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Hexagenia Bilineata (Ephemeroptera: Ephemeridae) Persists at Low Levels of Abundance in the Lower Fox River, Wisconsin

Phillip A. Cochran
St. Norbert College

Andrew P. Kinziger
Frostburg State University

HEXAGENIA BILINEATA (EPHEMEROPTERA: EPHEMERIDAE) PERSISTS AT LOW LEVELS OF ABUNDANCE IN THE LOWER FOX RIVER, WISCONSIN

Philip A. Cochran[1] and Andrew P. Kinziger[1,2]

ABSTRACT

After burrowing mayflies *(Hexagenia bilineata)* were first noted in the vicinity of the DePere Dam on the Fox River in 1991, adults have been observed in small numbers each summer since then. It is possible that the Fox River population has remained at low levels because of an Allee effect. In addition, it is possible that the population is still limited by poor environmental quality, presumably in the upper layer of sediment inhabited by the larvae. Two other relatively sensitive species associated with benthic habitat, the sea lamprey *(Petromyzon marinus)* and the lake sturgeon *(Acipenser fulvescens),* have been observed in the Fox River in recent years. Collectively these species provide an indication of improved environmental conditions, but it is not yet clear that any of the three have established populations capable of successfully reproducing in the lower Fox River on a consistent basis.

Adults of the burrowing mayfly *Hexagenia limbata* (Serville) formerly achieved nuisance levels in Green Bay of Lake Michigan (Schuette 1928), but reduced water quality caused by input from the lower Fox River resulted in their complete elimination by 1969 (Harris et al. 1987). It was noteworthy, therefore, when Cochran (1992) observed adult *H. bilineata* (Say) in the vicinity of the DePere Dam on the lower Fox River, 12 km upstream from Green Bay, during the summer of 1991. Herein we report that *H. bilineata* persists in the vicinity of the DePere Dam but has not achieved the large emergences characteristic of this genus elsewhere in its range (Fremling 1960).

Adult mayflies were collected during routine activities in the vicinity of the DePere Dam, including a daily commute by the senior author on foot over the Claude Allouez Bridge. In addition, student technicians in our biology department who lived during the summer in the vicinity of the St. Norbert College campus (just upstream from the DePere Dam) were shown specimens of *H. bilineata* and asked to collect any that they observed. We have used the specific designation "*Hexagenia bilineata*" throughout this manuscript to refer to our collections because any specimens for which identifications could be made belonged to this species (some individuals were damaged or were not captured because they were out of reach). However, because *H. limbata*

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[1]Division of Natural Sciences, St. Norbert College, DePere, WI 54115-2099.
[2]Present address: Dept. of Biology, Frostburg State University, Frostburg, MD 21532.

Table 1. Collections of adult *Hexagenia bilineata* in the vicinity of the DePere Dam on the lower Fox River, Brown County, Wisconsin. Multiple sightings on a given date are indicated in parentheses. The 1997 season was in progress at the time of manuscript revision.

Year	Dates of Occurrence	Total
1992	June 24 (2), July 4, July 8, July 11	5
1993	July 28, July 29	2
1994	July 8 (3), July 14, July 31	5
1995	July 1, July 17, July 20	3
1996	June 28, June 29	2
1997	July 7, July 18 (4), August 19	6

occurred in this system historically (Schuette 1928) and conceivably might return, and because some authors we have cited did not specify which species they were discussing, we have used only the generic name in those contexts in which either or both species might be involved.

Adult *H. bilineata* were collected each summer during the years 1992–1997 (Table 1), albeit in low numbers. This period includes the "flood" year of 1993, when summer monthly mean discharges at various locations along the Fox River were among the highest on record (Holmstrom et al. 1996).

Although *H. bilineata* has been present in the Fox River since at least 1991, it has not achieved the characteristically large emergences noted in other parts of its range. Independent evidence suggests that population density of *Hexagenia* in the lower river is low: only a single individual was collected in 58 Ekman grabs collected over a 10 km reach of river (both upstream and downstream from the DePere dam) during the period 10 June–11 August, 1992 (John Rafferty, personal communication). We suggest two possible explanations for the apparent lack of a population increase. These hypotheses are not mutually exclusive.

First, the *Hexagenia* population in the lower Fox River may be subject to an Allee effect (Brewer 1988), by which reproduction is relatively inefficient at low population levels. Such an effect would tend to keep a newly reestablished population at low numbers. Indeed, it has been suggested that the large synchronized emergences typical of many mayflies increase the probability of finding a mate (Corbet 1964) or increase survival through satiation of predators (Sweeney and Vannote 1982). We note the consistent presence near the DePere Dam of several species of birds that feed on emergent insects, including a colony of cliff swallows *(Petrochelidon pyrrhonota)* that nest on the Claude Allouez Bridge.

Second, it is possible that populations of *Hexagenia* in the lower Fox River are still limited by poor environmental quality, presumably at the sediment-water interface (e.g., Sullivan et al. 1983). Evidence to support this hypothesis might be provided by another species, the sea lamprey *(Petromyzon marinus),* first reported from the Fox River in 1991 (Cochran 1994). It may be no coincidence that neither species has been subsequently observed in large numbers. Like *Hexagenia,* sea lampreys undergo a burrowing larval stage of relatively long duration and relatively low tolerance for environmental degradation.

Krieger et al. (1996) recently described the recovery of *Hexagenia* spp. in western Lake Erie. That swarms of adults were not recorded until approxi-

mately two decades after water quality responded to pollution abatement may be consistent with an Allee effect. Kolar et al. (1997) developed a model of recolonization of western Lake Erie that suggested that recovery to pre-1950s population densities would take 10–41 years if population growth was logistic, even in the absence of such factors as low-oxygen events, competition with chironomids, toxic sediments, and fish predation. Addition of any of these factors to the model typically led to substantially increased recovery times.

The presence—and absence—of *Hexagenia* elsewhere in the Green Bay drainage has been recently noted. Lillie (1995) recorded at least some individuals of one or more species in the Wolf, Menominee, and Peshtigo rivers but he found none in the Oconto or Embarrass rivers (it should be noted that his surveys were targeted heavily toward mayflies that inhabit sand-bottomed habitat). Choudhury et al. (1996) specifically noted the absence of *Hexagenia* from the diet of lake sturgeon *(Acipenser fulvescens)* in Lake Winnebago because it is such an important component of lake sturgeon diets in other systems. They attributed the lack of *Hexagenia* to the highly eutrophic nature of Lake Winnebago. Kempinger (1996) found *Hexagenia* in 9.9% of 131 age-0 lake sturgeon captured in the Wolf River. A link between *Hexagenia* and lake sturgeon, such as that suggested by Cavender (1997) in Lake Erie, is of especial interest in the present context. The lake sturgeon, like *Hexagenia bilineata* and the sea lamprey, is a sensitive benthic species recently observed in the lower Fox River (Cochran 1995). All three species are indicators of improved water quality, but in all three cases, it is unclear if the benthic habitat has improved to the point that successful reproduction can occur on a consistent basis.

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