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Rhythmic Hexagenia mayfly emergences and the environmental factors which influence them[1,2]

CALVIN R. FREMLING (Winona State College, Minnesota, U.S.A.)

With 2 figures on 1 folder

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[2] The author would like to acknowledge assistance received from the following people at Iowa State University of Science and Technology. Many of the emergence records reported here were collected by CLARENCE CARLSON and THOMAS WENKE. Dr. KENNETH D. CARLANDER has provided guidance during the study and in the preparation of the manuscript.

Mass emergences of mayflies (*Hexagenia* spp.) are familiar phenomena to people who live along the Mississippi River. On several nights each summer the river cities are virtually blanketed by mayflies. Tree limbs droop under their weight, drifts of the insects form under street lights, traffic is impeded and shoppers desert the streets. Snowplows are called out in extreme cases to reopen bridges which have been made impassable. The insects are also attracted by the powerful arc and mercury vapor lights of towboats which transport freight on the Upper Mississippi River. The boats travel 24 hours a day and depend upon their search lights to spot unlighted channel markers at night. Their lights and even their radar are often made nonfunctional by the swarms of insects.

The biology of the *Hexagenia* mayflies in the Upper Mississippi drainage basin has been reported by NEEDHAM (1920), NEEDHAM, TRAVER and HSU (1935), LYMAN (1943, 1944, 1955), BURKS (1953), HUNT (1953) and FREMLING (1960).

During the summer of 1957—1961, specimen vials and instruction sheets were distributed to ship captains and lock personnel along the Upper Mississippi River and more than 250 collections of adult *Hexagenia* spp. have thus been made. The emergence patterns of all four years are quite similar and the records of 1958 are presented as an example (fig. 1).

Analysis of the collections indicates that emergences of *Hexagenia bilineata* occur rhythmically at intervals of about 6 to 11 days from mid-June through mid-August. Rhythmic *Hexagenia* emergences have previously been reported on the Mississippi River as early as 1916 by NEEDHAM (1920) and COKER (1929). The emergences often encompass great expanses of river and a given emergence seems to take place at almost the same time from St. Paul, Minnesota, to St. Louis,

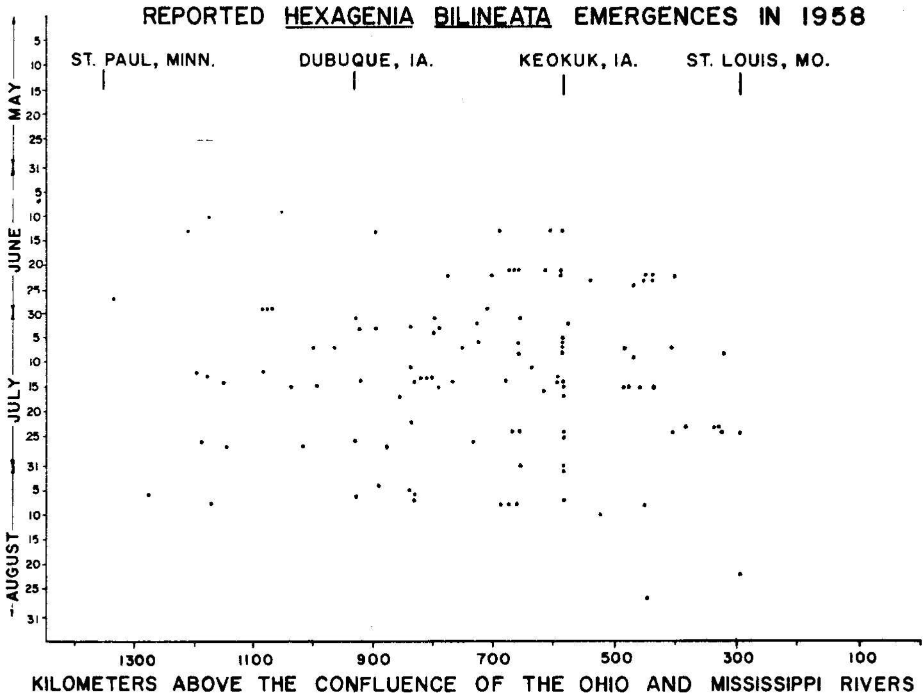

Fig. 1. Locations and dates of *Hexagenia bilineata* emergences on the Upper Mississippi River during 1958.

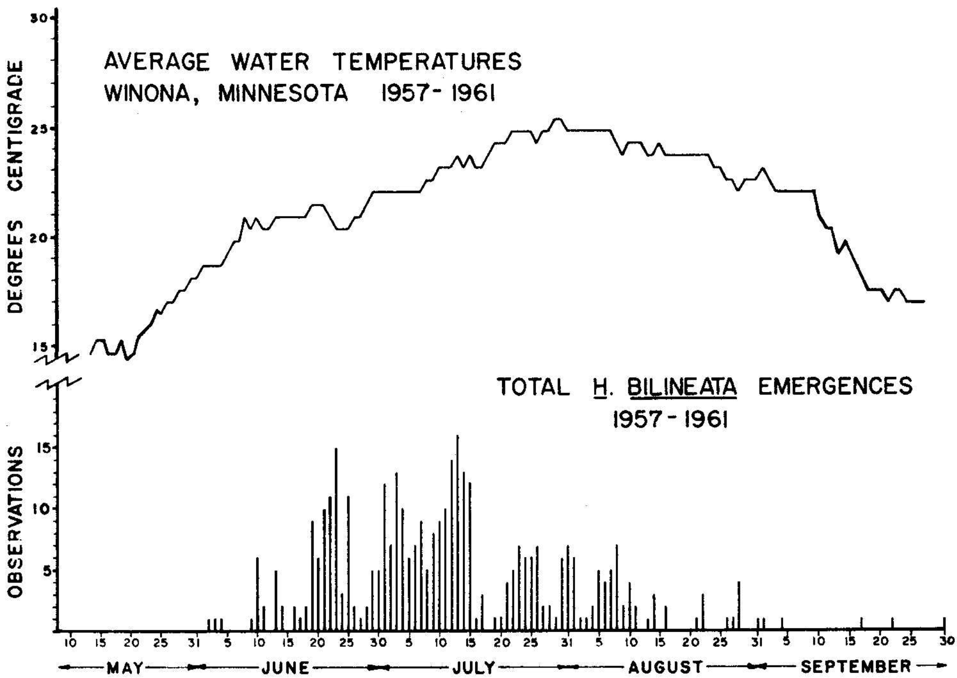

Fig. 2. Combined *Hexagenia bilineata* emergence records for the years 1957—1961 on the Upper Mississippi River as compared with the average river temperature at Winona, Minnesota, for the same years.

Missouri, a distance of over 1040 river km. There appears to be no tendency for an emergence to begin earlier in the southern extremity of the Upper Mississippi River as might be expected.

Combined emergence records for 1957—1961 indicate that the emergence peak consistently occurs in mid-July and that it occurs prior to the maximum summer water temperatures (fig. 2).

The total *H. bilineata* population of the Upper Mississippi River seems to exist as at least 8 sub-populations. The individuals which emerge during the peak of a given emergence are sexually isolated, by time, from the individuals which emerge during the peak of the succeeding emergence because the adults seldom live longer than one day. Even though the sub-populations may have their own gene pools it is difficult to understand how each sub-population is able to emerge simultaneously from the northern and southern limits of a 1040-km expanse of river. It seems probable that the emergence phenomenon is synchronized by some exogenous factor. Yet, no correlation has been found thus far between emergence time and water temperature, air temperature, water level or moon phase.

At the present time research is being continued to learn more about the environmental factors which influence mass *Hexagenia* emergences. Records of emergence will continue to be collected by ship captains and since 1960 an effort has been made to supply collecting equipment to each lock master and boat-livery operator on the Upper Mississippi River.

Self-addressed, stamped mailing tubes of collecting materials have also been distributed to resort owners, teachers and lake residents who live near bodies of water which have large mayfly populations. Over 100 cooperators have thus been enlisted since 1961 and the research area now includes three continental drainage systems (Red River, St. Lawrence River, and Mississippi River) and corresponding parts of North Dakota, South Dakota, Iowa, Minnesota, Wisconsin, Ontario and Manitoba. It is hoped that more will be learned by these methods concerning the magnitude of the coordinating environmental factors.

The effects of environmental factors are also being studied under controlled laboratory conditions and a method has been devised whereby large numbers of mayfly eggs may be collected for experimental purposes. A water-filled funnel is extended by a short segment of rubber tubing which is closed by a pinch clamp. Living imago mayflies are gathered from beneath a waterfront light and are brought to the laboratory where they are placed, a few at a time, on the surface of the water. Upon contact with the water the females release their eggs which settle slowly into the stem of the funnel where they can be tapped off in any desired volume. Over 200 cc of eggs have been gathered in one evening by this method.

Mayfly eggs have been successfully stored in .005 cm-thick polyethylene bags of water in a refrigerator for periods up to 50 days. Without refrigeration the eggs hatch in 11—12 days. When removed from prolonged refrigeration at 4° C the eggs hatch in about 9 days at room temperature although the percentage of hatch is less. Polyethylene bags have also proved to be excellent containers for rearing *Hexagenia* nymphs. Mud and water are placed in a bag and after eggs have been added the bag is hung in a convenient place for observation.

One large batch of eggs has been divided into two portions. One portion has been stocked in one-half of a 2.4 metre-long horse trough which has a fine screen divider in it and which has been filled with mud and water. The second group of eggs has been refrigerated for 2 weeks to retard development and they have been stocked into the second compartment. Circulation is maintained in the tank to provide a uniform environment in both compartments. The development of both groups will be studied to determine the effect of the retardation upon emergence time.

Attempts have been made to develop a population of *Hexagenia* mayflies in an isolated habitat. Over 90 l of imago *H. bilineata* and *H. limbata* were scattered upon the surface of a half-hectare farm pond and the females were seen to release their eggs. A portion of the eggs, upon return to the laboratory, hatched in eleven days. No nymphs were ever recovered from the pond, however. Oxygen sampling revealed no dissolved oxygen depletion and the pond supported bluegill sunfish and perch. It was thought, although it could not be demonstrated by conventional methods, that there was a dissolved oxygen depletion at the mud-water interface.

The oxygen content of the thin layer of water at the mud-water interface is of vital concern to most benthic organisms since they use that water for respiration. Conventional samplers do not sample this zone, however.

During the course of the present study a simple method has been devised whereby the dissolved oxygen content at the mud-water interface can be accurately measured. A 10.2 × 22.9 cm polyethylene bag (0.005 cm thick) is filled with one liter of distilled water. A dozen glass marbles are added to the bag for ballast and the contained air is expelled through the neck of the bag. The neck of the bag is then tied. The bag is placed on the lake bottom for 30 hours (at summer temperatures) and is then raised. One corner of the bag is clipped and the bag is quickly lowered into the mouth of a funnel which extends upward from the neck of a standard 300 ml dissolved oxygen bottle. The liter of water in the bag is sufficient to flush the bottle thoroughly. The dissolved oxygen content is then determined by the standard WINKLER method. The method has proved to be an excellent one and has demonstrated a drop of over 2.5 p. p. m. in the lower 15 cm of water on several occasions. The technique is described fully in a paper being submitted for publication to the Journal of Limnology and Oceanography.

Dredging operations have been facilitated by a screened-pail (FREMLING 1961) which rapidly separates benthic organisms from the mud which contains them.

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Discussion

ERIKSEN: Do you find *Hexagenia limbata* in farm ponds at all? The reason I ask is perhaps in a newly established pond, silt may not yet be present for burrowing. Likewise, sufficient organic matter may not yet have accumulated for food.

FREMLING: I have never found either *H. limbata* or *H. bilineata* in a farm pond even when the bottom seemed ideal. I feel certain that the oxygen content at the mud-water interface is the limiting factor.

TARZWELL: In 1938 Wheeler Reservoir in North Alabama was new. In June of that year there was a very large emergence of *Hexagenia.* Trees were broken by their weight. That year there was only one emergence. In subsequent years other emergences developed, each appearing at a uniform period after the one just before. This process continued until the end of observation in 1943, at which time emergences occurred from mid-June until mid-August. None of them were as large as the one in June 1938.

DENDY: Is not the phenomenon of dominant emergence of one species of aquatic insects rather common in new waters? *Tendipes crassicaudatus* dominated a recently filled pond for the first season. In following seasons the emergences were spread over a longer period and were less massive.

FREMLING: Yes, I believe that this is true. Perhaps, in the newly created body of water we see in miniature what has occured on a large scale over a long period of time on the Mississippi River. The establishment of broods is also well known in the cicada, of course.

NELSON: Is there a synchronous hatching of the eggs from one female?

FREMLING: In the laboratory the eggs hatch over a period of several days. They often adhere to each other and form small clumps. The eggs in the center of the clump hatch later because they get less oxygen. In nature the eggs probably drift downward for a sufficient distance so that they become dispersed and probably do not clump. It seems likely to me that hatching would be much better synchronized under natural conditions.

C. O. BERG: How long does it take for the dissolved oxygen in the water in the plastic bag to come into equilibrium with that of the ambient water?

FREMLING: The diffusion rate is a logarithmic function and the curve becomes asymptotic in about 30 hours at 20° C. At 2° C equilibrium is not reached until about 50 hours.