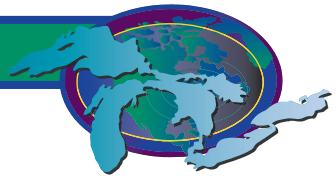

Hexagenia

Indicator # 122

Overall Assessment

Status:	**Mixed**
Trend:	**Improving**
Rationale:	**There is a lack of time-series data and historical information. To date, only one area (western Lake Erie) has exhibited any substantial recovery of *Hexagenia* despite anecdotal reports of recovery for many areas in the Great Lakes during the mid- to early 1990s. After an absence of 50 years, emerging *Hexagenia* were observed in the open waters of western Lake Erie in 1992. Studies confirmed the return of nymphs to sediments between 1995 and 2005. At that time, the annual average density of nymphs was approximately 300 nymphs/m^2, a density similar to known historical abundances of nymphs in the basin. The return of this taxon may be entering the final stage of its recovery (stable annual abundances). However, large decreases in density (1997 to 1998 and 2001 to 2002) and poor young-of-year recruitment into the population (3 of 6 years) indicate that 'restoration' of nymphs has not been totally successful. The cause(s) for population decreases and failed recruitment is not known, but it is suspected to be related to residual pollution. Effects of residual pollution will likely decrease as pollution-abatement programs continue.**

Lake-by-Lake Assessment

Lake Superior

Status:	Poor
Trend:	Undetermined
Rationale:	Lack of time-series and historical information. Baseline (2001) information on the abundance of *Hexagenia* has been obtained for Duluth Harbor, Minnesota and Wisconsin.

Lake Michigan

Status:	Poor
Trend:	Undetermined
Rationale:	Lack of time-series and historical studies. There have been no scientific conformations of anecdotal reports of *Hexagenia* except for sporadic accounts of adults near the Fox River, Green Bay, Wisconsin. The absence of *Hexagenia* in Green Bay, Wisconsin was confirmed in 2001.

Lake Huron

Status:	Poor
Trend:	Undetermined
Rationale:	Lack of time-series and historical information. There have been no scientific conformations of anecdotal reports of *Hexagenia* adults. The absence of *Hexagenia* in Saginaw Bay was confirmed in 2001.

Lake Erie

Status:	Western Lake Erie - Good;	SW-shore of Central Lake Erie - Mixed
Trend:	Western Lake Erie - Improving;	SW-shore of Central Lake Erie - Deteriorating
Rationale:	To date, western Lake Erie is the only place where *Hexagenia* have been documented to be recovering in the Great Lakes. Initial signs of recovery of *Hexagenia* (i.e., appearance and increasing distribution of adults) along the south shore of central Lake Erie occurred 1997-2000. However, since that time, reports have decreased and intensive lake sampling (2001-2004) has not been able to confirm *Hexagenia* recovery.	

Lake Ontario

Status:	Not Assessed
Trend:	Undetermined
Rationale:	Lack of baseline studies and historical information. There have been no scientific conformations of anecdotal reports of mayflies near the Bay of Quinte, Ontario.

Purpose

- To assess the distribution and abundance of burrowing mayflies (*Hexagenia*) in the Great Lakes
- To establish a quantitative goal for the restoration of *Hexagenia* nymphs in mesotrophic waters of the Great Lakes

Ecosystem Objective

Historical mesotrophic habitats should be restored and maintained as balanced, stable, and productive elements of the Great Lakes ecosystem with *Hexagenia* as the key benthic invertebrate organism in the food chain (paraphrased from Edwards and Ryder, eds. 1990). In addition, this indicator supports Annex 2 of the Great Lakes Water Quality Agreement (United States and Canada 1987).

State of the Ecosystem

In the early 20th century, mesotrophic ecosystems in the Great Lakes had unique faunal communities that included commercially valuable fishes and associated benthic invertebrates. The primary invertebrate taxon associated with mesotrophic habitats was *Hexagenia*. *Hexagenia* was chosen by the scientific community to be a mesotrophic indicator because it is important to fishes, is relatively long lived, lives in sediments where pollution often accumulates, and is relatively sensitive to habitat changes brought on by urban and industrial pollution associated with changes as mesotrophic systems deteriorate to eutrophic systems (Schloesser and Hiltunen 1984; Schloesser 1988; Reynoldson *et al*. 1989). For example, *Hexagenia* was very abundant and important to yellow perch and walleye in the 1930s and 1940s. Then in the mid-1950s, *Hexagenia* was eliminated by low oxygen and resulting anoxic conditions created by urban and industrial pollution, and growth of yellow perch declined (Beeton 1969; Burns 1985).

Initiation of pollution-abatement programs in the 1970s improved water and sediment quality in *Hexagenia* habitat throughout the Great Lakes, but the recovery of *Hexagenia* populations has been elusive (Krieger *et al*. 1996; Schloesser *et al*. 2000). Then in the early 1990s, soon after the invasion of exotic dreissenid mussels, anecdotal reports occurred of adult *Hexagenia* (winged dun and spinner) in many bays and interconnecting rivers of the Great Lakes after absences of 30 to 60 years (Figure 1).

The first sign of the potential recovery of *Hexagenia* in western Lake Erie began with an anecdotal report of adult mayflies in open waters of the basin by scientists on the research vessel CCGS *Limnos* (Krieger *et al*. 1996; Madenjian *et al*. 1998; Schloesser *et al*. 2000). Nymphs were confirmed in sediments at very low densities (ca. 9 nymphs/m^2) in 1993, and intensive studies began in 1995 (Krieger *et al*. 1996; Schloesser, unpublished data; Figure 2). Densities of nymphs increased between 1995 and 1997 and then decreased between 1997 and 1998. This pattern of increasing densities followed by a large decrease occurred again between 2001 and 2002. A population study of *Hexagenia* revealed that sharp declines in densities were partly attributable to failed young-of-year (YOY) recruitment (Bridgeman *et al*. 2005; Figure 3). No YOY nymphs were found in 1997, which corresponded to the largest observed decline in *Hexagenia* density during the last decade. A similar decline occurred between 2001 and 2002 when few YOY nymphs were produced. However, a slight increase occurred between 2002 and 2003 even though relatively few YOY nymphs were recruited into the population, indicating that some other factor(s) contributed to density fluctuations observed in western Lake Erie in the 1990s and 2000s.

Anecdotal reports of winged *Hexagenia* mayflies in the 1990s also included the south shore of Lake Michigan (near Chicago, IL); the Fox River near Green Bay (Lake Michigan); Saginaw Bay near Standish, MI (Lake Huron); the south shore of central Lake Erie near Sandusky, OH; Presque Isle, PA (eastern Lake Erie); and the northern shore in the Bay of Quinte near Picton, ON (Lake Ontario). To date, only the possible recovery of *Hexagenia* along the south shore of central Lake Erie has been investigated (Krieger *et al.* 2007). An initial recovery of nymphs occurred along the south shore between 1997 and 2000. However, intensive scientific surveys between 2001 and 2004 indicate that a sustained recovery of *Hexagenia* along the shore of south central Lake Erie has not occurred.

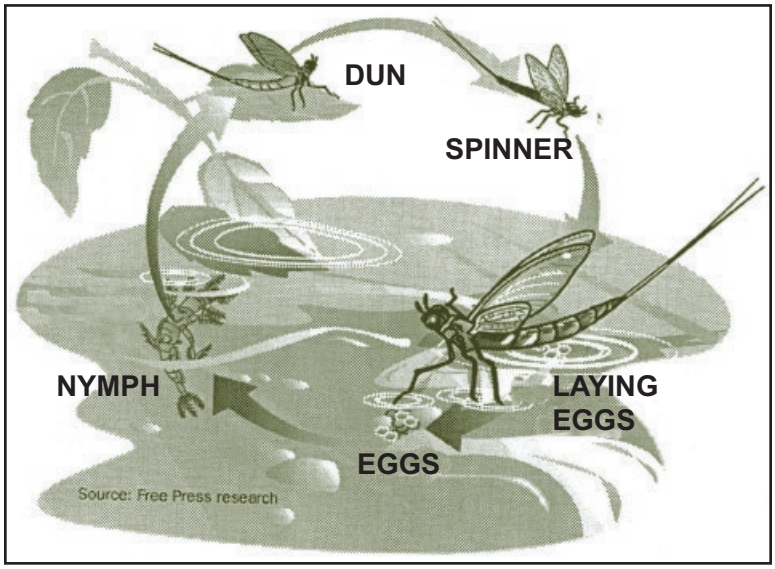

Figure 1. Typical life-cycle of a burrowing mayfly such as *Hexagenia* found in the Great Lakes.
Source: Drawn by Martha Thierry, courtesy of the Detroit Free Press

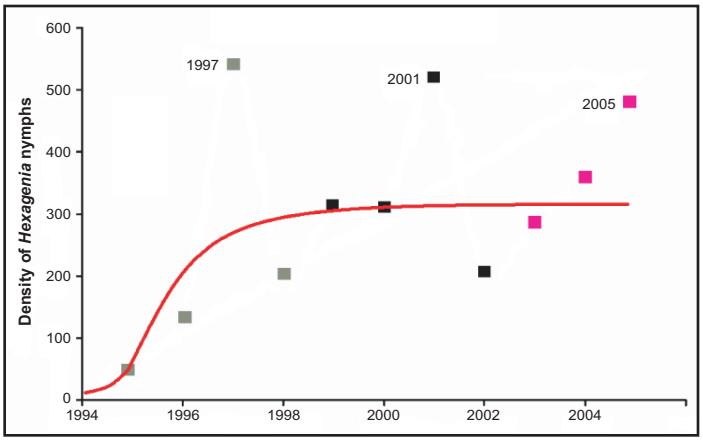

Figure 2. Densities (number/m^2) of *Hexagenia* obtained in three studies (colored markers) in western Lake Erie 1995-2005. Line of abundance fit by eye.
Source: Unpublished data, D. Schloesser

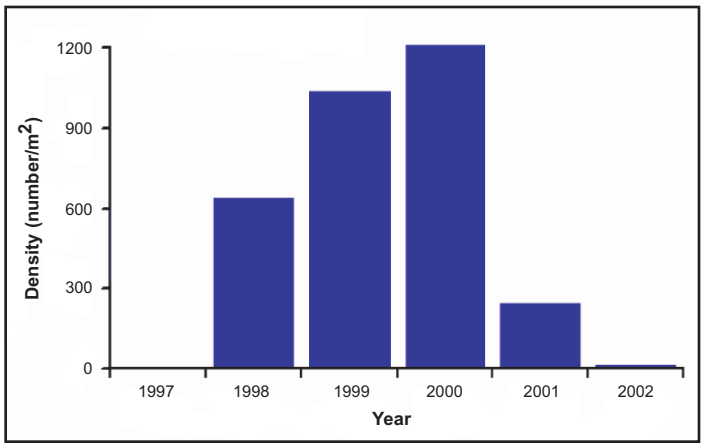

Figure 3. Recruitment of young-of-year *Hexagenia* in western Lake Erie 1997-2002
Source: Schloesser and Nalepa (2001); Bridgeman *et al.* (2005)

Pressures

Hexagenia are extirpated at moderate levels of pollution and may even show a graded response to the degree of pollution (Edsall *et al.* 1991, Schloesser *et al.* 1991). High *Hexagenia* abundance is strongly indicative of adequate levels of dissolved oxygen in overlying waters and uncontaminated surficial sediments. Probable causative agents of impaired *Hexagenia* populations include excess nutrients, oil, heavy metals, and various other pollutants in surficial sediments.

A portion of the general public has developed a negative perception of *en masse* swarms of adult *Hexagenia* because they can disrupt recreational use of shorelines, and this perception has been incorporated into management goals for the recovery of *Hexagenia* in western Lake Erie (see Management Implications below). Such perceptions may create pressures for management to implement actions that manage lake systems below the natural carrying capacity of *Hexagenia* in mesotrophic waters of the Great Lakes.

Management Implications

Management entities in both Europe and North America desire some level of abundance of burrowing mayflies, such as *Hexagenia*, in mesotrophic habitats (Fremling and Johnson 1990, Bij de Vaate *et al.* 1992, Ohio Lake Erie Commission 1998). Recoveries of burrowing mayflies, such as *Hexagenia* spp., in rivers in Europe and North America and now in western Lake Erie clearly show how properly implemented pollution controls can bring about the recovery of large mesotrophic ecosystems. With recovery, *Hexagenia* in the Great Lakes will probably reclaim its functional status as a major trophic link between detrital energy pools and economically valuable fishes such as yellow perch and walleye.

The recovery of *Hexagenia* in western Lake Erie reminds us of an outstanding feature associated with using *Hexagenia* as an indicator of ecosystem health - the massive swarms of winged adults that are typical of healthy, productive *Hexagenia* populations. These swarms are highly visible to the public who use them to judge success of pollution-abatement programs by seeing a 'real' species that signifies the return of a 'real' habitat to a desirable condition in the Great Lakes. This public perception has influenced target values set by management for the recovery of *Hexagenia* in western Lake Erie (i.e., imperiled and good above excellent, Figure 4). However, values above excellent are based on societies' perception of excessive *en masse* emergences of winged *Hexagenia* which affect electrical power generation, vehicle traffic, and outdoor activities. These values may not represent the best scientific information for the historic, natural carrying capacity of *Hexagenia* in mesotrophic waters. For example, the target value of excellent is based on historical densities, a desire to return the system to an earlier, more 'pristine' condition and to provide prey for valuable fishes. Yet, there is no scientific information that indicates densities of nymphs above 'excellent' would be in conflict with historical data, previous system conditions, and prey availability to fishes.

Comments from the author(s)

In the early 20th century, *Hexagenia* were believed to be abundant in all mesotrophic waters of the Great Lakes including Green Bay

(Lake Michigan), Saginaw Bay (Lake Huron), Lake St. Clair, western Lake Erie, Bay of Quinte (Lake Ontario), and portions of interconnecting rivers and harbors. Thirty years of pollution-abatement programs may have allowed *Hexagenia* to return to other areas of the Great Lakes besides western Lake Erie as evidenced by anecdotal sightings of winged mayflies in the 1990s. However, anecdotal reports have slowed and only one scientific study (Krieger *et al.* 2007) has been performed to confirm anecdotal reports, and that study in central Lake Erie could not verify any *Hexagenia* recovery.

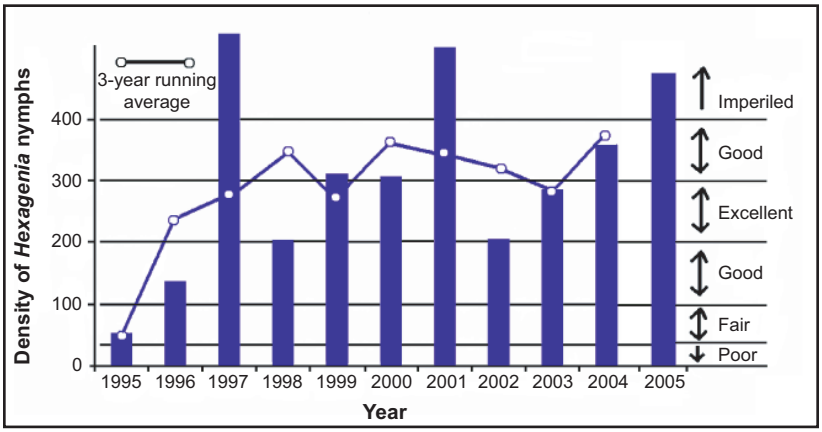

Figure 4. Densities (number/m²) of *Hexagenia,* three-year running average of densities, and subjective target-reference values of desired abundance (i.e., poor, fair, good, etc.) in western Lake Erie.
Source: Based on - Ohio Lake Erie Commission (2004)

The only sustained recovery of *Hexagenia* in the Great Lakes (i.e., western Lake Erie) should be monitored for another 4 to 6 years to determine annual variability and the carrying capacity of this taxon in mesotrophic waters. If scientifically measured, the recovery will provide management agencies with a quantitative endpoint of *Hexagenia* density, which can be used to measure recovery to a mesotrophic state in waters throughout the Great Lakes. In addition, a scientifically determined carrying capacity of *Hexagenia* may also be useful as a benthic indicator for remediation of contaminated sediments and as a guide for acceptable levels for food for valuable percid communities. Contaminant levels in sediments that meet USEPA and OMOE guidelines (i.e., "clean dredged sediment") and IJC criterion for oil and hydrocarbons (i.e., "sediment not polluted") will not impair *Hexagenia* populations. There will be a graded response to concentrations of metals and oil in sediment exceeding these guidelines for clean sediment. Reductions in phosphorus levels in formerly eutrophic habitats are likely to be accompanied by colonization of *Hexagenia*, if surficial sediments are otherwise uncontaminated. Since *Hexagenia* can be one of the largest and most abundant prey for percid fishes such as yellow perch and young walleye, the reestablishment of *Hexagenia* in nearshore waters of Great Lakes should be encouraged.

Acknowledgments
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