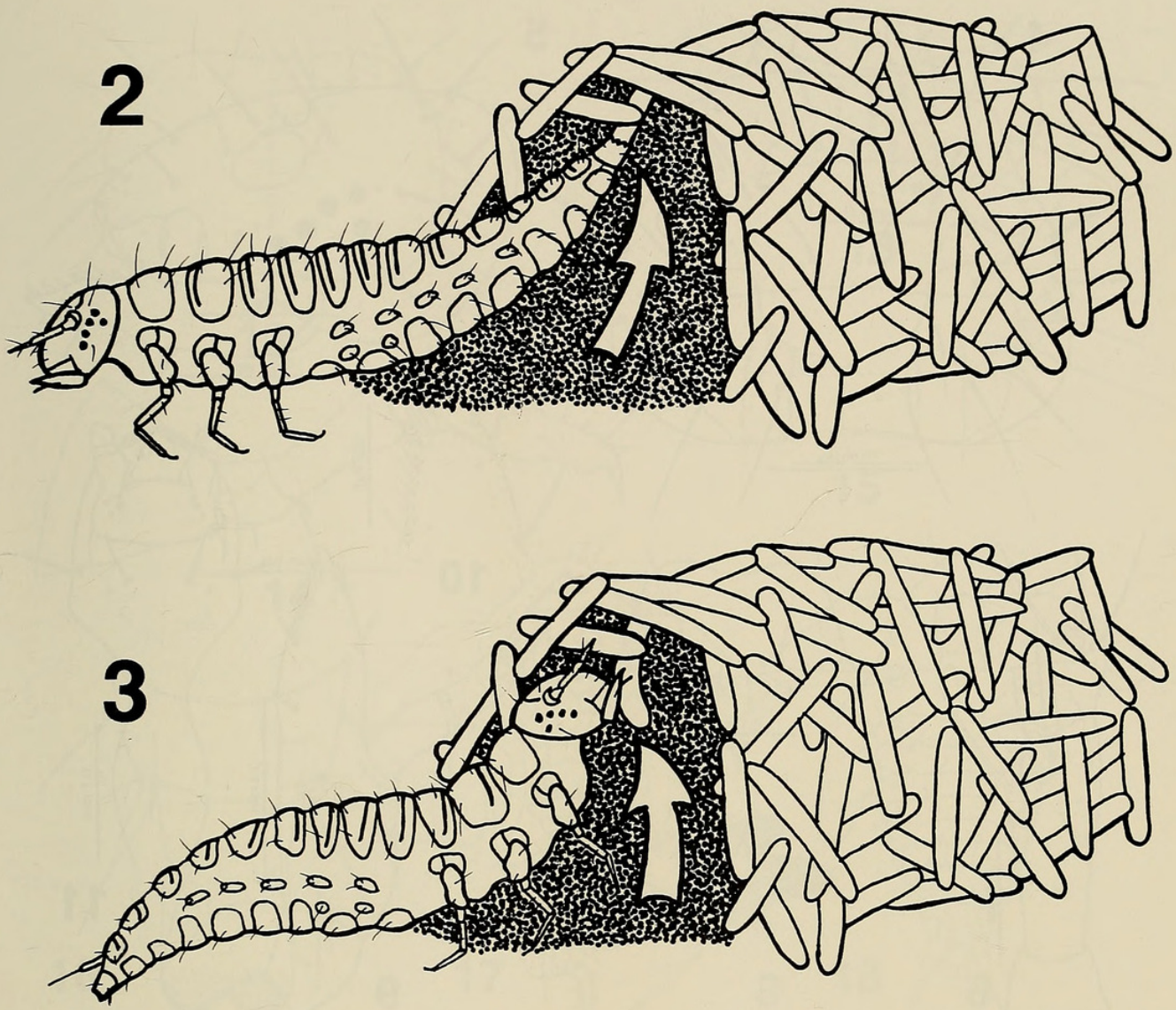
(1986) summarized our knowledge of *A. aurea*. This species is a resupinate to pileate, annual fungus causing brown cubical rot within dead conifers and hardwoods. The pore surface is yellow when fresh, turning yellowish-buff to pale brown upon drying. The pores are circular to angular with 2–4 per millimeter. The spores are cylindrical-ellipsoid and smooth, about 5.0–8.5 × 3.0–4.0 μ.

The genus *Auriporia* is exclusively a north temperate group with *A. aurea* the only species in North America. Known from the northeastern U.S., southwest and Pacific Northwest, *A. aurea* appears to be widely distributed throughout most of North America. However, this species is rarely collected, probably due to its cryptic nature of occurring within downed logs. Two other species of *Auriporia* occur in Europe and Asia respectively.

Specimens of *S. castaneum* were encountered only on fresh, yellow areas of *A. aurea*. Both adults and larvae were collected together from the surface of the fungus. In many instances, the larvae and adults crawled down the narrow pores of the host fungus making hand collection of these specimens difficult. No trophic exchanges or other beneficial behaviors were directly observed between adults and larvae. Additional known adult hosts of *S. castaneum* are: *Pleurotus ostreatus* (Jacq. ex Fries) Kummer (pers. observ.), *Fomitopsis pinicola* (Swartz ex Fries) Karsten, *Polyporus alboluteus* Ellis and Everhart, and *Ganoderma* sp. (pers. comm., A. F. Newton, Jr.).

Feeding behavior. Larvae began grazing on the surface of *A. aurea* immediately after eclosion and fed both day and night during development.

Second and third larval instars were observed to construct longitudinal, meshwork-like canopies from digested food excreted from the anus over occupied parts of the host fungus (Fig. 2). Larvae constructed the retreats by first excreting an elongated fecal pellet near the entrances of burrowed cavities, then reorienting themselves and positioning the fecal pellet into place using the mandibles (Fig. 3). The retreats were quite fragile and ephemeral, often decaying in about 48 hours. The fecal pellets were held together with a viscous fluid and did not



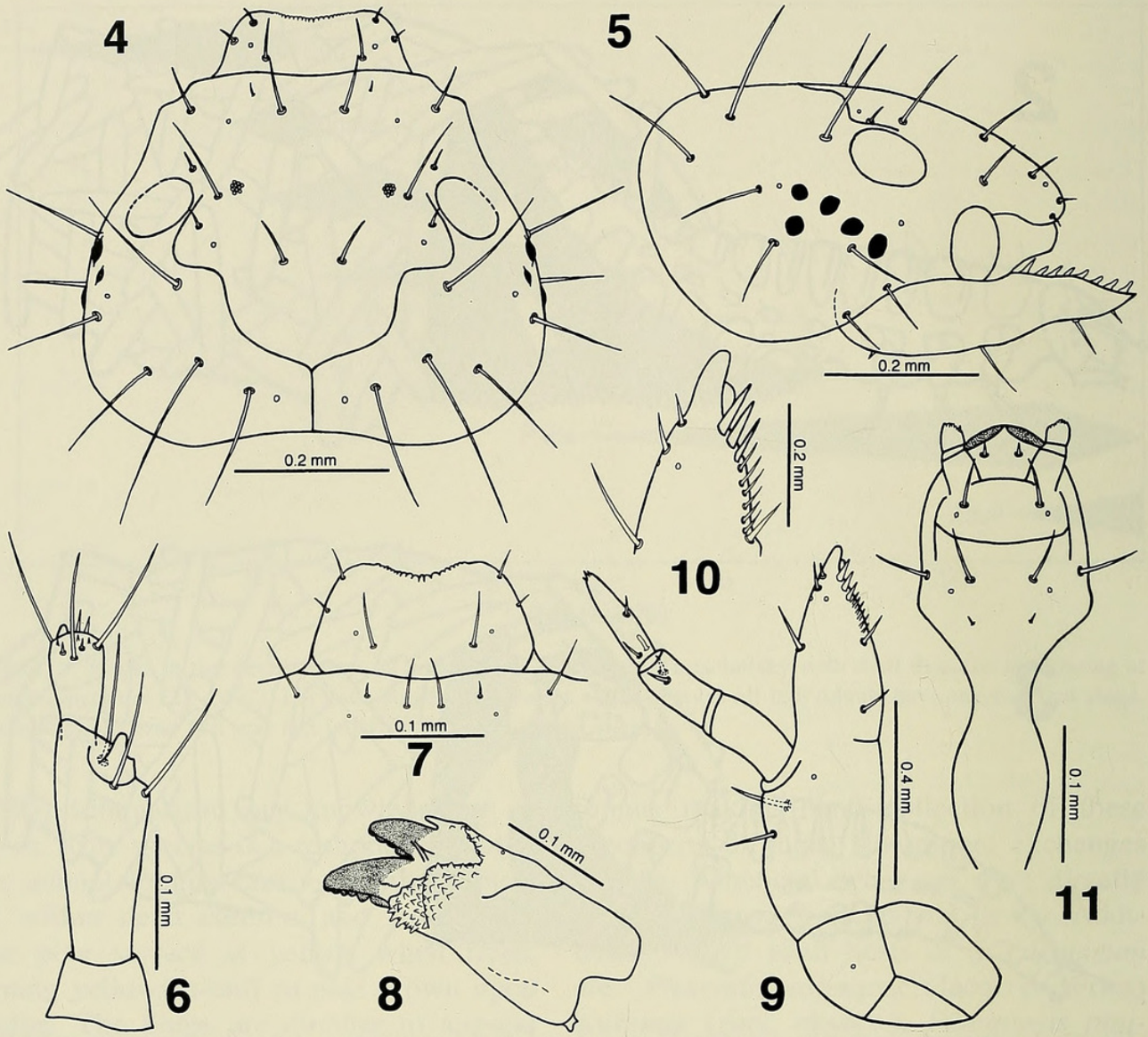
Figs. 2, 3. Retreat construction behavior of second and third larval instars of *Scaphisoma castaneum* Motschulsky. 2, Deposition of a fecal pellet into the canopy of the retreat. 3, Final manipulation of the fecal pellet into place using the mandibles.

appear to be arranged in any definite pattern. Each retreat was approximately 2 cm long and was occupied by a single larva. While in the retreats, larvae fed on the surface of the fungus and repaired any damaged areas to the retreats. The function of the excavated retreats remains unclear, however, they probably serve as an adaptation to hide the larvae from potential predators/parasites and/or to provide suitable microhabitats perhaps to prevent desiccation. To this end, one behavioral observation is of note: when a shadow passed over a retreat, the larva immediately crawled back into its retreat. This observation suggests a probable anti-predatory function for these retreats.

Immature Stages of *Scaphisoma castaneum* Motschulsky

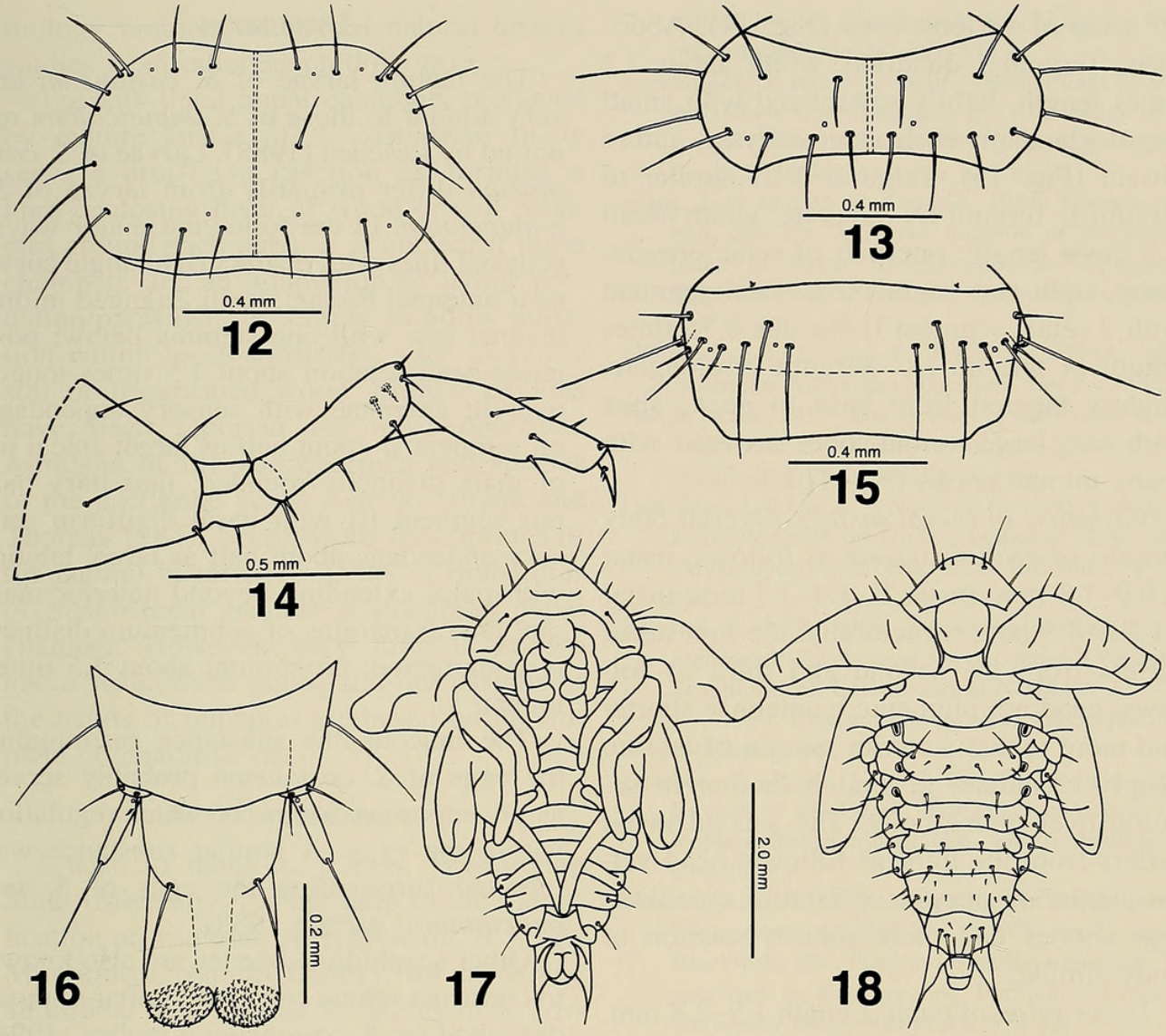
Description of egg. Length 0.3–0.6 mm. Color white, smooth, spherical, surrounded by mucous-like substance.

Description of larval instar III. Length 2.9–4.3 mm. Body elongate, gently curved, parallel-sided, flattened dorsoventrally. Color whitish with sclerotized areas light brown; head dark yellow to brown. Vestiture length variable, setae simple. Head oval, length about 0.9 times width; ecdysial



Figs. 4–11. *Scaphisoma castaneum* Motschulsky, larval instar III. 4, Head (dorsal view). 5, Head (lateral view). 6, Antenna (ventral view). 7, Labrum (dorsal view). 8, Mandible (ventral view). 9, Maxilla (dorsal view). 10, Mala of maxilla (dorsal view). 11, Labium (ventral view).

lines distinct, lateral arms lyre-shaped, complete from back of head to bases of antennae with near right angles midway between antenna fossae and fork; epicranial glands distinct, near end of ecdysial lines (Fig. 4); five pigmented stemmata on each side, arranged in one distinct row with one stemma below row (Fig. 5). Antenna with segment I asetose, short, length about 0.6 times width; segment II about 4.0 times longer than segment I, constricted portion 0.25 times length, segment II trisetose, bearing small, mesal, sensory appendage; segment III about 0.4 times length of segment II, three prominent, long setae surround numerous small, fine setae (Fig. 6). Labrum with anterior margin serrate, 8–9 tooth-like projections on each side of midline; surface with three pairs of setae (Fig. 7). Adoral surface of labrum (epipharynx) with numerous, very fine, inwardly and anteriorly directed hairlike processes on each side of midline; small patch of sensory pores present near anterior surface. Mandibles with right and left similar in size and shape; broad, with extensive pseudomola of numerous small teeth, asetose; divided into two acute lobes with ventral lobe larger than dorsal lobe; margins of lobes prominently serrate (Fig. 8). Maxilla (Fig. 9) with



Figs. 12–18. *Scaphisoma castaneum* Motschulsky. 12–16, Larval instar III. 12, Pronotum (dorsal view). 13, Mesonotum (dorsal view). 14, Prothoracic leg (anterior view). 15, Abdominal tergum I. 16, Abdominal terga IX and X. 17, 18, Pupa: 17, Ventral aspect. 18, Dorsal aspect.

cardo oval, divided into three regions; stipes broadest at middle, tapering slightly at base; mala acute with a large, unarticulated spine at apex and two smaller, articulated spines more proximally on mesal surface; adoral surface with 9–10 closely spaced, spine-like setae in a single row (Fig. 10); maxillary palpus three-segmented not including basal palpifer, segment I asetose, about 0.8 times the length of segment II, segment II bisetose, segment III conical and bisetose, about 1.4 times as long as segment II, base with very small digitform sensory appendage, apex with three very short setae at apex. Labium composed of submental, mental and premental sclerites; ligula broadly rounded with spines on each side of the midline; labial palpus 2-segmented, short, stub-like, segment I about 1.4 times longer than segment II, segment II with 3–4 very short setae at apex (Fig. 11). Thorax. Pronotum transverse, moderately sclerotized, anterior and posterior angles broadly rounded; ecdysial suture well developed medially (Fig. 12). Mesonotum oval, width about 3.7 times length, moderately sclerotized; ecdysial suture well developed (Fig. 13). Metanotum similar to mesonotum. Legs long, each of similar size and configuration; 4 setae present on coxae, 4 setae on trochanter, 7 setae on both femur and tibia, and 2 minute setae present on tarsus;

all setae of various sizes (Fig. 14). Abdomen. Tergum I quadrate, width about 2.2 times length, lightly sclerotized with small tergal gland on each side; ecdysial suture absent (Fig. 15). Terga II–VIII similar to tergum I. Tergum IX quadrate, width about 2.2 times length; one pair of setae present. Urogomphi two segmented; basal segment with 2 setae; segment II slender, 0.75 times length of tergum IX. Tergum X elongate, slightly tapered from base to apex; apex with two large, round lobes covered with many minute hooks (Fig. 16).

Variation in larval instars. Overall body lengths of each instar are as follows: instar I, 0.9–1.3 mm; instar II, 1.4–2.7 mm; instar III 2.9–4.3 mm. Structurally, the first instar differs from the second and third as follows: head not pigmented; antennae shorter and more robust; anterior margin of labrum deeply crenulate; general reduction in setation over entire body. The second instar differs from the third as follows: head yellow; anterior margin of labrum crenulate; legs shorter and more robust; setation of body similar.

Description of pupa. Length 1.9–2.8 mm. Color white throughout. Eyes inconspicuous. Major body spines as in Figs. 17, 18. General body form broadly oval with wing pads distinctive. Three pairs of functional spiracles near the lateral margin on each thoracic segment.

Material examined. USA. WASHINGTON. WHITMAN Co.: Lyle Grove Biological Area, 12.9 km SW of Pullman, 640 m elev., 12 May 1994 and 21 May 1994, R. S. Hanley & W. J. Turner, from *Auriporia aurea* in downed log of *Pinus ponderosa.* Fifty-two eggs, 160 larvae and 141 associated adults; 2 prepupae, 27 pupae and 37 reared adults.

Voucher specimens were deposited in the James Entomological Collection, Washington State University and the remainder in the personal collections of the author and W. J. Turner, Washington State University.

Discussion

The mature larvae of *S. castaneum* are very similar to those of *S. impunctatum* reported by Leschen (1988). Larvae of *S. castaneum* differ primarily from larvae of *S. impunctatum* in the following major ways: ecdysial lines with distinct right angle curve near antennal fossae; ocelli arranged in one distinct row with one stemma below; posterior head setation about 1.5 times longer overall; antennae with sensory appendage on segment II about half as large; apical tip of mala distinctly rounded; maxillary palpus segment III with basal digitform sensory appendage about half as large; labium with palpi extending beyond anterior margin, lateral margins of submentum distinctly compressed; urogomphi about 1.5 times longer.

The mucous-like substance surrounding the eggs of *S. castaneum* probably serves as an important means of water regulation within the eggs. A similar substance was reported surrounding the eggs of *S. impunctatum* (Leschen 1988).

Other scaphidiine beetles are also known to construct retreat canopies similar to those described for *S. castaneum.* Leschen (1994) reported that larvae of the genera *Scaphidium* and *Toxidium* construct retreat canopies near or on the mycelium of host fungi. These retreats were constructed by each larva positioning elongated fecal pellets into a roof made of frass using their mandibles, as seen in *Scaphidium,* or their anus, as in *Toxidium.* The larvae of *Caryoscapha americanum* used in Ashe's (1984) study were also reported to construct retreats by excavating incomplete longitudinal caverns within the host mushroom.

Leschen (1994) suggests that retreat building behavior in species of *Toxidium* and *Scaphidium* may be convergent with preliminary evidence suggesting that retreat building may be more widespread throughout the Scaphidiinae than previously known. I agree with Leschen's comment that interpreting retreat building as a ho-

mology requires additional natural history studies from other scaphidiine taxa.

The silk-lined pupal chambers produced by mature larvae of *S. castaneum* likely serve a protective function by forming a hard enclosing layer of wood or soil particles around each pupa. It is unclear if these chambers are an adaptation to avoid predation/parasitism or simply to allow pupation within loose substrates, such as sandy soil or fragmented wood. Similar cavities have been reported for most described members of the Aleocharinae and species of the paederine genus *Astenus* (Frank and Thomas 1984). No previous descriptions of the natural histories or habits of immatures of *Scaphisoma* include a silk-lined pupal chamber. However, very little is known about scaphidiine pupae and discussions of the habits of pupation are based on incomplete comparative data.

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