FS-069

# Mayflies and Lake Erie

## *A sign of the times*

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Mayflies are insects that are abundant throughout much of the world and spend almost their entire lives in lakes or streams as immature nymphs or "wigglers." 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 to spend their adult life. As adults, they survive only a short time — from a few hours to a couple of days — earning for them the scientific name Ephemeroptera. Adult mayflies vary in length from less than a quarter of an inch (about 5 mm) to over an inch (25 mm) and are known in different parts of North America by several names, including dun, fishfly, shadfly, and Junebug. Some of these names, such as Junebug, refer to different insects in different geographical areas, so it is least ambiguous to refer to mayflies simply as mayflies or Ephemeroptera.

## The connection between mayflies and Lake Erie

Before severe pollution plagued Lake Erie, mayflies were familiar to most lakeshore dwellers. Several kinds of mayflies lived in the soft bottom mud of shallow regions of the lake; others crawled on submersed bedrock and boulders along the shoreline and the shallow reefs of the western basin. Only one kind, however — called *Hexagenia* by scientists and known locally in the U.S. as "Canadian soldier" — usually drew the attention of the non-biologist. Winged *Hexagenia* emerge from the lake, often synchronously and in huge numbers, and form swarms along and inland of the shoreline. The insects don't bite, but their swarms are generally considered a nuisance. They are attracted to and congregate under bright lights, and decomposing piles of the insects smell fishy and serve as breeding grounds for flies. Swarms of *Hexagenia* can also pose a traffic hazard. Thousands of mayflies resting on the pavement in the glow of streetlights get flattened by cars, making the roads dangerously slick.

*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. Now, its numbers are once again commanding public attention. At least one south shore city on the western basin posted road signs in the summer of 1996 warning motorists of slippery conditions due to the "may fly hatch." In June of the same year, *Hexagenia* caused a brownout over much of northwestern Ohio. So many of them were attracted to the lights of a major electrical substation near the lake shore that as they settled on the equipment they conducted electricity across the insulators. Although in general there appears to be no direct impact on human health caused by the mayfly swarms, a few accounts refer to an allergic reaction (Edmunds et al. 1976) called "Junebug fever" (Teale 1960). For most people, though, the mayfly swarms are just an annoyance, as the insects fly into people's mouths, or land on their clothes, or crawl into their hair and behind their eyeglasses.

Before their disappearance in the 1950s, the bottom-dwelling nymphs of *Hexagenia* were important in the diets of Lake Erie sport and commercial fishes. In addition, these larger fish ate forage fishes, which also ate *Hexagenia*. Fishes that fed on nymphs included yellow perch (*Perca flavescens*), freshwater drum (*Aplodinotus grunniens*), channel catfish (*Ictalurus punctatus*), trout perch (*Percopsis omiscomaycus*), spottail shiner (*Notropis hudsonius*), silver chub (*Hybopsis storerianus*), and mooneye (*Hiodon tergisus*). The nymphs were especially easy prey for most kinds of fish when they swam from the bottom sediments up to the surface of the lake to molt. Fish also seized the winged mayflies as they rested on the water or flew over it. On shore, many birds devoured them, making *Hexagenia* an important part of both the aquatic and near-shore food webs. With its comeback, evidence since the early 1990s indicates that *Hexagenia* once again is becoming a major component in the diets of several Lake Erie fishes, including yellow perch, freshwater drum, and trout perch.

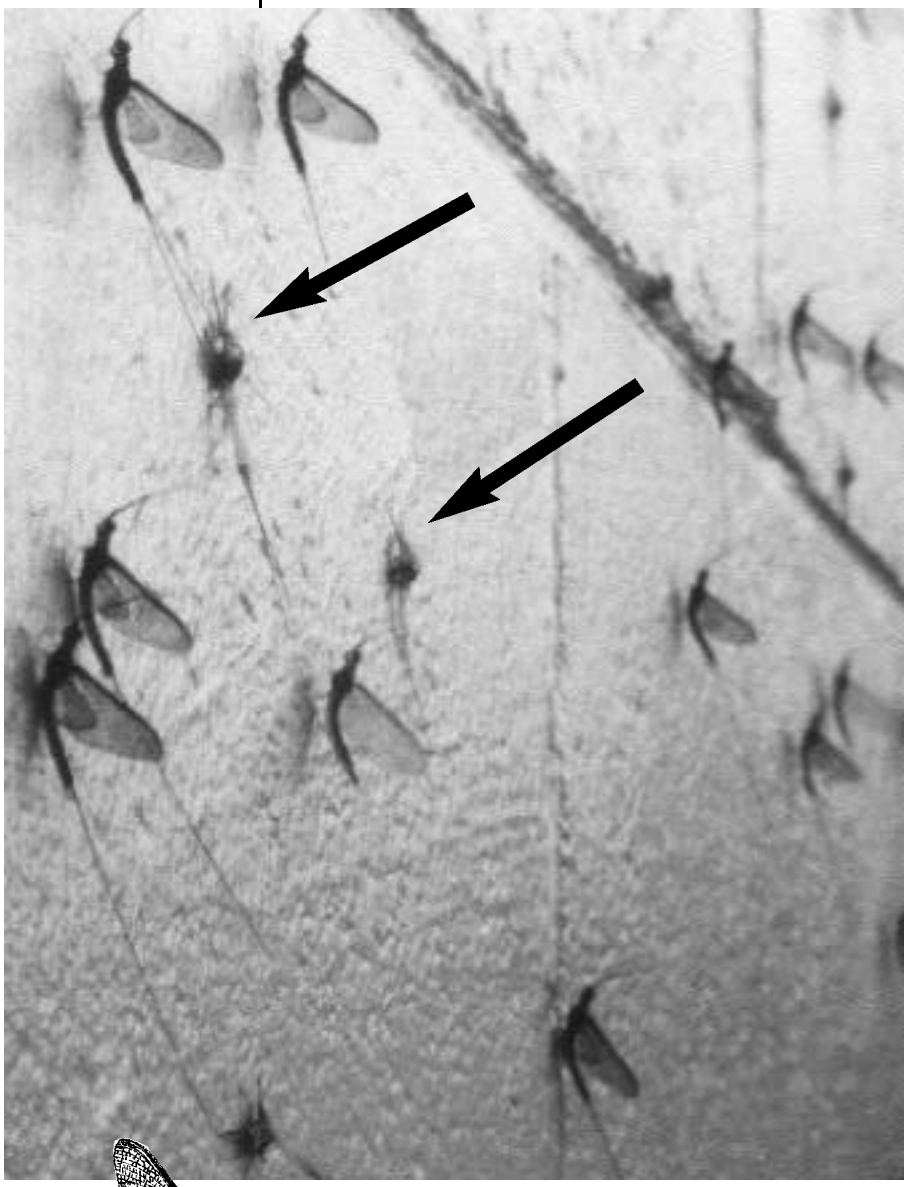
## The life cycle of *Hexagenia*

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 1/2 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 5 inches (13 cm) deep. By undulating its body and moving its feathery abdominal gills in sweeping motions, the nymph keeps the burrow oxygenated. *(see illustration on page 4.)*

The nymphal life of *Hexagenia* lasts from about one year in warm climates to two years or more in colder regions. It is believed that many *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 *(see photo on page 3)* emerges a fully winged subimago (subadult), which after only a few minutes takes flight.

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 and female subimagoes molt a final time, leaving behind a subimaginal exoskeleton *(see photo below)*. They are now sexually mature imagoes (adults). Neither the subimago nor imago eat, because their mouthparts are not completely developed. 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 her eggs, and dies. Thus, the winged adult *Hexagenia*, the only stage in the insect's life cycle that most people see, lives only about one day.



*Winged* Hexagenia *and shed skins of subadults (arrows) on exterior wall, Point Place (Toledo), Ohio, June 1996.*

## Why are there swarms of *Hexagenia* now?

The late-June, early-July swarms of mayflies reported since 1995 in some communities 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. *Hexagenia* has been native to 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. Initially, those nutrients primarily washed from the bare, newly deforested landscape, particularly from that northwestern area of Ohio once known as the Black Swamp. Annual plowing added a new supply of nutrients each year. As urbanization and industrialization spread along the shoreline, municipal sewage also became a major source of nutrients to the western basin. These nutrients included phosphorus, the "limiting nutrient" for algal growth in the lake; that is, phosphorus was in shortest supply among the nutrients needed for algae to grow. Therefore, addition of ever-increasing quantities of phosphorus to Lake Erie led to ever-increasing growths of algae.

By the middle of the twentieth century, overfertilization had led to nuisance algal growths, visible as large rotting mats washed onto beaches and as thick green scum floating on the surface. The decaying vegetation, along with the remains of excessive numbers of zooplankton (tiny animals that feed on the algae), sank to the bottom of the lake. During most of the nineteenth century and the first half of the twentieth century, more and more nutrients were added to Lake Erie as the result of human activities, and these nutrients were converted to additional food for the *Hexagenia* nymphs as well as other kinds of invertebrates. Winged *Hexagenia* provided a route for the partial export of nutrients (and perhaps some pollutants) from the lake back to the land.

At the lake bottom, further decay of the plant and animal remains 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. After a brief partial recovery of the population, the mayflies were entirely gone from most of the western basin by the mid-1960s. Arguments have also been presented that long-lived toxic pollutants, such as the insecticide DDT, may have played a role in the demise of *Hexagenia* and in preventing its return in the 1970s and 1980s.

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 to enforce implementation of technologies that gradually led to improved water quality. Less raw sewage and fewer toxic chemicals were dumped into the Great Lakes. Lake Erie gradually responded to pollution abatement measures. 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), 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. Zebra mussels may have played a role. No direct evidence is available to explain the sudden return of *Hexagenia*, but the swarms of winged mayflies near the lakeshore in the mid-1990s attest to the number of nymphs that have colonized the bottom sediments throughout the western basin.

## Should we expect bigger swarms of mayflies in the future?

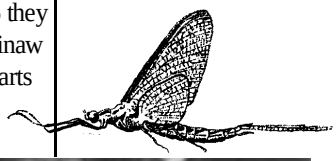
After the mayflies began to recolonize the western basin, since about 1991, their annual average densities in the sediment have increased dramatically. In 1995, the average density of nymphs was 34 per square meter; in 1996, 102 per square meter; and in 1997, 404 per square meter. The increase in the number of nymphs has corresponded with an increase in the sizes of the adult swarms along the lakeshore. Scientists think that the swarms may continue to increase in size for several more years because the rate of increase in the abundance of nymphs has not slowed (as of 1997).

The average densities of nymphs in the island area of the western basin in the 1940s and early 1950s, shortly before they disappeared, ranged from 300 to 500 per square meter, with local densities of more than 1,000 per square meter (Britt 1955). By 1997, some areas of the western basin were once again harboring more than 1,000 nymphs per square meter. However, in areas of soft sediment covered with the shells of zebra mussels and quagga mussels, *Hexagenia* had achieved only low densities. The next few years should reveal the basin's present carrying capacity (sustainable maximum densities) of the *Hexagenia* nymphs.

## Will the swarms spread beyond the western basin?

The first evidence that *Hexagenia* was spreading eastward from the western basin appeared in late June 1996, when swarms were reported in the Huron, Ohio, area. If, as believed, the mayflies returned to the western basin as a result of cleaner water and sediments, it is expected that they will spread to other suitable, clean, well-oxygenated parts of Lake Erie. In 1997, the first of a series of annual volunteer surveys sponsored by the Lake Erie Protection Fund documented the presence of small numbers of winged *Hexagenia* from Huron to Conneaut, Ohio (Krieger, 1998). Future surveys will show whether their numbers are increasing.

Burrowing mayflies were also native to other regions of the Laurentian Great Lakes, including Green Bay (Lake Michigan) and Saginaw Bay (Lake Huron). A return of *Hexagenia* to the lower Fox River, which feeds into Green Bay, has been documented recently, but as of the winter of 1996 they were not yet reported to be recolonizing Green Bay or Saginaw Bay. *Hexagenia* populations also have been increasing in parts of the upper Mississippi River, where they also are native.



*Exoskeletons of* Hexagenia *nymphs floating on lake surface at Port Clinton, Ohio, June 1995.*

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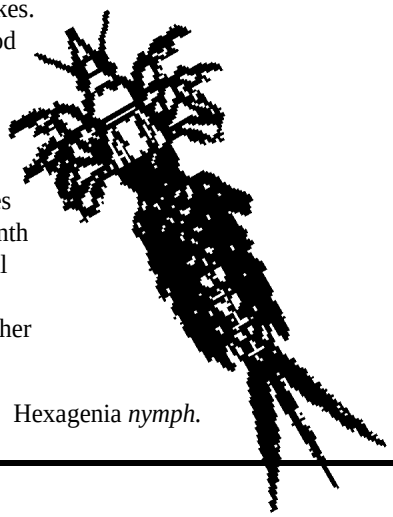
## Can we control mayflies?

As is true of other highly successful and widespread invertebrate and fish species in the Great Lakes, such as the unwanted zebra mussel and Eurasian ruffe *(Gymnocephalus cernuus)*, we have no effective controls for *Hexagenia*. Insecticides to control the nymphs would kill other fish food organisms and would probably render the water unfit for fish and unsafe for humans. Surely a return to the sort of nutrient enrichment and toxic contamination that probably led to the disappearance of the mayflies four decades ago is unacceptable to most Great Lakes citizens.

Besides, *Hexagenia* is native to the Great Lakes. Historically, it played an important role in the food webs of the lakes' aquatic ecosystems. The recent swarms of this clean-water-loving insect bear testimony to the successful, if still incomplete, efforts to improve the environmental quality of Lake Erie. Scientists agree that the inconveniences caused by swarms of mayflies during about a month each summer are more than offset by the potential benefits to the sport and commercial fisheries of the western basin of Lake Erie and parts of the other Great Lakes.



Hexagenia *nymph.*

*Credit: Great Lakes Science Center, U.S.G.S.*

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