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J. Great Lakes Res. 19(4):648–659
Internat. Assoc. Great Lakes Res., 1993

Deformities of Aquatic Larval Midges (Chironomidae: Diptera) in the Sediments of the Buffalo River, New York

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ABSTRACT. *We conducted an extensive survey of the benthic macroinvertebrate fauna of the heavily polluted Buffalo River (New York) Area of Concern (AOC), with specific emphasis on assessment of morphological deformities of aquatic larval midges (Chironomidae: Diptera). Sediments were sampled on seven occasions during 1990 - 1991, from as many as 20 sites. Abnormal mouthparts (menta) were most frequent among larvae of the genus* Chironomus, *occurring in 29.0% of all specimens in the Buffalo River (n = 755), and 22.4% in the adjacent Ship Canal (n = 98). Individual sites in the downstream section of the river yielded even higher deformity frequencies; 36.9% (n = 84), 48.1% (n = 27), and 66.7% (n = 9). The frequencies of abnormalities in this genus at all sites within the AOC were well above levels normally observed (0 - 3%) at non-industrial sites. Additionally, abnormal mouthparts (ligulae) were seen in 3.1% of larvae of the genus* Procladius *(n = 1,677). While individual downstream samples of* Procladius *were occasionally as much as 15.4% abnormal (n = 26), this genus was much less prone to morphological deformities than* Chironomus. *Abnormal menta were also noted in the genera* Polypedilum, Cryptochironomus, *and* Dicrotendipes, *but were infrequent. Community parameters such as richness and diversity of the chironomid fauna, and the prevalence of oligochaetes, provide further evidence of decreased environmental quality within the downstream reaches of the Buffalo River. The data presented here provide one biologically relevant measure against which to gauge the effectiveness of pollution abatement strategies within the AOC.*

INDEX WORDS: *Chironomid larvae, deformities, sediments, Buffalo River.*

INTRODUCTION

The impact of industrial contaminants remains one of the greatest threats to the health of aquatic ecosystems. Increasing attention has focused on the responses of affected organisms (Milbrink 1983, Baumann 1984, Warwick 1990b, Dermott 1991) and communities (Wilhm and Dorris 1966, Rosenberg and Wiens 1976, Krieger 1984, Thornley 1985, Hart *et al.* 1986) as general indicators of environmental degradation. The occurrence of morphological abnormalities in aquatic larval midges (Chironomidae) offers one promising, biologically relevant early warning of the effects of contaminants on the biota (reviewed in Warwick 1988, 1990b).

Hamilton and Saether (1971) noted deformed mouthparts (menta) in larvae of the midge *Chironomus* in western Lake Erie and in two British Columbia lakes. Deformed specimens occurred in areas of industrial or agricultural (insecticide) chemical input, but not in areas receiving only domestic effluents. Subsequent studies (Hare and Carter 1976, Koehn and Frank 1980, Weiderholm 1984, Warwick 1985, Warwick 1990a, Warwick *et al.* 1987, Warwick and Tisdale 1988, Pettigrove 1989, Dermott 1991) have further demonstrated the connection between chemical contamination and abnormalities of several chironomid genera, and the apparent lack of any influence of nutrient loading (Hare and Carter 1976) or thermal discharge (Koehn and Frank 1980).

This study represents a 1-year evaluation of the benthic macroinvertebrate fauna of the heavily industrialized Buffalo River, with emphasis on the distribution of the Chironomidae, and on morphological abnormalities of five chironomid genera: *Chironomus, Procladius, Polypedilum, Cryptochi-*

ronomus, and *Dicrotendipes*. The results obtained here may be compared with those from other environments, both industrial and non-industrial, and provide one measure against which to gauge the success of future remediation efforts within the Buffalo River.

STUDY SITE

The Buffalo River flows into eastern Lake Erie, and forms part of the harbor of Buffalo, New York (Fig. 1). Although its watershed comprises 1,155 km^2 (Lee *et al.* 1991) and is largely rural or residential, the lowest 9 km of the river pass through a heavily industrialized section of the city. An oil refinery and tank farm, rail yards, chemical and dye manufacturers, scrap yards, and active and abandoned grain elevators line most of these 9 km. The International Joint Commission (IJC) lists the lower Buffalo River as one of 43 Great Lakes Areas of Concern (AOC).

A navigable channel is maintained for most of

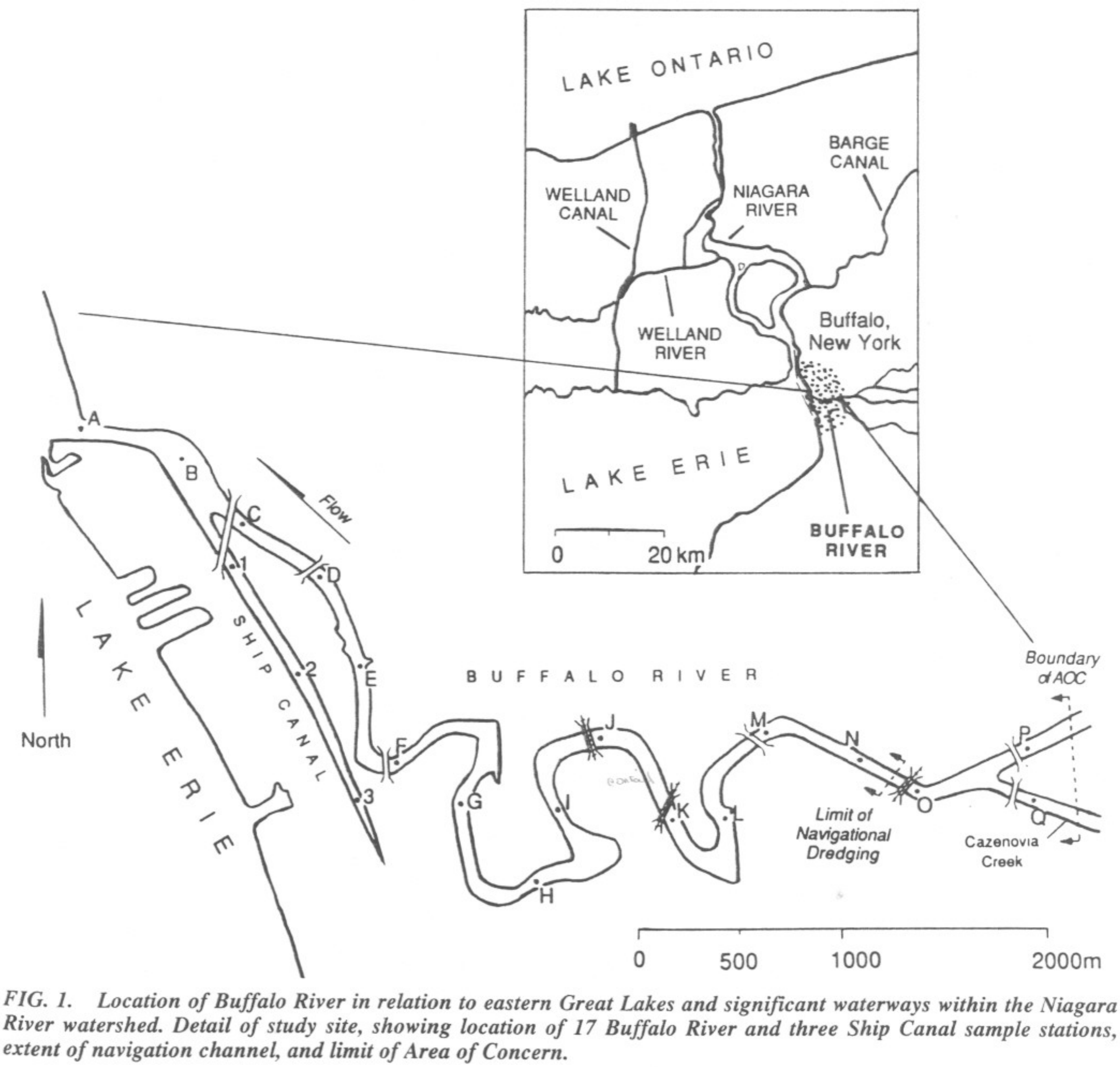

FIG. 1. Location of Buffalo River in relation to eastern Great Lakes and significant waterways within the Niagara River watershed. Detail of study site, showing location of 17 Buffalo River and three Ship Canal sample stations, extent of navigation channel, and limit of Area of Concern.

the river within the AOC, ending at the Conrail railway bridge downstream of site O (Fig. 1). Depth at the upper end of this channel is approximately 6-7 m, increasing to 7-8 m downstream from site M. The river is shallower upstream of site O, particularly above the confluence with Cazenovia Creek (1-2 m). Sediments are coarse and gravelly at upstream sites O, P, and Q, but consist mainly of fine muds and silts downstream from these sites. Organic debris such as leaves and twigs were sometimes encountered. Gravel-sized coal slag was often present in sediments at sites C, D, and at site #1 in the Buffalo Ship Canal.

The Buffalo River suffers numerous water quality impairments as defined by the IJC, including restrictions on recreation, fish consumption, water consumption, and loss of wildlife habitat (Lee *et al.* 1991). A long history of industrial discharge, urban drainage, and leakage from disposal facilities has contaminated river sediments with both heavy metal and hydrocarbon pollutants (Nelson and Hites 1980, Lee *et al.* 1991).

METHODS

Sediments were sampled from the entire Buffalo River AOC on seven occasions between 16 November 1990 and 16 November 1991. Twelve sites were sampled initially, with five sites added later to increase the spatial resolution of this study (Fig. 1). Sampling extended approximately 9 km from the river's confluence with Cazenovia Creek to its mouth at the Buffalo harbor. Three additional sites were sampled along the Buffalo Ship Canal.

Six petite Ponar grab samples (15 cm × 15 cm) were taken at each site on each date, and combined before analysis to yield one sample. Previous experience in the Buffalo River suggested that multiple grabs were neccessary to obtain adequate numbers of the genus *Chironomus* for assessment of abnormalities (M. D. Dickman, personal communication). Two of the six grabs were taken in the middle of each river site, and two roughly one-quarter the distance across from each bank, but within the deep navigation channel.

Sediments were passed through a 0.5 mm bucket seive in the field, retaining debris and macroinvertebrates which were transferred to glass jars. Samples were preserved in 5-10% formalin immediately upon return to the lab. Rose Bengal dye was added, and organisms were separated from remaining debris with forceps at low magnification, and preserved in 70% ethanol. Invertebrates were initially sorted into chironomids, oligochaetes, and "others," the latter of which included gastropods, sphaerid clams, zebra mussels (*Dreissena polymorpha*), leeches, and a very few other insect larvae.

Chironomid samples from each site were numerically coded and slide-mounted in random order, to ensure that assessment of abnormalities was not biased by prior knowledge of a specimen's site of origin. Some very large samples, and some samples dominated by the abundant genus *Procladius* (easily recognized under a dissecting scope), were subsampled. Head capsules were removed with a sharpened probe and cleared in warm 10% KOH. They were then transferred by pipette to distilled water and by forceps to 70% ethanol (Simpson and Bode 1980). Head capsules were mounted in Canada balsam on glass slides (see Warwick 1990b). An ordinary pencil eraser was used to apply pressure without breaking the cover slip, to fully flatten the head capsule. Chironomids were identified to genus using Simpson and Bode (1980) and Oliver and Roussel (1983). Additionally, representative specimens of the genus *Chironomus* were keyed to species group.

We catalogued the overall abundance of chironomids and oligochaetes within each sample, and calculated generic richness (# of genera) and Simpson's diversity [$D = 1/\sum(p_i^2)$, where p_i is the proportion of the community represented by genus i (Begon *et al.* 1990)], expressed as the reciprocal, for each sample of chironomids. Means and standard errors for the entire sampling period are presented for these parameters at each site.

We assessed abnormalities of the labial plates (menta) of Chironomini, and ligulae of Tanypodinae, as aberrant morphology of these heavily sclerotized structures is readily apparent, even to those without detailed entomological knowledge. Abnormal *Chironomus* menta were characterized by missing or fused teeth, extra teeth, gaps in the mentum, strong asymmetry, or a combination of these traits (Fig. 2.1). Abnormal *Procladius* ligulae deviated from the symmetrical five-toothed structure seen in normal specimens (Fig. 2.2).

Specific numerical indexing of morphological response (as in Warwick 1985, 1991; Dermott 1991) was not undertaken, but *Chironomus* specimens with multiple mentum abnormalities were noted, and considered most severely affected. Slightly asymmetrical specimens (usually involving the tripartite medial teeth) were labelled "mildly abnormal," and were not included with more definitely "deformed" larvae.

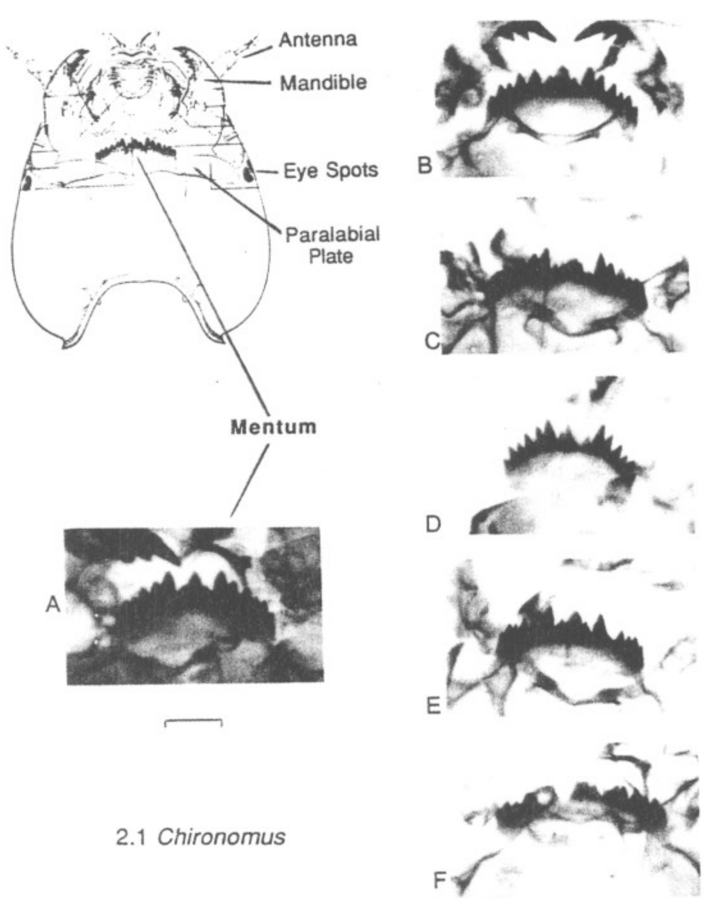

FIG. 2.1 Diagram of **Chironomus** *spp. head capsule (modfied from Oliver and Roussel 1983), and normal (A) and abnormal (B - F) menta (mentum = hypostoma, labial plate). Scale bars (photographs) = 100 μ. A. Normal. Six lateral teeth each side, trifid medial teeth, symmetrical throughout. B. One missing lateral tooth. C. Notably asymmetrical medials with small accessory teeth. D. Gap within medials. E. Gap within laterals, with one missing lateral tooth. F. Extensive deformities of medials, and missing laterals on both sides (multiple mentum abnormalities).*

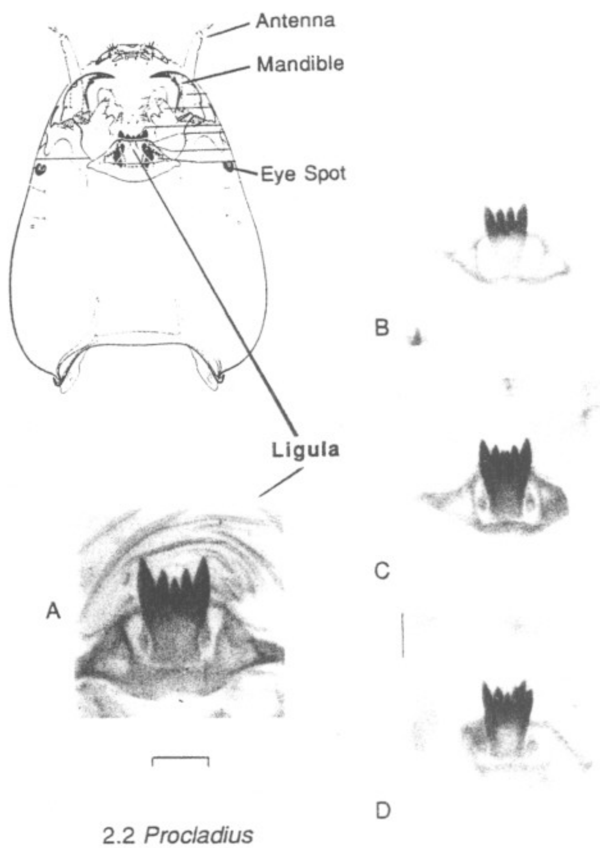

FIG. 2.2 Diagram of **Procladius** *spp. head capsule (modfied from Oliver and Roussel 1983), and normal (A) and abnormal (B - D) ligulae. Scale bars = 100 μ. A. Normal. Five teeth, symmetrical. B. Four symmetrical teeth. C. Six symmetrical teeth. D. Asymmetrical forked and extra teeth.*

RESULTS

Benthic Community

The benthic fauna of the Buffalo River were consistently dominated by the Oligochaeta and Chironomidae. Chironomids were virtually the only insects found in the river. A very few Coleoptera, Ephemeroptera, and family Ceratopogonidae (Diptera) were found, but formed an insignificant portion of the insect community. Sphaerid clams and gastropods were common below site F and above site L, and zebra mussels (*Dreissena polymorpha*) were abundant below site D. However, *Dreissena* were also found as far upstream as site P. Leeches were occasionally encountered below site H, and amphipods were infrequent and scattered.

The numbers of chironomids and oligochaetes were roughly inversely proportional upstream of site K (Fig. 3). The lowest oligochaete densities (less than 3,000 m^{-2}) were found at sites P and Q, where chironomids were most abundant (nearly 2,000 m^{-2} at site Q). Chironomids decreased and oligochaetes increased downstream to sites K and L, where oligochaetes were 30 times as numerous as chirono-

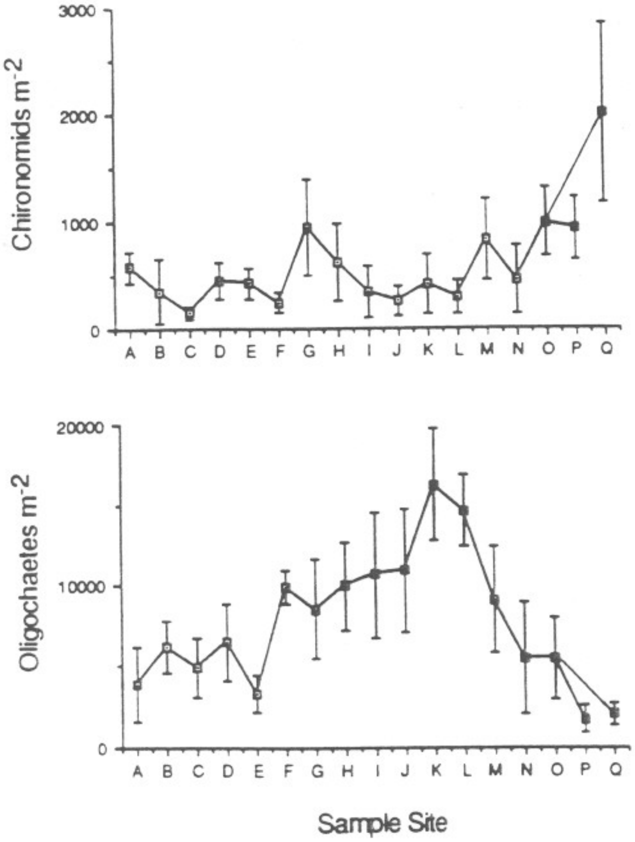

FIG. 3. Mean abundance (organisms m^{-2}) and standard errors of chironomid larvae and oligochaetes for the entire sampling period at Buffalo River sites. Separate lines from sites P and Q converging at site O indicate separate headwaters of Cazenovia Creek and upstream reaches of the Buffalo River (see Fig. 1).

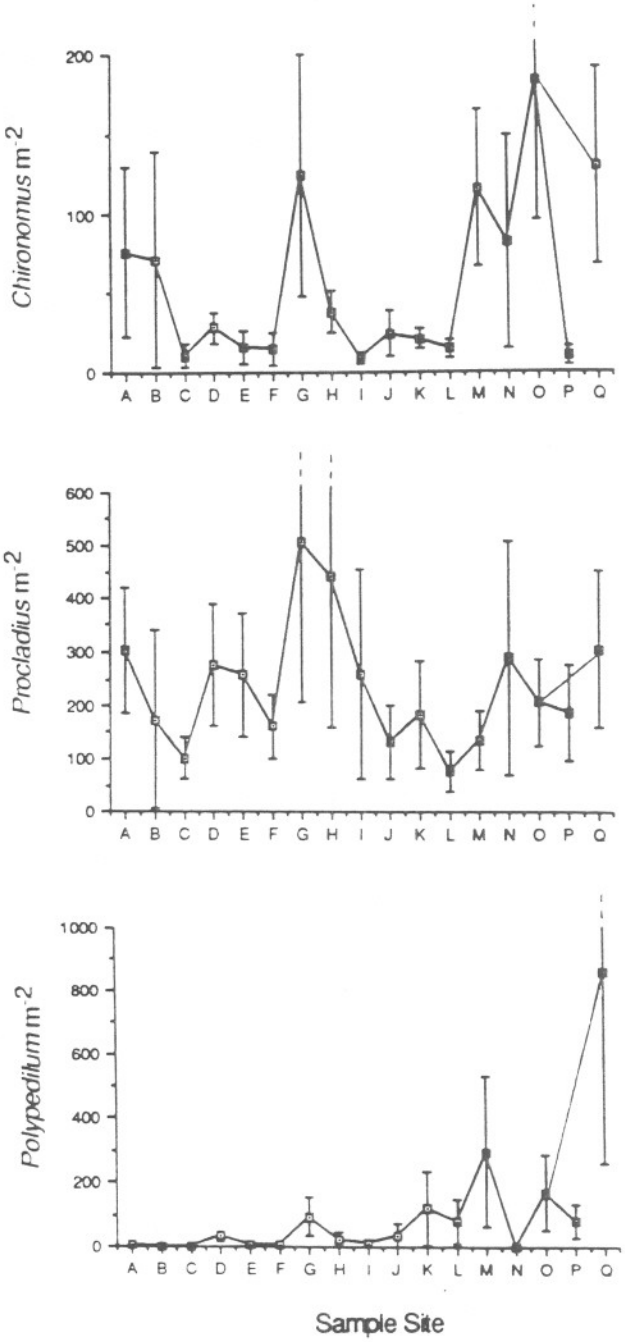

FIG. 4. Mean abundance (organisms m^{-2}) and standard errors of the three most numerous chironomid genera at Buffalo River sites, **Chironomus, Polypedilum,** *and* **Procladius.** *Note different ordinate scales.*

mids. Often there remained little more than a mass of oligochaetes when sediments from these sites were sieved. Oligochaete numbers decreased further downstream, but remained an order of magnitude above the density of chironomids. Chironomids averaged approximately 400 m^{-2} downstream of site M, being notably common at site G, and scarce at site C.

Twenty-six chironomid genera were encountered in the Buffalo River, but half of these were represented by fewer than five specimens. The distribution of the most abundant genera, *Chironomus*, *Polypedilum*, and *Procladius,* is presented in Figure 4. No genus was common at any site on all seven sampling dates, and the large standard errors associated with high densities of these genera reflect seasonal variability of the chironomid community. *Procladius* was abundant at sites G and H on 22 May 1991, and *Polypedilum* was extremely numerous at Site Q in Cazenovia Creek on 16 November 1991. The sharp increase in *Chironomus* at site G largely reflects the abundance of this genus here on 5 July 1991.

Although high densities of these genera occurred irregularly, *Polypedilum* and *Chironomus* were predictably scarce in some sections of the river. *Polypedilum* was rarely found below site G, despite its abundance upstream. Likewise, *Chironomus* was consistently scarce between sites C and F, and I and L (Fig. 4), and was often absent.

Generic richness and diversity (Simpson's) of the chironomid community were substantially higher at the uppermost sites, O, P, and Q (Fig. 5). Both factors generally decreased further downstream, with a notably low richness and diversity at site C, where chironomids as a whole were rare. Site N also displayed low chironomid richness and diversity, but was sampled only three times. A complete discription of the chironomid community is available, upon request, from the authors.

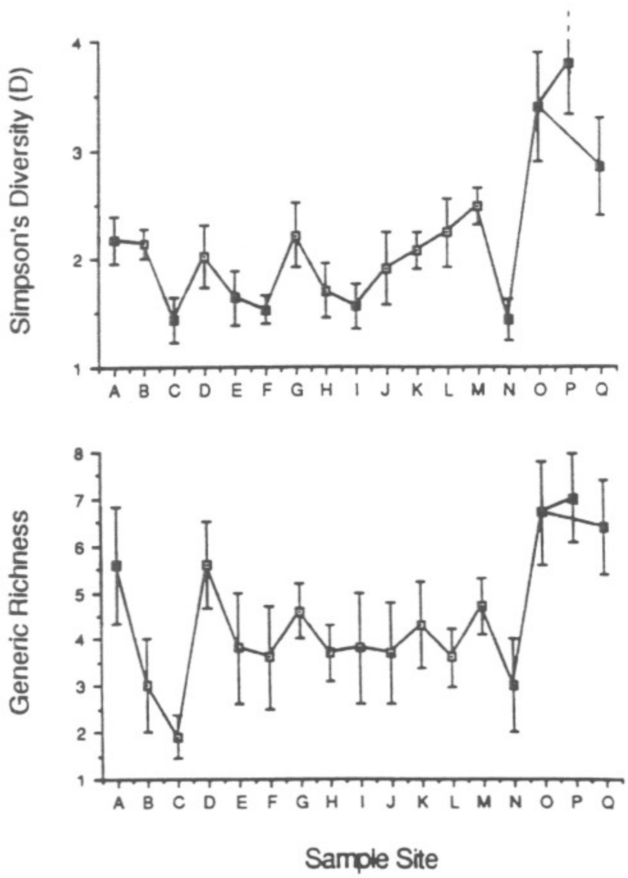

FIG. 5. Mean generic diversity (Simpson's) and richness of the chironomid community (with standard errors) at Buffalo River sites.

Chironomid Abnormalities: genus *Chironomus*

Abnormal menta or ligulae were noted in five chironomid genera, *Chironomus, Procladius, Polypedilum, Cryptochironomus,* and *Dicrotendipes,* in the Buffalo River and Ship Canal (Table 1). Of these, only *Chironomus* consistently displayed an elevated frequency of such abnormalities. Of 755 *Chironomus* (mostly *thummi* group) encountered in the river, 29.0% had abnormal menta (Table 1). In the ship canal, 22.4% of the 98 *Chironomus* specimens (*C. thummi* and the much larger *C. plumosus* group) were abnormal.

There were even higher frequencies of irregularities in *Chironomus* menta at some individual sites over the course of the sampling period (Table 2, Fig. 6). Abnormalities were most prevalent downstream, notably at sites A (31.9%, n = 72), B (34.5%, n = 29), D (48.1%, n = 27), and G (36.9%, n = 84). Mentum abnormalities were less frequent at upstream sites M (27.7%, n = 112), N (25.0%, n = 29), O (23.0%, n = 139) , and Q (24.6%, n = 122). Specimens with multiple mentum abnormalities were proportionally more abundant downstream of site K, mainly at sites where the overall incidence of abnormalities was highest (Fig. 6). Samples of the genus *Chioronomus* may be unreliably small at some river sites (Fig. 6–sites C, E, F, I, L, and P), although site C had the highest frequency of mentum abnormalities of any site (66.7%, n = 9). There was no significant correlation of the incidence of mentum abnormalities with *Chironomus* scarcity or abundance at sample sites.

TABLE 1. Frequency of abnormal menta of **Chironomus, Polypedilum, Cryptochironomus,** *and* **Dicrotendipes,** *and of abnormal ligulae of* **Procladius,** *in the Buffalo River and Ship Canal between 16 November 1990 and 16 November 1991.*

Genus	# Mounted	% Abnormal
Chironomus thummi (River, total)	755	29.0%
C. thummi (River, 3rd instar, small specimens)	77	7.8%
Chironomus (Ship canal, *C. plumosus* and *C. thummi*)	98	22.4%
Procladius (ligula)	1,677	3.1%
Polypedilum	598	2.3%
Cryptochironomus	360	0.8%
Dicrotendipes	45	4.4%

TABLE 2. Frequency of abnormal menta (percentage of slide-mounted specimens) of the genus Chironomus *in the Buffalo River at all sites and on all sample dates. Number of specimens mounted given in parentheses.* Chironomus *was absent from many samples. A dash (—) indicates that no sample was collected at a site on the date indicated. Data are pooled by site in the far right-hand column, and by date in the bottom row.*

Site (Depth)	Nov 90	Mar 91	May 91	July 91	Aug 91	Sept 91	Nov 91	**Site Totals**
A (7-8 m)	(11) 27.3%	(0)	(3) 33.3%	(53) 32.1%	(3) 66.7%	(1) 0.0%	(1) 0.0%	**(72) 31.9%**
B (7-8 m)	—	—	—	—	—	(1) 0.0%	(28) 35.7%	**(29) 34.5%**
C (7-8 m)	(0)	(0)	(0)	(0)	(3) 33.3%	(0)	(6) 83.3%	**(9) 66.7%**
D (7-8 m)	(0)	(2) 0.0%	(7) 85.7%	(9) 44.4%	(6) 33.3%	(1) 0.0%	(2) 50.0%	**(27) 48.1%**
E (7-8 m)	—	—	(0)	(7) 28.6%	(0)	(0)	(4) 25.0%	**(11) 27.3%**
F (7 m)	(0)	(1) 100.0%	(0)	(10) 40.0%	(0)	(0)	(2) 50.0%	**(13) 38.5%**
G (7 m)	—	—	(4) 75.0%	(56) 28.6%	(18) 61.1%	(0)	(6) 16.7%	**(84) 36.9%**
H (7-8 m)	(3) 0.0%	(2) 50.0%	(4) 100.0%	(9) 22.2%	(13) 14.3%	(0)	(4) 25.0%	**(36) 27.8%**
I (7 m)	—	—	(1) 100.0%	(3) 33.3%	(0)	(1) 0.0%	(1) 100.0%	**(6) 50.0%**
J (7 m)	(0)	(0)	(0)	(2) 50.0%	(6) 33.3%	(0)	(14) 38.5%	**(22) 36.4%**
K (7 m)	(1) 100.0%	(3) 33.3%	(9) 11.1%	(2) 0.0%	(2) 0.0%	(1) 0.0%	(4) 25.0%	**(20) 20.0%**
L (7 m)	(3) 66.7%	(5) 0.0%	(1) 0.0%	(0)	(0)	(1) 0.0%	(4) 0.0%	**(14) 14.3%**
M (7 m)	(27) 13.0%	(22) 36.4%	(1) 100.0%	(0)	(48) 34.7%	(5) 20.0%	(9) 11.1%	**(112) 27.7%**
N (6-7 m)	—	—	—	—	(3) 33.3%	(1) 100.0%	(24) 20.8%	**(28) 25.0%**
O (3-4.5 m)	(16) 31.3%	(1) 0.0%	(2) 50.0%	(2) 0.0%	(37) 27.0%	(27) 7.4%	(54) 26.4%	**(139) 23.0%**
P (1-1.5 m)	(1) 0.0%	(0)	(2) 50.0%	(6) 0.0%	(1) 0.0%	(0)	(0)	**(10) 10.0%**
Q (1-2.5 m)	(9) 0.0%	(0)	(11) 9.1%	(38) 13.2%	(58) 39.7%	(4) 25.0%	(2) 0.0%	**(122) 24.6%**
Totals by Date	**(67) 20.9%**	**(36) 30.6%**	**(43) 46.5%**	**(197) 26.4%**	**(200) 35.5%**	**(43) 11.6%**	**(168) 27.4%**	

The 77 small 3rd instar *Chironomus* found in the river and ship canal were notably less prone to mentum irregularities than the larger 4th instar larvae more frequently collected (Table 1). Only 7.8% of the smaller specimens were abnormal.

The frequency of *Chironomus* mentum abnormalities varied with sample date (Table 2), but, as with variation among sites, was not correlated with abundance. Abnormalities were proportionally most common in May 1991, occurring in 46.5% of specimens (20 of 43). The much larger samples of July, August, and November 1991 ranged between 26.4% and 35.5% abnormal. The lower (in terms of the Buffalo River) incidence of abnormal menta in September 1991 (11.6%) is probably a reflection of the dominance of this sample by small 3rd instar larvae. Only 17 of 43 specimens on this date were 4th instar.

Abnormalities of other genera

Of 1,677 slide mounted *Procladius*, 3.1% had ligulae which deviate from the standard symmetrical five-toothed structure (Table 1, Fig. 2.2). Most frequently observed was the presence of only four teeth, although ligulae of these specimens were usually symmetrical. *Procladius* with six symmetrical teeth were occasionally seen. Fourteen specimens, or 0.8% of all slide mounts, displayed asymmetrical abnormalities of the ligula, including fused, forked, or uneven extra teeth (Fig. 2.2). No irregularities of the paraglossa, mandibles, or paralabial teeth were noted in this genus (see Warwick 1989 and 1991; Dermott 1991).

While abnormal *Procladius* larvae were generally infrequent, the incidence was elevated in some individual samples. Eleven samples had abnormal ligulae in more than 5% of the mounted larvae, with nine of these occuring downstream of site K. Notably, 11.5% (n = 26) and 15.4% (n = 26) of *Procladius* had abnormal ligulae at site D on 26 March and 9 August, respectively, and 10.5% (n = 19) and 12.0% (n = 25) of larvae were abnormal at sites I and J on 22 May. Ligulae were abnormal in 18.2% (n = 11) of the specimens at site N on 9 August, but this sample may be unreliably small.

Mentum abnormalities were seen in 2.4% of the 598 mounted *Polypedilum* specimens (Table 1). Abnormal menta either lacked one lateral tooth, or displayed irregularities in the normally paired medial teeth. Abnormal specimens were most frequent between sites D and J, even though this genus was far more abundant further upstream (Fig. 4).

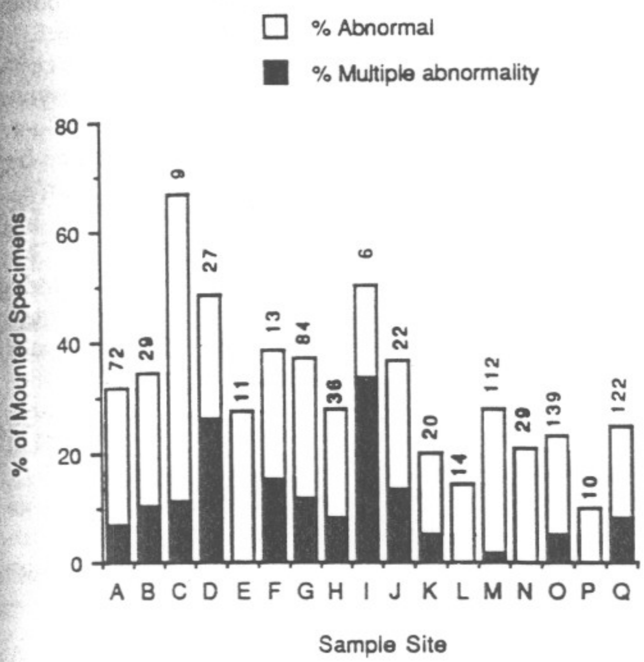

FIG. 6. Frequency of Chironomus larvae with abnormal menta, and with multiple mentum abnormalities, at Buffalo River sites, expressed as a percentage of all Chironomus larvae slide-mounted at each site, pooled over all sample dates. Sample size given above each column. See Figure 2 for descriptions of abnormalities.

Three *Cryptochironomus* (0.8%), and two *Dicrotendipes* (4.4%) larvae had abnormal menta (Table 1). In each case, one lateral tooth was missing. More detailed descriptions of mentum abnormalities in *Polypedilum, Cryptochironomus,* and *Dicrotendipes* can be found in Warwick and Tisdale (1988) and Warwick (1990a).

DISCUSSION

Benthic Community

Our current evaluation of the Buffalo River benthic fauna indicates a community impacted both by industrial contamination and probable nutrient input.

The nearly total dominance of the fauna by oligochaetes suggests heavy nutrient enrichment. According to the community index of Goodnight and Whitley (1961; cited in Nalepa and Thomas 1976, Krieger 1984, Thornley 1985), <60% tubificids indicates "good" conditions, and >80% tubificids indicates organic enrichment. On this basis, only upstream sites P and Q displayed good water conditions. In contrast, the benthic fauna of sites I - L were at least 95% oligochaetes, and most downstream sites yielded more than 90% oligochaetes. The standard of Wright *et al.* (1955, in Nalepa and Thomas 1976, Krieger 1984) of more than 5,000 oligochaetes m^{-2}, indicating serious pollution, is exceeded at the majority of middle and lower Buffalo River sites (Fig. 3).

Krieger (1984) found a similar oligochaete-dominated benthic community within the Black, Cuyahoga, and Ashtabula river harbors (average of 91% tubificids), and Thornley (1985) and Dermott (1991) observed a predominance of tubificids in the most heavily developed sections of the Detroit and St. Clair rivers. In the past, Johnson and Matheson (1968) reported an extremely oligochaete-dominated fauna in Hamilton Harbour, a site characterized by urban and industrial development similar to that of the Buffalo River.

Lake typology based on assemblages of chironomid larvae is well established (Saether 1975, 1979; Winnell and White 1985), and may be generally applicable to a deep, slow moving, soft-bottomed lotic environment such as the Buffalo River. Some reaches of this river may exhibit periods of transitory stratification, and alternate between downstream-flow and lake-seiche or wind driven current regimes (Wang and Martin 1991, and pers. obs.).

The dominant chironomids in the Buffalo River (tribe Chironomini, including *Chironomus, Polypedilum,* and *Cryptochironomus*; and subfamily Tanypodinae, including *Procladius*) represent Saether's (1979) eutrophic indicator groups. Downstream sites C - J fall within the three most eutrophic categories of Saether's classification. Oligotrophic indicators such as *Heterotrissocladius, Protanypus,* and *Paracladius* were notably absent.

Based on their prevalence in areas of both contamination and eutrophication, the chironomids common to the Buffalo River are often regarded as pollution-tolerant (Nalepa and Thomas 1976, Warwick 1989, Warwick 1990b, Dickman *et al.* 1992). Krieger (1984) reported that *Procladius* and *Chironomus* dominated the insect fauna of harbors in central southern Lake Erie, although *Chironomus* spp. were completely absent from Lorain and Cleveland harbors. We also noted a paucity of this genus in some Buffalo River samples (see Fig. 4). The genera *Procladius, Chironomus,* and *Cryptochironomus* comprised the majority of specimens in Lake Ontario near the Niagara River outfall (Nalepa and Thomas 1976). Industrially contaminated Port Hope Harbor (Warwick *et al.* 1987) and the Lac St. Louis and LaPrairie basins of the St. Lawrence River (Warwick 1990a) were dominated by *Procladius* and *Chironomus* spp.

While the higher richness and diversity of Buffalo River chironomids at upstream sites (Fig. 5) may be due in part to more heterogeneous substrate (gravel, sand, and organic debris), a less diverse community downstream suggests deterioration of environmental quality. A surprising number of chironomid genera (26) were found in the river, but those organisms occurring only as scattered individuals may represent sporadic input from cleaner regions upstream of the study site.

Chironomid Abnormalities: *Chironomus*

The frequency of mentum abnormalities within the genus *Chironomus* was elevated at all Buffalo River sites (Table 2, Fig. 6), with some sites among the highest frequencies yet observed (see Table 3). Our assessment of abnormalities was notably conservative, as menta with mild, but definite, asymmetry of the medial teeth were not included. Such specimens are usually characterized as deformed by other researchers (see Warwick and Tisdale 1988).

Table 3 presents a compilation of studies assessing the incidence of abnormal menta of the genus *Chironomus*. The data of Wiederholm (1984) are conservative, as specimens with one missing lateral tooth (see Fig. 2.1 B) were not included. Based on our Buffalo River observations, it is reasonable to suggest that inclusion of such specimens could double the deformity frequencies reported by Wiederholm.

Sites characterized by substantial industrial or agricultural chemical input (Table 3–marked by an asterisk [*]) almost invariably diplayed high frequencies of abnormal menta, often greater than

TABLE 3. Reported frequencies of mentum abnormalities in **Chironomus** *spp., and number of specimens mounted, at North American and European sites. Asterisk (*)–designates sites with known or probable contamination; N.A.–Number of slide mounted specimens not available from reference; [a] –Either mentum or mandible abnormalities; [b]–Does not include specimens with only one missing lateral tooth; [c]–Range of frequencies at 11 different Buffalo River sites with >20* **Chironomus** *specimens total.*

Site	*# Mounted*	*% Abnormal*	*Reference*
*Lake Erie, near Maumee R.	3	100.0%	Hamilton and Saether (1971)
Lake Erie, entire lake	>1,700	0.0%	"
*Parry Sound Harbor, L. Huron	85	76.5%[a]	Hare and Carter (1976)
Parry Sound, other stations	79	1.3%[a]	"
*Teltowkanal, Germany	N.A.	25.4 - 37.6%	Koehn and Frank (1980)
*Pasqua Lake, Saskatchewan	354, 32	2.3%, 3.1%	Warwick (1980a)
Bay of Quinte, L. Ontario, subfossil (up to 2800 ya)	N.A.	0.09%	Warwick (1980b)
Bay of Quinte, fauna of 1972	N.A.	1.99%	"
Lake Malaren, Ekoln Bay, Sweden, subfossil	126	0.8%[b]	Wiederholm (1984)
L. Malaren, Granfjarden Bay	282	1.4%[b]	"
L. Malaren, Vasterasfjarden Bay, subfossil	26	0.0%[b]	"
*L. Malaren, Vasterasfjarden Bay, fauna of 1969	28	10.7%[b]	"
*Port Hope Harbor, turning basin L. Ontario	40	83.0%	Warwick *et al.* (1987)
*Tobin Lake, Saskatchewan	487, 154	21.1%, 14.9%	Warwick and Tisdale (1988)
*Lac St. Louis and LaPrairie Basins, St. Lawrence R.	20 *C. plumosus* 34 *C. thummi*	40.0%, 26.5%	Warwick (1990a)
*Welland River, Ontario	230	14.0%	Dickman *et al.* (1992)
Welland R., reference site	>200	2.3%	Dickman *et al.* (1991)
*Buffalo River	20-139[c] (see Fig. 6)	20.0 - 48.1%[c]	This study
*Buffalo Ship Canal	98	22.4%	"

20.0%. The degree of natural variation in menta within the different *Chironomus* species is unclear, but current data suggest it is *much* below the levels seen at these contaminated sites. Profundal Lake Erie (Hamilton and Saether 1971), uncontaminated Parry Sound, Lake Huron (Hare and Carter 1976), a non-industrial section of the Welland River, Ontario (Dickman *et al.* 1991), and subfossil chironomid remains from Lake Malaren, Sweden (Wiederholm 1984), and the Bay of Quinte, Lake Ontario (Warwick 1980b) yielded abnormal *Chironomus* menta in the range of 0.0 - 2.3% of the specimens (Table 3). These results, especially the very low frequency of abnormal menta observed in pre-industrial subfossil *Chironomus*, suggest that the incidence of aberrant specimens in unstressed populations is minimal (Warwick 1980a, Wiederholm 1984).

Abnormal *Chironomus* larvae, particularly specimens with multiple mentum irregularities, were proportionally more abundant at Buffalo River stations below site K (Fig. 6). However, chironomids at upper sites, including sites O and Q, which are upstream of any major industrial facilities, were often more than 20.0% abnormal. We feel that the long industrial history of the Buffalo River (Lee *et al.* 1991) has resulted in adverse impacts throughout the AOC, and not just near current industrial sources. These upper sites also receive runoff from urban surroundings through storm-drains emptying into Cazenovia Creek near site Q. Still, the higher frequency of abnormalities at lower sites reflects a general downstream environmental degradation also evidenced by extreme dominance of oligochaetes, and by decreased chironomid abundance, richness, and diversity (Figs. 3 and 5). At other study areas, notably Parry Sound (Hare and Carter 1976) and the Welland River (Dickman *et al.* 1991, 1992), contaminant sources were more easily identified than in the Buffalo River, and there were sharper distinctions between highly deformed populations near industrial sources, and normal fauna at unimpacted sites.

Abnormalities of Other Genera

Among other chironomid genera, *Procladius* shows promise as a contaminant indicator similar to *Chironomus*. *Procladius* with abnormal ligulae have been observed at a number of sites, often co-occurring with deformed *Chironomus* (Warwick 1989, 1991; Pettigrove 1989, Dermott 1991). Overall, 3.1% of *Procladius* larvae examined in the Buffalo River and Ship Canal had abnormal ligulae (Table 1), but several individual samples were more than 10.0% abnormal (Results). Warwick (1989) reported frequencies of deformed ligulae up to 6.7% in Lac St. Louis, and even higher in the small samples from the LaPrairie Basin. In Port Hope Harbor, 12.3% of *Procladius* ligulae were abnormal (Warwick 1991). Pettigrove (1989) observed elevated abnormalities of *Procladius* at several sites in the Murray and Darling rivers of Australia, possibly related to pesticide contamination, including one site where 24.0% (n = 25) of larvae had abnormal ligulae. Dermott (1991) observed abnormalities in up to 14.5% of *Procladius* at industrial sites in the St. Clair River.

As with *Chironomus* larvae, the level of natural variation in ligula morphology inherent to the different species of *Procladius* is unclear. At a non-industrial control site in Lake Superior, 4.0% of *Procladius* had abnormal ligulae, with 35.0% of these characterized by four symmetrical teeth (Dermott 1991). More than half of the abnormal *Procladius* ligulae from the Buffalo River were of this type. It is reasonable to infer that this type of abnormalitiy may represent a natural variant, and that these specimens should be interpreted conservatively.

When the genera *Chironomus* and *Procladius* occur together at industrial sites, morphological irregularities are far more frequent among *Chironomus* larvae (Warwick 1989, 1991; Dermott 1991, Diggins and Stewart, present study), often by a factor of ten or more. We agree with the contention of Warwick (1989) and Dermott (1991) that *Procladius* is more tolerant of industrial contamination, and tends to show morphological response at contaminant levels where *Chironomus* is highly affected, or has been eliminated. This suggests the potential of *Procladius* as a bio-indicator in the most degraded environments, where it may be the only chironomid present.

Conclusions

The genus *Chironomus* has been seriously affected throughout the Buffalo River AOC, and frequently displays mentum abnormalities. The genus *Procladius* is apparently more tolerant of industrial pollution, or may respond to a different suite of contaminants than does *Chironomus*. However, our evidence suggests that *Procladius* is at or near its threshold for morphological response in the lower reaches of the river.

The chironomid fauna of the Buffalo River offer an excellent tool to assess environmental change, either positive or negative. Successful sediment remediation and future discharge reduction should be reflected by increased abundance of *Chironomus,* with a decreased incidence of abnormal menta. Conversely, any further degradation of the river by additional contaminant discharge or spills, or by resuspension or exposure of toxic sediments, could result in even more severe deformities of *Chironomus*, and more frequent ligula deformities among *Procladius* larvae. We are currently monitoring the condition of the macrobenthos in the vicinity of two Buffalo River sites (sites E and N, Fig. 1) where a study involving pilot-scale removal of contaminated sediments was conducted during July-August 1992.

We feel that the value of community descriptions as indicators of aquatic ecosystem health is greatly enhanced when assessments of chironomid abnormalities are included in the monitoring. While there is little doubt that characteristic benthic communities may indicate degraded habitats (including the Buffalo River), the complexity of factors affecting community composition may preclude direct comparison of sites widely differing in basic environmental parameters.

In contrast, the incidence of chironomid abnormalities offers a biological contaminant marker, applicable *in situ*, to environments as diverse as major harbors, drainage canals, small streams and ponds, and the profundal and littoral zones of most lakes. All that is needed is the presence of the indicator organisms. Fortunately, two of the most promising genera, *Chironomus* and *Procladius*, are among the most ubiquitous. Progress toward numerically indexing the response of different chironomid genera (Warwick 1985, 1991), and toward a better understanding of the specific causes and mechanisms of abnormal larval development, could greatly expand the predictive power of this indicator. Currently, although not an indicator of specific contaminants, the occurrence of abnormal chironomid larvae can serve as an economical and biologically relevant first-step evaluator and long-term monitor of the benthic environment, and can suggest where more intensive bioassay and chemical testing would be most effectively employed.

ACKNOWLEDGMENTS

This study was supported by the Great Lakes Protection Fund (Grant #FG6901001). A number of students assisted in laboratory and field work, notably R. Bellinger, C. Conklin, C. Pace, and S. Pericak. William Morten of Guelph, Ontario, assisted in verifying our taxonomic identifications. We also thank Dr. Mike Dickman and his co-workers at Brock University for their generous early aid to this project.

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Submitted: 17 November 1992
Accepted: 6 August 1993