Indicator: *Hexagenia* Density and Distribution in the Detroit River

Background

The abundance of the different types of aquatic invertebrates in various places of the river is controlled largely by the current and its effects on the river bottom. These differences in habitat must be taken into account when one attempts to evaluate potential effects of human-related activities on the benthic community.

Currents in the main part of the river wash away fine sediments, leaving a substrate composed mainly of stones and hard clay (erosional areas). Some animals can shelter beneath or between the stones, but the most abundant species can attach themselves to the substrate or build shelters for themselves (e.g., net-spinning caddisflies, limpets, dreissenid mussels, flatworms).

Slower-flowing parts of the Detroit River (depositional areas) have a muddy or sandy bottom. These are also the areas where debris carried from upstream settles out. The benthic animals living here burrow into the mud and feed upon the organic debris and the attached bacteria and fungi present in the sediments. When the organic content of the sediments is high, bacterial respiration can remove much of the oxygen from the water, making the habitat suitable only for tolerant species. These are also regions where pollutants that aren't water soluble tend to collect. Because oils and trace amounts of metals adhere to the organic matter in the mud, the zoobenthos of depositional zones tend to bioaccumulate these materials from their food.

The most common benthic animals living in depositional zones are worms (Oligochaeta), midge larvae (Chironomidae), and *Hexagenia* mayfly nymphs (Ephemeroptera) (Figure 1). *Hexagenia* is a dominant component of the benthic fauna of muddy and silty sediments in mesotrophic lakes and rivers. Historically, *Hexagenia* mayflies were abundant throughout the Huron-Erie Corridor and the western basin of Lake Erie. Mayfly nymphs dig U-shaped burrows. They undulate their abdomen and wave their feather-like gills which forces oxygen-rich water through the burrow. Because mayflies can't survive in water that lacks oxygen, they are good indicators of the amount of organic pollution (e.g., sewage). For example, when water quality conditions are good, one expects to find 100 *Hexagenia* larvae/m^2 or more in clean muddy sediments of Lake Erie (Wright and Tidd 1933). *Hexagenia* mayflies have been proposed as an ecosystem indicator of mesotrophic conditions in soft-sediment habitats of the Great Lakes

Figure 1. Hexagenia *mayfly nymphs (Ephemeroptera) (Photo credit: Lynda Corkum).*

(Reynoldson et al. 1989). The Ohio Lake Erie Commission's (2004) *Hexagenia* index classifies conditions as excellent where sediments contain 200-300 larvae/m^2. Areas dominated by worms and midges, rather than mayflies, are classed as having degraded water quality or benthic conditions.

Thornley and Hamdy (1984), Hudson et al. (1986), Manny et al. (1988) and Farara and Burt (1993) all reported *Hexagenia* as an indicator of relatively undegraded benthic conditions in the soft sediments of the Detroit River. *Hexagenia* densities of less than 20/m^2 in depositional habitats suggest degradation (Thornley and Hamdy 1984; Ciborowski 2003b). However, Edsall et al. (2001) reported that *Hexagenia* production (i.e., a combined estimate of growth and abundance) was a more sensitive indicator of suitable ecological conditions than density alone.

Status and Trends

Larval Distribution

Some of the earliest Great Lakes zoobenthos surveys were conducted in 1929-1930 by Wright and Tidd (1933) in western Lake Erie and at the mouth of the Detroit River, as well as other Lake Erie tributaries. Among other zoobenthos, they reported snails, fingernail clams, and worms. However, mayfly larvae were conspicuously absent, indicating light to moderate pollution at the Detroit River mouth.

The Trenton Channel has long been identified as a degraded area based on zoobenthos composition and abundance. Surveys conducted between 1949 and 1956 showed that the lower Detroit River and the western Trenton Channel were dominated by pollution-tolerant forms, indicating a decrease in water quality from the 1929-1930 surveys. Carr and Hiltunen (1965) showed that the spatial extent and severity of degradation at the mouth of the Detroit River had increased substantially from that described by Wright and Tidd (1933). Later surveys reported that although the Detroit River mouth contained only very pollution-tolerant organisms (worms and leeches), zoobenthos composition and abundance upstream of Belle Isle was indicative of good water quality (Vaughan and Harlow 1965).

Several surveys of the bottom fauna of the Detroit River were conducted between the 1960s and 1990 (Thornley 1985; Hudson et al. 1986; Ferrara and Burt 1993). In 1968, the bottom fauna over large tracts of the Detroit River suggested that sediments and water quality were degraded. Mayflies were found in only about 25% of the locations sampled, and then only in low numbers (10-20/m^2, Thornley and Hamdy 1984). Mayflies were completely absent from the United States shoreline except near the upstream end of Belle Isle (Figure 2). Almost no zoobenthos could be found in the vicinity of Zug Island.

Pollution controls put in place during the 1970s resulted in improved water and sediment quality in many areas. When the river was surveyed again in 1980, mayflies were found at over 70% of the locations examined, and they were 5 times more abundant than in 1968 (Thornley 1985; Figure 3). Densities exceeded 20/m^2 in both the upper and lower reaches of the Detroit River, being absent mainly south of Zug Island and in the Trenton Channel.

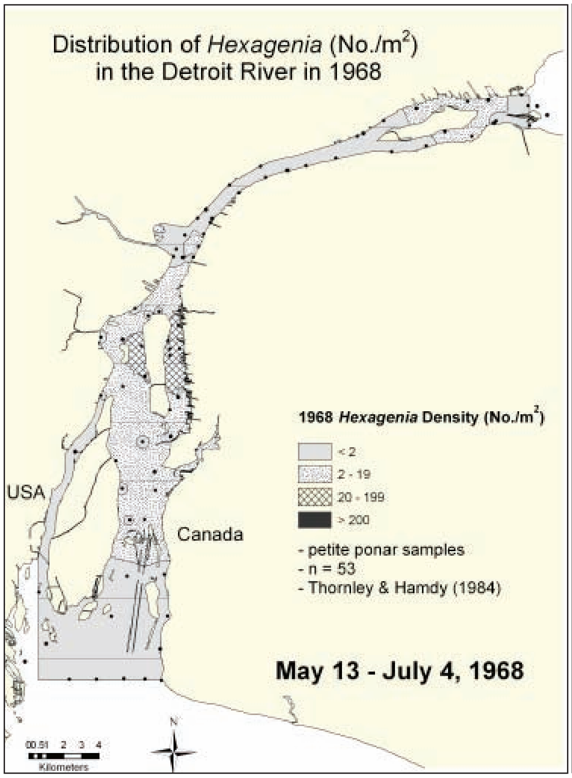


Figure 2. *Density of* Hexagenia *in the Detroit River in 1968 interpolated from data compiled from Thornley and Hamdy (1984). Areas containing fewer than 20 nymphs/m^2 indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.*

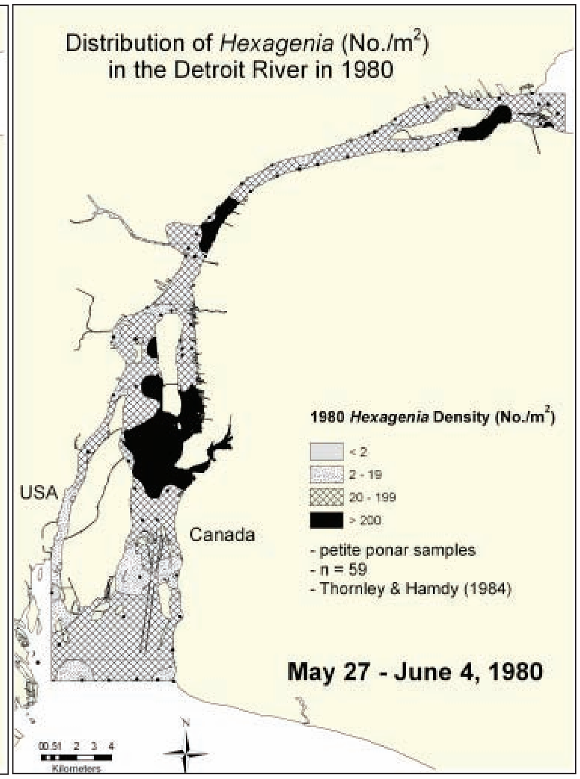


Figure 3. Density of Hexagenia *in the Detroit River in 1980 interpolated from data compiled from Thornley and Hamdy (1984). Areas containing fewer than 20 nymphs/m^2 indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.*

Few changes in either the distribution or abundance of mayfly nymphs were seen between the 1980 survey, a 1983 investigation (Hudson et al. 1986), and a study done in 1991 (Farara and Burt 1993). In 1991, *Hexagenia* mayflies were found at about 60% of locations sampled, at densities of between 8 and 100 nymphs/m^2 (Figure 4). However, more of the river supported densities slightly less than the 20/m^2 criterion suggested to indicate impairment (Ciborowski 2003b) than had been observed in 1980. Worms and midges remained the most common invertebrates along the United States shoreline of the river downstream from Zug Island.

Little benthic sampling was conducted in the Detroit River through most of the 1990s, so information on health of the zoobenthic community during this time is scarce. However, the flying adult stages of *Hexagenia* and other aquatic insects became more numerous along both the Canadian and United States sides of the river and along the shores of Lake Erie (Ciborowski and Corkum 1988; Kovats 1990; Kovats et al. 1996; Corkum et al. 1997) suggesting that some improvements in river condition had been occurring.

The Detroit River was next intensively studied in 1999. Samples were collected from almost 150 locations (Wood 2004; Figure 5). Densities exceeded the 20 nymph/m^2 impairment threshold at the head of the river and on the Canadian side of the lower reaches. Few nymphs were collected in the midreaches, however.

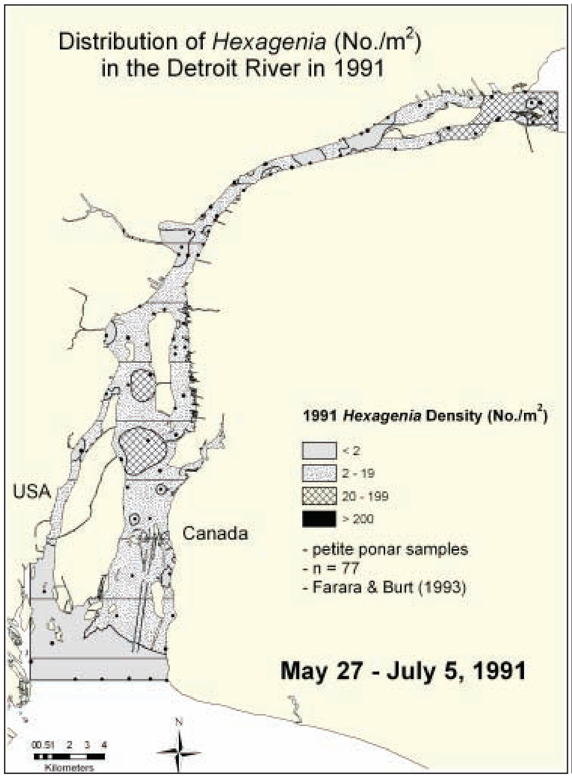


Figure 4. Density of Hexagenia *in the Detroit River in 1991 interpolated from data compiled from Farara and Burt (1993). Areas containing fewer than 20 nymphs/m*^{2} *indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.*

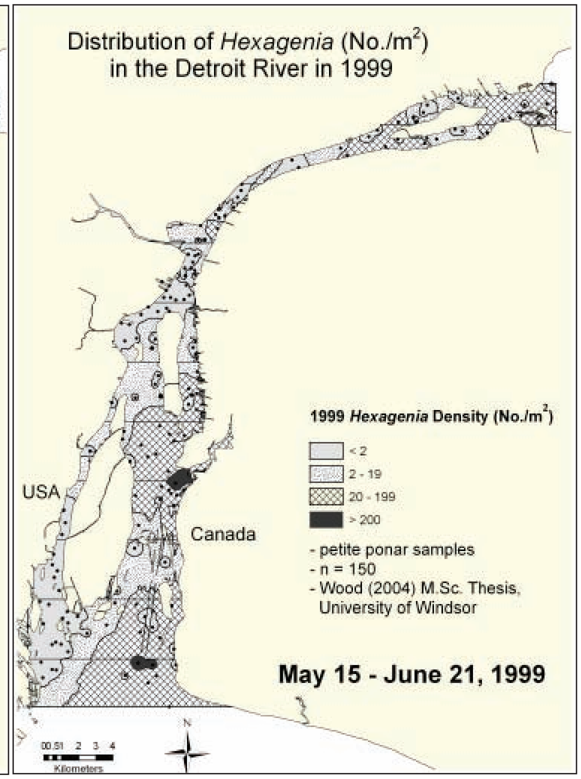
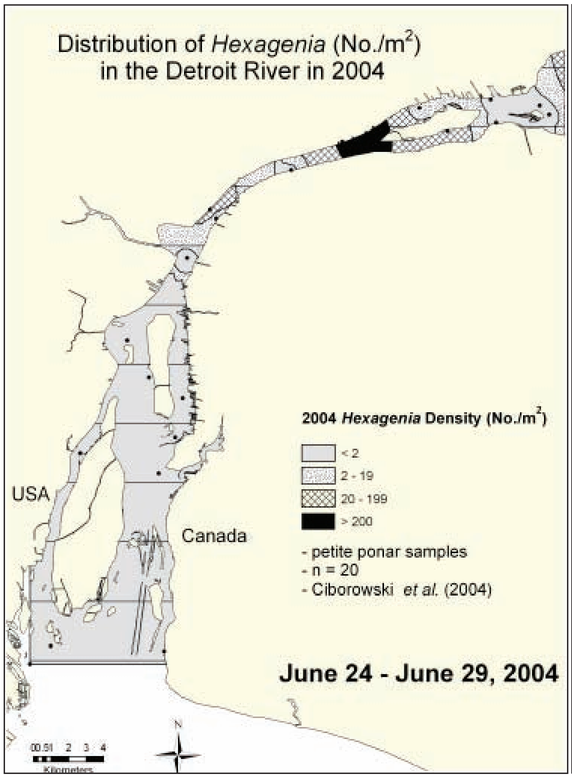


Figure 5. Density of Hexagenia *in the Detroit River in 1999 interpolated from data compiled from Wood (2004). Areas containing fewer than 20 nymphs/m*^{2} *indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.*

The entire Huron-Erie Corridor was sampled in 2004. A suite of 20 randomly-selected locations sampled in July and August 2004 produced a distributional pattern similar to that observed in 1968 (Ciborowski et al. 2006; Figure 6). However, this was partly due to the timing of sampling. In 2004, many samples were collected in July after the period of maximum emergence, but before nymphs representing the next generation had hatched from their eggs. Densities were moderate or high in much of Lake St. Clair and lower reaches of the St. Clair River (Figure 7).

Riverwide Frequency and Abundance

Figure 8 summarizes the trends in *Hexagenia* abundance average across all samples for surveys conducted since 1968. *Hexagenia* mayfly nymphs were found in 70% of the 59 stations sampled in 1980 compared to only 26% of 53 stations in 1968 (Thornley and Hamdy 1984). The greatest changes in occurrence occurred along the Canadian shoreline. The mean density of *Hexagenia* in 2004 was 20/m^2, but distribution was restricted to fewer locations than previously (Ciborowski et al. 2006), partly due to timing of sampling, as indicated above.



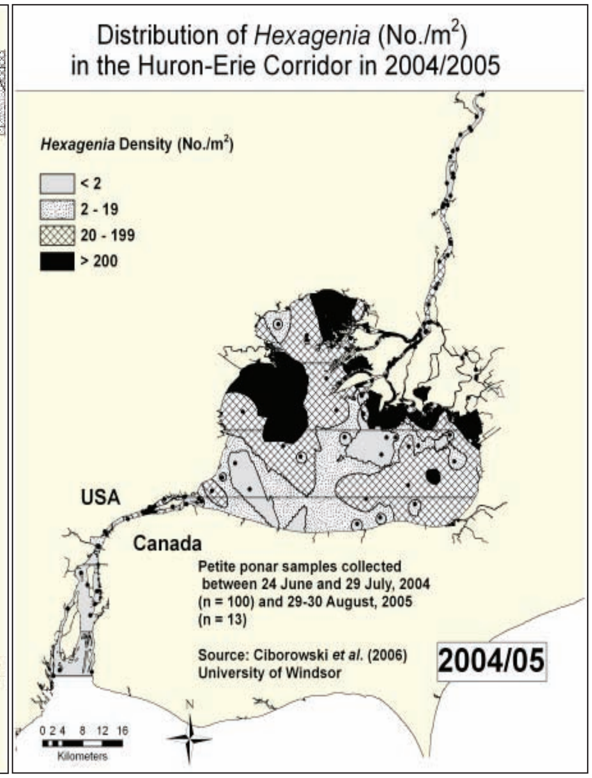


Figure 6. Density of Hexagenia *in the Detroit River in 2004 interpolated from data compiled from Ciborowski et al. (2006). Areas containing fewer than 20 nymphs/m^2 indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.*

Figure 7. Density of Hexagenia *in the Huron-Erie Corridor in 2004/05 interpolated from data compiled from Ciborowski et al. (2006). Areas containing fewer than 20 nymphs/m^2 indicate either degraded benthic conditions (if sediments are soft) or unsuitable habitat for mayflies (if sediments are hard). Map by Anita Kirkpatrick.*

Adult Abundance and Contaminant Burdens

Improvements in Detroit River water quality have been most obviously shown in the numbers of night-flying insects that are attracted to streetlights and storefronts along the river during warm summer evenings. Both *Hexagenia* mayflies and moth-like caddisflies emerge from the river in summer to mate and lay their eggs. Emerging *Hexagenia* (commonly called fishflies or June bugs) are most abundant for a few weeks from the middle of June until mid-July. Strong winds can carry the insects long distances inland from the river, but typically, most travel only a few hundred meters (Kovats et al. 1996).

Although the insects are a nuisance, they are an important food for birds and fishes during their emergence period. They also provide a valuable tool for monitoring contaminant levels in the river. On a warm evening, a black light placed beside the river will quickly attract enough biomass to provide a sample that can be analyzed for PCBs, heavy metals, and other pollutants associated with contaminated sediments (Corkum et al. 1995). Ciborowski and Corkum (1988), Kovats (1990), and Corkum et al. (1997) analyzed organic contaminant burdens in *Hexagenia* mayflies emerging at the head of the Detroit River near Peche Island. Concentrations of PCBs, pesticides, and other organochlorine compounds were virtually identical in 1986, 1989, and 1994. Yet, the numbers of emerging insects, and their distribution along the river, have continued to increase through the 1990s (Corkum et al. 1997).

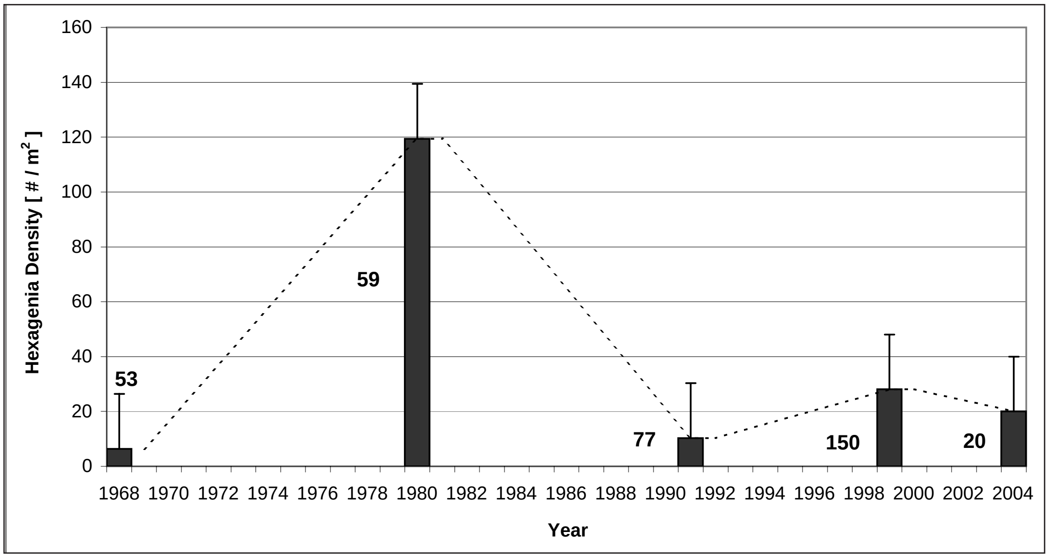


Figure 8. Mean ±SE density of Hexagenia *in the Detroit River between 1968 and 2004. The number of sites sampled each year is indicated. *Data compiled from Thornley and Hamdy (1984), Farara and Burt (1993), Wood (2004), and Ciborowski et al. (2006).*

Contaminant burdens (PCBs, pesticides, and other organochlorine compounds) of *Hexagenia* adults collected from shorelines of western Lake Erie in 1994 were elevated relative to collections made in offshore areas. Adults collected from Monroe, Michigan, adjacent to the mouth of the Detroit River had the highest burdens of any samples. Burdens of trace metals were not unduly elevated. *Hexagenia* larvae collected from the vicinity of Middle Sister Island in western Lake Erie had high burdens of organochlorine compounds and polycyclic aromatic hydrocarbons (Corkum et al. 1997).

Management Next Steps

The available data show which portions of the river have historically been most heavily degraded by organic enrichment and those that are still affected by nutrient-rich water, primarily sewage and stormwater. The present-day distribution of *Hexagenia* nymphs suggests that current sediment and water quality conditions have not improved enough to permit nymphs to develop in those degraded areas. However, surveys have been conducted too infrequently to permit us to ascertain the extent to which year-to-year variation in distribution reflects changing pollution status vs. normal fluctuations in the mayfly population. Continued attention to point sources of pollution will be necessary to permit *Hexagenia* to populate all of the depositional habitats in the Detroit River.

Research/Monitoring Needs

Hexagenia surveys have been conducted too infrequently to permit one to ascertain whether the time trend patterns represent changing environmental conditions or random interannual variation. Ideally, sampling should be conducted yearly, and surveys should be completed in the spring, prior to the period of adult emergence (ideally during the months of April and May). Sampling methods (collection times, determination of site locations, number of sites sampled) should be standardized across years to improve the precision of riverwide density estimates.

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(Sections of this summary are taken directly from Ciborowski (2003a))