RECURRENCE OF HEXAGENIA MAYFLIES DEMONSTRATES IMPROVED WATER QUALITY IN POOL 2 AND LAKE PEPIN, UPPER MISSISSIPPI RIVER

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ABSTRACT

Hexagenia mayflies are good indicators of general water quality because they have long life cycles and because their burrowing nymphs, which are unable to tolerate anaerobic conditions or swim long distances, live in sediments where toxins tend to accumulate. While chemical tests only describe water quality in terms of specific parameters and times, *Hexagenia* distribution indicates synergistic effects of many toxins, anoxia and other stresses throughout the year. Over 1,400 collections of imagoes and subimagoes along the Upper Mississippi River in 1957–1968, 1976 showed that most of the 29 navigation pools supported large populations, as did impoundments upstream of Minneapolis-St.Paul. Populations were non-existant or meager in Pool 2 and Lake Pepin, however, due to METRO pollution. Collections made in 1986 showed that recent pollution abatement measures have enabled *Hexagenia* to attain nuisance levels in the two areas, thus establishing that mayfly distribution can be utilized to assess the well-being of a river which is so large that it is difficult to monitor effectively or economically by standard methods.

INTRODUCTION

Sixteen years ago, at the First International Conference on Ephemeroptera, Fremling (1973) discussed the effects of water pollution on the distribution of *Hexagenia* mayflies in the United States and reported that on the Upper Mississippi River (UMR) *Hexagenia* had been virtually eliminated from most of the 45 km reach downstream from metropolitan Minneapolis-St. Paul (METRO) and from much of Lake Pepin (Fig. 1). This report documents recurrence of *Hexagenia* in the affected areas and discusses the environmental improvements which made it possible. As in 1970, it will be demonstrated that mayfly distribution can be utilized to assess the well-being of a river which is so large that it is difficult to monitor effectively and economically by standard chemical and physical methods.

DESCRIPTION OF STUDY AREA

The Mississippi is the largest river in North America, flowing 3,731 km from its source at Lake Itasca, Minnesota to its mouth in the Gulf of Mexico (Fig. 1). The present study area extends 145 km downstream through the METRO corridor from St. Anthony Falls Lock and Dam through Lake Pepin. Locations within the study area are given as river km above the confluence of the Mississippi and Ohio Rivers (RKM UMR). The METRO area has a population of 1.85 M and its domestic and industrial sewage is treated by 12 treatment plants. The Metropolitan Wastewater Treatment Plant (MWTP), operated by the Metropolitan Waste Control Commission (MWCC), is the largest, treating about 81% of METRO sewage (833 M $1.d^{-1}$). The river within the study area is impounded by four lock and dam

I.C. Campbell (ed.) Mayflies and Stoneflies, 243–248.

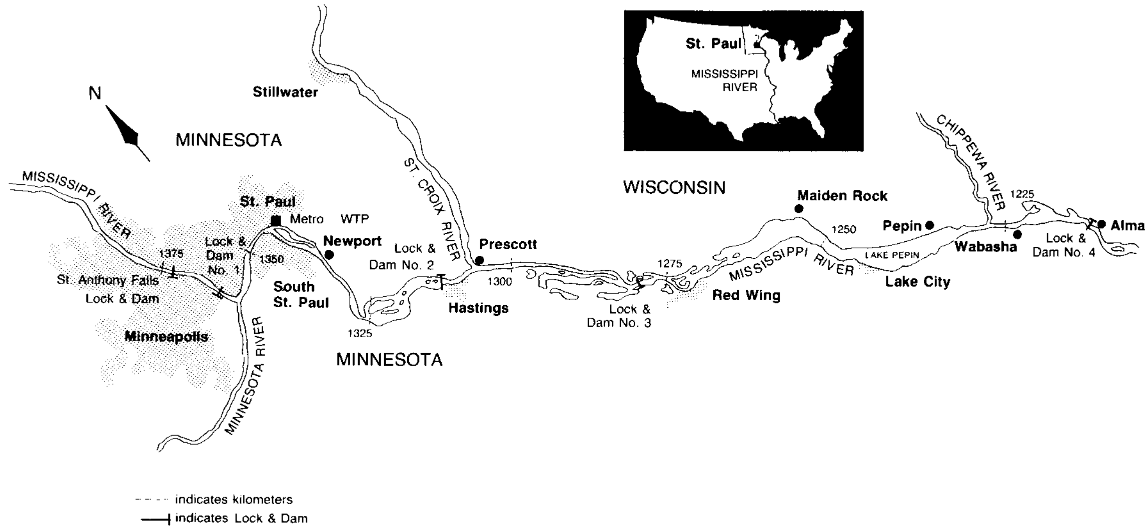

Fig. 1. Map of the study area.

systems. Lake Pepin is a natural impoundment created by the damming action of the delta of the Chippewa River. The ecological history of the UMR has been summarized by Fremling and Claflin (1984).

HEXAGENIA BIOLOGY

The life histories of *Hexagenia* mayflies are well known (Needham *et al.* 1935, Hunt 1953, Fremling 1960, Swanson 1967). The genus is probably confined to the Western Hemisphere, being found from the Rio Negro of Argentina to Great Slave Lake in the Northwest Territories of Canada (Edmunds *et al.* 1976). Burrowing nymphs dig U-shaped respiratory tubes in silted bottoms of lakes, streams, irrigation canals, and ponds, where their distribution is dictated primarily by sediment type and dissolved oxygen concentration at the mud-water interface. Nymphs consume organic detritus, algae, bacteria, protozoans, other small organisms, and large amounts of indigestible inorganic matter. They apparently selectively ingest organic matter of high caloric content (Zimmerman *et al.* 1975). Rate of growth is a function of temperature; life cycles are completed in as little as 12 weeks under laboratory conditions (Fremling 1967) and 17 weeks in Utah irrigation canals (Edmunds *et al.* 1976), but require as long as 2 years in northern lakes (Hunt 1953) and streams (Leonard and Leonard 1962). The life cycle is completed in one year or less within the study area. In prime habitats, last instar nymphs may often be found in concentrations of more than 340 m^{-2}. Carlander *et al.* (1967) estimated the June, 1963 *Hexagenia* population of navigation UMR Pool 19 at about 11.9×10^9. Two species, *H. bilineata* and *H. limbata,* dominate the UMR; they tend to emerge en masse at intervals of 6-11 days, causing nuisance problems from mid-June until mid-August (Fremling 1968). *Hexagenia* nymphs are important members of the aquatic ecosystem, tilling the bottom and converting organic detritus and its contained organisms into high-quality fish food, thus completing a food chain that is short and efficient. A long life cycle ensures their availability to fish at all seasons. Because nymphs pass through many moults, they are food for a wide variety of fish of various sizes.

Hexagenia distribution has been drastically altered by man in recent years; his pollutants eliminated the insect from portions of Lake Michigan's Green Bay (Lee 1962), most of Lake Erie (Britt 1955, Beeton 1961, Carr and Hiltunen 1965), and segments of the Illinois and Mississippi Rivers (Mills *et al.* 1966, Fremling 1964, 1970).

Hexagenia mayflies are good indicators of water quality because of their long lives and intimate association with sediments where toxins accumulate. They are especially vulnerable to anoxia which may kill them directly or cause them to abandon their burrows (Fremling 1970). While chemical tests only describe water quality in terms of specific parameters and times, *Hexagenia* distribution measures the synergistic effects of many toxins, anoxia and other stressors throughout the year.

Imagoes have been used to monitor levels of polychlorinated biphenyls (PCBs) along the UMR (Mauck and Olson 1977, Clements and Kawatski 1984). Nymphs are now widely used in North America as bioassay animals in toxicity tests. Laboratory culture methods have been developed (Fremling 1967), as well as artificial substrates, testing apparatus and protocol (Fremling and Schoening 1973, Fremling 1975, Fremling and Mauck 1980, Henry *et al.* 1986).

METHODS

In 1958, ship captains, lock masters, harbor operators, and interested river residents were solicited to collect mayflies along the Mississippi and its tributaries (Fremling 1973). The system, used annually through 1969, was re-employed in 1976 and 1986. Shipping strikes, floods, recruitment of new cooperators and other variables made it impossible to keep collecting effort constant from year to year and throughout the river corridor. Distribution records could have been confounded by downstream drift of nymphs, upstream flight of female imagoes prior to oviposition, and transport by towboats. Subimagoes of both sexes and imago males are the most reliable indicators, since they only fly short distances from their emergence site. Certainly, the presence of adult mayflies in an area indicates the best possible scenario, while their dearth demonstrates lack of suitable environment. In addition to being economical in terms of time, money and resources, the method can be educational for the general public. River residents have come to associate mayflies with water quality, realizing that their presence does not prove that the river is clean enough to drink or to swim in, but that it is in good biological condition.

CHANGES IN WATER QUALITY

Scarpino (1985) has reviewed the 1890-1950 water quality history of the UMR in the METRO corridor, where early pollution control was dictated largely by development of the river for navigation. Channelization practices begun in 1878 included dredging and construction of groynes which constricted the river, increasing its velocity and ability to transport sewage away from METRO. In 1917, the US Army Corps of Engineers (USACE) completed the Twin Cities Lock and Dam (now Lock and Dam No. 1), creating an 8 km pool which received most of METRO's untreated sewage. In 1930, the USACE finished Lock and Dam No. 2 at Hastings; its 60 km pool extended upstream to the foot of the Twin Cities Lock and Dam and became the resting place for the remainder of METRO sewage, including wastes from packing houses and stock yards. An investigator for the Bureau of Fisheries concluded that during the month of August the river for 72 km below St. Paul lacked sufficient oxygen to sustain fish life of any type. Because of intolerable health and aesthetic problems created by the pooled sewage, the MWTP and many other treatment facilities were constructed in the METRO area. In the succeeding years, most small treatment plants were consolidated with MWTP, wastewater treatment efficiency was increased, MWTP effluent quality was markedly improved (Fig. 2), by-passes due to combined sewer over-

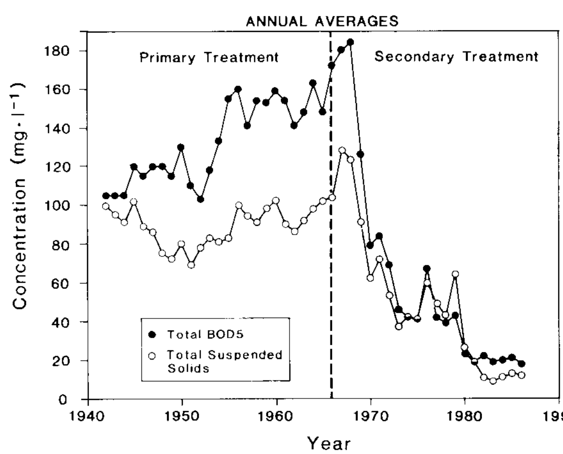

Fig. 2. Metropolitan Wastewater Treatment Plant performance, 1942–1986.

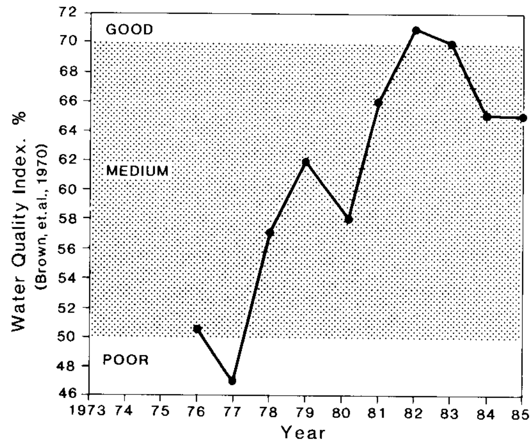

Fig. 3. Yearly August water quality index at Newport (RKM 1336), 1976–1985.

flow were reduced and water quality was improved as a result (Figs 3, 4).

RESULTS AND DISCUSSION

During the 1957-1969, 1976 studies, 1,164 collections of *H. bilineata* and 209 collections of *H. limbata* were made along the UMR between Cairo, Illinois and Brainerd, Minnesota. During that time, only 6 *H. bilineata* and 2 *H. limbata* emergences were reported from Pools 1 and 2, even though the broad, silty reaches of Pool 2 were potentially excellent *Hexagenia* habitat. Pool 1 offered poor habitat because it was narrow, relatively swift and had a bottom composed

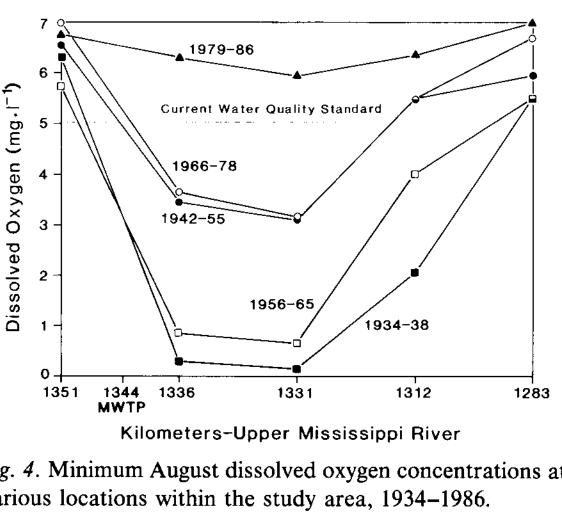

Fig. 4. Minimum August dissolved oxygen concentrations at various locations within the study area, 1934–1986.

mainly of sand and rock. Both *Hexagenia* species were abundant in pooled reaches upstream from METRO.

Only two benthos studies are known from the 1957–1976 period, but they substantiate the absence of *Hexagenia* in Pool 2. Tubificid worms were the only macroinvertebrates collected during July, 1959 reconnaisance dredging in Pool 2 by personnel of the Minneapolis-St. Paul Sanitary District (1961). In 27 collections of Pool 2 benthos in spring and late summer, 1973, Colingsworth and Gudmundson (1973) found no *Hexagenia*. Collections were dominated by chironomid midge larvae and tubificid worms, both highly pollution-tolerant forms.

During the 1957–1976 period, only 8 *H. bilineata* and 3 *H. limbata* collections were made from Lake Pepin, the repository for some of METRO's pollutants. Trapp (1979) sampled 50 stations for benthos in Lake Pepin during May and July, 1976 and collected only 28 *Hexagenia* nymphs. Frequency of occurrence of *Hexagenia* within samples was 1.5% while frequency of occurrence of *Chironomus plumosus* was 88%. Adult *Chironomus* caused severe nuisance problems along the waterfront and on highways.

The 1986 response of *Hexagenia* to improved water quality was dramatic. Collectors reported 21 *H. bilineata* and one *H. limbata* mass emergences from Pool 2 where the insects caused nuisance problems at harbors and in downtown St. Paul (Lewis 1986), the most dramatic incident occurred on the night of June 23, 1987, when snowplows were needed to clear the Interstate Highway 494 bridge in St. Paul (Foley 1987). Benthos sampling in Pool 2 by MWCC personnel in July, 1985 yielded a wide variety of taxa (including occasional stoneflies and hydropsychid and polycentropid caddisflies), with the lower reaches dominated by chironomids, oligochaetes and *Hexagenia,* as well as other mayflies. At RKM 1314, just above L & D 2, *Hexagenia* were found at concentrations of 421 m^{-2}. In Lake Pepin, 26 collections of *H. bilineata* and two of *H. limbata* were made between June 30 and July 30, 1986. Benthos sampling of Lake Pepin in 1986 repeated the study done in 1976, but yielded 369 *Hexagenia* nymphs; frequency of occurrence of *Hexagenia* within samples was 84% while the frequency of occurrence of *Chironomus* was 78%. Highest concentrations of *Hexagenia* were in the upper third of the lake (Claflin, personal communication 1987).

CONCLUSIONS

The results of this study support the use of *Hexagenia* distribution to assess water quality. Comparison of 1957–1976 and 1985–1986 results demonstrates that water quality has improved significantly within the study area, allowing *Hexagenia* to thrive in areas that were previously denuded.

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