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Taxonomic Studies on the Ephemeroptera

II. The Genus Hexagenia

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The hexagenids are the ephemerids that first attracted my attention to the order Ephemeroptera. Ever since 1927, I have been gradually accumulating data with the specific intention of revising as thoroughly as possible this highly important and abundant genus. During the past year, efforts have been made to see the type specimens and to compile distributional data concerning each species and subspecies. I have seen the material in the British Museum (Natural History) (B.M.), the Canadian National Collection (C.N.C.), the Cornell University Collection (C.U.), the Illinois Natural History Survey (I.S.), the Museum of Comparative Zoology (M.C.Z.), the Museum of Zoology of the University of Michigan (U.M.), the Ohio State University Collection (O.S.U.), and the Oklahoma Natural History Survey (O.S.), as well as the private collections of Professor Fred Ide (Ide), Dr. Earle Lyman (Ly.), and Mr. W. T. Davis (Davis). The letters or names in parentheses as given above are the respective abbreviations that are utilized in the distributional data which accompany each species or subspecies. In addition, the collection of the American Museum of Natural History (A.M.N.H.) and my own collection have been available. Dr. William Upholt has loaned me paratypes of his *Hexagenia limbata californica* as well as having sent other material.

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To the authorities of the American Museum of Natural History and particularly to Dr. Frank E. Lutz, I am indebted for research facilities without which this work could not have been accomplished.

HEXAGENIA Walsh

Walsh, Proc. Ent. Soc. Phila., vol. 2, p. 197, 1863.

Eaton, Trans. Ent. Soc. Lond., pt. 1, p. 64, 1871. Revisional Mono. Rec. Ephemeridae. pt. 1, pp. 48-49, 1883.

Needham, Bull. U. S. Bur. Fish., vol. 36, pp. 269-292, 1920.

Ulmer, Arch. Naturg., Bd. 87, Abt. A, Hft. 6. pp. 233-239, 1921.

McDunnough, Canad. Ent., vol. 56, p. 90, 1924.
Traver, Ann. Amer. Ent. Soc., vol. 24, pp. 591-620, 1931.
Lestage, Bull. Ann. Soc. Ent. Belg., vol. 71, pp. 39-40, 1931.
Spieth, Jour. N. Y. Ent. Soc., vol. 41, p. 347, 1933.
Needham, Traver, Hsu, etc., Biology of Mayflies, p. 258, 1935.

Hexagenia is a member of the family Ephemeridae, subfamily Ephemerinae. There are six genera in the subfamily: Ephemera L., Pentagenia Walsh, Ichthybotus Eaton, Eatonica Navas, Eatonigenia Ulmer, and Hexagenia Walsh.

In 1863 Walsh described and defined the genus Hexagenia as follows:

Hexagenia n.g. Wings four, hind wings wide, all with numerous cross veins; costal cross-veins in the front wing numerous, never absent on the middle of the costa. First tarsal joint distinct in the anterior legs ♂ ♀, indistinct and connate in the four posterior legs ♂ ♀, in all the legs shorter than the 2nd tarsal joint; anterior tibia ♂ much longer than the femur; anterior ♂ legs very long, much longer than anterior ♀ legs; all the other ♂ ♀ legs short, the hind legs not attaining the tip of the abdomen. Two long abdominal setae, pilose at the tip under the lens, the intermediate seta rudimental. Eyes ♂ separated by a space about as wide as the orbit of the posterior ocellus—Species *bilineata* Say, *limbata* Pictet.

All species of Hexagenia have medium to large sized adults and fossorial nymphs. The genus can now be defined as follows:

Adult.—Male fore leg at least two-thirds length of but never longer than the body; male fore tarsi about one and one-half times tibia; fore tarsal claws of male obtuse, but outer ones considerably smaller than inner ones. Female fore tarsi and tibia about equal in length; outer fore tarsal claws of female acute, inner ones obtuse. Prothorax of both sexees roughly a truncate cone tapering anteriorly and slightly pinched in the anterior third; the posterior two-thirds slightly inflated and with the posterior edge almost a straight line. At its greatest width, the posterior edge, the prothorax is wider than it is long. Fore wing with CU_2 meeting anal margin distal to middle so that the CU_1 area is relatively small; the unforked A_1 parallels the CU_2 and thus is sinuate and not straight; marginal intercalaries of CU area typically not reticulated; A_2 present, curved, never straight.[1] Genitalia of male with three or four segmented forceps arising from a narrow, roughly rectangular plate; second segment of forceps longest; third and the fourth when present slender, their combined length less than that of the first segment. Penes double, separated to base. Female subanal plate convexly curved distally. Lateral cerci long; medial caudal filament rudimentary, usually consisting of five sender segments.

Nymph.—Single median obtuse frontal protuberance which is at least as long as wide. Labrum with an almost straight anterior margin; mandibular rami slender, up-curved, sparsely setose but never spinose; maxillary palps slender, three segmented; labial palps two segmented. The paraglossae robust, each with a large, posteriorly extended lobe, thus placing the paraglossal attachment to the prementum on the middle of the medial surface. Hypopharynx with only a faint indentation; paragnaths large. The fore tibia with a large

1 I am using the venation system advanced by Tillyard in 1931 (see Spieth, N. Y. Ent. Soc., vol. 41, pp. 58-72, 1933). This nomenclature is similar to that employed by Needham, Traver, Hsu, etc. (Biol. of Mayflies, 1935) except that what they consider as the outer fork of the radial sector, is here called the anterior median or MA.

anterodistal spur on the flattened outer surface; metatibia with a posterior spur that is almost equal in length to the tarsus.

Genotype.—*H. bilineata* (Say).

The nymphs of Eatonica and Eatonigenia are unknown. Judging from the adults, the nymphs of these genera are probably extremely close to those of Hexagenia. The nymph of Pseudeatonica n. subg. is also unknown. The discovery of it may necessitate a revision of our present definition of the hexagenid nymph.

The genus is widely abundant in the Nearctic region, sparsely distributed in the Neotropical region, and reported from India (*H. indica* Chopra) and the Philippines (*H. philippina* Navas). Navas' description derived from a single specimen is so inadequate that it is impossible to tell whether the generic placement is correct. Chopra (1924) described *H. indica* from 11 ♀ specimens. Discovery of the male of this species may well show that it does not belong to Hexagenia. Certainly the hind wing and the thorax, as described, are atypical for Hexagenia. That the genus should exist in these two widely separated localities, but be completely absent from China and Japan, seems unlikely. From the latter localities, however, rather comprehensive collections of the closely related genus Ephemera have been made. If Hexagenia lives in this area, it should certainly have been found. It seems probable that both *H. indica* and *H. philippina* belong to Eatonigenia which is closely related to Eatonica from Africa. Hexagenia is therefore primarily restricted to Nearctica and the Neotropical region, is completely absent from the Australian and Ethiopian regions, and is at best only sparsely represented in the eastern fringe of Palearctica. In the Neotropical region all known hexagenid species belong to the subgenus Pseudeatonica.

Biology and Speciation in Hexagenia

Hexagenid subimagoes usually emerge during the night or in the very early morning, and then fly to the vegetation surrounding the body of water in which they spent their nymphal life. Invariably they orient themselves so as to avoid bright light, especially direct sunlight, usually resting upon a dark background. This avoidance of bright light and a preference for the under sides of leaves, stems, etc., result in a considerable amount of movement among the newly emerged population in the first hour or so after sunrise. For the remainder of the day, after having concealed or partially concealed themselves, they remain rather inactive unless some agent intrudes upon them. During the afternoon they may shed their subimaginal skins and become full-fledged adults.

There is evidence that often the subimaginal stage may last longer. Lyman (personal communication) found *H. limbata viridescens* at Douglas Lake, Mich., remaining in the subimaginal state for 36 to 48 hours. Ide (personal communication) thinks that during cold, damp, overcast periods the length of the subimaginal period of the ephemerids is invariably lengthened. It should always be remembered that such variability is to be anticipated

in any and all phases of the activity of these insects. The conclusions that are stated in this paper are based mainly upon my own observations and doubtless further study will show variations and differences that have not been observed by the author.

A short time before or just at sunset, the imagoes become active and gradually assemble for the nuptial dance over the edge of the shore. Lyman (personal communication) found *H. limbata viridescens* invariably dancing over vegetation. Other species or subspecies seem much more flexible in their choice of the substratum over which to conduct the nuptial dance. After the nuptial flight and copulation, the females fly out over the body of water to lay their eggs and die shortly afterwards. The nuptial dance lasts until darkness at which time those males which are not exhausted apparently fly back to await the nuptial dance of the next day. Thus the majority of the individuals may live as winged insects less than 24 hours and spend most of this time resting in semi-concealment. Big, husky, strong flying insects that the hexagenids are, there are few enemies that they need to avoid during their short imaginal life span. Birds unquestionably are their greatest predators, but attacks are primarily restricted to the short nuptial flight or shorter movement flights of the early morning. We can rather safely assume that selection pressure has a very short time to act upon the winged individuals and that, due to the size and vigorousness of the hexagenids, there are few things in their environment that can effectively act as selection pressure agents.

There is, however, one period in the adult life span where selection pressure can act very effectively, i.e., in the nuptial flight and the copulatory act. During that time, it is necessary for the male (1) to be able to find the female (by means of the nuptial flight movements and the eyes), (2) to grasp the female (by means of the fore legs and abdominal appendages), (3) to effect copulation (by means of the penes and genital forceps), and (4) to inseminate sperm which fertilize the ova and form viable zygotes that will develop into new individuals. It is to be expected that such things as fore leg length, ratio of wing area to weight, genital forceps and penes, compound eyes of males, and cercal length, all of which are involved in the nuptial flight and subject to acute selection pressure, would in any effective breeding population be relatively constant. Other characters such as size, pigmentation of the body as a whole and pigmentation of parts of the body as units, being rather nonadaptive and not subject to rigid selection pressure, would vary widely.

Another factor that must be considered is that the effective breeding population of the hexagenids is relatively sedentary. Perforce, the female must and does deposit eggs near the spot where her mother deposited eggs. The individuals have neither the time nor the ability during their short winged life to migrate extensively. Likewise the females must copulate with the males that are available at the particular time they reach maturity. Furthermore, there is no chance, due to their short life spans, for repeated matings over a period of days, although the females may copulate with more than one male.

The total area in which hexagenids or any other ephemerids can live is

exceedingly small in comparison to the land mass area on which terrestrial forms dwell. Thin ribbons and small patches of water distributed over large land areas represent the available space in which the ephemerids can live. In North America the fresh waters represent an amazingly small percentage of the total continental area, probably less than 0.04%. Even much of this water area is unsuitable due to ecological conditions. Thus no hexagenids are found in the Arctic and Subarctic lakes and streams, in streams filled exclusively with rubble, gravel or sand, in deeper regions of the Great Lakes or in those parts of smaller lakes, where anaerobic conditions prevail for a time during each year. Although the population of hexagenids may be exceedingly dense in local areas, i.e., along the shores of the Great Lakes and in the larger rivers, nevertheless the population is distributed in thin strips and small patchees over the surface of the land masses. The amazing thing is that the species remain as constant as they do with such a tenuous distribution.

If there is any considerable movement, migration and interchange of populations in the hexagenids, it is restricted to the nymphs. The eggs, it should be mentioned, are heavy, sticky, demersal objects that drop immediately to the substratum and become attached, leaving no chance of transportation by currents.

In lake-dwelling species, there is ample evidence (Neave, 1932) that the nymphs do not migrate extensively and that whatever migration does take place is concerned with the search for a suitable substratum in which the nymph may burrow.

In stream forms (Denham, 1938), the nymphs are washed out of their burrows and carried downstream, especially during sharp, sudden rises in the stream level. Just what the mortality rate is in these uprooted nymphs is unknown. Assuming it is relatively low, even then the movement is always downstream and always restricted to the same stream or stream system.

The nymph, in contrast to the adult, has a long life span. Here, then, adequate opportunity for natural selection to make its effect felt should be available. Habitat preference, the avoidance of enemies, the selection of food, the time of emergence, etc., would allow isolation of different species. The nymphs, it should be remembered, however, are all fossorial and have descended from a common ancestor who must have been a burrower. On the basis of observations on burrowing forms in other parts of the animal kingdom, it seems logical to conclude that the hexagenids will have nymphs displaying considerable morphological similarity. This is confirmed by the fact that only in those species that are widely separated phylogenetically do we find any great structural differences in the nymphs. These, however, are always accompanied by differences in habitat selection.

From an analysis of the biology of the genus, we can expect that within each species: (1) considerable variation will occur in the coloration and size of the imagoes between individuals from the same area, and between populations of various areas; (2) morphological characters such as genitalia, compound eyes, wing area in relation to body weight, and the total fore leg

length will vary only slightly within each species; (3) the nymphs of a given species will be much more uniform and less subject to variation both individually and between populations than are the adults; (4) speciation probably proceeds from the nymphs rather than from the aerial stages.

Taxonomic Characters

The truism that no single taxonomic character is always reliable and adequate must, of course, always be carried in mind. Further, there is no doubt that for an accurate and complete exposition of a species, all characters, no matter of what kind, must be considered. Some characters such as color and the extent of the color pattern are highly variable in the hexagenids and these have often been the basis, particularly in the instance of imagoes, for the separation of closely related populations. Such characters, although perfectly valid and useful, in order to be correctly utilized demand goodly series from numerous localities so that the range of individuals and geographical variability can be adequately determined. Size also has been employed, but this is fraught with danger from two sources: (1) Ide (1935) has shown that there is considerable seasonal variation in the size at least of individuals of *Iron humeralis* and *I. pleuralis*. There is no cause for doubting that the same type of variation is characteristic of hexagenids. (2) Numerous investigations have shown that specimens from that part of their range where the average temperature is low tend to be larger than are individuals from an area where the average temperature is high. Although no such experiments have been conducted on the hexagenids, there is reason to believe that they follow the same patterns. Finally, we can expect clinal variability in many of the characters, whether morphological or physiological. Small samples from single or few localities can not and do not elucidate such a phenomenon. It can be concluded that only adequate series from numerous localities and at various dates will give an adequate picture of the divers species and subspecies.

Taxonomy

Excluding *indica* Chopra and *philippina* Navas which possibly do not belong to Hexagenia, the following species belong to the genus: *albivitta* (Walker), *atrocaudata* McD., *bilineata* (Say), *callineura* Banks, *limbata* (Serville), *mexicana* Eaton, *recurvata* Morgan, *rigida* McD. *Albivitta, callineura,* and *mexicana* are members of the subgenus Pseudeatonica. On the basis of present information most of the above species are not divisible into subspecies, either geographical or ecological. *H. limbata,* however, possesses the following subspecies: *californica* Upholt, *limbata* (Serville), *occulta* (Walker), *venusta* Eaton, and *viridescens* (Walker). *H. munda* has the following subspecies: *affiliata* McD., *elegans* Traver, *marilandica* Traver, *munda* Eaton, and *orlando* Traver.

The following are considered as synonyms: *carolina*→*marilandica; kanuga* and *weewa*→*elegans; rosacea* and *mingo*→*occulta; pallens*→*venusta.* It should be noted that each of these synonymized species except *kanuga* was described

from one to a few specimens from a single locality. For *kanuga* nine specimens from two localities were available.

Synonyms that have been indicated by previous workers are: *H. fulva, illustrius,* and *reticulata→Eatonica schoutedeni; H. chaperi→Eatonigenia chaperi; H. variabilis→H. limbata; H. decolorata→Campsurus decoloratus. Ephemera atrostoma* Weber was tentatively placed in Hexagenia by Eaton in 1871. Later (1883) he changed it to Palingenia but the species is still imperfectly known.

Keys

The following keys are offered with trepidation. In general, keys for species and subspecies are always fraught with danger for the individual who knows little or nothing about a group. For the person who knows the group, they are superfluous. This is particularly true for keys to subspecies and the following ones are no exception. The key to the species, however, I feel is workable and can be used with some confidence.

Key to the Male Imagoes of the Subgenera and Species of Hexagenia

1. Genital forceps (fig. 27) 4-jointed ..... subgenus Hexagenia 2
   Genital forceps (fig. 38) 3-jointed ..... subgenus Pseudeatonica 7
2. Tips of penes recurved (fig. 39); wing membrane infused with raw umber ..... *H. recurvata*
   Tips of penes not recurved; wing membrane mostly hyaline 3
3. Penes (fig. 27) short, broad, and blunt; abdominal color patterns as in figs. 1 and 2 ..... *H. atrocaudata*
   Penes and abdominal color patterns different from above 4
4. Penes (fig. 37) slender, long, almost straight; abdominal color patterns as in figs. 25 and 26 ..... *H. rigida*
   Penes and abdominal color patterns different from above 5
5. Penes (fig. 28) slender, beak-like; abdominal color patterns as in figs. 3 and 4 ..... *H. bilineata*
   Penes and abdominal color patterns different from above 6
6. Penes (fig. 29) hook-shaped; costal cross veins of mesothoracic wings heavily marginated; costal membrane unevenly colored ..... *H. limbata*
   Penes (fig. 33) less hooked-shaped than in *limbata;* costal cross veins of mesothoracic wings appear not to be marginated; costal membrane evenly colored becoming lighter distally ..... *H. munda*
7. Wing membrane uniformly deep brown ..... *P. mexicana*
   Wing membrane mostly hyaline 8
8. Dorsal abdominal color pattern as in fig. 24; abdominal sternites infuscated laterally ..... *P. albivitta*
   Dorsal abdominal color pattern as in *albivitta;* abdominal sternites immaculate ..... *P. callineura*

Key to Typical Male Imagoes of the Subspecies of Hexagenia limbata

1. Abdominal color pattern (figs. 12, 13) much reduced; dorsum of abdomen largely yellow in color ..... *H. limbata venusta*
   Abdominal color pattern and coloration different from above 2
2. Abdominal color pattern (figs. 7, 8) extremely extensive; dorsum of abdomen largely blackish brown ..... *H. limbata viridescens*
   Abdominal color pattern and coloration different than above 3
3. Abdominal color pattern as in figs. 5, 6 ..... *H. limbata limbata*
   Abdominal color pattern as in figs. 10, 11 ..... *H. limbata occulta*

Dorsal abdominal color pattern much as in *limbata* but infused usually with bright red; ventral abdominal color pattern as in *venusta*.....*H. limbata californica*

KEY TO TYPICAL MALE IMAGOES OF THE SUBSPECIES OF HEXAGENIA MUNDA

1. Abdominal color pattern (figs. 22, 23) with oblique lines on tergites 8 and 9 narrowly reaching anterolateral corners of segments; dorsal abdominal ground color tan .....*H. munda orlando*
   Abdominal color pattern with oblique lines on tergites 8 and 9 not reaching anterolateral corners; dorsal abdominal ground color not tan 2
2. Dorsal abdominal color pattern (figs. 18, 20) without medial longitudinal line in segments 1-6 3
   Dorsal abdominal color pattern (figs. 14, 16) with medial longitudinal line 4
3. Abdominal color pattern as in figs. 20, 21 .....*H. munda marilandica*
   Abdominal color pattern as in figs. 18, 19 .....*H. munda munda*
4. Abdominal color pattern (figs. 14, 15) extensive and clear-cut; robust subspecies from north central and northeastern U. S. and south central and eastern Canada .....*H. munda affiliata*
   Abdominal color pattern (figs. 16, 17) less extensive and clear-cut; usually less robust than in *affiliata;* mainly from southeastern and southern U. S. exclusive of Florida .....*H. munda elegans*

HEXAGENIA ATROCAUDATA McD.

Hexagenia bilineata form *munda* Eaton. Needham, Bull. U. S. Bur. Fish., vol. 36, pl. 81, fig. 64, 1920.

Hexagenia atrocaudata McD., Canad. Ent., vol. 56, p. 92, fig. 2, 1924. Canad. Ent., vol. 59, pp. 117-118, fig. 2, 1927. Traver, Ann. Ent. Soc. Amer., vol. 24, pp. 611-613, 616, figs., 1931. Needham, Traver, Hsu, etc., Biology of Mayflies, pp. 262-263, fig. 84, 1935.

Specific characteristics:

♂ imago, dried.—Compound eyes large, nearly contiguous; fore legs about two-thirds body length; fore tarsi short, only slightly longer than the tibia; wing membrane hyaline, faintly tinged with sienna; venation piceous except humeral cross vein, base of fore costa and base of cubital medial region; costal and subcostal areas of fore wing distal to bulla infuscated with raw umber; basally subcostal area lightly tinged with raw umber; distal margin of hind wings purplish black; proximal cross veins of fore wing between R_1 and MP_1 and of disk of hind wing narrowly margined. Ground color of abdomen ochreous tinged with fuscous; tergal color pattern (fig. 1) black; sternal color pattern (fig. 2) fuscous to black; genitalia (fig. 27) fuscous yellow, penes broad and short; cerci piceous brown with narrow yellow intersegmental bands. Length: body 20-24 mm.; wing 18-21 mm.

♀ imago, dried.—Except for dimorphic differences, similar to male; coloration like that of male in all respects. Length: body 19-24 mm.; wing 18-22 mm.

Variations in imagoes.—The amount of variation in this species is small. Some individuals are darker, i.e., the yellow ground color is infuscated with deeper tints, and there is some size variation. The color pattern is remarkably constant.

Nymph, in alcohol.—Head and thorax dorsally chestnut brown; legs much lighter brown; setae on under surfaces of legs amber; tarsal claws swollen;

compound eyes olive brown dorsally; mandibular processes (fig. 40) strongly arced especially at about one-half their length; distally they are an intense brown shading to black; frontal process (fig. 44) truncate, labrum asymmetrical with front margin nearly straight; first joint of maxillary palp longer than body of galea-lacinia, entire palp slender and long. Body of gills blackish purple except for base, gill filaments lavender purple; abdominal color pattern of future adult visible both ventrally and dorsally; cerci and caudal filament brown. Length: 25-30 mm.

Variations in nymphs.—The degree of truncateness of the frontal process is variable; some nymphs, especially females and young nymphs, exhibit less truncateness than do males and mature individuals. The color pattern is also less definite in younger stages.

Type locality.—Ottawa, Canada, 10. IX. 23.

Holotype.—No. 691, Canadian National Collection.

Remarks.—The adult can be easily recognized by its distinctive abdominal color pattern and the genitalia of the male. The mature nymph can be recognized by the truncate frontal process, the strongly arced mandibular process, the asymmetrical labrum, and the abdominal color pattern.

Range:

It ranges (fig. 59) through the southern highlands, the Hudson valley, across eastern Canada, the north-middle United States, and down into the Ozark highlands. It is not to be found in the warmer lowlands of Ohio, Indiana, Illinois, Kentucky, and Missouri. Imago specimens of this species that I have seen were collected at the following localities:

Illinois. Momence 21. VIII. 36 (I.S.); Richmond 15. VIII. 38 (I.S.);

Indiana. Howe 7. VIII. 29, 14. IX. 16 (M.C.Z.); Monticello—. IX. 27; Oswego VIII. 27; Warsaw 9. VIII. 28;

Maryland. New Windsor—. VIII. 26;

Michigan. Alma 23-28. VII. 29; Ann Arbor 12. VII. 33 (U.M.); Delhi 9. VIII. 34 (U.M.); E. Lansing 14-21. VIII. 36; Lowell 27. VII. 29; Mich. Agri. Coll. campus 16. VIII. 10 (M.C.Z.);

Missouri. Ozark 16. IX. 37;

New York. Deposit 15. VIII. 34; Ithaca 4. VIII. 30 (C.U.), 11-28. VII. 31 (C.U.);

Ohio. Columbus—. VIII.—(O.S.U.);

Ontario. Lyn 11. VIII. 26 (C.N.C.); Ottawa 25. VIII. 22, 10. IX. 23, 25. VIII. 24, 30. VIII-4. IX. 25 (all in C. N. C.); Woodbridge 11. VIII. 34 (U. M.);

Pennsylvania. Chambersburg 18. VIII. 26 (C.U.);

West Virginia. So. Fk. Potomac Riv. 6. VIII. 30 (C.U.); Cacapon Riv. 13-18. VIII. 30 (C.U.)

McDunnough has reported the species from Straight Creek, W. Va., 8. VIII.—. Traver records the species from E. Aurora, Hagaman and Rochester, N. Y.; Pendleton Co., Greenbrier River, New River, Athens and Smoke Hole, W. Va.; N. Tazewell, Va., Ashe Co., N.C.; Kingston, Ringold and Rome, Ga.

Biology:

The nymphs inhabit clear, cool streams. They are lacking in large, slow-

moving, turbid rivers as well as in all warm streams. Agriculture, with its subsequent changes of the stream beds, has probably reduced the range of the species. Emergence is in the late summer from the last of July to the middle of September. The nuptial dance takes place over the stream. The females fly about two to four feet above the water, while the males dance up and down from near the surface to ten feet high. The fresh eggs are a dark chocolate brown.

HEXAGENIA BILINEATA (Say)

Baëtis bilineata Say, West. Quart. Rep., vol. 2, p. 303, 1824. Leconte, Complete Writings of T. Say, vol. 1, p. 203, 1859.

Palingenia bilineata (Say). [non] Hagen, Syn. Neuropt. No. Am., p. 41, 1861. Walsh, Proc. Acad. Nat. Sci. Phila., vol. 14, p. 373, 1862. [partim] Hagen, Proc. Ent. Soc. Phila., vol. 2, p. 174, 1863.

Palingenia limbata Guerin. Hagen, Syn. Neuropt. No. Am., p. 41, 1861.

Hexagenia bilineata (Say). Walsh, Proc. Ent. Soc. Phila., vol. 2, p. 199, 1863. Eaton, Trans. Ent. Soc. Lond., pt. 1, p. 66, 1871. Revisional Mono. Rec. Ephemeridae, pt. 1, pp. 50-51, [non] pl. 7, fig. 11, 1883. [non] Clemens, Canad. Ent., vol. 45, pp. 331-332, fig. 1, 1913. [partim] Needham, Bull. U. S. Bur. Fish., vol. 36, p. 278, 1920. Ulmer, Arch. Natur., Bd. 87, Hft. 6, pp. 235-239, figs. 5, 7, 1921. [non] Wiebe, Ohio Jour. Sci., vol. 26, pp. 267-274, pl. 1, 1926. McDunnough, Canad. Ent., vol. 56, p. 90, 1924; op. cit., vol. 59, pp. 116-120, fig. 1, 1927. Traver, Ann. Ent. Soc. Am., vol. 24, pp. 591-594, 611-613, figs., 1931. J. Elisha Mitch. Sci. Soc., vol. 53, p. 76, 1937. Needham, Traver, Hsu, etc., Biology of Mayflies, pp. 263-264, fig. 84, 1935.

Hexagenia bilineata form *falcata* Need., Bull. U. S. Bur. Fish., vol. 36, fig. 62, 1920.

Specific characteristics:

♂ imago, dried.—General coloration dark; fore legs subequal to body length; fore tarsi long, one and four-fifths of tibia; first tarsal segment extremely short; compound eye separated dorsally by approximately one-half the eye diameter; wings hyaline, membrane tinged with pale raw umber; apical portion, beyond bulla, of costal and subcostal areas of fore wing a more intense raw umber; distal margin of hind wing broadly banded with purplish black; cross veins of disk of hind wing and all cross veins anterior to MP_1 in fore wing marginated. Abdominal tergites (fig. 3) largely purplish black; pleural folds and adjacent areas of tergites 1-8 yellow; posterior margins of 1-8 narrowly edged with white; abdominal sternites (fig. 4) with fuscous coloration on yellow background. Genitalia (fig. 28) fuscous with second forceps joint tinged with black; distal joints slender; penes beak-shaped; cerci bistre narrowly ringed with white at base of each segment. Length: body 14.5-21 mm.; wing 13-17 mm.

♀ imago, dried.—Coloration and color pattern similar to those of the male. The wing membrane is less strongly tinted and the general coloration is slightly lighter. Length: body 17-23 mm.; wing 17-22 mm.

Variations in imagoes.—The amount of variation is moderate. The intensity as well as the extent and definition of the color pattern, especially that of the abdomen, are rather variable. The ground color varies from a yellow to a

light raw umber; the pattern color varies from pitch black to burnt umber. Thus the abdominal sternites of some individuals are almost uniformly darkly colored, while in others the yellow ventral triangles occupy most of the area. The intensity of the pigmentation of the wing membrane, the amount of infuscation of the cross veins and the intensity of the thoracic color also vary. Such variability is to be found within a series taken at a single locality on a single day. Specimens from the southeastern part of the range are smaller and somewhat lighter in color.

Nymph, in alcohol.—Mandibular processes long, slender and gradually arced, with the tips tending to cross distally; frontal process conical; the future imaginal color pattern shows through the thin exoskeleton in mature individuals; general coloration dark.

Variations in nymphs.—The nymph, in a well preserved state, is rare in most collections. I have none in my own collection and have seen only one individual that could with certainty be considered a representative of the species. The variation therefore can not be given at this time.

Type locality.—St. Peter's Riv., Minn., now known as the Minnesota River.

Holotype.—♀ non-existent.

Remarks.—Say based his description of the species upon a ♀ imago from St. Peter's River. If a female from the upper Mississippi valley is studied by means of a hand lens in clear daylight, it will be found that Say's description fits very well. The species was correctly determined by Walsh and Eaton. Ulmer (1920) has clearly differentiated it from *limbata*. Phylogenetically it is distinct and can be readily recognized by the genitalia and the abdominal color pattern. There is no other species with which it can be confused.

Range:

H. bilineata (fig. 62) ranges through the entire Mississippi valley drainage and along the eastern Piedmont area. It is lacking in the St. Lawrence drainage, the northeastern United States, the southern Appalachian highlands and the coastal plain. Imagoes of the species that I have seen were collected at the following localities:

Alabama. Muscle Shoals 14. VII. 33; Tuscaloosa 2. VII. 36 (C.U.);

District of Columbia. Washington 22. VI.—(M.C.Z.);

Georgia. Albany 22. VI. 39 (I.S.); Cartersville 1. VII. 39 (I.S.); Clarksville 1. VII. 39 (I. S.); Cornelia 1. VII. 39 (I.S.); Demerest 1. VII. 39 (I.S.); Ringold 14. VI. 39 (I.S.); Rome 13. VII. 30; Rupert 22. VI. 39 (I.S.); Thomaston 3-8. VI. 39 (I.S.);

Illinois. Alton 21. VII. 38 (I.S.); Antioch 11. VII. 38 (I.S.); Cairo 21. VII. 39, 27. VIII. 38, 1. VIII. 05 (all in I.S.); Decatur 12-23. VI. 38 (I.S.), 16. VII. 39 (I.S.); Elizabeth 22. VI. 27 (I.S.); Fulton 20. VIII. 27 (I.S.); Galena 25. VII. 75 (A.M.N.H.); Grafton 18. VI. 39 (I.S.); Harrisburg 16. VIII. 37 (I.S.); Kankakee 2-4. VIII. 38 (I.S.); Mahomet 3. VIII. 37 (I.S.); Metropolis 5. VIII. 05 (I.S., C.N.C.); Mound City 26. VII. 39 (I.S.); Oregon 13. VII. 26 (I.S., C.N.C.); Pontiac 22. VIII. 38 (I.S.); Prophetstown 19. VII. 27 (I.S.); Quincy 6. VII. 38 (I.S.); Ripley 7. VII. 38 (I.S.); Rock Island 7. VII. 25 (I. S., C.N.C.), no date

(M.C.Z.); Rosiclare 5. VII. 35 (I.S.); Savanna 20. VII. 27 (I.S.); 11. IX. 32 (I.S.);

Indiana. Elnora 15. VIII. 31; Foote's Lake, Gibson Co., 7. VII. 30; Gosport 20. VI. 32; Hazelton 16. VI. 36; La Crosse 6. VIII. 29; Mt. Vernon 26. VII-13. VIII. 34, 18. VIII. 36;

Iowa. Burlington 26. VIII. 29; Dubuque 1932 (C.U.); Fairport 6-12. VII. 31 (C.U.); Muscatine 12. VII. 31 (C.U.); Pleasant Valley 5. VII. 28 (C.U.);

Kentucky. Cloverport 26. VII. 03 (C.U.); Lexington 14. VII. 13 (C.U., I.S.), 16. VI. 35 (C.U., I.S.);

Louisiana. Baton Rouge 17. IV. 34 (U.M.);

Maryland. Montgomery Co. 14. VI. 11 (Davis, C.N.C.);

Mississippi. Lucedale 20. VI. 32 (C.U.);

Missouri. Hannibal 26. VI. 33; Hollister 10. VII. 38 (I.S.), 10. IX. 32; Rockaway Beach 13. VI. 36;

New Mexico. Red River 6. VIII. 38 (O.S.);

Ohio. Cincinnati 2. VIII. 01 (C.N.C.);

Oklahoma. Blue 10. VI. 39 (O.S.); Hugo 11. VI. 39 (O.S.); Snyder 11. VI. 37 (O.S.); Tahlequah 17. VI. 39 (O.S.);

Tennessee. Knoxville 24. VI. 16, 19. VI. 31,—. VI. 31 (all in C.U.); Monteagle 17. VII. 31 (C.U.);

Texas. San Antonio 27. V. 27 (C.N.C.); Waco 22. VI. 33 (C.U.);

Virginia. Great Falls 21. VI. 31; Alexandria Co. 22. VI. 10 (Davis).

The species has also been reported by Traver from Gadsden, Ala.; Atlanta, Marietta, and the Tombigee River, Ga.; and St. Cloud, Minn.

Biology:

The species is restricted to the larger lowland rivers and large creeks, and is completely lacking in clear bodies of water such as lakes and upland streams. The nymph apparently dwells in the deeper waters and consequently is rare in collections. Dr. Burks of the Ill. Nat. Hist. Sur. (personal communication) has collected extensively in the shallower waters of streams in which *bilineata* dwells and has been unable to acquire the nymph. The use of a dredge seems necessary to collect this species in the nymphal form. The advent of agriculture with the subsequent erosion and consequent changes in stream beds may have extended the range of this species.

The imagoes emerge from the middle of June to the middle of September. The peak of emergence seems to occur during August.

HEXAGENIA INDICA Chopra

Hexagenia indica Chopra, Rec. Ind. Mus., vol. 26 p. 416, figs. 1-3, 1924. Ulmer, Arch. Hydro., Suppl. Bd. 16, p. 478, 1939.

Eleven spent females were collected on the surface of Chilka Lake, India. Of these two were pinned and the remainder, some fragmentary, were placed in "spirits." The description was derived from one of the bottled specimens. Whether this species belongs to Hexagenia or Eatonigenia, or perhaps represents a new genus, can not be determined until the male and the nymph are known. From the description it is possible to determine that the species is not a typical member of Hexagenia in that (1) the pronotum lacks the two lateral,

darkly colored, longitudinal stripes; (2) there is a medial, longitudinal, narrow ridge on the pronotum which continues on the mesonotum ending in a blunt spine posteriorly and this is repeated on the metanotum; (3) the ninth abdominal segment is the largest; (4) the hind wing is atypical, the MP_2 being attached to the Cu_1 as in Ephemera. I have not seen the type specimen.

Type locality.—Chilka Lake, Barkuda Island, India, August, 1919.

Type.—7528/H_2, Zoological Survey of India (Indian Museum).

HEXAGENIA LIMBATA (Serville)

This species has always been the despair of ephemeropterists. Four reasons are responsible for the confusion that has surrounded *limbata:* (1) No one worker has ever seen all of the types of the various species of Hexagenia from North America. (2) The two specimens upon which the original description and definition were based were merely indicated as being from "l'Amerique septentrionale." (3) Most important of all, the species *limbata* is made up of a number of geographical subspecies. (4) No student of the ephemerids has ever had sufficient material from the entire range of the species to study it from the point of view of its geographical subspecies. As a result older workers termed the subspecies merely variations and some recent workers have advanced them all to the rank of full species. Both procedures have obscured the true picture. A combination of factors has thus been responsible for the welter of confusion that exists around *limbata.*

Male imagoes of the species are characterized by (1) the hooked penes (*limbata* type, fig. 29), and (2) the costal margin of the mesothoracic wing having the cross veins marginated and the coloration of the membrane uneven, thus giving a spotted appearance to this area. The known nymphs of all subspecies have dome-shaped frontal protuberances and relatively short, moderately upcurved mandibular rami that do not cross distally. Ecologically it is highly adaptable, being found in many different types of water. It seems equally at home in lakes and streams. Whether the lake is large or small, whether the stream is sluggish and silt-laden or rapid and clear appears to be immaterial.

After studying all available material, I have divided the species into the following subspecies: *californica, limbata, occulta, venusta,* and *viridescens.* For all of these subspecies intergrading specimens of geographically adjoining subspecies have been found. Where *occulta, venusta,* and *limbata* meet, all three intergrade. The zones of intergradation are often rather wide, and from a given locality at a single date a series may often be collected that ranges from typical specimens of one subspecies through various degrees of intergradation to typical individuals of the other subspecies. It should not be overlooked that whatever the make-up of these intergrading series at a given locality, they appear on the basis of all present information to form a single interbreeding population for that particular area.

HEXAGENIA LIMBATA LIMBATA (Serville)

Ephemera limbata Serville, in Guerin-Meneville, Iconographie Regne Animal, tome 3, p. 384; tome 2, insects, pl. 60, fig. 7, 1829-31. Gray, in Grif. Class Insecta, vol. 2, p. 786, pl. 94, fig. 7, 1832.

Ephemera limbata Guerin. Rambur, Hist. Nat. Neuropt., p. 295, pl. 8, fig. 2, 1842.

Palingenia limbata (Serville). Pictet, Hist. Nat. Ins. Neuropt., Ephemerines, pp. 146-148, pl. 12, figs. 1, 2, 3, 1843-45. Walker, List Neuropt. Ins. Brit. Mus., pt. 3, p. 548, 1853.

Palingenia limbata (Pictet). [partim] Hagen, Syn. Neuropt. No. Am., pp. 41-42, 1861. [partim] Proc. Ent. Soc. Phila., vol. 2, p. 176, 1863. Walsh, Proc. Acad. Nat. Sci. Phila., vol. 14, p. 373, 1862. Proc. Ent. Soc. Phila., vol. 2, p. 199, 1863.

Hexagenia limbata (Pictet). Walsh, Proc. Ent. Soc. Phila., vol. 2, p. 197, 1863. Hagen, Stett. Ento. Zeit., vol. 51, pp. 11-13, 1890. Needham, Bull. U.S. Bur. Fish., vol. 36, p. 279, 1920.

Hexagenia limbata (Guerin). Eaton, Ent. Mo. Mag., vol. 5, p. 85, 1868. [partim] Trans. Ent. Soc. Lond., pt. 1, pp. 65-66, 1881. [partim] McDunnough, Canad. Ent., vol. 56, p. 90, 1924. Canad. Ent., vol. 59, pp. 119-120, 1927. Traver, Ann. Ent. Soc. Am., vol. 24, pp. 611-613, 1931. Needham, Traver, Hsu, etc., Biology of Mayflies, pp. 265-266, 1935.

Hexagenia bilineata (Say). [partim] Eaton, Revisional Mono. Rec. Ephemeridae, pt. 1, pp. 50-53, 1883.

Hexagenia variabilis Eaton. [partim] Revisional Mono. Rec. Ephemeridae, pt. 1, pp. 55-58, 1883.

Hexagenia limbata (Serville). Ulmer, Arch. Natur., Bd. 87, Abt. A, Hft. 6, pp. 233-239, 1921.

Guerin's description is as follows:

Cette espèce est nouvelle. Voici la description que M. Serville en a faite. Un peu plus grande que l'*E. lutea*. Thorax roux, avec un tache noire sur le prothorax de chaque côté. Abdomen jaune, varié de brun. Filets plus de trois fois plus longs que le corps, bruns, annelés très—finement de jaunâtre. Appendices anals grêles. Pattes jaunes, les antérieures ayant le tibia noir, assez longues, moins longues que le corps. Ailes transparentes, non tachées, ayant le bord antérieur des premières presque transparent dans sa moitié interne, et le bord externe des secondes brun.—Hab. l'Amérique septentrionale.

The specimens that Serville utilized were eventually acquired by Selys-Longchamps. Eaton (1871, p. 8) saw the male imago which is the type. No other ephemeropterist saw Serville's specimens until Ulmer (1921) compared two specimens in the Selys' collection with three other specimens that Pictet (1842) had studied. Ulmer concluded that Pictet's and Serville's material were the same. He published drawings of the dorsal view of the abdomen and the genitalia of this species. He did not, however, definitely state that his drawings were made from the Serville specimen (one Serville specimen now lacks the entire abdomen).

From the original description plus Ulmer's drawings and statements and Eaton's 1871 (not his 1883) description, it is possible to determine that the true *limbata* is a light yellow species having brown abdominal markings, a ruddily marked thorax, clear wings with the hind wing tipped with brown, and the fore tarsi lighter than the fore tibiae. Specimens that meet the above qualifications are to be found in North America in the area from middle western Illinois to the Columbia River region. All specimens I

have seen from this area conform to these specification. McDunnough (1927) first noted that specimens from British Columbia were almost typical. Traver (1935) also came to a similar conclusion. Independently, then, three workers have decided that the western material seems to be representative of the true *limbata*. During the summer of 1939 I had planned, while studying in Europe, to see the original types but was prevented from doing so by the outbreak of war. The description given below is derived from an individual collected at Robson, Brit. Col.

Subspecific characteristics:

♂ imago, dried.—Entire frontoclypeal area, antennal socket, scape and base of pedicle yellow; a spot between compound eyes and antennae, distal half of pedicle and flagellum fuscous; vertex yellow faintly tinged with raw umber; compound eyes separated by half their diameter.

Pronotum with lateral edges broadly yellow, submedial longitudinal black stripes and a medial translucent yellow area. Prosternum yellow anteriorly, piceous posteriorly. Mesonotum tawny; mesoscutellum tipped with piceous; metanotum yellow with scutellum tipped with black; meso- and metapleura tawny with episterna tinged with fuscous; meso- and metasterna blackish bistre. Fore coxae yellow on anterior surface but bistre otherwise; fore trochanter, femur and tibia intense blackish burnt umber; fore tarsal segments light fuscous, darker at joinings and claws; meso- and metathoracic legs yellow, with tarsi and tarsal claws tinged with fuscous. Wing membranes hyaline; fore wing with extremely faint raw umber infuscation in costal and subcostal areas and with the cross veins in this area marginated, thus giving a characteristic spotted appearance to the costal and subcostal areas; hind wing with purplish brown outer margin; all veins, except at base of wings and in anal areas bistre; cross veins of disk of hind wing and those anterior to the MP_1 of fore wing lightly marginated with bistre.

Abdominal ground color yellow; abdominal color pattern clear cut, restricted, and of bistre black. Tergal color pattern (fig. 5) consists of a medial line, interrupted at the segmental joinings, and an oblique lateral line on each side that arises from the medial line at the posterior edge of each tergite and extends to the anterolateral corner. Sternites (fig. 6) with a continuous mid-ventral bistre black line, which narrows at the anterior edge of each sternite. This line is continuous with the dark coloration of the thoracic sternites; a pair of submedial lateral yellow dots in each sternite emersed in the bistre black band. In anterolateral corner of each sternite a bistre black spot. This spot appears as a continuation of the oblique lateral tergal stripes. Genitalia (fig. 29) with penes strongly hooked; distal forceps joints sturdy; second forceps joint not strongly arced. Penes (fig. 29) yellow, tinged with umber; forceps yellow at base changing to piceous distally. Cerci burnt umber with narrow yellow joinings. Length: body 18-20 mm.; wing 16-18 mm.

♀ imago, dried.—Similar to the male except for the normal dimorphic differences. The color pattern, especially of the abdomen, and the dark mar-

gined hind wing seem to be fairly reliable characters for the recognition of the females.

Variations in imagoes.—The meso- and metathoracic nota may vary from a uniform light yellow to light burnt umber. In those individuals with yellow nota, the scutella are of the same color as is the surrounding area. The extent and distinctness of the color pattern of the abdominal tergites are also variable. The ventral abdominal color pattern may consist merely of a medial line or the line may be expanded on each sternite to form a triangle based upon the posterior sternal margin. Occasional individuals tend to lack the mid-dorsal dark tergal line.

Nymph.—Unknown.

Type locality.—Unknown but probably the Columbia River area.

Type.—Selys Collection in the Musée Royal d'Histoire Naturelle de Belgique.

Remarks.—The types probably were collected in the Pacific northwest. David Douglas explored this region in 1824, '25, '26, and '27. From his Journal (1836) we know that he collected insects along the water courses. *H. limbata* is the largest and most obvious of the western ephemerids and there is little doubt that the specimens which Serville received could have been collected by Douglas. Serville, a noted French entomologist, was known to be interested in the Neuroptera and at one time (Audinet-Serville and Lefebure, 1833) even announced that he and Lefebure planned "d'une Iconographie descriptive des Neuroptères." It would therefore easily be conceivable that Douglas sent his neuropterous collections to Serville.

The subspecies, along with the other members of the species, is characterized by the strongly hooked penes (fig. 29) and the heavily marginated costal cross veins with costal membrane pigments unevenly distributed, thus giving a spotted appearance to this area. *Limbata* can be separated from *californica* by the lack of the red infuscation of the dorsum of the abdomen, from *viridescens, venusta,* and *occulta* by the dorsal abdominal color pattern.

In the eastern part of its range, *limbata* intergrades with *occulta.* Along the southern edge of its range, it intergrades with *venusta.* Probably in the extreme western part of the country it may intergrade with *californica.* In the area where *occulta, venusta,* and *limbata* meet, the picture is rather complex and only with difficulty can specimens be placed. In fact for the purpose of recording data, it is often necessary to make arbitrary separations.

Range:

The known range (fig. 53) is obviously incomplete. Typical specimens of the subspecies that I have seen were collected at the following localities:

British Columbia. Oliver 22. VII. 23 (C.N.C.); Penticton 12-16. VII. 23 (C.N.C.); Robson 27. VIII. 35; Salmon Arm 24. VII. 25 (C.N.C.); Summerland 6. VII. 25, 21. VI. 34 (C.N.C.); Vernon 23. VII. 23 (C.N.C.);
Colorado. Colo. no date (A.M.N.H.); Clear Cr. no date (M.C.Z.);
Idaho. Priest Lake, —. VIII. 19;
Illinois. Havana 21. VI. 26 (C.N.C.);
Michigan. Dexter, Huron Riv. 4. VI. 39 (L.y.);

Oregon. Portland, no date (M.C.Z.); Williamson Riv., Kalamath Co. 7. VI. 33 (M.C.Z.);
Washington. Wash. Terr. no date (A.M.N.H.).

I have seen intergrades of *limbata-venusta* from:
Iowa. Iowa Co. 1. VII. 39 (C.N.C.);
Kansas. Lawrence 26. VI. 30 (C.N.C.);
Utah. Utah Lake 5. VII. 75 (C.N.C.).
Intergrades of *limbata-venusta-occulta* are from:
Illinois. Homer Pk. 30. VI. 27 (C.N.C.); Havana 21. VI. 26 (C.N.C.); Oregon 9. VIII. 25 (C.N.C.); Rockford 12-13. VI. 38 (I.S.).
Intergrades of *limbata-occulta* are from:
Illinois. Galena 12. VI. 75 (A.M.N.H.); Ottawa 26. VIII. 29;
Manitoba. Treesbank 19. VI. 23 (C.N.C.).

Biology:

The biology of this subspecies is unknown.

HEXAGENIA LIMBATA CALIFORNICA Upholt

Hexagenia californica Upholt, Pan-Pac. Ent., vol. 13, nos. 1-2, pp. 85-86, 1937.

Subspecific characteristics:

♂ imago, in alcohol.—Ground color yellow, tinged with red on the abdomen; extensive dark color pattern; fore tarsal joints uniform ruddy brown; costal and subcostal membrane of fore wing as in *limbata;* cross veins of hind wing disk and in area from R_1 to MP_1 of fore wing heavily marginated with black; hind wing distal margin heavily infuscated; outer margin of fore wing narrowly infuscated; wing membrane hyaline tinged with ochreous. Dorsal abdominal color pattern as in *limbata* but with reddish infuscation around color pattern; oblique lines of tergites eight and nine reach anterolateral corners of segment; dark brown spots in anterolateral corners of sternites as in *venusta;* interrupted blackish brown medial longitudinal line on sternum much as in *venusta;* lateral infuscations of ruddy color in connection with these lines tend to form triangles, especially on anterior sternites; genitalia of the *limbata* type. Length: body 17-20 mm.; wing 17-18 mm.

♀ imago, in alcohol.—Similar to male except for dimorphic differences. Dorsal abdominal color pattern as in fig. 9. Length: body 20-25 mm.; wing 18-22 mm.

Variations in imagoes.—Imagoes of the subspecies vary in the amount of red suffusion, some almost lacking it entirely. The dark color pattern appears to be relatively constant. More material must, however, be available before the entire range of variability can be determined since specimens from only one locality are now known.

Nymph.—Unknown.

Type locality.—Kingsburg, Fresno Co., Calif., 30. VI. 36.

Holotype.—No. 4350, Calif. Acad. Sci. Ent.

Remarks.—The ventral color pattern definitely places *californica* as a relative of *venusta* from which it can easily be separated by the dorsal color

pattern. The dorsal abdominal color pattern, the infuscated hind wing margin and the genitalia all show the relationship of *californica* to *limbata*. *H. californica* can be separated from *limbata* by the ruddy coloration.

Range:

Known as yet from only a single locality. Specimens in the M.C.Z. from Utah Lake appear to be intergrades between *limbata* and *californica*. Further collecting will probably show that it intergrades with both *venusta* and *limbata* on the edges of its range.

Biology:

Unknown. The type series emerged 23.VI.30-6.VII.30.

HEXAGENIA LIMBATA OCCULTA (Walker)

Palingenia occulta Walker, List Neuropt. Ins. Brit. Mus., pt. 3, p. 551, 1853. Hagen, Syn. Neuropt. No. Am., p. 43, 1861.

Palingenia limbata Guerin. [partim] Hagen, Syn. Neuropt. No. Am., p. 41, 1861.

Palingenia bilineata Say. [partim] Hagen, Syn. Neuropt. No. Am., p. 41, 1861. Proc. Ent. Soc. Phila., vol. 2, p. 174, 1863. [partim] Walsh, Proc. Ent. Soc. Phila., vol. 2, pp. 199-202, 1863.

Hexagenia limbata Guerin. [partim] Eaton, Trans. Ent. Soc. Lond., pt. 1, p. 67, 1871.

Hexagenia variabilis Eaton, [partim] Revisional Mono. Rec. Ephemeridae, pt. 1, pp. 55-57, 1883. Hagen, Stett. Ent. Zeit., vol. 51, p. 12, 1890. Needham, N. Y. State Mus. Bull. 47, p. 427, 1901. Rpt. Mich. Geol. Sur., p. 262, 1907. Morgan, Ann. Ent. Soc. Am., vol. 4, p. 99, 1910.

Hexagenia bilineata Say [partim] Needham, Bull. U. S. Bur. Fish., vol. 36, p. 280, 1920.

Hexagenia limbata var. *occulta* (Walker). McDunnough, Canad. Ent., vol. 59, p. 119, 1927.

Hexagenia occulta (Walker). Traver, Ann. Ent. Soc. Am., vol. 24, pp. 611-613. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 269, 1935.

Hexagenia mingo Traver, Ann. Ent. Soc. Am., vol. 24, p. 597, 1931. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 267, 1935.

Hexagenia limbata occulta (Walker). Neave, Contr. Canad. Biol. and Fish., vol. 7, pp. 182-197, 1932. Canad. Field-Nat., vol. 46, p. 54. Spieth, Ann. Ent. Soc. Amer., vol. 33, pp. 327-328, 1940.

Subspecific characteristics:

♂ imago, dried.—General body color reddish brown, with a relatively small amount of yellow in comparison to that found in *venusta* and *limbata*. Similar to *limbata*, *viridescens*, and *venusta* in that the costal cross veins are heavily margined and the pigment of the costal membrane is unevenly distributed. Distal margin of hind wing may or may not be infuscated with purplish black. Fore femur and tibia burnt umber instead of the brighter red of *venusta* and *limbata;* middle and basal sections of tarsal segments only slightly lighter than joinings. Dorsal abdominal color pattern (fig. 10) extensive and not clear cut as in *affiliata;* the oblique lines of tergites 8 and 9 reach anterolateral corners of the tergites; ventral abdominal color pattern (fig. 11) with triangles attaining anterior margin; cercal segments dark distally and ochreous in basal halves and at joinings. Genitalia (fig. 30) with the penes of the *limbata* type. Length: body 14-19 mm.; wing 15-19 mm.

♀ imago, dried.—General over-all color yellow; dorsal abdominal color pattern similar to that of male; ventral abdominal color pattern reduced; distal margin of metathoracic wing clear; wing membrane tinged with ochreous; cerci ochreous and not darker at joinings as in *viridescens*. No definite characters are known which consistently separate female specimens of the subspecies from those of *affiliata* and *viridescens*. Length: body 19-24 mm.; wing 19-24 mm.

Variations in imagoes.—Imagoes of the subspecies vary enormously in the amount of reddish brown color that suffuses the body. In some individuals this almost obliterates any yellow color with the result that the typical color pattern is almost, if not totally, obscured. Such individuals, when preserved, are almost indistinguishable from those of *viridescens*. Other specimens have only a small amount of suffused reddish pigmentation, and in such instances the color patterns are clear cut and the yellow ground color stands out distinctly. The suffused individuals are found most often in the Great Lakes, Michiman, Minnesota, and the cooler waters of Canada. In Illinois, Indiana, and southern Ohio the specimens are less suffused with red.

Nymph.—Future abdominal color pattern of imago visible; frontal prominence (fig. 48) dome-shaped; mandibular tusk (fig. 41) relatively short and only slightly up-curved; abdominal gills 2-7 with basal one-third greyish white, distal two-thirds purplish black.

Type locality.—"Arctic America between Lake Winnipeg and Lake Superior."

Lectotype.—British Museum (Natural History).

Remarks.—Typical specimens of *occulta* can be identified by the abdominal color pattern (figs. 10, 11), the fore wing margin and the strongly hooked penes. They are usually smaller and always paler than *viridescens*, their color pattern is more extensive than in the true *limbata*, and they lack the large amount of yellow coloration found in *venusta*. Often individuals are so infused with brownish red as to be almost without a distinct color pattern.

The subspecies lives mostly within the area that was covered by the last glacier. It apparently has migrated into this area from the southern and middle western sections of the country. It is probably the most variable, certainly the most widespread and abundant subspecies of *limbata*. In Indiana and Illinois it intergrades with *venusta;* in northern Illinois and probably in Minnesota it intergrades with *limbata* proper, while in the area of northern Michigan and western Ontario it intergrades with its close relative *viridescens*.

Range:

As shown in fig. 52 this subspecies ranges from Saskatchewan to New Brunswick, south into Connecticut, Pennsylvania, Ohio, Kentucky, Indiana, and Illinois. It also extends down the Appalachians into West Virginia, North Carolina, and probably western Virginia. Specimens of *occulta* that I have seen were collected at the following places:

District of Mackenzie. Ft. Rae, Great Slave Lake 12. VIII. 23 (C.N.C.);

Illinois. Algonquin 21. VII. 06, 17. VIII. 06 (I.S.); Antioch 10. VI. 33 (I.S.); Elgin 13. VI. 39 (I.S.); Kankakee 5. VIII. 38 (I.S.); McHenry 30. VI. 31 (I.S.);

Momence 4. VI. 32, 15. VI. 38, 22. VI. 38, 5. VIII. 38, 16. VIII. 38 (I.S.); Oregon 9. VII. 25 (I.S.); Richmond 15. VIII. 38 (I.S.); Rockford 12. VI. 38 (I.S.); White Heath 24. VI. 16 (I. S.); Zion 11. VI. 36 (I.S.);

Indiana. Bloomington 26. V. 30, 3.VI. 29; Lake James 5-19. VII. 29; Lake Wawasee 2-3. VII. 27; 6. VII. 27; 19. VIII. 27; Logansport 24. VI. 28; Mongo 5. VIII. 29; Oswego 17. VIII. 27; Warsaw 9. VIII. 28, 9. VII. 27;

Kentucky. Georgetown 29. V.—. (I.S.);

Manitoba. Aweme 23. VII. 30, 10. VII. 25 (C.N.C.); Grand Beach 13. VII. 25 (C.N.C.); Lander 1. VIII. 21 (C.N.C.); Melita 2. VIII. 21 (C.N.C.); Victoria Beach 9. VII. 28 (C.N.C.); Winnipeg 10-12. VII. 23 (C.N.C.);

Michigan. Alma 28. VII. 29; Ann Arbor 24. VII. 33 (U.M.), 6. VI. 39 (Ly.); Aurelius 10. VII. 38 (I.S.); Baldwin 28. V. 39 (I.S.); Burt Lake, Cheboygan Co., 26. VI. 32 (U.M.); Cheboygan 1. VII. 35 (U.M.); Douglas Lake 11. VII. 27 (U.M.); Gogebic Lake 30 VI. 34, 21. VII. 36; Higgins Lake 9. VII. 32 (U.M.); Interlochen 29. VI. 29; Manistique 22. VII. 36; Menominee 6. IX. 37 (I.S.); Munuskong Pk. 26. VI. 32 (U.M.); Rockford 27. VII. 29; St. Ignace 16. VIII. 27 (U.M.); Sagenaw Bay 16. VI. 38 (I.S.), 19-20. VI. 38 (Ly.); Sand Pt. 20. V. 32 (U.M.);

New Brunswick. French Lake 2. VII. 28 (C.N.C.);

North Carolina. Penrose 14. VII. 30 (C.U.);

New York. Lewiston 11. VII. VII. 04 (Davis); Nyak. —. VI. 34; Rousses Pt. 12. VII. 27 (C.N.C.);

Ohio. Cleveland 5. VII. 27; Columbus 5. VI. 23 (O.S.U.), —. V.2? (O.S.U.); Port Clinton 5. VII. 28, 22. VI. 29, 29. VI. 29; Put-in-Bay 4. VII. 22 (C.N.C.); Ross Co. —. VI. 25 (O.S.U.); Sandusky 28. VI. 34; Vermillion 20, VII. 33;

Ontario. Hogs Back 23. VI. 23 (C.N.C.); Kingston 10. VII. 38; Lake of Bays 11. VII. 20 (C.N.C.); Lake Nipigon 26. VII. 23 (C.N.C.); Minaki 10. VII. 28 (C.N.C.); Niagara 6. VII. 04; North Bay 5. VII. 38, 19. VII. 26 (C.N.C.); Normandale 6. VII. 25 (C.N.C.); Orillia 11. VI. 25 (C.N.C.); Ottawa 13. VI. 20 (C.N.C.), 8. VII. 23 (C.N.C.), 19. VIII. 25 (C.N.C.), 10-24. VIII. 29 (C.N.C.), 2. VII. 38; Ottawa West 21. VI. 20 (C.N.C.); Rockport 10. VII. 34; Sault Ste. Marie 22. VII. 36;

Province of Quebec. Alymer 24. VI. 24 (C.N.C.), 12. VII. 23 (C.N.C.), 14. VIII. 20 (C.N.C.); Chateauquay 18. VI. 25 (C.N.C.); Lachine 6. VIII. 24 (C.N.C.); Lacolle 5. VII. 28 (C.N.C.); Lanoraie 9. VI. 15 (C.N.C.); Montreal 28. VI. 23 (C.N.C.);

Saskatchewan. Wakesin Lake 17. VII. 39 (C.N.C.);

West Virginia. Millwood 25. VI. 30 (C.U.);

Wisconsin. Bayfield 4. VIII. 31 (I.S.); Janesville 18. VIII. 37 (I.S.); Trout Lake 11. VII. 39 (I.S.).

Intergrades of *occulta* and *venusta* are from:

Illinois. Havana 10-20. VI. 38 (I.S.); 10. VIII. 07 (I.S.); Momence 15. VI. 39 (I.S.);

Manitoba. Winnipeg—? (C.N.C.).

Intergrades of *occulta* and *viridescens* are from:

Manitoba. Berens Riv. 27. VI. 38 (C.N.C.);

Michigan. Douglas Lake 11. VII. 37 (U. M. and Ly.); Interlochen 29. VI. 29; Manistique 22. VII. 36; Rockford 27. VII. 29;

Ontario. Kingston 10. VII. 38.

Intergrades with *limbata* were listed under that subspecies.

Biology:

Neave (1932) has clearly shown that *occulta* and *rigida* in Lake Winnipeg take two years for their life histories to be completed. My estimate (1938) of one year for *occulta* in northern Indiana is obviously wrong.

H. limbata occulta inhabits both lotic and lenitic waters, but is most prolific in the shallow waters of the larger lakes. The nymph prefers a rather firm mud in which to burrow. In lake regions where marl is abundant, it chooses a marly mud. Emergence occurs from May (in the southern part of the range) to late August and early September. The greatest number of individuals in most parts of the range emerge during the middle two weeks of July. In the Great Lakes area, the imagoes appear in swarms. Most of the emergence takes place in the early part of the night. At this time, the subimagoes are positively phototactic and congregate around street lights. The imagoes, after the nuptials and oviposition are completed, are also phototactic, but to a lesser degree. Neave (1932) has given an excellent account of the biology of the subspecies population that lives in Lake Winnipeg.

HEXAGENIA LIMBATA VENUSTA Eaton

Hexagenia venusta Eaton, Revisional Mono. Rec. Ephemeridae, pt. 1, p. 54, 1883. Ulmer, Archiv. Naturg., Bd. 87, Abt. A, Hft. 6, pp. 235, 237, and 239, 1921. McDunnough, Canad. Ent., vol. 59, p. 119, 1927. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 274, 1935. Spieth, Ann. Ent. Soc. Am., vol. 34, p. 88, 1941.

Hexagenia pallens Traver. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 271, 1935.

Subspecific characteristics:

♂ imago, dried.—General body color bright yellow with darker overlying color pattern exceedingly restricted. Fore femur and tibia clear madder brown; basal two-thirds of fore tarsal segments 2-4 yellow and remainder of fore tarsus fuscous. Wing membrane hyaline tinged with yellow; cross veins of costal and subcostal areas heavily infuscated except distally. This infuscation spreads over the membrane to some extent. Distal margin of hind wing narrowly infuscated; cross veins of metathoracic wing disc and mesothoracic wing membrane between R_1 and MP_1 narrowly infuscated. Dorsal abdominal color pattern (fig. 12) consisting of oblique, lateral, bay color triangles. Medial fuscous stripe on segments 8 and 9; sternal color pattern (fig. 13) consisting of a slender, chestnut brown stripe that extends from the genital plate to the prosternum of the thorax and small, bay colored spots that occupy the anterolateral corners of all abdominal tergites. Cerci yellow with narrow, madder brown joinings. Usually at every fourth joint, the madder brown extends over the entire segment. Genitalia (fig. 31) of the *limbata* type. Length: body 15-20 mm.; wing 11-15 mm.

♀ imago, dried.—Similar to male in coloration. The color pattern, especially the ventral abdominal stripe, is distinctive. The cross veins of the fore wing costal and subcostal areas are faintly infuscated. Length: body 18-26 mm.; wing 16-22 mm.

Variations in imagoes.—Excluding those specimens that are intergrades with *limbata* and *occulta,* the variation is restricted mainly to size differences and to the extent of the dark color pattern, some individuals almost lacking the latter and some, such as the nine specimens Belfrage collected in Texas (Spieth, 1941) having it greatly expanded. The extreme variation in paleness is reached in male specimens in which the musculature and epidermal materials of the abdomen have been completely atrophied, leaving only the transparent digestive, respiratory, and vascular systems and the transparent cuticula. Such a phenomenon is found in many other species of ephemerids but only rarely occurs in Hexagenia. Naturally since the abdominal color pattern is mainly epidermal and not cuticular, such individuals possess pale abdomens and lack a color pattern. A male of this type was described as *H. pallens* by Traver. I have also seen similar specimens not quite so pale in the Illinois Nat. Hist. Sur. Coll.

Nymph.—Future abdominal color pattern of imago visible; general appearance immaculate with a large amount of yellow coloration; frontal prominence (fig. 49) dome shaped; mandibular tusks (fig. 42) short and only slightly up-curved; abdominal gills 2-7 purplish.

Type locality.—Dallas, Tex.

Lectotype.—British Museum (Natural History).

Remarks.—Typical specimens can be separated from *limbata, occulta,* and *viridescens* as well as from all other species by the general yellowness of the entire body and the abdominal color patterns. They have in common with the other subspecies of *limbata* the spotted fore costal margin, the hooked penes and nymphs with short, only slightly up-curved mandibular rami and cone shaped frontal prominences.

The subspecies represents a southwestern form that extends north and eastward into the central part of the United States, i.e., Ohio, Illinois, and Indiana. The typical individuals are quite distinct and easily identified. In the hill country of eastern Oklahoma and in Missouri, *venusta* and *munda* can be found living together and emerging at the same time, but there are no intergrades of these known, and I have inspected long series of individuals. In Indiana, Illinois, and Ohio specimens unquestionably show intergradation with *occulta.* It should be noted that in this area the chances of hybridization are somewhat reduced since *occulta* emerges mainly from June to late July, while *venusta* tends to emerge later. *Venusta* apparently is the parent stock of the species *limbata.*

Ulmer (1921) has indicated *venusta* males as having short fore legs when compared with *limbata.* Measurements of numerous specimens show that the ratio of the fore leg length to that of the body is about the same in *limbata, occulta,* and *venusta.* Only in comparison to *bilineata* is the fore leg of *venusta* distinctly shorter.

Traver (1935) described *pallens* from a single male and a number of females collected at one locality. As shown above, the male is merely a pale

venusta. Females of the type series are typical *venusta* representatives. As also noted above, such series have been collected at other localities.

Range:

The known range is shown by fig. 55. Note how it overlaps that of *munda*, *limbata*, and *occulta*. Specimens of *venusta* that I have seen were collected at the following localities:

Illinois. Beardstown, 25. VI. 31 (I.S.); Champaign 15. VI. 39 (I.S.); Decatur 16. VII. 39 (I.S.); Havana 12. VII. 32 (I.S.), 19-24. VII. 39 (I.S.); Homer Pk. 30. V. 25 (C.N.C.), 2. VII. 30 (C.N.C.), 30. VI. 27 (I.S.), 25. VII. 31. (I.S.); 6. VII. 27 (I.S.); Momence 22. VI.—(I.S.), 21. VIII, 36 (I.S.); Monticello 14. VII. 25 (I.S.); Murphysboro 20. VI. 39 (I.S.); Ottawa 26. VIII. 29; Pontiac 11. IX. 38 (I.S.); Rock Island, no date (M.C.Z.); Rockville 3. VIII. 38 (I.S.); Springfield 10. VII. 31 (I.S.); Urbana 10. VI. 39 (I.S.), 3. VIII. 39 (I.S.);

Kansas. Douglas Co.—.VII.—.(M.C.Z.); Lawrence 20. VI. 32 (C.N.C.) 25. VI. 19 (C.U.), 28. VII. 19 (C.U.); Manhattan. —. —. 32 (C.U.); Ottawa Co. 24. VI. 34 (I.S.);

Missouri. Clinton 8. VII. 21 (M.C.Z.); Kansas City 12. VI. 21 (M.C.Z.); Kirksville 29. VI. 22 (M.C.Z.); Osborn, DeKalb Co.—. VII. 26 (C.N.C.); Ozark 30. V. 38. —. VIII-X. 38; Rockaway Beach 13. VI. 36;

Nebraska. Lincoln —. VIII. —. (M.C.Z.);

Oklahoma. Ardmore 27. VII. 37, 8. VI. 39; Clinton 4. VI. 39; Cherokee 4. VII. 34; Delaware Co. 9. VIII. 39; Flint 6. VI. 34; Henryetta 19. VII. 37; Hinton 13. VII. 37; Holdenville 17. VII. 37; Oklahoma Co. 22. V. 31; Page 23. VI. 34; Price's Falls 2. VI. 37 (I.S.); Sallisaw 21. VI. 37; Stillwater 26. VII. —, 2. IX. 38, 2. VIII. 39, 4. VIII. 35; Wichita Nat. Forest 6. VI. 39; Watts 16. VI. 39; Yost Lake 26. VI. —;

Tennessee. Memphis, no date (M.C.Z.);

Texas. Austin 10. V. 01 (M.C.Z.), 7. V. 33 (C.U.); Brazos Co., no date (M.C.Z.), August (C.N.C.); Dallas, no date (B.M.N.H.), 18. X. 35 (C.N.C.); Huntsville 27. VI. 31 (C.U.); San Marcos 15. IV. 39 (I.S.); Texarkana 13. IX. 30; Texas, no date (B.M.N.H.); Waco 22. VI. 33 (C.U.); W. Texas, no date (B.M.N.H.); Winter Haven 31. III. 33 (C.U.), 29. V. 33 (C.U.).

Intergrades of *venusta* and *occulta* are from:

Illinois. Antioch 18. VI. 38 (I.S.); Havana 27. VI. 07 (I.S.), 8. VI. 07 (I.S.), 24. VIII. 39 (I.S.); Kankakee 15. VI. 38 (I.S.), 2-5. VIII. 38 (I.S.), 17. VI. 39 (I.S.), 15. VII. 28 (I.S.); Wyanet 2. VII. 37 (I.S.), 16. VII. 38 (I.S.);

Indiana. Bluffton 20. VII. 29, 26. VIII. 29;
Minnesota. Rapidan 18. VIII. 38 (I.S.);
Ohio. Columbus 4. VIII. 23 (O.S.U.).

See also *occulta* and *limbata* for other intergrades.

Biology:

Little is known of the biology of *venusta* except that it seems to prefer sluggish, relatively warm waters. As mentioned above, in the northern part of its range it tends to emerge late in the summer, indicating that it needs a considerable heat budget for its development. In the southern part of its range, it emerges from late March through June and July into August and even September.

HEXAGENIA LIMBATA VIRIDESCENS (Walker)

Palingenia viridescens Walker, List Neuropt. Ins. Brit. Mus., pt. 3, p. 550, 1853.

Hexagenia viridescens (Walker), McDunnough, Canad. Ent., vol. 59, p. 118, fig. 1, 1927. Traver, Ann. Ent. Soc. Amer., vol. 24, pp. 611-613, 1931. Needham, Traver, Hsu, et.., Biology of Mayflies, p. 275, 1935. Spieth, Ann. Ent. Soc. Amer., vol. 23, p. 329, 1940.

Subspecific characteristics:

♂ imago, dried.—General body color blackish brown with reduced amount of yellow when compared to *occulta*. Compound eyes large when compared with *occulta*. As in other subspecies of *limbata* the costal cross veins are marginated and the pigment of the costal membrane is unevenly distributed. Distal margin of hind wing infuscated with purplish black. Fore femur and tibia blackish burnt umber; fore tarsal segments piceous. Dorsal abdominal color pattern (fig. 7) with paired submedial dashes, and with dark color filling most of the segments. Ventral abdominal color pattern (fig. 8) extensive but not clear cut. Genitalia (fig. 32) of the *limbata* type. Cerci burnt umber, paler at the joinings. Length: body 18-20 mm.; wing 18 mm.

♀ imago, dried.—General over-all color dark dorsally and ochreous ventrally; dorsal abdominal color pattern similar to that of male; ventral abdominal color pattern faint; hind wing margin infuscated with purplish black; wing membrane tinged with smoky; cerci yellow tinged with smoky and darker at joinings. Length: body 22-25 mm.; wing 22-25 mm.

Variation in imagoes.—Except for the intergrades with *occulta*, the known variation is small, being restricted mainly to the intensity and extent of the dark coloration.

Nymph.—Unknown.

Type locality.—"St. Martin's Falls, Albany River, Hudson's Bay."

Lectotype.—British Museum (Natural History).

Remarks.—Typical specimens can be separated from *occulta* by the black, rather than ruddy, coloration, the dorsal abdominal color pattern, the relatively larger eye size and the slightly larger size of the individuals. The dark hind wing margin of the females seems typical. This subspecies is closely related to *occulta* and apparently has evolved since the retreat of the glacier. The two subspecies are unquestionably the most closely related of any in Hexagenia. Dark specimens of *occulta* when dried can be separated from *viridescens* only with difficulty. The lack of ruddy color in *viridescens* seems to be the surest method of separation.

Range:

As shown in fig. 51, the subspecies is centered in the area south of Hudson's Bay and is flanked on all sides by *occulta*. It is absent in the United States except in Michigan. Whether typical specimens occur in Michigan is rather doubtful. Specimens of the subspecies that I have seen were collected at the following localities:

Michigan. Cheboygan Co. 4. VII. 35 (U.M.); Gogebic Co. 5. VIII. 19 (U.M.); Manistique 22. VII. 36;

Ontario. St. Martins Falls, Albany Riv., no date (B.M.N.H.); Georgian Bay 1. VII. 12 (C.N.C.), 13. VII. 32 (C.N.C.); Go-Home-Bay 5. VII. 32 (C.N.C.); Honey Harbor 14. VI. 32 (C.N.C.); Lake Nipissing 21. VI. 29 (U.M.); London's Bay 20. VI. 12 (C.N.C.); Orillia 9. VI. 25 (C.N.C.); Severn 16. VI. 25 (C.N.C.); Smoky Falls, Mattagami Riv. 11. VII. 34 (C.N.C.).

Intergrades of *viridescens* and *occulta* are from:

Manitoba. Berens Riv. 27. VI. 38 (C.N.C.);

Michigan. Douglas Lake 15-20. VII. 39 (Ly);

Ontario. Bobcaygeon 22. VI. 32 (C.N.C.).

See also the discussion under *occulta*.

Biology:

The biology of the subspecies is almost unknown, but judging from the emergence dates and its close relationship to *occulta*, we shall probably find that the two are somewhat similar in their activities.

HEXAGENIA MUNDA Eaton

The species was described by Eaton from a single specimen. Study of the type plus many other specimens shows that *munda* can be characterized by (1) the penes (munda type=carolina type of Traver) (fig. 33) and (2) the costal margin of the mesothoracic wing in which the cross veins appear unmarginated and the pigment is uniformly spread through the membrane of this area. The known nymphs have a conical frontal protuberance and long, slender, strongly up-curved mandibular rami.

Ecologically the species seems to prefer small to medium sized streams and is not found in the Great Lakes or large rivers.

After studying all available material, I have divided the species into the following subspecies: *affiliata, elegans, marilandica, munda,* and *orlando*. All of these subspecies intergrade wherever geographically adjoining populations are in contact.

Munda has been confused with *limbata*. In general the two occupy different parts of North America, but wherever respective subspecies of *munda* and *limbata* do overlap, there are no indications of intergradations. Although close relatives, it seems wise to keep the two species separate.

HEXAGENIA MUNDA AFFILIATA McD.

Hexagenia affiliata McDunnough, Canad. Ent., vol. 59, p. 118, 1927. Traver, Ann. Ent. Soc. Am., vol. 24, pp. 611-613, 1931. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 261, 1935.

Subspecific characteristics:

♂ imago, dried.—Ground color typically bright yellow, reduced in area by extensive dark color pattern; basal one-half of fore tarsal joints 2-4 light; costal and subcostal membrane of anterior wing uniform, clear burnt umber;

lighter distally; cross veins of hind wing disk and of area between R_1 and MP_1 of fore wing margined with black; hind wing margin typically not infuscated. Dorsal abdominal color pattern (fig. 14) clear cut with yellow submedial areas distinct and the oblique lines of segments 8 and 9 not reaching the anterolateral corners. Ventral abdominal color pattern (fig. 15) with brown triangles not reaching anterior margin. Penes (fig. 33) of the *munda* type. Length: body 17-25 mm.; wing 16-21 mm.

♀ imago, dried.—Can be separated from *occulta* by means of the dorsal abdominal color pattern and from *orlando* by the brighter yellow ground color. Length: body 22-28 mm.; wing 22-25 mm.

Variations in imagoes.—Imagoes of the subspecies do not vary as excessively as do those of *occulta* which live in the same area. Although the type and typical specimens lack a dark border to the hind wing, some individuals have the distal margin of the metathoracic wing infuscated. Typically the ground color of the abdomen and thorax is a bright yellow. In some individuals this yellow is obfuscated by a ruddy brown which may completely obliterate the ventral abdominal markings. In all other respects such individuals conform with the type.

Nymph.—Unknown.

Type locality.—Sparrow Lake, Severn, Ont., 16-21.VI.25.

Holotype.—No. 2426, Canadian National Collection.

Remarks.—*Affiliata* can be separated from *elegans, munda, marilandica* by the dorsal abdominal color pattern and the extensive dark coloration. Its brighter yellow ground color and the failure of the oblique lines of the dorsal color pattern to reach the anterolateral corners of tergites 8 and 9 distinguish it from *orlando*. The genitalia and the immaculate color pattern serve as sure means of distinguishing male individuals from those of *occulta*. Females are separated with difficulty.

The subspecies is the most northern representative of *munda,* a stock primarily restricted to the southeastern part of the country. This *munda* stock, after the retreat of the last glacier, apparently invaded the cleared area and developed into *affiliata*.

In the Canadian National Collection there are nine specimens from S. Milford, Nova Scotia, and two from Wayland, Mass., that are rather atypical for *affiliata*. At the Museum of Comparative Zoology there are specimens from eastern Massachusetts that agree with these aberrant individuals. It is possible that adequate collections will prove that they represent a "weak" subspecies yet to be described.

Range:

Its range (fig. 54) almost completely overlaps that of *occulta* except in the eastern part of the United States where *affiliata* seems to be the common hexagenid. Specimens that I have seen were collected at the following localities:

Connecticut. Southington Ct. 6. VII. 21;

Indiana. Orland 31. VII. 29; Oswego 17. VIII. 27; Warsaw 7. VIII. 28;

Iowa. Iowa Co.? 19. VI. 34 (C.N.C.);

Maine. Jefferson 13. VIII. 39 (M.C.Z.); Passadumkeag 3. VIII. 38 (M.C.Z.); Woodstock 3. VIII. — (M.C.Z.);

Michigan. Alma 28. VII. 29; Douglas Lake 10-30. VII. 39 (Ly.); Gogebic Lake 19. VIII. 37 (I.S.); Twinn Lake 22. VIII. 37 (I.S.);

Minnesota. No. Red River 1854 (M.C.Z.); St. Anthony's Pk., no date (M.C.Z.);

New Hampshire. Squam Lake 8. VII.—(M.C.Z.);

New Jersey. New Jersey 22. VI. 84 (M.C.Z.); Trenton, no date (C.N.C.);

New York. Hudson 11. VI. 25 (C.U.); Ithaca 3. VIII. 35 (C.U.); Lake George 26. VII. 29 (C.U.); 20. VIII. 20 (C.U.); Rossi 6. VI. 64 (M.C.Z.); Rousses Pt. 12. VII. 27 (C.N.C.);

Ohio. Columbus 5. VI. 23 (O.S.U.);

Ontario. Bobcaygeon 22. VI. 32 (C.N.C.); Hogs Back 19. VII. 23 (C.N.C.); Kingston 23. VII. 23 (C.N.C.); Ottawa West 21. VI. 20 (C.N.C.); Severn 16-21. VI. 25 (C.N.C.); Whitby 6. VII. 26 (C.N.C.);

Pennsylvania. Harrisburg 19. VI. — (M.C.Z.);

Province of Quebec. Hemmingford 3. VII. 27 (C.N.C.); Lacolle 5. VII. 28 (C.N.C.); Ottawa Golf Club 16. VII. 23 (C.N.C.).

Biology:

Affiliata lives in both lakes and streams but never reaches such abundance as *occulta*. It apparently is absent from the Great Lakes and from warm, turbid waters. As yet I know it to have been taken only from clear, clean, usually cool streams and small lakes. It emerges from early June to the middle of August with the main emergence in middle to late July.

HEXAGENIA MUNDA ELEGANS Traver

Hexagenia elegans Traver, Ann. Ent. Soc. Am., vol. 24, p. 594, figs., 1931. J. Elisha Mitch. Sci. Soc., vol. 47, p. 103, 1932. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 265, 1935.

Hexagenia weewa Traver, Ann. Ent. Soc. Am., vol. 24, p. 605, 1931. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 276, 1935.

Hexagenia kanuga Traver, J. Elisha Mitch. Sci. Soc., vol. 53, p. 29, 1937.

Subspecific characteristics:

♂ imago, dried.—Reddish brown with the ground color more yellow than tan as in *orlando;* fore femur and tibia clear madder brown; fore tarsal segments 2-4 with basal two-thirds cream colored; costal and subcostal membrane of fore wing a clear burnt umber, paler distally. Costal and subcostal cross veins not margined; cross veins of disk of hind wing and those cross veins between R_1 and MP_1 of fore wing infuscated; distal margin of hind wing purplish in some individuals. Tergal abdominal color pattern (fig. 16) with oblique lines of eighth and ninth segments not attaining the anterolateral corners of tergites; sternal abdominal color pattern (fig. 17) as in *orlando;* penes (plate 5, fig. 36B) of the *munda* type. Length: body 15-18 mm.; wing 11-14 mm.

♀ imago, dried.—Bright yellow instead of tannish yellow as in *orlando*. Dorsal abdominal color pattern (fig. 16) reduced in comparison to that of *orlando*. Length: body 20-22 mm.; wing 19-20 mm.

Variations in imagoes.—This subspecies is more variable than are its close relatives *orlando* and *marilandica*. The spotting of the cross veins and of the margin of the hind wing shows considerable difference between individuals. Two paratypes in my collection show this variation very well. The color of the color pattern also exhibits variability. This, is as is also true in *marilandica,* is apparently clinal, and individuals from the northern part of the range possess much more reddish pigment than do those further south.

Nymph.—Unknown.

Type locality.—Chowan Riv., Winton, N. C., second week in August, 1930.

Holotype.—No. 917.1 in Cornell Univer. Coll.

Remarks.—The subspecies can be easily separated from *orlando* by the yellow rather than tan ground color and by the oblique streaks of tergites 8 and 9 not reaching the anterolateral corners of the tergites. From *marilandica* it is distinguished by the continuous dorsomedial abdominal stripe. The average size is somewhat smaller than that of *marilandica*. The types themselves are rather atypical for the subspecies. They were collected near the northern edge of the range, are small and have considerable reddish pigmentation. Note should be taken that the types (Traver, 1931) apparently were collected as subimagoes and allowed to transform. Often this results in abnormal coloration. Some of the paratypes have much more extensive dark color pattern than does the holotype. In fact the holotype is probably an intergrade between *marilandica* and the typical *elegans*. The types of *kanuga* are more nearly typical of the subspecies. *H. weewa* Traver, although considered as a synonym of *elegans* for the sake of convenience, is in reality an intergrade showing characters of *orlando, marilandica,* and *weewa. H. elegans* is the costal plain subspecies of *munda,* extending inland to the Piedmont of the southeast and as far west as eastern Oklahoma. As mentioned under *orlando, elegans* and *orlando* intergrade in northern Florida. *Elegans* intergrades with *marilandica* along the western junction of its range. In Oklahoma, when it comes into contact with *munda,* it also intergrades with this subspecies.

Range:

The subspecies ranges (fig. 56) from Maryland to Texas and Oklahoma, being found mainly along the coastal plains and inland to the highlands. Typical *elegans* imagoes that I have seen were collected at the following localities:

Alabama. Tuscaloosa 26. VI. — 2. VII. 36 (C.U.);
District of Columbia. Washington, no date (M.C.Z.), 10. VII. 26 (C.U.), 9. VII. 29 (C.U.);
Florida. Chipola Lake 8. IV. 27 (C.U.);
Georgia. Americus 22. VI. 39 (I.S.); Athens 12. VIII. 31 (C.U.); Atlanta 2. VI. 39 (I.S.), 12. VII. 39 (I.S.); Butler 22. VI. 39 (I.S.); Canton 25. VII. 31 (C.U.); Cartersville 17. VIII. 31 (C.U.), 3. VI. 39 (I.S.); Hollywood 1. VII. 39 (I.S.); Jonesboro 26. VI. 32 (C.U.); Keysville 27. VI. 30; Kingston 3. VIII. 31 (C.U.); Rome 3. VIII. 31 (C.U.), 26-30. VI. 31 (C.U.), 15. VII. 39 (I.S.); Spring Creek —. VIII. 13 (C.U.); Thomaston 8. VI. 39 (I.S.); Tiger 30. VI. 39 (I.S.); Zebulon 8. VI. 39 (I.S.);

North Carolina. Hendersonville 6. VII. 35 (C.U.); Winton —. VIII. 30 (C.U.), 8. VIII. 30 (C.U.);

Oklahoma. Broken Bow 4. VII. 37, 14. VII. 37, 15. VII. 37, 29. VII. 37, 21. VIII. 37, 25. VIII. 37, 3. IX. 37, 6. IX. 37, 21. IX. 37, 13. VI. 39 (all in O.S.); Eagletown 12. VI. 39 (O.S.), 28. VI. 37 (O.S.); Flint 19. VI. 37 (O.S.); Grant 1. VII. 37 (O.S.); Idabell 30. VI. 37 (O.S.); Quinton 12. VI. 34 (O.S.); Sherwood 27. VI. 37 (O.S.); Summerfield 14. VI. 39 (O.S.);

South Carolina. Florence 16. V. 29 (C.U.);

Texas. San Marcos 15. IV. 39 (I.S.);

Virginia. Dyke 18. VII. 13 (Davis); Great Falls 13. VI. 10 (Davis).

Intergrades of *elegans* and *munda* are from:

Oklahoma. Broken Bow 13. VI. 39, 21. VIII. 37; Hugo 11. VI. 39 and Sayre 8. VII. 37 (all in O.S. coll.).

Intergrades of *elegans* and *marilandica* are from:

District of Columbia. Washington 9. VII. 29 (C.U.);

Georgia. Alcova Riv., Monroe Co., 12. VIII. 31 (C.U.); Americus 22. VI. 39 (I.S.); Athens 3-12. VIII. 31; Cartersville 3-17. VIII. 31 (C.U.); Lawrenceville 25. VII. 31 (C.U.); Rome 29. VI. 31 (C.U.), 3-16. VIII. 31 (C.U.); Tocoa Falls 5. VII. 31 (C.U.);

North Carolina. Bryson City 16. VIII. 29 (C.U.); Winton —. VIII. 30 (C.U.).

Intergrades of *elegans* and *orlando* are from:

Florida. High Springs 14. VI. 30.

Biology:

Little is known about the biology of the subspecies. It emerges, according to present information, from April to September. The various localities where the subimagoes have been collected leave no doubt that the nymph inhabits both lotic and lenitic waters.

HEXAGENIA MUNDA MARILANDICA Traver

Palingenia bilineata Say. [partim] Hagen, Syn. Neuropt. No. Am., p. 41, 1861.

Palingenia limbata Guerin. [partim] Walsh, Proc. Ent. Soc. Phila., vol. 2, p. 176.

Hexagenia marilandica Traver, Ann. Ent. Soc. Am., vol. 24, p. 599, 1931. J. Elisha Mitch. Sci. Soc., vol. 53, pp. 28, 85, 1937. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 266, 1935.

Hexagenia carolina Traver, Ann. Ent. Soc. Am., vol. 24, pp. 601, 616, 1931. J. Elisha Mitch. Sci. Soc., vol. 47, p. 103, 1932; vol. 53, p. 85, 1937. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 264, 1935.

Subspecific characteristics:

♂ imago, dried.—Ground color of a brighter yellow than that of *elegans;* legs similar to those of *elegans;* hind wings without any trace of a dark border; costal and subcostal areas pigmented with uniform light brown, otherwise as in *elegans*. Dorsum of abdomen (fig. 20) lacking a medial stripe on segments 1-6 inclusive; oblique stripes not attaining anterolateral margins of tergites 8 and 9; considerable component of red pigmentation in the color pattern. Sternal color pattern as in fig. 21. Genitalia (fig. 35) with the penes of the *munda* type. Length: body 18-24 mm.; wing 14.5-17 mm.

♀ imago, dried.—Similar to male except for usual dimorphic differences. Abdominal color pattern typical. Length: body 18-32 mm.; wing 17-25 mm.

Variations in imagoes.—The red pigmentation often found in individuals of the subspecies varies considerably, some specimens lacking it completely. The oblique lines of the abdominal tergites often have a narrow band arising from their anterior ends which parallel the anterior borders of the tergites. Sometimes, as in the type, the abdominal color pattern gives the appearance of a lateral zigzag line on tergites 1-6. Typically, however, tergites 1-6 display only a pair of lateral oblique lines on each segment. The ventral color pattern also varies in extent, sometimes being almost lacking on sternites 1-6.

Nymph.—In mature specimens the adult abdominal color pattern can be discerned through the exoskeleton. Frontal protuberance (fig. 47) cone shaped; mandible (fig. 43) with very long, slender, strongly curved ramus; gills purplish.

Type locality.—Conococheague Park, Washington Co., Md., June 3, 1925.

Holotype.—No. 921.1 in Cornell Univ. Coll.

Remarks.—The males of the subspecies can easily be separated from those of *munda, elegans,* and *orlando* by the dorsal abdominal color pattern. Females of *marilandica,* however, are distinguished from those of *munda* only with difficulty. The subspecies interbreeds with *elegans* along the eastern side of its range and with *munda* on the western side.

The holotype of the subspecies is not as typical as might be hoped for, since it was collected on the northern edge of the range. The specimens described by Traver as *carolina* are more typical of the subspecies but, due to the law of priority, the valid name must be *marilandica.* The nymph when mature possesses long, strongly up-curved mandibular processes. This seems to be true for all the nymphs of the southeastern subspecies and distinguishes them from nymphs of *venusta* and *occulta,* which have short and relatively straight tusks.

Range:

The subspecies as shown in fig. 58 occupies a narrow and elongated range along the eastern side of the southeastern highlands, extending in small numbers down into the lower elevations. Its area overlaps broadly with that of *elegans.* Typical examples of both, along with intergrades, can be taken in the same nuptial swarm. Specimens of *marilandica* that I have seen were collected at the following localities:

Alabama. Tuscaloosa 29. VI. —. 2. VII. 36 (C.U.);

District of Columbia. Washington 9. VII. 29 (C.U.); 10. VII. 26 (C.U.); no date (M.C.Z.);

Florida. Chipola Lake 4. VIII. 27 (C.U.); Rock Bluff 19. VII. 30;

Georgia. Alcova Riv., Monroe Co. 12. VIII. 31 (C.U.); Americus 30. VII. 31 (C.U.); 22. VI. 39 (I.S.); Athens 13. VI. 32 (C.U.), 12. VIII. 31 (C.U.); Atlanta 10. VII. 31, 18. VII. 31, 1. VIII. 31, 5. VIII. 31, 16. VIII. 31, 7. VI. 32, 10. VI. 32, 20. VI. 32 (all at C.U.), 28. VII. 32 (I.S.); Canton 25. VII. 31 (C.U.); Cartersville 24. VII. 31 (C.U.), 16-17. VIII. 31 (C.U.); Cleveland 10. VII. 31 (C.U.); Cornelia 1. VII. 39 (I.S.); Dalton 5. VIII. 31 (C.U.); Decatur 26. VIII. 31 (C.U.); Jonesboro 24-26. VI. 32 (C.U.); Keysville 27. VI. 30; Lakemont 30. VI. 39 (I.S.); Lawrenceville 25. VII. 31 (C.U.); Rome 29. VI. 31, 20. VI. 32, 3. VIII. 31, 16. VIII. 31, 23. VIII. 31 (all at C. U.); Thomaston 8. VI. 39 (I.S.); Tiger 30. VI. 39 (I.S.); Toccoa Falls 3-5. VII. 31 (C.U.); West Point 4. VI. 32 (C.U.);

Maryland. Cabin John Run 13. VI. 10 (Davis); Conococheague Pk. 3. VI. 25 (C.U.); Hagerstown 4. VIII. 24 (C.U.);
North Carolina. Bryson City 7. VII. 30; Franklin 27. VI. 29 (C.U.); Hamburg Lake 6. VI. 29 (C.U.); Murphy 27. VII. 30; Swananea 19. VI. 38 (I.S.); Tyron 13. VI. 26 (C.U.); Wilkesboro 3. VII. 30; Winton —. VIII. 30 (C.U.);
New Jersey. Singac. —. VI. 15 (C.N.C.);
South Carolina. Clemson Coll. 23. VI. 33 (C.U.); 1. VII. 34 (C.U.);
Virginia. Mountain Lake 20. VIII. 31 (C.U.).

For intergrades with *munda* and *elegans*, see those subspecies.

Biology:

All available data indicate that the subspecies lives in both lotic and lenitic waters but apparently it is most common in the streams of higher elevations in the southeast. Known emergence dates are from early June to late July.

HEXAGENIA MUNDA MUNDA Eaton

Hexagenia munda Eaton, Revisional Mono. Rec. Ephemeridae, pt. 1, p. 53, 1883. McDunnough, Canad. Ent., vol. 59, p. 118, 1927. Needham, Traver, Hsu, etc., Biology of Mayflies, pp. 268-269, 1935.

Subspecific characteristics:

♂ imago, dried.—Ground color bright yellow; dark color pattern rather extensive; basal two-thirds of fore tarsal joints two to four light; costal and subcostal membrane of mesothoracic wing uniform, clear burnt umber, lighter distally; cross veins in these areas not marginated; cross veins of hind wing disk and the area between R_1 and MP_1 of fore wing margined with black; metathoracic wing margin narrowly infuscated with blackish grey. Dorsal abdominal color pattern (fig. 18) clear cut and with the oblique lines of tergites 8 and 9 not reaching the anterolateral corners. Ventral abdominal color pattern (fig. 19) with triangles not reaching anterior margin. Genitalia of the *munda* type (fig. 34). Length: body 18-25 mm.; wing 14-20 mm.

♀ imago.—Many subimago females in my collection belong to *munda* but they are in alcohol and so nearly like those of *marilandica* that an adequate description can not be constructed at this time.

Variation in imagoes.—Upon the basis of present information, the greatest variation occurs on the dorsum of the abdomen where there is a tendency in some individuals to form a dark medial line.

Nymph.—Unknown, doubtless of the same type as found in *marilandica*.

Type locality.—Morgantown, N. C. (Morrison), 1877.

Holotype.—Museum of Comparative Zoology, Mass.

Remarks.—This subspecies can be separated from its relatives *affiliata*, *elegans*, *marilandica*, and *orlando* by the dorsal abdominal color pattern. As mentioned above, the females are similar to those of *marilandica*.

Eaton's description when checked against the type is quite accurate. It should be noted that the sepia prothoracic lines which continue onto the pterothorax are much narrower on the latter and that the entire ninth sternite and the genital plate are colored with brown ochre. Specimens from Missouri do

not show this latter character but, until topotypical material has been collected, it must be at least mentioned.

The type specimen was collected on the extreme eastern edge of the range. In fact, the drainage from which it must have been collected flows into the Atlantic Ocean. There is always the possibility with a single specimen that the nymph had been carried down stream by the current, especially after sharp rises in the stream level (Denham, 1938) and managed to maintain itself in a region where the species normally does not exist. Although considerable collecting has been done in North Carolina, no other specimens of the subspecies have ever been found. Traver (1935) reported a specimen from Georgia as belonging to *munda*. After seeing it, I consider it to be an intergrade between *elegans* and *marilandica*.

A specimen in the Cornell Univ. Coll. from Ann Arbor, Michigan, has characteristics much like those of *munda,* but it should be remembered that *affiliata* is similar to *munda* except for the abdominal color pattern, i.e., the medial dorsal stripe. This Ann Arbor specimen is probably an aberrant *affiliata*. In this connection, it is interesting that a considerable series of *occulta* from Baldwin, Michigan, 28.IV.39 (I.S.), has eight individuals which lack the medial stripe on the abdominal tergites. Careful study shows that these are, however, aberrant *Hexagenia limbata occulta* and do not even belong to the subspecies *munda*. All other individuals collected at the same time and place are typically *occulta*.

Numerous specimens from Missouri are typical and agree with the type well, but in eastern Oklahoma *munda* and *elegans* clearly intergrade.

Range:

At present the species is known (fig. 57) from North Carolina, Illinois, Missouri, and Oklahoma. Further collecting will probably show it to be present in Kentucky, Tennessee, and possibly western Virginia. Specimens that I have seen are from the following localities:

Illinois. Monticello 11. VI. 34 (I.S.);

Missouri. Ozark 30. V. 38;

Oklahoma. Eagletown 12. VI. 39; Flint 6-8. VI. 34; Reagan 1-3. VI. 37 (I.S.); Sayre 8. VII. 37; Tahlequah 17. VI. 39.

A specimen from Dalton, Ga., 5.VIII.31 (C.U.), appears to be an intergrade between *munda* and *marilandica*. For intergrades between *munda* and *elegans,* see the statements given under *elegans*.

Biology:

Nothing is known about the biology of the subspecies although it probably is similar to that of the other subspecies of *munda*.

HEXAGENIA MUNDA ORLANDO Traver

Hexagenia orlando Traver, Ann. Ent. Soc. Am., vol. 31, pp. 608-611, 1931. Needham, Traver, Hsu, etc., Biology of Mayflies, p. 270, 1935.

Subspecific characteristics:

♂ imago, dried.—Ground color tawny with color pattern deep VanDyke brown; fore femur and tibia chestnut brown; proximal two-thirds of fore tarsal joints 2-4 light tan; all tarsal joinings black; costal and subcostal membrane of fore wing a uniform, clear burnt umber becoming lighter distally; no infuscation of costal and subcostal cross veins; cross veins of disk of metathoracic wings and the area between R_1 and MP_1 of fore wing as in *elegans*. Dorsal abdominal color pattern (fig. 22) with a distinct medial stripe and with the oblique stripes of tergites 8 and 9 narrowly reaching the anterolateral corners. Ventral color pattern as in fig. 23. Penes (plate 4, fig. 36A) of the *munda* type. Length: body 17-20 mm.; wing 14-15 mm.

♀ imago, dried.—Ground color tawny with blackish color pattern; legs as in male; wing membrane hyaline, tinged with grey; sternal abdominal color pattern consists of medial ganglionic dashes. Length: body 15-24 mm.; wing 15-20 mm.

Variations in imagoes.—Upon the basis of present material, the amount of variation seems small. Male metathoracic wings sometimes have the distal border faintly pigmented; the female wing membrane may be strongly tinged with light tan and the extent of the dorsal abdominal color pattern varies slightly in both sexes.

Nymph.—Unknown.

Type locality.—Orlando, Fla., May 20, 1927.

Holotype.—No. 919.2 in Cornell Univ. Coll.

Remarks.—*H. munda orlando* can be distinguished from *elegans* and *affiliata* by the tan color and the oblique tergal lines reaching the anterolateral corners of tergites 8 and 9. The dorsal abdominal color pattern distinguishes it from *munda* and *marilandica*. The tan color, the penes, and the pigmentation of the costal and subcostal areas of the male's fore wings separate it from *occulta*. This is the Floridian subspecies of *munda*. It intergrades with *elegans* in a narrow belt across northern Florida.

Range:

The peninsula of Florida, according to present information (fig. 57), represents the range of this subspecies. The specimens listed by Traver (1935) from Decatur, Georgia, belong to *elegans*. Specimens that I have seen were collected at the following localities:

Florida. DeFuniak Spgs. 7. X. 14 (A.M.N.H.); Everglade 7. IV. 12; Gainesville 17. VII. 30; Lakeland 7. V. 12 (A.M.N.H.); Lake Geneva 2. VII. 38 (I.S.); Lake Tohopekaliga 11. IV. — (M.C.Z.); Orlando 20. V. 27 (C.U.); Sebring 25. III. 38 (A.M.N.H.).

Intergrades of *orlando* and *elegans* are from:

Florida. High Springs 17. VI. 30 and Rock Bluff 19. VII. 30.

Biology:

Little is known about the biology of this subspecies. It seems apparent, from the places where the imago has been collected, that the nymph must live

in lenitic waters. Known emergence dates are from March to October. There is a bare possibility that the subspecies may mature in one year's time.

HEXAGENIA RECURVATA Morgan

Hexagenia recurrata Morgan *(lapsus calami)*, Ann. Ent. Soc. Am., vol. 6, p. 395, fig. 3, 1913.

Hexagenia recurvata Morgan. Needham, Bull. U. S. Bur. Fish., vol. 36, p. 279, figs. 8, 12, 1920. Ulmer, Arch. Naturg., Bd. 87, Hft. 6, Abt. A, p. 239, 1921. Traver, Ann. Ent. Soc. Am., vol. 24, pp. 611-613, 615, figs., 1931. Needham, Traver, Hsu, etc., Biology of Mayflies, pp. 271-272, figs., 1935.

Specific characteristics:

♂ imago, dried.—General color piceous to dark brown without distinct abdominal color pattern; clypeus unique in being bilobed and enlarged; compound eyes separated by space equal to half the eye diameter; pronotum lacking typical submedial longitudinal stripes; all wing veins black; wing membrane raw umber; all cross veins margined with bistre, and in the basal and distal parts of fore wings and distal part of hind wings the bistre infuscation fills the entire membrane; axillary membrane of wings yellow. A_1, A_2, and A_3 clearly present in fore wing; abdominal tergites uniform burnt umber; posterior and pleural margins narrowly tawny; slight indications of elongate, lighter, subdorsal stripes. Sternites slightly lighter and duller than tergites; a pair of submedian dots and submedial oblique streaks on each segment. Genitalia as in fig. 39; penes with tubular, recurved tips; basal joint of forceps unique, second joint strongly bowed; cerci piceous becoming lighter distally. Length: body 18-20 mm.; wing 15-18 mm.

♀ imago, dried.—Similar to male except much more lightly colored. All venation narrowly infuscated and never fusing as happens in the distal and basal parts of the male wings. Length: body 19-24 mm.; fore wing 19-22 mm.

Variation in imagoes.—The amount of variability appears to be slight. Only the intensity of the brown infuscation, especially that of the abdomen, seems to differ between individuals.

Nymph.—Frontal process (fig. 50) angular, lacking setae at base; mandibular tusks (fig. 45) short, sturdy, almost straight and heavily fringed with long hairs along entire length. Labrum slightly curved along margin; first joint of maxillary palp equals galea-lacinia. First abdominal gill usually single; bodies of remaining gills purplish; abdomen without distinct color pattern. Cerci uniform fuscous; terminal filament yellow. Length: ♂ 23-25 mm.; ♀ 22-25 mm.

Variations in nymphs.—Most nymphs have a simple first abdominal gill, although a few individuals do have a bifid gill which approaches that of Icthybotus nymphs in appearance.

Type locality.—Not indicated.

Holotype.—Not designated.

Remarks.—This, the most striking of all hexagenid species, was indicated by Morgan in 1913 but the imago was not described until 1935. It can readily

be identified by the bronzy wings, the uniform abdominal coloration, and the distinctive genitalia of the male. The genitalia, which are somewhat like those of *Eatonigenia chaperi* from Borneo, have the long, strongly bowed second forceps joint arising from the dorsal surface of the short, semi-globose first joint and the penes have tubular, recurved tips. The unique frontal process, the almost straight mandibular tusks, and the usually non-bifid first abdominal gill easily distinguish the nymph. The species is not closely related to any other North American member of the genus. The anal area of the fore wing, with three anal veins of which the second almost parallels the first, is remarkably like that of *Icthybotus hudsoni* of New Zealand. The lack of subdorsal, dark, pronotal streaks also distinguishes the species from other North American ones and perhaps relates it to *H. indica* Chopra.

Range:

It is found (fig. 61) from Maine to the upper peninsula of Michigan and has been recorded as far south as West Virginia. The cutting off of the timber, especially in the coniferous areas of the northeastern and middle-northern United States, has probably reduced the range of the species. Specimens of the species that I have seen were collected at the following localities:

Maine. Passadumkeag Bog 12. VI. 33 (C.U.);
Massachusetts. Granby 12. IX. 03, nymph (C.U.);
Michigan. Marquette Co. 28. VII. —, nymph (C.U.);
New York. Freeville 23. V. 31; Herkimer Co. 5. VI. 25 (C.U.); Ithaca 5. VII. 24 (C.U.); McLean 30. V. 37; Michigan Hollow 5. V. 16, nymph (C.U);
North Carolina. Valle Crucis, late autumn 1934 (C.U.);
Ontario. Kearney, Sand Lake 5. VII. 26 (C.N.C.), 17. VI. 34 (Ide);
Province of Quebec. Baie Gagnon 18. VII. 38 (I.S.); Grand Lac Tremblay 21. VII. 38 (I.S.); Grand Lac Jacques-Cartier 12. VII. 28 (I.S.); Knowlton 24. VI. 28 (C.N.C.), 15. V. 28 (C.N.C.); 5. VI. 30 (C.N.C.); Petit Lac des Roches 29. VII. 38 (I.S.); Pekoula Riv. 21. VII 38 (I.S.);
West Virginia. Elk Garden 21. VIII. 30, nymph (C.U.).

Biology:

H. recurvata emerges during May and June in the northeastern United States. Due perhaps to its restricted habitat, the population is relatively small.

HEXAGENIA RIGIDA McD.

Hexagenia bilineata form *falcata* Needham, Bull. U. S. Bur. Fish., vol. 36, 11b?, 1883.

Hexagenia bilineata form *falcata* Needham, Bull. U. S. Bur. Fish., vol. 36, figs. 61 and 65, 1920.

Hexagenia rigida McDunnough, Canad. Ent., vol. 56, pp. 90-92, fig. 3, 1924; Canad. Ent., vol. 59, pp. 117-118, fig. 1, 1927. Traver, Ann. Ent. Soc. Am., vol. 24, pp. 611-613, 1931. Neave, Cont. Canad. Biol. and Fish., vol. 7, no. 15, pp. 1-8, 20-25; Canad. Field-Nat., vol. 46, p. 54, 1932.

Specific characteristics:

♂ imago, dried.— A reddish brown species with a yellow ground color; compound eyes separated by the diameter of the eye; coxae, trochanter, femur, and tibia of fore leg burnt umber; fore tarsi bistre with basal two-thirds of segments 2, 3, 4, and 5 lighter; joinings and claws sepia; wing membrane

faintly tinged with grey; area proximal to humeral cross vein heavily infuscated with bistre, remainder of costal and subcostal areas tinged with light raw umber; all veins except those at base of wings and in anal area black; cross veins of disk of hind wing and those anterior to MP_1 of fore wing margined with black; distal margin of hind wing sometimes infuscated. Abdominal tergites (fig. 25) with yellow ground color, often obscured with ferruginous, and an extensive chestnut to bistre color pattern. Abdominal sternites (fig. 26) with yellow ground color and the following color pattern: (1) a mid ventral brown line, especially prominent on distal sternites; (2) a dark area in the anterolateral corners of each sternite, and (3) dark, oblique streaks on each sternite arising from the posterolateral corners. Often these streaks fuse with the anterolateral patches of the following sternites so that there appears to be an oblique stripe extending from the submedial part of one sternite to the lateral edge of the next posterior. These sometimes connect with each other and form a continuous wavy lateral line on each side of the abdomen. Sometimes all elements fuse to form ventral triangles. Genitalia (fig. 37) with bistre colored, slender, almost straight penes; cerci raw umber with piceous joinings. Length: body 14-20 mm.; wing 13-19 mm.

Variations in imagoes.—*H. rigida* displays great variation among the individuals of any large series collected at a given locality. In the males the yellow ground color may be obfuscated with ferruginous or may be very pale. The hind wing margin may be infuscated with sepia or completely hyaline. The color pattern of the abdominal sternites may range from bistre triangles that occupy the greater part of the sternite and almost completely obscure the yellow ground color to small anterolateral bistre patches with the greater part of the sternite bright yellow in color.

Nymph.—Frontal projection (fig. 46) cone shaped rather than dome shaped as it is in *H. limbata occulta;* the mandibular tusks rather sharply arced in the middle; gills brown; in male nymphs the straight penes are characteristic; abdomen with the color pattern of the adult. The genitalia represent the safest character for separating this nymph from *occulta.*

Type locality.—Orillia, Ont., 21.VII.20.

Holotype.—No. 690 Canadian National Coll., Ottawa.

Remarks.—The distinct penes and color pattern of the tergites plus the anterolateral patches of the sternites constitute the best set of characters for the identification of the species. The females are almost indistinguishable from those of *Hexagenia limbata occulta* which lives in the same area and emerges at the same time as does this species. Neave (1932) has shown that the eggs of *rigida* can be separated from those of *occulta* by the chorionic markings. In *rigida* the lines are crenellated while in *occulta* they are straight and heavy.

Range:

H. rigida is confined mainly (fig. 60) to the upper two-thirds of the Mississippi drainage and to the St. Lawrence drainage. It has been taken from the eastern hills of Oklahoma, from Lake Winnipeg, from Montreal, and from Grand Isle, Vt. In the east it extends as far south as Harrisburg, Pa. Appar-

ently upper temperature limits and the choice of a substratum for the nymphs are controlling factors in its distribution. Specimens of *rigida* that I have seen are from the following localities:

Illinois. Chicago 6. VIII. 94 (I.S.); Illinois Riv., 1886 (M.C.Z.); Kankakee 10. VII. 25 (C.N.C., I.S.), 31. V. 38 (I.S.), 15. VI. 38 (I.S.), 2. VIII. 38 (I.S.), 17. VI. 39 (I.S.); Momence 15, VI. 38 (I.S.); Oregon 13. VII. 26 (I.S., C.N.C.); Rockford 12 and 29. VI. 38 (I.S.); Wilmington 15. VI. 38 (I.S.), 1. VII. 35 (I.S.);

Iowa. Fairport. —. VII. 18 (C.U.);

Kansas. Lawrence 26. VI. 30 (C.N.C.);

Manitoba. Winnipeg 11-20. VI. 11 (C.N.C.);

Michigan. Burt Lake 28. VI. 38 (I.S.), 6. VII. 23 (C.U.); Detroit 28. VI. 38 (I.S.); Lowell 27. VII. 29; Saginaw Bay, Bay Co. 19. VI. 38 (I.S.);

Missouri. Hollister 14. VI. 38 (I.S.); Ozark 30. V. 38;

New Brunswick. Fredericton 17. VII. 28 (C.N.C.); French Lake 2. VII. 28 (C.N.C.);

New York. Buffalo 25. VII. 06 (C.U.); Crown Pt. 14. VI. 27 (C.U.); Niagara 22. VII. 37, 12. VII. —; Rousses Pt. 12. VIII. 27 (C.N.C.);

Ohio. Columbus 10. VI. 23 (O.S.U.); Gib Island 18. VI. 38 (O.S.U.); Ross Co. 25. VI. — (O.S.U.); Vermillion 20. VII. 33;

Oklahoma. Tahlequah 17. VI. 39; Watts 16. VI. 39;

Ontario. Bobcaygeon 22. VI. 32 (C.N.C.); Bothwell 13. VII. 25 (C.N.C.); Brittania 23. VI. 20 (C.N.C.); Forestville 15. VI. 31 (C.N.C.); Fort Stanley. —. —. 22 (C.N.C.); Georgian Bay 5-18. VII. 12 (C.N.C.); Grand Head 6, VII. 39 (C.N.C.); Norman 19. VII. 08 (C.N.C.); Normandale 6. VII. 25 (C.N.C.); North Bay 19. VII. 26 (C.N.C.), 5. VII. 38; Ottawa West 21. VII. 20 (C.N.C.); Pt. Pelee 24. VII. 25 (C.N.C.), 8. VII. 27 (C.N.C.), Severn 11-16. VI. 25 (C.N.C.); Smoky Falls 12. VII. 34 (C.N.C.); Turkey Pt. 8. VI. 31 (C.N.C.);

Pennsylvania. Harrisburg 12. VI. — (M.C.Z.);

Province of Quebec. Alymer 22. VI. 38; Cascades Pt. 5. VII. 36; Gracefield 21. VI. 37 (C.N.C.); Ile Bizard 24. VI. 34 (C.U.); Knowlton 13. VII. 29 (C.N.C.), 1. VIII. 29 (C.N.C.), 26. VI. 30 (C.N.C.); Lanoraie 9. VI. 15 (C.N.C.); Lachine 6. VII. 25 (C.N.C.); 27. VI. 36; Laprairie 7. VII. 24 (C.N.C.); Montreal 30. VI. 77 (M.C.Z.), 28. VI. 23 (C.N.C.); St. Annes 24. VI. 25 (C.N.C.).

Biology:

The species is found in the same habitat as the various subspecies of *H. limbata*. The nymph lives both in lakes and in larger streams. Neave (1932) has shown that in Lake Winnipeg it is restricted mainly to near shore line and to relatively protected areas. *Rigida* and *occulta* emerge at the same time, imagoes of *rigida* having been recorded from late May (Missouri) to late July (Quebec). In all areas, however, the peak of emergence is in late June and early July. *H. rigida* is never as abundant as the subspecies of *limbata* with which it occurs. Neave (1932) estimates, on the basis of thousands of specimens, a ratio of seven *occulta* to one *rigida* in Lake Winnipeg.

Hexagenia subgenus **Pseudeatonica** new subgenus

Subgeneric characteristics:

Imago.—With the characters of Hexagenia except that (1) the male genitalia (fig. 38) are three jointed, with first joint straight and about one-half the length of second joint; the second joint long, robust, strongly arced in basal third and tapering distally; the third joint slender and short; (2) the

cerci are more robust basally, and (3) the veinlets between A_1 and the edge of the mesothoracic wings are reduced to 4-6 in number instead of 8 or 9.

Nymph.—Unknown.

Subgenotype.—*Hexagenia (Pseudeatonica) mexicana* Eaton.

Range:

South and Central America.

HEXAGENIA (PSEUDEATONICA) ALBIVITTA (Walker)

Baëtis albivitta Walker, List Neuropt. Ins. Brit. Mus., pt. 3, p. 566, 1853. Hagen, Syn. Neuropt. No. Am., p. 304, 1861.

Palingenia continua Eaton, Trans. Ent. Soc. Lond., vol. 5, p. 199, 1860.

Hexagenia albivitta (Wlk.) Eaton, Trans. Ent. Soc. Lond., pt. 1, p. 64, 1871. Ulmer, Stett. Ent. Zeit., vol. 81, p. 108, 1920. Needham and Murphy, Bull. Lloyd Lib., No. 24, Ent. Ser., No. 4, pp. 27-28, fig. 23, 1924.

Hexagenia albivittata (Wlk.) Eaton, Mono. Rec. Ephemeridae, pt. 1, p. 49, 1883.

Hexagenia benedicta Navas, Bol. Soc. Ent. Espana, vol. 5, no. 3-4, pp. 55-56, 1922.

Hexagenia dominano Navas, Revista Mus. Paulista, vol. 20, pp. 732-733, 1 fig., 1936.

Specific characteristics:

♂ imago, dried.—Fore femur and tibiia fuscous tinged with red; tarsal segments black; entire venation piceous; wing membrane tinged with yellowish grey, much more intense in costal and subcostal areas, and cross veins of disk of hind wing marginated with brown; mediodorsal longitudinal white stripe running entire length of body, tinged with red on head. Lateral piceous stripes of pronotum continued along meso- and metanota; black serrated stripe (fig. 24) along abdomen above white spiracular line. This stripe consists "of a series of triangular spots, each with its hypotenuse descending obliquely from the hinder margin toward the lower anterior angle of the dorsum of the segment and enclosing some small black intermediate markings in the anterior portion of some of the segments, viz.:—in both sexes a short linear streak adjacent to the dorsal vessel in the last few segments" (Eaton). Abdominal sternites ferruginous laterally with lighter medial area. Cerci with broad alternating bands of reddish fuscous and yellow. Genitalia as in fig. 38. Length: body 15 mm., wing 15 mm.

♀ imago, dried.—Similar to male except that the abdominal color pattern is more extensive and the legs are yellower.

Nymph.—Unknown.

Type locality.—"Para and Brazil."

Types.—British Museum (Natural History). I have not seen this type.

Remarks.—The white dorsal stripe and the black longitudinal markings are very distinctive. *Albivitta* is a close relative of *H. callineura* but can be separated from it by means of the dark ventral markings. Further studies may show these to be subspecies. The genitalia and wing separate the species from the

true hexagenids. Eaton (1883), without giving any reasons, emended Walker's original name *albivitta* to *albivittata*. The International Code does not sanction such a procedure and I therefore follow Ulmer (1921) in using Walker's name *albivitta*.

H. benedicta and *H. dominano* were each described from singe females collected near San Paulo, Brazil. The original descriptions leave no doubt as to their connection to the distinct *albivitta* and, although I have not seen the types, I am therefore placing them as synonyms of Eaton's species.

Range:

Eaton (1883) reports the species from Buenos Ayres, Argentine, and Espirito Santo, Brazil. I have seen his Buenos Ayres specimens and also a ♂ imago from the "mouth of the Parana." Additional collecting will probably show the range of the species to include all eastern Brazil, all of Paraguay, Uruguay, and northeastern Argentina.

Biology:

Unknown.

HEXAGENIA (PSEUDEATONICA) CALLINEURA Banks

Hexagenia callineura Banks, Proc. Acad. Sci. Phila., vol. 66, p. 613, 1914.

Specific characteristics:

♀ imago, dried.—General color yellowish white marked with fuscous and piceous; broad lateral prothoracic stripes continuing on pterothorax as in *albivitta;* fore coxae brown tinged with piceous, fore femur and tibia chestnut brown; tips of fore tarsal segments 2, 3, 4 and all of 5 plus the claws piceous; remainder of fore tarsi yellow; meso- and metathoracic femora and tibia yellow, tipped distally with chestnut; meso- and metathoracic tarsi as in fore tarsi except paler. Wings wholly hyaline; longitudinal veins pale except for costa, subcosta and radius of mesothoracic wing and costa and subcosta of metathoracic wing. All cross veins except in anal areas piceous; in disk of metathoracic wing cross veins margined with black; in mesothoracic wing cross veins of disk between R and IMP_2 margined. Dorsum of abdomen and cerci as in *albivitta;* venter of abdomen immaculate. Length: body 15 mm.; wing 19 mm.

♂ imago.—Unknown.

Nymph.—Unknown.

Type locality.—Cali, Colombia, 1000 meters.

Holotype.—Museum Comparative Zool., Mass.

Remarks.—The species is close to *albivitta* and can be separated from it by the pale venter of the abdomen which is infuscated in *albivitta*.

Range:

Besides the type I have seen material from Playas de Montalvo, Los Rios, and Banos, Ecuador.

Biology:

Unknown.

HEXAGENIA (PSEUDEATONICA) MEXICANA Eaton

Hexagenia mexicana Eaton, Revisional Mono. Rec. Ephemeridae, pt. 1, p. 50, 1883. Ulmer, Arch. Natur., Bd. 87, Abt. A, Hft. 6, pp. 235, 237, 1921.

Specific characteristics:

♂ imago, dried.—General color blackish fuscous with yellow abdominal markings. Femur and tibia of fore leg pitch brown; fore tarsus pitch black; meso- and metathoracic legs mostly yellow with femora distally clouded with fuscous; meso- and metathoracic tarsal joinings, the last tarsal segments and the claws smoky. Wing membranes transparent brown throughout; hind wings darker than fore wings; all veins piceous; mesothoracic cross veins except in costal, subcostal and anal areas margined with piceous; metathoracic cross veins except in costal and anal areas margined with piceous. Abdominal tergites with yellow areas surrounded by piceous brown. Three yellow areas, a medial and two lateral ones on tergites 1-7; on segments 8 and 9 the medial areas have been filled in with the piceous brown so that only the lateral spots are present; tergite 10 wholly piceous brown. Sternites discolored; genital forceps fuscous becoming piceous distally (3 jointed with tapering second joint); penes fuscous, apparently shaped somewhat as in *rigida*. Length: body 12 mm.?; wing 13 mm.

The body of the holotype has some fungus on it and the abdomen is both crushed and discolored. Further material must be available before a complete description can be given.

♀ imago.—Unknown.

Nymph.—Unknown.

Type locality.—Mexico (Salle).

Holotype.—Museum Comparative Zool., Mass.

Remarks.—*H. mexicana* can easily be recognized by the uniformly dark pigmented wings. The abdominal color pattern, when adequately known, will also serve to identify this striking species. The genitalia and the metathoracic wing veinlets of the anal region indicate its relationship to *callineura* and *albivitta*.

Range:

This species is known from Mexico to Peru.

Biology:

Unknown.

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EXPLANATION OF PLATES

PLATE 1: 1. Dorsal abdominal color pattern of a ♂ *Hexagenia atrocaudata* McD. 2. Ventral abdominal color pattern of a ♂ *Hexagenia atrocaudata* McD. 3. Dorsal abdominal color pattern of a ♂ *Hexagenia bilineata* (Say). 4. Ventral abdominal color pattern of a ♂ *Hexagenia bilineata* (Say). 5. Dorsal abdominal color pattern of a ♂ *Hexagenia limbata limbata* (Serville). 6. Ventral abdominal color pattern of a ♂ *Hexagenia limbata limbata* (Serville). 7. Dorsal abdominal color pattern of a ♂ *Hexagenia limbata viridescens* (Walker). 8. Ventral abdominal color pattern of a ♂ *Hexagenia limbata viridescens* (Walker).

PLATE 2: 9. Dorsal abdominal color pattern of a ♀ *Hexagenia limbata californica* Upholt. 10. Dorsal abdominal color pattern of a ♂ *Hexagenia limbata occulta* (Walker). 11. Ventral abdominal color pattern of a ♂ *Hexagenia limbata occulta* (Walker). 12. Dorsal abdominal color pattern of a ♂ *Hexagenia limbata venusta* Eaton. 13. Ventral abdominal color pattern of a ♂ *Hexagenia limbata venusta* Eaton. 14. Dorsal abdominal color pattern of a ♂ *Hexagenia munda affiliata* McD. 15. Ventral abdominal color pattern of a ♂ *Hexagenia munda affiliata* McD. 16. Dorsal abdominal color pattern of a ♂ paratype of *Hexagenia munda elegans* Traver.

PLATE 3: 17. Ventral abdominal color pattern of a ♂ paratype of *Hexagenia munda elegans* Traver. 18. Dorsal abdominal color pattern of the ♂ type of *Hexagenia munda munda* Eaton. 19. Ventral abdominal color pattern of the ♂ type of *Hexagenia munda munda* Eaton. 20. Dorsal abdominal color pattern of a ♂ *Hexagenia munda marilandica* Traver. 21. Ventral abdominal color pattern of a ♂ *Hexagenia munda marilandica* Traver. 22. Dorsal abdominal color pattern of a ♂ paratype of *Hexagenia munda orlando* Traver. 23. Ventral abdominal color pattern of a ♂ *Hexagenia munda orlando* Traver. 24. Dorsal abdominal color pattern of a ♂ *Hexagenia (Pseudeatonica) albivitta* (Walker).

PLATE 4: 25. Dorsal abdominal color pattern of a ♂ *Hexagenia rigida* McD. 26. Ventral abdominal color pattern of a ♂ *Hexagenia rigida* McD. 27. Left half of the male genitalia of *Hexagenia atrocaudata* McD. 28. Left half of the male genitalia of *Hexagenia bilineata* (Say). 29. Left half of the male genitalia of *Hexagenia limbata limbata* (Serville). 30. Left half of the male genitalia of *Hexagenia limbata occulta* (Walker). 31. Left half of the male genitalia of *Hexagenia limbata venusta* Eaton. 32. Left half of the male genitalia of *Hexagenia limbata viridescens* (Walker). 33. Left half of the male genitalia of *Hexagenia munda affiliata* McD. 34. Left half of the male genitalia of *Hexagenia munda munda* Eaton. 35. Left half of the male genitalia of *Hexagenia munda marilandica* Traver. 36A. Left half of the male genitalia of *Hexagenia munda orlando* Traver.

PLATE 5: 36B. Left half of the male genitalia of *Hexagenia munda elegans* Traver. 37. Left half of the male genitalia of *Hexagenia rigida* McD. 38. Left half of the male genitalia of *Hexagenia (Pseudeatonica) albivitta* (Walker). 39. Male genitalia of *Hexagenia recurvata* Morgan. 40. Right mandible of *Hexagenia atrocaudata* McD. 41. Right mandible of *Hexagenia limbata occulta* (Walker). 42. Right mandible of *Hexagenia limbata venusta* Eaton. 43. Right mandible of *Hexagenia munda marilandica* Traver. 44. Frontal protuberance of nymph of *Hexagenia atrocaudata* McD. 45. Right mandible of *Hexagenia recurvata* Morgan. 46. Frontal protuberance of nymph of *Hexagenia rigida* McD. 47. Frontal protuberance of nymph of *Hexagenia munda marilandica* Traver. 48. Frontal protuberance of nymph of *Hexagenia limbata occulta* (Walker). 49. Frontal protuberance of nymph of *Hexagenia venusta* Eaton. 50. Frontal protuberance of nymph of *Hexagenia recurvata* Morgan. 51. *Distribution of *Hexagenia limbata viridescens* (Walker). ● = distributional localities of *viridescens*. × = distributional localities of *viridescens-occulta* intergrades. 52. *Distribution of *Hexagenia limbata occulta* (Walker). ● = distributional localities of *occulta*. × = distributional localities of *occulta-viridescens* intergrades. o = distributional localities of *occulta-venusta* intergrades.

PLATE 6. 53. *Distribution of *Hexagenia limbata limbata* (Serville). ● = distributional localities of *limbata*. × = distributional localities of *limbata-venusta* intergrades. ϕ = distributional localities of *limbata-venusta-occulta* intergrades. o = distributional localities of *limbata-occulta* intergrades. 54. *Distribution of *Hexagenia munda affiliata* McD. 55. *Distribution of *Hexagenia limbata venusta* Eaton. ● = distributional localities of *venusta*. × = distributional localities of *venusta-occulta* intergrades. 56. *Distribution of *Hexagenia munda elegans* Traver. ● = distributional localities of *elegans*. × = distributional localities of *elegans-munda* intergrades. o = distributional localities of *elegans-orlando* intergrades. 57. *Distribution of *Hexagenia munda munda* Eaton and *H. munda orlando* Traver. ● = distributional localities of *munda*. × = distributional localities of *orlando*. + = distributional localities of *munda-marilandica* intergrades. o = distributional localities of *orlando-elegans* intergrades. 58. *Distribution of *Hexagenia munda marilandica* Traver. ● = distributional localities of *marilandica*. × = distributional localities of *marilandica-elegans* intergrades. 59. *Distribution of *Hexagenia atrocaudata* McD. 60. *Distribution of *Hexagenia rigida* McD. 61. *Distribution of *Hexagenia recurvata* Morgan. 62. *Distribution of *Hexagenia bilineata* (Say).

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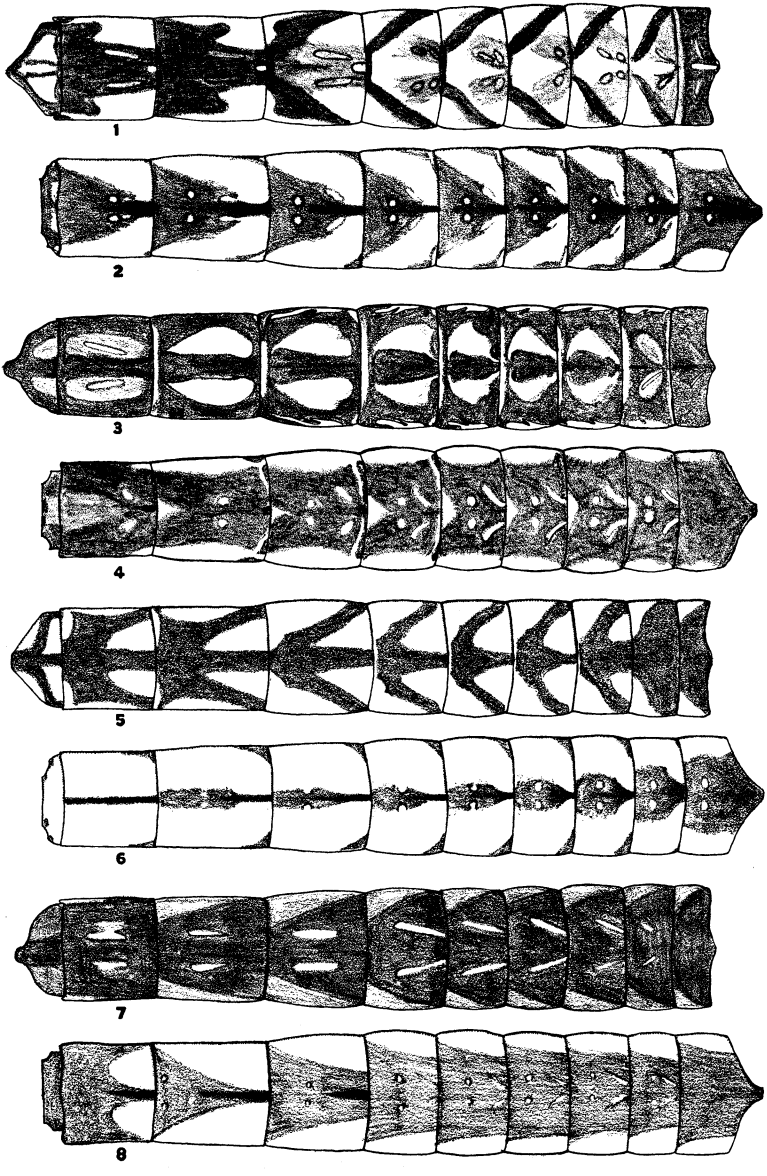
PLATE 1



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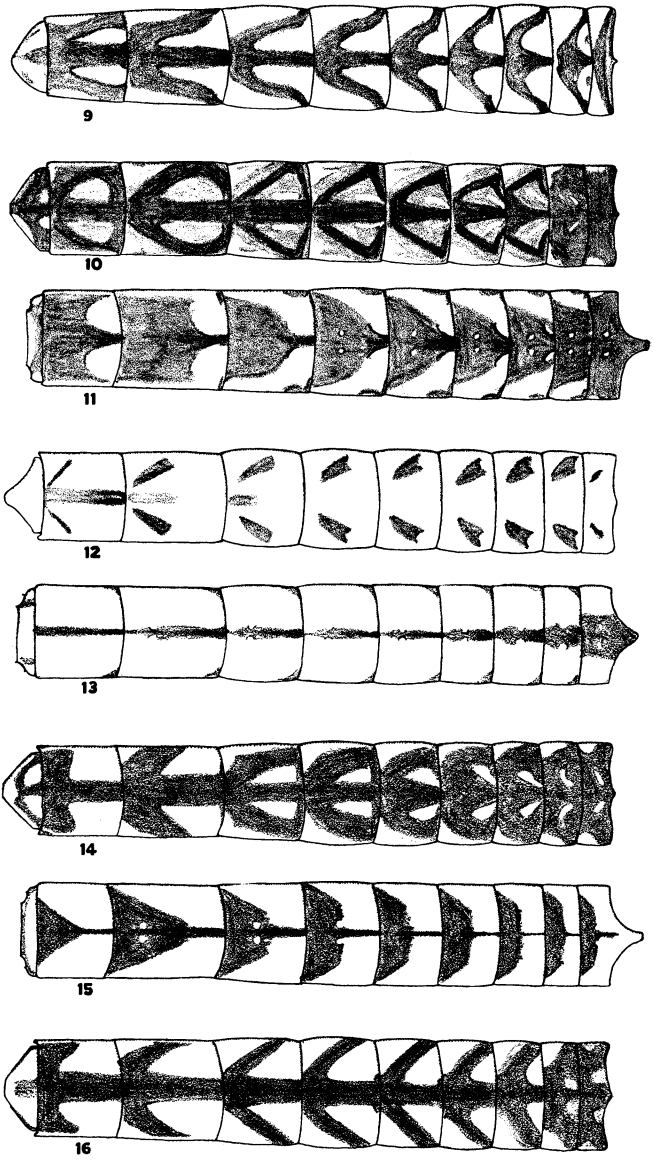

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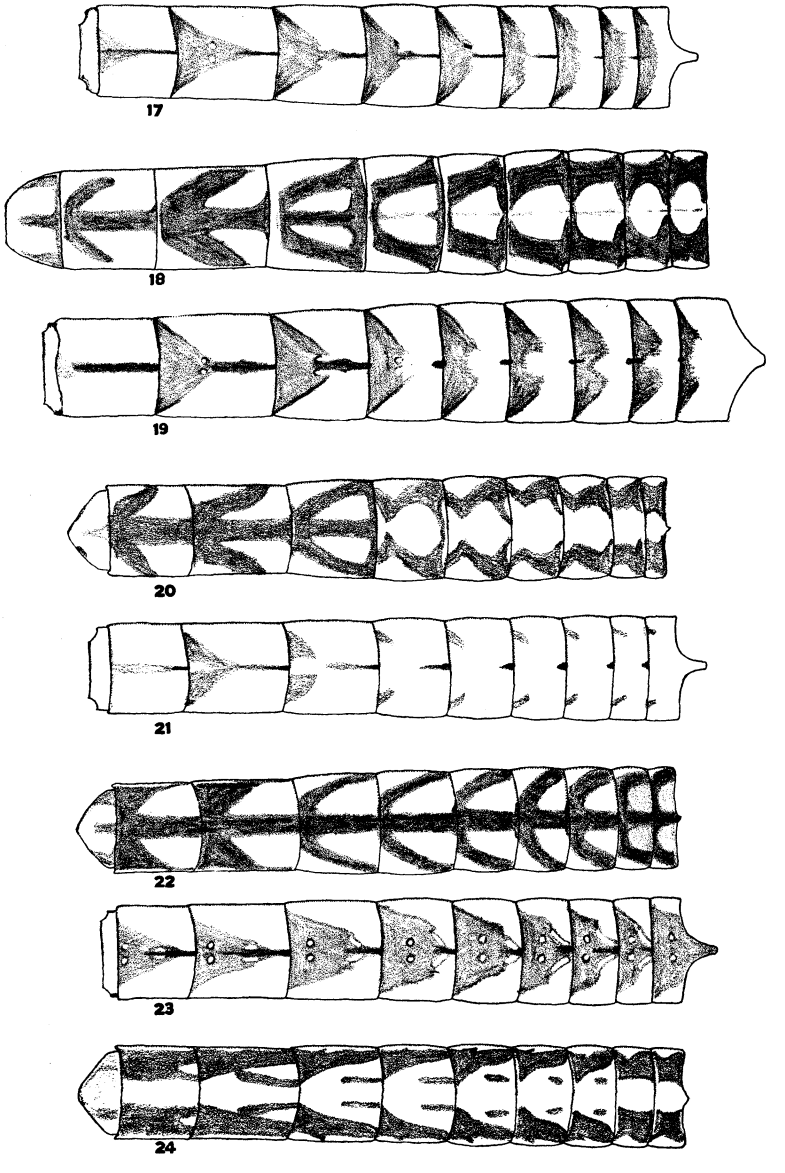

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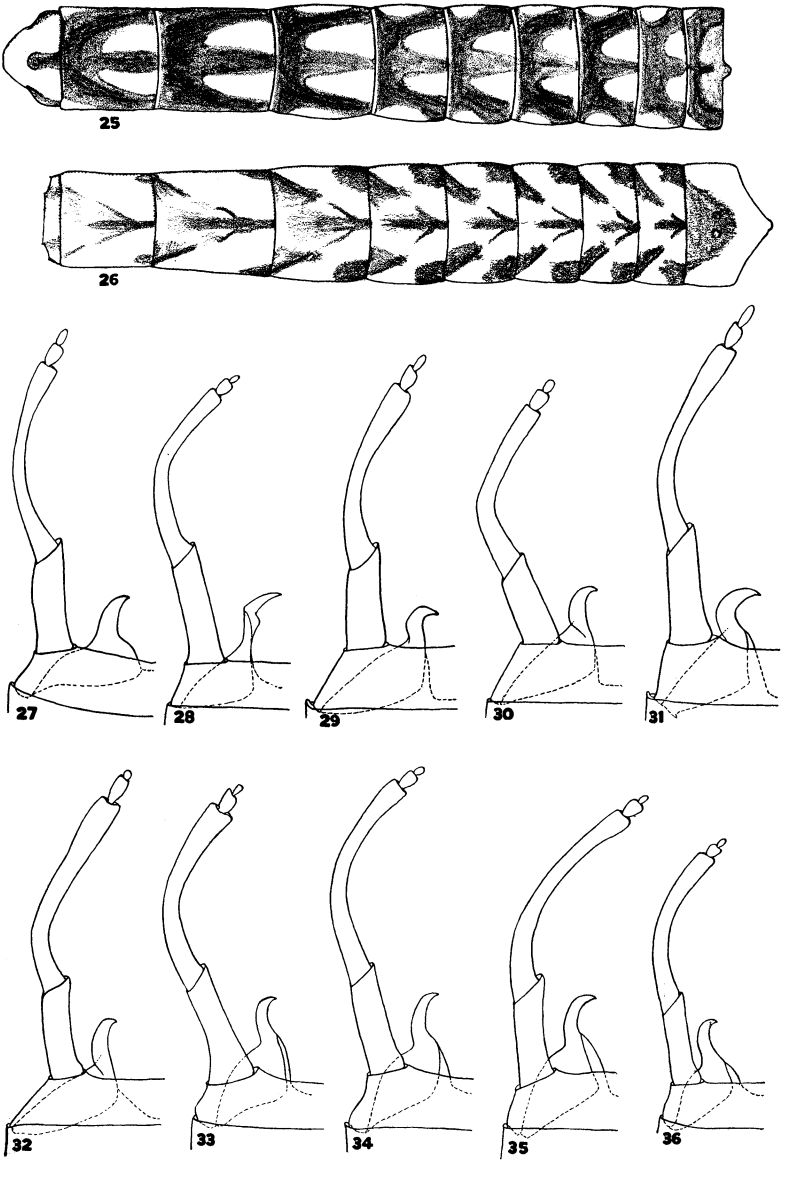

PLATE 5

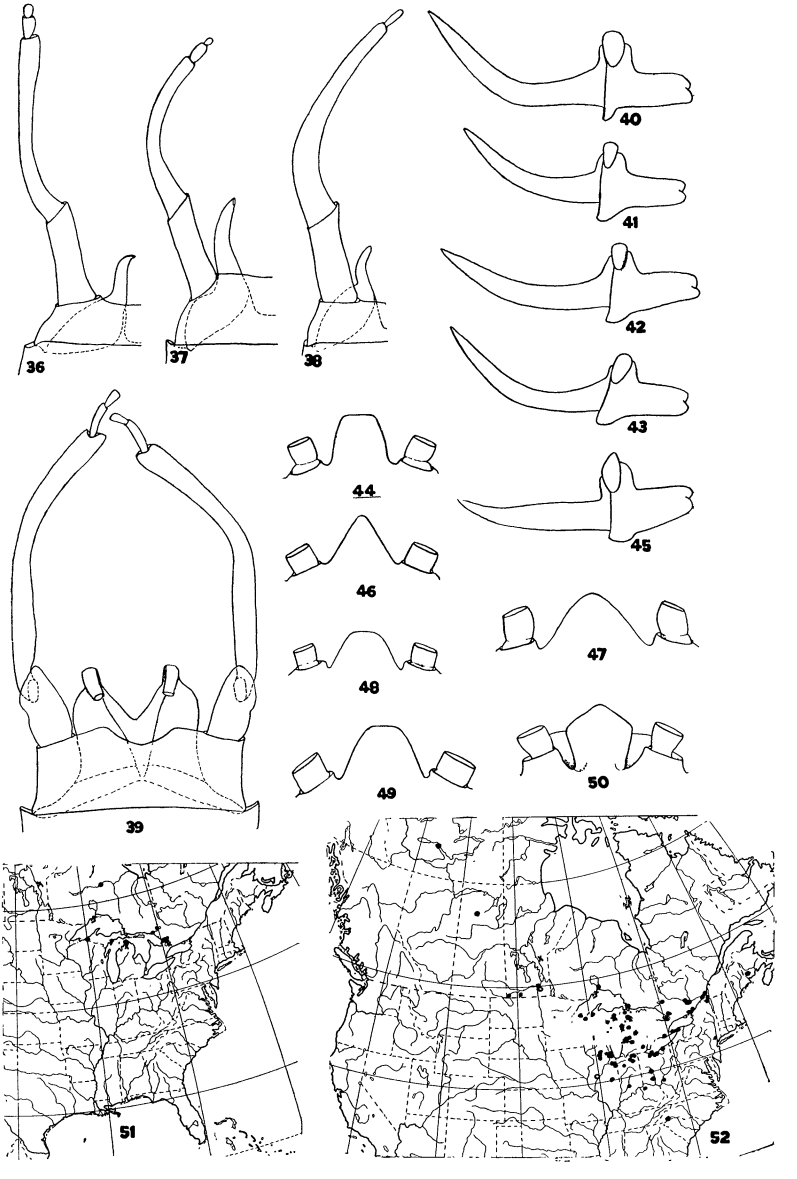

PLATE 6