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4.14. Rhagophthalmidae Olivier, 1907

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Distribution. The genus *Rhagophthalmus* Motschulsky is widely distributed throughout the Oriental region, from the Ryukyu Islands, southwestern Japan to India, Sri Lanka and the East Indies. *Diopstoma adamsi* Pascoe is known from southern India and Sri Lanka, *Menghuoius* Kawashima from China, Vietnam and Myanmar and *Mimochotyra* Pic from Java. The genus *Dodecatoma* Westwood occurs in India, the Philippines and the East Indies and *Diplocladon* Gorham in India, southeast Asia and the East Indies. [Westwood 1843; Gorham 1883; Olivier 1910, 1911; Wittmer 1944, 1997; Wittmer & Ohba 1994; Wittmer 1997; Kawashima 2000, 2002; Kawashima & Satô 2001; Kawashima & Sugaya 2003; Li *et al.* 2008.]

Biology and Ecology. Rhagophthalmid larvae occur in soil and litter and are predaceous. Females are apterous and incompletely (*Rhagophthalmus*) or completely (*Diplocladon*) larviform. Males, females and larvae are all luminescent. Adult males and females of the genus *Rhagophthalmus* are crepuscular or nocturnal. After sunset, females have been observed to curve the end of the abdomen over the back and emit a continuous, yellowish-green light from a rectangular light organ located on abdominal sternite VIII. Males fly quickly, searching for light-emitting females, and upon discovering one, they mount her dorsally and attempt copulation. If the male is accepted, the female stops luminescence at once. After oviposition, females completely change their mode of luminescence, producing continuous light from the spot-like organs scattered over the body (two lateral rows, one mesodorsal),

and protecting the eggs by curling her body around them. Larvae are probably nocturnal, and produce a type of luminescence similar to that of the females after the oviposition. Larvae, which are rarely collected, may be found in leaf litter where they feed on millipedes (Arthropoda: Diplopoda) in a manner similar to that used by phengodid larvae in the New World. Similar adult behavior was observed in *Dioptoma adamsi*. The habits of *Mimochotyra*, *Dodecatoma* and *Menghuoius* are not known, but males of the last two are attracted to lights at night. *Diplocladon* larvae and larviform females are soil- and litter-dwelling predators which have three small light organs on most body segments; they are commonly called star-worms. Spot-like male light organs appear to be present laterally on the first five or six abdominal segments and do not occupy the central portion of each ventrite. [Green 1912; Ridley 1934; Haneda 1950; Harvey 1952; Wittmer & Ohba 1994; Ohba *et al.* 1996; Kawashima 2000; Ohmiya *et al.* 2000; Kobayashi *et al.* 2001, 2002, 2003.]

Morphology, Adult males (Fig. 4.14.1 A, D–H, I). Length about 6.5–25 mm. Body about 2.4–3.2 times as long as wide, usually widest behind middle, sometimes just anterior to middle, more or less flattened, with short appendages. Densely clothed with recumbent or suberect hairs (Fig. 4.14.1 A, I).

Head large, transverse, sometimes as wide as or wider than pronotum, not abruptly constricted posteriorly, never completely retracted within prothorax. Posterior edge of head capsule biemarginate. Occipital region without transverse ridge or stridulatory file. Frontal region moderately to strongly, gradually declined anteriorly. Eyes large and strongly protuberant, narrowly separated to subcontiguous ventrally, posteriorly shallowly to deeply emarginate; usually finely faceted (coarsely faceted below in *Dioptoma*), without interfacetal setae. Antennal insertions exposed from above, narrowly separated to almost contiguous; subantennal grooves absent. Frontoclypeal suture absent; anterior edge of clypeus straight to slightly concave. Gular sutures narrowly separated or confluent. Corpotentorium absent. Cervical sclerites present. Antennae short, not or barely reaching beyond posterior edge of head, 12-segmented (Fig. 4.14.1 H), usually filiform or serrate from antennomere 4 or 5 to 11 (unipectinate from 3 to 11 in *Dodecatoma*, bipectinate from 3 to 11 in *Diplocladon*), with sensilla located on anterodistal portions of flagellomeres. Mouthparts reduced and anteroven-trally oriented. Labrum free, strongly transverse. Mandible usually very small (larger in *Menghuoius*; Fig. 4.14.1 D), very narrow and elongate, strongly, gradually curved mesally with sharply acute apices; retinaculum and mola absent; mesal surface of mandibular base without brush or fringe of hairs. Maxilla with articulated, apically setose galea and reduced lacinia; apical palpomere fusiform. Ligula short, undivided and membranous or absent; apical labial palpomere fusiform.

Pronotum 0.55–0.8 times as long as wide, usually widest posteriorly at or near base (widest at middle in *Dioptoma*); sides straight, moderately curved or straight posteriorly and curved anteriorly, not explanate; base not or slightly narrower than elytral bases; lateral pronotal carinae usually complete, simple, without raised margin (incomplete in *Diplocladon* and *Dodecatoma*); anterior edge broadly rounded, with or without raised margin; anterior angles not produced, sometimes absent; posterior angles broadly right to acute (rounded in *Dioptoma*); posterior edge tri-emarginate with raised margin; disc without paired basal impressions, without or with weak longitudinal groove. Prosternum in front of coxae much shorter than shortest diameter of procoxal cavity, flat. Prosternal process absent. Notosternal sutures complete. Procoxae projecting well below prosternum, without concealed lateral extensions. Trochantins exposed, slender, setose. Procoxal cavities weakly impressed, strongly transverse, contiguous, externally broadly open, without narrow lateral extensions; internally open. Scutellar shield not abruptly elevated, anteriorly simple, posteriorly broadly rounded or truncate. Elytra 1.4–2.7 times as long as wide and 2.5–5.5 times as long as pronotum, irregularly punctate, without scutellary striole; with three or four vague, longitudinal carinae; apices independently rounded and separated by broad gap, sometimes exposing one or more abdominal tergites; epipleuron very narrow, complete or incomplete. Mesoventrite separated by complete sutures from mesanepisterna, which are distinctly separated at midline; anterior edge on same plane as metaventrite, without paired procoxal rests, sometimes with short discrimen. Mesoventral cavity absent. Mesocoxae conical and projecting, with exposed, setose trochantins. Mesocoxal cavities weakly impressed, narrowly separated, open laterally (closed by both mesanepisternum and mesepimeron); mesometaventral junction absent due to fusion of meso- and metaventrites. Metaventrite moderately to strongly convex, with straight sides; discrimen moderately to very long; postcoxal lines absent; exposed portion of metanepisternum moderately elongate. Metacoxae contiguous or narrowly separated, horizontally or obliquely oriented, not extending laterally to meet elytra; plates moderately or weakly developed, sometimes obliterated laterally. Metendosternite with lateral arms short or absent, laminae absent, anterior process moderately long and anterior tendons moderately or very close together. Hind wing short and broad; apical field very short, with anterior and posterior oblique narrow sclerites; radial cell large, about twice as long as wide, with inner posterobasal angle right or obtuse; cross-vein r3 usually present (absent in *Dodecatoma*); medial spur straight; medial field with five free veins; MP₃₊₄ with basal cross-vein and spur; wedge cell well developed and apically truncate or absent; CuA₁ joining MP₄; anal lobe well developed, AP undivided, extending to wing margin; anal

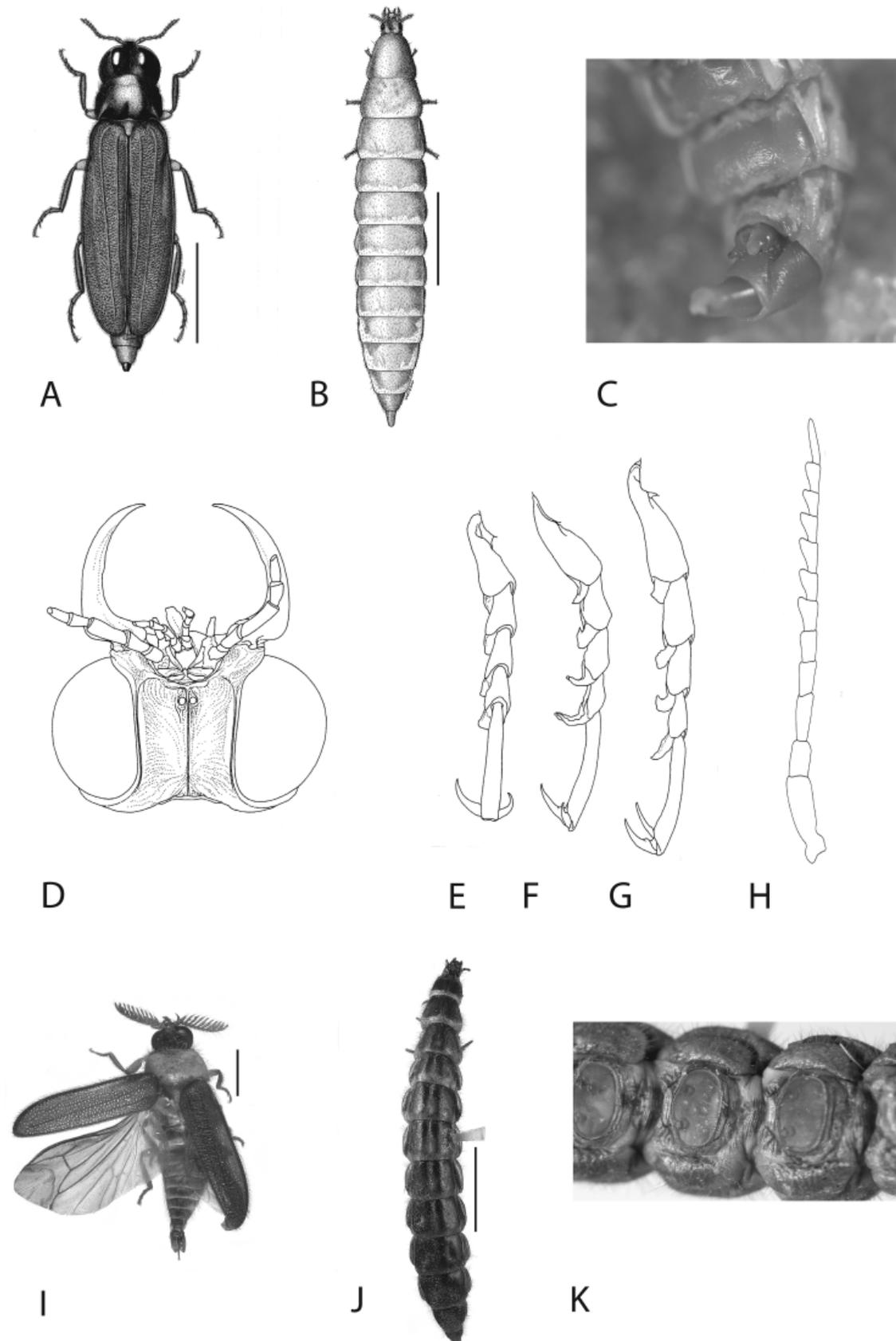


Fig. 4.14.1. A, *Rhagophthalmus ohbai* Wittmer, adult male (© I. Kawashima), line = 4 mm; B, *R. ohbai*, adult female, line = 5 mm; C, *R. ohbai*, ovipositor, ventral view; D, *Menghuoius ingens* (Fairmaire), adult male, head; E, *M. ingens*, fore tarsus; F, *M. ingens*, mid tarsus; G, *M. ingens*, hind tarsus; H, *M. ingens*, antenna; I, *Diplocladon hasselti* Gorham, adult male, line = 2.5 mm; J, *D. hasselti* adult female, line = 8 mm; K, *D. hasselti* adult female, abd. segments IV–II (left to right), ventral view, showing discs. A, B, from Ohba *et al.* 1996 (© I. Kawashima); C, I–K (© M. Branham); D–H from Kawashima 2000 (© I. Kawashima).

embayment weak or absent. Femoral attachment of mid trochanter strongly oblique with base of femur separate from coxa. Legs slender; tibial spurs well developed; tarsi 5-5-5; usually with ventral membranous lobes on tarsomeres 1-4 (Fig. 4.14.1 E-G) or on penultimate tarsomere only; pretarsal claws simple or slightly dilated at base.

Abdomen flattened, with eight free ventrites; ventrite I not much longer than II, without post-coxal lines; intercoxal process absent. Functional spiracles on abdominal segment VIII present. Spiracles located on pleural membrane. Luminous organs present as small spots on dorsal sides of thoracic and ventral sides of abdominal segments. Anterior edge of sternite VIII in male without median strut. Anterior edge of sternite IX in male without spiculum gastrale; tergite IX truncate. Tergite X well developed and free. Aedeagus trilobate, symmetrical; short, broad and somewhat flattened; phallobase without anterior strut; parameres individually articulated to phallobase, not outwardly hooked, joined together at base; anterior edge of penis without or with very short struts. [Olivier 1911; Green 1912; Haneda 1950, 1985; Harvey 1952; Wittmer & Ohba 1994; Wittmer 1997; Chen 1999; Kawashima & Satô 2001; Kawashima & Sugaya 2003.]

Morphology, Adult Females (Fig. 4.14.1 B, C, J, K), *Rhagophthalmus*. Length about 15-20 mm. Incompletely larviform (head with compound eyes and 6- or 7-segmented antennae; tarsi 5-segmented with two pretarsal claws; ovipositor present [Fig. 4.14.1 C]). Body elongate, subcylindrical and subparallel. Color of thorax and abdomen pale to dark yellow; head more or less reddish brown. Surface almost smooth and glabrous, with scattered fine setae (Fig. 4.14.1 B).

Head prognathous, small, somewhat flattened; sides more or less arcuate. Frontoclypeal region concave and declined. Epicranial stem and frontal arms absent. Posterior edge of head capsule triangularly produced forming mesal lobe. Antennae 6 or 7-segmented, moniliform, with dome-like sensorium on preapical antennomere. Compound eyes consisting of 40 to 50 ommatidia. Frontoclypeal suture not clearly indicated, incomplete mesally. Labrum completely fused to head capsule (suture absent); clypeolabrum produced to form nasale, which is triangularly notched at apex. Mandibles symmetrical, relatively large, strongly, gradually curved mesally and slightly overlapping, with narrowly acute apex lacking a canal opening; retinaculum and mola absent. Ventral mouthparts retracted. Cardo small and triangular; stipes fairly large, elongate and subquadrate, the largest maxillary element; galea small, 1-segmented, conical with subacute apex; lacinia absent; palp 4-segmented, with well developed short, cylindrical palpifer; apical palpomere conical with subacute apex. Labium with elongate, subquadrate mentum and no clearly delimited submentum; prementum relatively small; sides weakly but clearly diverging

anteriorly; ligula small; labial palps 2-segmented, with well developed palpomeres; apical palpomere conical with moderately acute apex. Gular sutures absent; gular region depigmented so that head capsule appears ventrally open, as in larva.

Thorax subparallel, segments weakly but gradually widened towards metathorax. Prothorax moderately elongate and narrowed towards widely arcuate anterior margin. Meso- and metathorax transversely rectangular in dorsal view. Thoracic terga weakly sclerotized, not heavily pigmented. Legs about equal in length, well developed and robust; coxae very large and elongate; tibia distinctly shorter than femur; tarsus 5-segmented; pretarsus with paired claws.

Abdomen twice as long as thorax, with ten visible segments. Terga relatively well-sclerotized but not heavily pigmented. Lateroterga and pleura clearly recognized in segments I to VIII. Segment X reduced, exposed, slender and cylindrical, without eversible multitubular holdfast organ. Transversely rectangular luminous organ occupying most of venter of abdominal segment VIII; spot-like luminous organs on pleural areas of meso- and metathorax, and abdominal segments I to IX and along the center line of the meso- and metaterga and abdominal terga I to VIII [Ohba *et al.* 1996].

Diplocladon. Completely larviform (head with stemmata and 3-segmented antennae; tibiotarsus and single pretarsal claw; ovipositor absent) (Fig. 4.14.1 J). Most characters as in larval description below, but area between antennae with large, longitudinally oval, granular disc, anterior portion of prothorax with four similarly granular areas, and sterna II-VIII each with a large, transversely oval disc occupying most of sternite with similar granular surface but surrounded by raised lip bearing long, stiff setae; sternum IX with similar subcircular disc (Fig. 4.14.1 K). [Ridley 1934; Haneda 1950; Harvey 1952; Crowson 1972.]

Morphology, Larvae (*Rhagophthalmus* and *Diplocladon*). Body elongate, subcylindrical, almost parallel-sided. Dorsal surfaces smooth, usually dark brown in color (membranous parts more or less tinged pale yellow to yellowish white), clothed with short, fine hairs; ventral surfaces unpigmented.

Head prognathous and partly retracted; about as long as wide, somewhat flattened; sides convergent towards base. Posterior edge of head capsule moderately to deeply biemarginate forming broad, mesal lobe. Epicranial stem and frontal arms absent. Median endocarina absent. Single stemma on each side relatively small, with well developed lens. Frontoclypeal suture present but incomplete laterally and curved or sinuate. Labrum completely fused to head capsule (suture absent); clypeolabrum complex, on two planes; dorsally broadly emarginate forming two rounded lobes, ventrally with two approximate, rounded lobes separated by narrow incision, sometimes with narrow, membranous, setose and apically acute epipharyngeal

process. Antennae 3-segmented; moderately long; antennomere 2 about twice as long as 1, apically enlarged and rounded; antennomere 3 much shorter and narrower; sensorium large and dome-like. Mandibles symmetrical, narrow and falcate, strongly to gradually curved mesally and broadly overlapping, with internal perforation opening on outer side just before narrowly acute apex; retinaculum and mola absent. Ventral mouthparts strongly retracted; maxillary articulating area absent. Cardo small and triangular, but with slender articulated internal process; stipes about twice as long as wide, subrectangular; galea palpiform; lacinia highly reduced or absent; palp 4-segmented, almost as broad at base as stipes; first three palpomeres very short and thick, palpomere 4 slightly longer than wide, subconical with narrowly rounded apex. Labium consisting of prementum, mentum and submentum, the latter two more or less connate with maxillae; mentum elongate and subquadrate, not clearly separated from small submentum; prementum dilated apically; ligula short, broad, subtriangular; palpus 2-segmented, separated by less than diameter of first palpomere; apical palpomere subconical. Hypopharyngeal sclerome absent. Hypostomal rods short, subparallel. Gular sutures absent; gular region depigmented so that head capsule appears ventrally open, but with internal transverse tentorial bridge.

Prothorax only slightly longer than meso- or metathorax, with rounded anterior edge; with cervical membrane, subtriangular, undivided presternum, and large precoxalia. Five-segmented legs well developed, robust; coxae long and subconical, widely separated at base; femur and tibia subequal in length, armed with stout spines and long setae; pretarsus claw-like, with two setae lying side by side, one short and stout, the other long and slender.

Abdomen more than twice as long as thorax, tapering posteriorly, with ten visible segments. Terga and sterna without armature. Laterotergites and laterosternites visible on segments I–VIII. Segment IX slightly shorter and narrower than VIII; tergum completely dorsal, without paired urogomphi; sternum IX well developed, simple. Segment X exposed, slender and cylindrical, without eversible multitubular holdfast organ. Luminous organs consisting of lateral spots on meso- and metathorax and abdominal segments I to IX and mid-dorsal spots on meso- and metathorax and abdominal segments I to VIII. Spiracles biforous, with paired chambers widely separated anteriorly on either side of scar and converging posteriorly; located in upper portions of laterotergites; those on segment VIII about same size as others on abdomen. [Wittmer & Ohba 1994; Ohba *et al.* 1996; Kawashima 1998.]

Phylogeny and Taxonomy. The family Rhagophthalmidae was originally proposed by Olivier (1907) for *Rhagophthalmus* and a few related genera distinguished by their short, 12-segmented

antennae and large, posteriorly emarginate eyes. Gorham (1895) noted the similarity of *Rhagophthalmus* and *Dioptoma* to *Diplocladon* and *Dodecatoma* and suggested that all could be included in Drilidae. However the first two were excluded from the drilid catalogue of Wittmer (1944). McDermott (1964, 1966) considered the genera *Rhagophthalmus*, *Dioptoma*, *Ochotyra* Pascoe and *Mimochotyra* to be a subfamily of Lampyridae, but Crowson (1972) transferred the group to Phengodidae, along with the *Diplocladon*, *Cydistus* Bourgeois and *Falsophrixothrix* Pic. Lawrence & Newton (1995) followed Crowson, recognizing Rhagophthalminae within the family Phengodidae. In the molecular phylogeny of Suzuki (1997), based on 16S mitochondrial RNA, *Rhagophthalmus* formed with *Stenocladus* Fairmaire a monophyletic group nested within a clade containing *Cyphonocerus* Kiesenwetter and Lampyridae but excluding Luciolinae and *Drilaster* Kiesenwetter. In the cladogram of Branham & Wenzel (2001, 2003), *Dioptoma*, *Diplocladon* and *Rhagophthalmus* formed a monophyletic group which was part of a trichotomy with the clade representing Lampyridae and the clade containing Lycidae, Omethidae, Telegeusidae and Phengodidae. Based on the placement of *Dioptoma* and *Diplocladon* with *Rhagophthalmus*, as well as seven synapomorphies that define this clade, Branham & Wenzel (2001) moved *Dioptoma* and *Diplocladon* out of Phengodidae into Rhagophthalmidae. In the most recent molecular phylogeny of Elateriformia (Bocakova *et al.* 2007), the rhagophthalmine genera *Rhagophthalmus* (as *Ochotyra* Pascoe) and *Mimochotyra*, plus *Bicladodrilus* Pic and an unplaced rhagophthalmine from Java consistently formed a monophyletic group with Phengodidae, supporting Crowson's earlier hypothesis (Crowson 1972).

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