Mayflies in Lake Erie

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Mayflies are insects that are abundant throughout much of the world and spend almost their entire lives in freshwater lakes or streams as immature nymphs. They remain in this stage for a year or more, clinging to submersed rocks and other hard objects or burrowing into soft bottom sediments, depending on the species. These insects emerge from the water in swarms to spend their adult life above the surface. As adults, they survive only a short time — from a few hours to a couple of days — earning for them the scientific name *Ephemeroptera*.

The connection between mayflies and Lake Erie

Before severe pollution plagued Lake Erie, mayflies were familiar to most lakeshore dwellers. The mayflies in Lake Erie that get noticed by lake-goers are in the genus, *Hexagenia*. Two species of *Hexagenia* currently reside in Lake Erie, *Hexagenia limbata* and *Hexagenia rigida*.

Hexagenia virtually disappeared from Lake Erie in the mid-1950s, but in a surprise comeback, the insect reappeared in the western basin in the early 1990s. The swarms of mayflies reported since the mid-1990s along the western basin of Lake Erie are reminiscent of the 1940s and 1950s, when even larger swarms were reported by newspapers from Toledo to Cleveland, OH. *Hexagenia* have occurred in Lake Erie for hundreds, perhaps thousands, of years. However, it probably was not as abundant during most of that time as during the first half of the twentieth century.

With European settlement of the Lake Erie basin came increasing inputs of plant nutrients. These nutrients included phosphorus, the "limiting nutrient" for algal growth in the lake. Therefore, the addition of increasing quantities of phosphorus to Lake Erie led to increasing growth of algae. At the lake bottom, decay of the algal remains and decomposition by bacteria and fungi consumed large amounts of dissolved oxygen. This in turn led to periods of very low oxygen concentrations during the warm summer months. Ultimately, in the 1950s, rates of decay during summer became so great that oxygen concentrations were reduced below levels essential for the survival of *Hexagenia* and many

other bottom-dwelling invertebrates. In September 1953, a period of exceptionally low oxygen levels caused the catastrophic loss of nearly the entire mayfly population in the western basin.

With the signing of the Great Lakes Water Quality Agreement in 1972 by the United States and Canada, a new era in the stewardship of Lake Erie began. The agreement, along with other legislation enacted within each country, such as the Clean Water Act in the U.S., created tools and technologies to enforce implementation of legislation that gradually led to improved water quality. Lake Erie steadily responded to pollution abatement measures. The invasion of the zebra mussel and quagga mussel (*Dreissena* spp.) brought about more-rapid changes, such as greatly increased water clarity and reduced abundance of phytoplankton (tiny algae suspended in the water column), particularly in shallower waters characteristic of nearshore areas and most of the western basin.

Hexagenia began to repopulate western Lake Erie in the early 1990s, but the changes in the lake that permitted it to return are not known. It is thought that dissolved oxygen levels near the lake bottom are now being sustained year-around above critical low concentrations; and perhaps much of the toxic materials that had accumulated in the sediments in which *Hexagenia* lives has been buried by a layer of less-contaminated sediment over the past three decades. Additionally, soft-sediment quagga mussel clusters may have also assisted with the successful recolonization of *Hexagenia*. Studies have shown that *Hexagenia* select for mussel covered sediments, likely as protection from fish predation and additional food resources from the mussels (Figure 1).

Before their disappearance in the 1950s, the bottom-dwelling nymphs of *Hexagenia* were important in the diets of Lake Erie sport fishes and recent studies show that *Hexagenia* are once again an important component of many fish diets. Fishes that feed on nymphs include yellow perch, freshwater drum, channel catfish, trout perch, spottail shiner, and silver chub. The nymphs are especially easy prey for most kinds of fish when they swim from the bottom sediments up to the surface of the lake to molt. On shore, many birds devour them, making *Hexagenia* an important part of both the aquatic and near-shore food webs.

The life cycle of *Hexagenia*

Female *Hexagenia* and most other mayflies deposit their eggs directly on or in the water. Individual *Hexagenia* females release as many as 8,000 oval eggs, each less than 0.5 mm long, which sink to the lake bottom. After several days to several months (dependent partly on the water temperature), a tiny nymph hatches from each egg. It immediately burrows into the lake sediment to feed on particulates and to construct a U-shaped burrow, with two openings at the sediment surface. The

nymph continually enlarges its burrow as it grows, so that the burrows of mature nymphs can be as much as 13 cm (5 in) deep. By undulating its body and moving its feathery abdominal gills in sweeping motions, the nymph keeps the burrow oxygenated.

The aquatic life stage of *Hexagenia* lasts from about one year in warm climates to two years or more in colder regions. It is believed that most *Hexagenia* nymphs remain in Lake Erie over two winters before they mature. As with all insects, they grow by shedding their exoskeleton or "skin" in a process called ecdysis or molting. *Hexagenia* nymphs undergo perhaps as many as 20 to 30 molts. When the nymph is ready for its final molt, it leaves the burrow at dusk or soon after and rapidly swims to the lake surface, where its exoskeleton splits lengthwise down its back. From the raft-like exoskeleton called exuviae, a fully winged subimago (subadult) mayfly emerges to quickly dry its wings and after only a few minutes takes flight. A thin layer of exuviae is easily seen on the surface of Lake Erie during the mayfly emergence. At this time, the *Hexagenia* are fully filled with air to assist with flying (this is why they “pop” if you step on them) and no longer have developed mouthparts.

Although the subimago may appear at first to be an adult mayfly, it is not fully developed sexually, and its color is usually a bit darker than the adult. During the night or the following day, male (darker and brown) and female (lighter and yellow) subimagoes molt a final time, leaving behind a subimaginal exoskeleton. They are now sexually mature adults. At dusk or at night, female imagoes fly into a large swarm of male imagoes. The males and females mate in flight during darkness.

Within minutes of mating, the female imago settles down to the lake surface, extrudes the eggs, and dies. Thus, the winged adult *Hexagenia*, is the only stage in the insect's life cycle that most people see, living only about one day.

How are *Hexagenia* doing now?

Hexagenia in Lake Erie have been successful in their recolonization of Lake Erie. From the shoreline, it may seem that adult populations fluctuate widely from year-to-year. However, where mayfly adults appear on shore is typically due to wind speed and direction during emergence and is not indicative of overall population size. To better understand *Hexagenia* population size, scientists take bottom sediment samples from the same sampling locations to examine overall trends in *Hexagenia* numbers. Since 2010, *Hexagenia* density and biomass in Lake Erie has reached, and in most cases exceeded, 1930s levels, suggesting that population of mayflies is currently in a relatively stable condition. However, some decline in mayfly density was observed between 1999 and 2014 and another decline

was recorded in 2019. Further research is needed to understand if this recent decline will continue or if this is a result of a long-term fluctuations in *Hexagenia* density.



Figure 1: Images of *Hexagenia* burrowing beneath quagga mussels. Image credit: K. Fussell.