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Chironomid (Diptera: Chironomidae) Larvae as Indicators of Water Quality in Irondequoit Creek, NY

George E. Cook
The College at Brockport

Chironomid (Diptera: Chironomidae) Larvae as Indicators of Water Quality in Irondequoit Creek, New York

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Abstract

Chironomid community structure and mouthpart deformities were examined as indicators of pollution or degradation of water quality in the Irondequoit Creek watershed. Differences in Simpson's diversity, taxa richness, and chironomid abundance were assessed in upper, middle, and lower creek locations to determine changes as the creek passes through increasingly populated areas. Differences in the same measures also were assessed in vegetation, mud, and gravel habitats in order to assure that any changes observed were not due to differences in chironomid community structure in dissimilar substrates. Diversity and taxa richness were highest in the upper creek and lowest in the lower creek. Abundance was highest in the middle creek. All three measures were highest in the gravel habitats and lowest in the vegetation habitats. Slight organic pollution impacts on the creek were indicated by lower diversity and richness values in the lower locations of Irondequoit Creek and by community structure differences. Mouthpart deformity comparisons were inconclusive because affected taxa were not present at all sites. This study brings into question the feasibility of using chironomid communities and deformity rates as indicators of water quality changes in the Irondequoit Creek system. Due to the high variance in chironomid distributions, a larger number of samples is needed to detect changes in chironomid communities. Other changes in sampling methods may also be necessary.

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Biographical Sketch

George Edward Cook was born [redacted]. He graduated in [redacted] from Westlake High School in Thornwood, New York. He completed his undergraduate education (begun in 1968 at the University of Rochester) in 1995, earning a Bachelor of Arts (B.A.) from the State University of New York, Empire State College. In the spring of 1996, he enrolled in the M.S. program, Department of Biological Sciences, SUNY College at Brockport. Mr. Cook is an avid amateur aquarist and fly fisherman.

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Introduction

Biological methods for determination of water quality in freshwater systems have become common and the techniques are well-documented (Bode *et al.* 1991; Warwick 1991, 1990b, 1989, 1985; Seidman *et al.* 1986; McCafferty 1981). Biological methods, rather than chemical or biological assay methods, are preferred because biological methods indicate long-term trends in water quality, instead of short-term results that reflect conditions only at the time that samples are collected (Warwick 1991). The increased complexity of the contaminant burden makes it difficult to determine water quality effects on organisms through chemical analysis alone (Warwick 1989; Warwick and Tisdale 1988). The number of chemicals, changes in individual chemicals over time, substances present at levels too low for detection (Bode *et al.* 1991), and interactions of many chemicals may make the effect of the total contaminant burden impossible to estimate by traditional chemical analysis (Warwick 1988). Warwick (1991) suggested that there are too many toxic compounds, degradation products, and synergistic and antagonistic effects for complex chemical analysis to be a reasonable option. Biological communities allow direct observation of the wide variety of environmental impacts of contaminants, without the necessity of carrying out complex chemical analyses (Hudson and Ciborowski 1996b). Biological communities are good indicators of aquatic conditions because they are subject to the sum total of chemical, physical, and biological processes over the length of organisms' life cycles (Warwick 1991).

Benthic invertebrate communities are excellent indicators of water quality conditions in freshwater systems (Bode *et al.* 1991), in part because of the wide variation in their

sensitivity to contaminants (Clements *et al.* 1992). They are relatively sedentary, so individuals collected in a particular area can be assumed to represent conditions in that area (Hudson *et al.* 1995). In particular, chironomids (the largest and frequently the most abundant family of aquatic insects) have been advocated for use as indicator organisms (Mason 1998; Seidman *et al.* 1986). Chironomids inhabit virtually every type of aquatic habitat (Timmermans *et al.* 1992; Warwick 1990a; Warwick 1988; Pinder 1986; McCafferty 1981) and are common inhabitants of polluted freshwater environments (Seidman *et al.* 1986). They can be found in streams and rivers (in pools, slow waters, still shallow margins, moderate and swift currents), freshwater ponds, lakes, pools, marshes, bogs, within underwater vegetation, on or within freshwater invertebrates, or in wet marginal areas along bodies of freshwater, tree holes, and plant cups holding water. Thus, they are possibly the most widely adapted of all aquatic insects (McCafferty 1981), representing all functional groups of benthic invertebrates (Warwick 1991). In addition to their presence in virtually all freshwater environments, chironomids make good subjects because of their relatively large size (Hudson and Ciborowski 1996b).

Armitage and Blackburn (1985) suggested that chironomid community structure alone can be used to characterize stream sites. As dominant benthic organisms, chironomids are important indicators of the overall biological integrity of watersheds (Mason 1998). Chironomids are also sensitive to environmental factors and their short life span guarantees that any morphological responses observed reflect conditions that are prevalent at the time of sampling. The larval stage is the longest stage in the chironomid life cycle and generally is the only stage during which feeding and energy storage take place (Warwick 1988). The larvae are sessile, thus exposure to contaminants at the

mud/water interface during this part of their life cycle is direct and certain (Clements *et al.* 1992; Warwick 1990a).

Chironomid larvae also represent an important transfer vector linking the movement of contaminants from sediments to higher trophic levels (Dickman *et al.* 1992). They often comprise the major portion of benthic invertebrate biomass associated with freshwater sediments and are often a significant portion of the diet of predatory invertebrates and fishes (Dickman *et al.* 1992; Seidman *et al.* 1986; McCafferty 1981). Most aquatic predators feed extensively on chironomids (larvae, pupae, or adults) at some point in their life cycles (Merritt and Cummins 1996).

There are two aspects of chironomid ecology that prove useful in the determination of water quality. The incidence and severity of morphological deformities (primarily deformities of the mentum, antennae, and mandibles) and community structure of chironomids are valuable indicators of both organic and toxic pollution (Lenat 1993; Warwick 1990a, 1988, 1985, 1980a; Warwick *et al.* 1987; Seidman *et al.* 1986; Armitage and Blackburn 1985; Wiederholm 1984a; Winner *et al.* 1980; Hare and Carter 1976; Hamilton and Saether 1971). Warwick (1989) advocated the use of morphological deformities in chironomid larvae as a measure of long-term, chronic toxicity of contaminants in freshwater ecosystems, with increases in both the numbers and severity of deformities indicating responses to environmental contamination. Earlier, Warwick (1985) had found an increased incidence of antennal deformities in chironomid larvae (genus *Chironomus*) in contaminated versus uncontaminated sites and attributed the differences to industrial and agricultural contamination. Also using *Chironomus* larvae, Warwick *et al.* (1987) found an increased incidence of mouthparts deformities in more

heavily polluted areas of Port Hope Harbour, Lake Ontario. There is also a correlation between frequency of mentum deformities and severity of contamination by organic and industrial pollution (van Urk *et al.* 1992). Deformities in response to contamination are known to occur in other insect taxa. Plecoptera larvae have been observed with high incidences of deformities in antennae, maxillae, labra, and cerci at sites downstream from domestic and industrial sewage outfall, while deformities have been absent or infrequent in larvae collected at pristine sites (Donald 1980).

Population densities of chironomids are also indicators of toxic stress. Chironomid deformities are often accompanied by changes in population levels and community structure. Urban and industrial pollution cause drops in abundance, biomass, species richness, diversity, and shifts in species dominance and composition (Wiederholm 1984a). Populations of individual chironomid taxa particularly sensitive to pollutants may be reduced by contaminants, changing community structure (Clements *et al.* 1992; van Urk *et al.* 1992; Dermott 1991; Warwick 1990a). Cushman (1984) found that measures of chironomid abundance, diversity, biomass, and number of taxa were actually better indicators of the effects of coal oil on experimental organisms than were measures of morphological deformities. Measures of community composition also are useful when pollution levels become too high and loss of sensitive species makes deformity indices useless (Warwick 1991).

This study was designed to examine the use of chironomid larvae to determine water quality in Irondequoit Creek and changes in water quality through the creek's watershed. In addition, it provides a baseline description of chironomid community structure and

mouthpart deformity rates that may be used to detect changes in water quality over time.

The specific questions addressed were:

- Are there differences among upper, middle, and lower creek sampling locations, as evidenced by differences in chironomid community structure and mouthpart deformity rates?
- Are there differences among mud, vegetation, and gravel habitats, as evidenced by differences in chironomid community structure and mouthpart deformity rates?
- Is there evidence of pollution or degradation of water quality in the Irondequoit Creek watershed, and which chironomid taxa are the best indicators of such degradation?
- Are current sampling designs adequate to obtain statistically reliable values for differences in chironomid communities in the watershed?

Study Area

Irondequoit Creek flows from southeast Monroe County and northwest Ontario County north to the southern end of Irondequoit Bay. Near its source, the creek flows through agricultural and lightly-developed rural areas. As it continues north, Irondequoit Creek flows through increasingly more populated suburban areas with light industrial development. It is an important recreational resource and supports numerous species of both warm water and cold water fish. Much of the creek's length is readily accessible to the public through county and town parks that vary considerably in their degree of development. These parks range from nearly untouched natural surroundings (*e.g.*, the section of Ellison Park north of Browncroft Boulevard and Linear Park, Penfield) to high-maintenance lawn and picnic facilities (*e.g.*, the remainder of Ellison Park and Ayer Park, East Rochester). Most of the remaining shade tree cover for the creek is found in these public parks.

For many years, Irondequoit Creek was used to provide power for mills and as an outlet for town and village sewage treatment plants. The serious degradation of water quality that resulted has largely been corrected since those sewage treatment plants have been replaced by the Monroe County Pure Waters Van Lare sewage treatment plant (Sutton 1998).

Materials and Methods

Selection of Sampling Sites

Sampling sites were chosen to include three substrates of chironomid habitat in three sections of Irondequoit Creek. The sampling of different habitats was deemed necessary because: 1) some chironomid taxa demonstrate preferences for particular types of substrates (Pinder 1986; Minshall 1984; Barber and Kevern 1973); and 2) similar substrates must be sampled in order to compare different sites (Armitage and Blackburn 1985).

Three sections of Irondequoit Creek were sampled to evaluate changes in water quality as the creek moves through agricultural, suburban, and urban areas of its watershed. Important criteria in site selection for stream assessment were that the stream was wadeable for kick samples and that collectors were assured of safe and convenient access (Mason 1998; Bode *et al.* 1991). The slow currents in the lower section of Irondequoit Creek (in the wetlands of Ellison Park, at the south end of Irondequoit Bay) allowed access by pontoon boat for Ekman grab sampling in mud areas, kick sampling in sandy areas, and net sweeps of submergent and emergent vegetation. Sampling in these areas was carried out in September, 1996 (Haynes and McNamara 1998).

An area of Irondequoit Creek flowing through Ellison Park south of Blossom Road was selected as the site farthest downstream that represented a gravel substrate (Figure 1). This site, and sites in the middle and upper reaches of the creek, were sampled in May, 1997. Mud, vegetation, and gravel habitat sites from the middle, suburban area of Irondequoit Creek were chosen in Powder Mill Park (Figure 2). Similar habitats for

sampling were selected in Mendon, New York, immediately upstream (south) of the location where the creek flows under Cheese Factory Road (Figure 3). A map showing the relative locations of the three collection sites on Irondequoit Creek may be seen in Figure 4. In addition to considerations of accessibility, sites were selected on the basis of habitat diversity and size (each location consisted of three types of habitat, each of which was composed of five adjacent replicate stations) and habitat comparability (temperature, current speed, substrate embeddedness, canopy cover, and substrate particle size should be as similar as possible for community comparisons to be meaningful (Bode *et al.* 1993, 1991)). Habitat measurements for the Irondequoit Creek sampling sites are summarized in Table 1, and the sampling design is shown below.

	upper creek					middle creek					lower creek				
mud	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
vegetation	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
gravel	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Five replicate samples were collected in each location/habitat unit of Irondequoit Creek. (Numbers 1-5 represent these replicates.)															

Sample Collection and Preparation

At the time of sampling, stream habitat variables were measured. Stream depth, width, current velocity, percentage of overhead canopy, substrate phi value, percentage of substrate embeddedness, temperature, conductivity, dissolved oxygen, pH, and type of aquatic vegetation present were the variables examined. Stream depth was measured at three locations (25%, 50%, and 75% of stream width) at the downstream limit of each

site, where stream width, stream current, and percentage of overhead canopy were also measured. Substrate embeddedness (a measure of the amount of fine particles in the substrate, determined by observing the proportion of individual rock and rubble items buried in the substrate) and phi value (a measure of substrate composition determined by multiplying the percentage of each particle size of boulders, rubble, gravel, sand, silt, and clay found at the site by a value assigned to each particle size) were estimated (Bode *et al.* 1993). Temperature, conductivity, dissolved oxygen, and pH were measured at the farthest upstream and downstream stations at each site.

Samples were collected in a standardized manner so that quantitative comparisons could be made among sites (APHA 1995). In areas of silt, muck, and fine sand, an Ekman grab was pushed by hand to a depth of about 15 cm into the substrate. At gravel and coarse sand sites, the standardized traveling kick method was used (Bode *et al.* 1991). The stream bottom was disturbed by kicking and shuffling the feet so that dislodged organisms were carried into a triangular dip net with an opening bottom width of 33 cm, height of 26 cm, and a 1 mm mesh size. This procedure was carried out over a distance of twenty feet during a two minute time interval. Vegetation samples were taken with the same triangular dip net. The net was swept through submergent, emergent, and drowned terrestrial vegetation until the net was half full of vegetation. During this procedure, collectors attempted to leave the underlying substrate undisturbed to minimize contamination of vegetation samples with organisms from the substrate.

Samples were immediately screened in the field with 0.5 mm mesh sieves to reduce the volume of fine sediments and mud. Large rocks, sticks, and plants were discarded after all organisms were removed and added to the sample (Bode *et al.* 1991). Screened

organisms were placed in labeled plastic containers and 4% formalin solution was added as a preservative. Within 48 hours, samples were transferred to 70% ethanol to which rose bengal dye was added (APHA 1995). Sorting was carried out by a team of undergraduate and graduate students. Samples were rinsed in tap water to remove alcohol and placed in a rectangular, flat-bottomed white plastic pan and organisms were picked out of the surrounding debris with jewelers' forceps. After this first sorting, organisms were placed in 70% ethanol in labeled vials and the remaining substrate was returned to the original jar and preservative solution for a second sort at a later date. Chironomid larvae were separated from the other organisms and counted by examination under a stereomicroscope at 10X to 45X.

Any samples in which over 100 chironomid larvae were found were subsampled (Mason 1998). Samples were placed in a rectangular pan with a 100-compartment grid marked on the bottom. Compartments were selected at random and the chironomids in each were removed until 100 chironomids had been selected. These subsampled chironomids were placed in 70% ethanol in labeled vials to be identified with the samples that consisted of fewer than 100 organisms. When identification of specimens was completed, the percentages of taxa found in the subsampled collections were multiplied by the total numbers of larvae found in those samples.

A second sort was performed on each site's sample of material left after the organisms were removed in the first sorting. Sorting is an expensive, time-consuming process and is one of the drawbacks to invertebrate sampling (Hudson *et al.* 1995). To help reduce this time investment, the second sort was subsampled. Ten rectangles (of the 100 in the plastic pan) were selected randomly and the organisms found were removed.

Chironomid larvae found in samples that had been subsampled were counted and that number was multiplied by ten and added to the total count from the first sorting. Chironomid larvae found in samples that had first-sort totals of less than 100 larvae were identified and the counts (multiplied by ten) were added to the taxa totals.

Identification of chironomid larvae, even to the sub-family level, and observation of morphological deformities of mouthparts and antennae require examination at magnifications of 100X to 450X under a compound microscope (Mason 1998; Merritt and Cummins 1996; Peckarsky *et al.* 1990; Beckett and Lewis 1982; Warwick 1980b). Before such examination is possible, the chironomid larvae must be mounted on glass slides. Each organism was first dissected to remove the head from the rest of the body. The head and body were then mounted in CMCP 9. Beckett and Lewis (1982) recommended a mixture of ⅔ CMCP 9 and ⅓ CMCP 9AF, the latter containing acid-fuschia red for staining hard to distinguish details. This wasn't necessary. A problem in chironomid larvae identification occurs when head and mouthpart structures obscure other structures that need to be observed for identification or morphological deformities. Mounting requires that the head capsule be placed with the ventral side up, so that mouthparts are clearly visible. The head capsule must be flattened by exerting gradually increasing pressure (sometimes not so gently (Merritt and Cummins 1996)) and rotating the coverslip. This procedure spreads the head and mouthparts, preventing the mouthparts from obscuring important diagnostic features and aberrant mouthparts (Beckett and Lewis 1982; Warwick 1980b). Some authors (Warwick 1980b) recommend that a pencil eraser be used to apply pressure to the coverslip, but this conceals any rolling of the head

capsule. If two probes are used, pressure can be safely spread over the coverslip while the position and orientation of the head capsule is observed at 32X under a stereomicroscope.

Prepared, mounted specimens were examined at 450X under a compound microscope. Identification was carried out using keys by Mason (1998), Merritt and Cummins (1996), Peckarsky *et al.* (1990), Bode (1983), Simpson *et al.* (1983), and Simpson and Bode (1980). While specimens were being identified, deformities in the mouthparts of the larvae were described and recorded.

After the problems of obscured structures have been resolved, chironomid larval identification still can be difficult. Diagnostic features are often difficult to see even after careful preparation of specimens (Merritt and Cummins 1996). Peckarsky *et al.* (1990) noted several reasons for difficulty in larval identification: there is a lack of larval keys (most species have been described only in the adult stage); different names exist for the same structures when described by different authors; keys and diagnoses are based on fourth-instar larvae (earlier instars may differ so much in structure and size ratios that they do not fit the description for their own taxon); structures may have been damaged during capture or mounting; and worn structures may be present (mouthparts important in identification and deformity analysis can be abraded by feeding and coarse substrates). Warwick and Tisdale (1988) made no attempt to identify chironomid larvae to species because of problems involved in the identification of immature stages. Even family identification of insects is sometimes difficult, unreliable, and occasionally impossible when limited to larvae and pupae (Waterhouse and Farrell 1985; McCafferty 1981). Adhering to the "Do Not Exceed" Rule (do not exceed the limits of available taxonomic keys and experience (Mason 1998)), identification of chironomid larvae for this study was limited to

the generic level. Two genera (*Cricotopus* and *Orthocladius*) are so difficult to distinguish that they were combined into a "*Cricotopus/Orthocladius* complex" category. The "Confirmation" Rule by Mason (1998) states that specimens should be sent to an expert. Specimens were sent to two experts for identification confirmations (Bode 1998; Bollman 1998).

Data Analysis

Diversity Indices

Chironomid larva numbers for each replicate sample were entered into a spreadsheet (Appendix A). Biological indices were selected in an effort to describe and distinguish the chironomid communities in Irondequoit Creek across locations (upper, middle, and lower creek) and habitats (gravel, mud, and vegetation). Three indices were chosen to describe the structure of the chironomid communities (Diggins and Stewart 1993). Simpson's diversity index [$d_s = N(N-1)/\Sigma n_i(n_i-1)$, where N = the total number of organisms in a sample and n_i = the total number of taxon i] is a measure of the degree of uncertainty of picking a particular taxon at random. In a site of low diversity, the certainty of picking a particular taxon at random is high, but high diversity makes it difficult to predict the identity of a randomly picked individual (Smith 1992). This diversity index may also be seen as an expression of the number of times one would have to take pairs of individuals at random from the entire aggregation to find a pair from the same taxon (Brower and Zar 1977). The second index, taxa richness, is simply a count of the number of different taxa present. It is a useful tool for indicating differences in communities (Canfield *et al.* 1995b;

Wiederholm 1984a). The number of chironomids found at each location and in each habitat was the third index value chosen to compare sites. A summary of Simpson's diversity, taxa richness and chironomid abundance values, by sampling location and habitat, is presented in Appendix B.

Community Similarity Measures

Sorensen's coefficient of community [$CC = 2c/(s_1+s_2)$, where c = the number of taxa common to both communities and s_1 and s_2 = number of taxa in communities 1 and 2] and the percentage similarity of community [$PS_C = 100 - 0.5 \Sigma|a' - b'| = \Sigma(a',b')$, where a' and b' are the respective percentages for each taxon of the total taxa in samples A and B] were measures used to compare locations in Irondequoit Creek and different habitats (mud, vegetation, and gravel) within the creek to one another. The coefficient of community does not consider the relative abundance of taxa, only their presence or absence. The coefficient of community overvalues rarer species, while the percentage similarity of community minimizes this by taking the abundance of taxa into account. Used together, these coefficients can help determine whether a high affinity of two samples is due not only to sharing of most taxa, but also to the occurrence of these taxa in about the same proportions (Smith 1992; Johnson and Brinkhurst 1971). Community similarity values are summarized in Appendix B.

Differences Among Locations and Habitats

Comparisons were made to determine differences in chironomid community structure in different habitats (mud, vegetation, and gravel) across creek locations and differences in chironomid community structure in different creek locations (lower, middle, and upper

creek sections) across habitat types. Several statistical procedures were employed to analyze the data concerning chironomid distribution and community structure in order to evaluate whether differences existed among the various locations and habitats. Simpson's diversity index, taxa richness (the number of taxa), and abundance (the number of chironomids) were computed for each replicate sample within each stream location and habitat, and CC and PS_C values were computed for each pair of habitat/location statistics.

To establish normality, sets of random numbers with the same mean and variance as field samples were created for Simpson's diversity, taxa richness, and abundance data. Field and created data received a Z-score transformation and were analyzed by regression. The roughly linear regression relationships observed were examined for sharp discontinuities over parts of the relationships and for curved tails at the ends of the relationships that indicated lack of normality (Sokal and Rohlf 1995). Taxa richness of field samples was the parameter closest to a normal distribution, and was used for a power analysis.

The nonparametric Kruskal-Wallis test for samples that are not normally distributed and have unequal variances (Zar 1996; APHA 1995; Brower and Zar 1977), was used to compare values among stream locations and habitats. Differences in sample sizes required the use of two different statistical tables (Zar 1996). In testing hypotheses regarding Simpson's diversity, taxa richness, and abundance measures, critical values of the Kruskal-Wallis distribution were determined by using the χ^2 approximation (number of groups = 3, n = 15). The Kruskal-Wallis distribution table was used in testing hypotheses regarding community similarity comparisons (number of groups = 3, n = 3). A conservative α of

0.025 was selected for statistical significance in consideration of the Bonferroni correction for multiple comparisons (Rice 1989). Nemenyi tests were used to determine which comparisons were responsible for significant differences found in the Kruskal-Wallis tests (Zar 1996).

Power and Minimum Detectable Differences

A major objective of this study was to determine how many replicate samples (n) must be taken in a habitat or at a location to detect a defined difference between communities at a defined level of statistical power. The use of nonparametric statistical tests does not allow analyses of power (Zar 1996). For most of the variables, data sets were not normally distributed, even when transformed, and therefore could not be analyzed by parametric procedures. However, the log-transformed taxa richness data set had an approximately normal distribution, so one-way ANOVA tests were performed for stream locations and habitats to provide approximate data needed to evaluate relationships between minimum detectable differences, variance, power, and sample size. Calculations were made for different power levels (90%, 70%, 50%; power = 1 - β, where β = 10%, 30%, 50%, and β is the probability of finding no differences between treatment means when real differences exist) and for different levels of minimum detectable differences in taxa richness (*i.e.*, 10, 30, 50% differences between observed means). The phi value (ϕ) needed to determine power from the statistical graph in Zar (1996) was first calculated using the formula:

$$\phi = \sqrt{\frac{n \Sigma (\mu_i - \mu)^2}{ks^2}}$$

(where n = the number of samples (15) in each group, $\mu_i - \mu$ = the difference between the mean of each group and the overall mean, k = the number of groups, and s^2 = the error MS). The sample sizes (**n**) necessary for different selected minimum detectable differences (10%, 30%, and 50%) at different selected power levels (90%, 70%, and 50%) were then calculated using the formula:

$$\phi = \sqrt{\frac{\mathbf{n}\,\delta^2}{2ks^2}}$$

(where values of ϕ were taken from the graph for selected power levels, **n** = the number of samples, δ = the minimum detectable difference (expressed in number of taxa), k = the number of groups, and s^2 = the error MS).

Deformity Calculations

Two values were calculated for the chironomid deformities within each taxon. The percentage of deformed chironomids was calculated, based only on the presence or absence of mouthpart deformities. In addition, a toxic score was calculated that was based on the incidence and severity of mouthpart deformities (Lenat 1993). Class I deformities were slight deformities. Class II deformities were more conspicuous and included extra teeth, missing teeth, large gaps, and distinct asymmetry. Class III deformities were severe and included at least two Class II characters. A toxic score was computed by adding the number of Class I deformities to twice the number of Class II deformities and triple the number of Class 3 deformities, then dividing by the total number of chironomid larvae [((# Class I)+(2*#Class II)+(3*#Class III)) /total # larvae = Toxic Score].

Results

Habitat Comparability

For biotic indices from different sites to be compared, water temperature, substrate particle size, substrate embeddedness, current speed, and canopy cover should be similar (Bode *et al.* 1993). Measures of dissolved oxygen, pH, and conductivity are used as additional monitors of notable water quality changes among sites (Bode *et al.* 1991). A summary of physical habitat measurements collected at the sampling sites in Irondequoit Creek is presented in the upper portion of Table 1. The lower portion of Table 1 compares habitat characteristics within the three gravel sites and within the three mud sites. Of the five habitat criteria important in site comparability, each pair of locations in the creek had at least four values for those criteria within the guidelines proposed by Bode *et al.* (1993, 1991). This indicated that the sites sampled were generally comparable.

In the gravel habitats, there were only two exceptions to complete comparability of the sites. The lower creek gravel phi value for particle substrate size differed from that of the upper creek gravel by 3.4 phi units, a value slightly greater than the 3 unit maximum difference suggested by Bode *et al.* (1991). The other exception was canopy cover. The canopy cover in the upper creek gravel collecting site was 6%, while canopy cover values for the lower creek and middle creek gravel sites were 60% and 45%, respectively. These differences were greater than the 50% maximum difference suggested.

Examination of the site comparability criteria for the mud substrate collecting sites revealed differences greater than recommended for current speed and canopy cover. The upper creek mud collecting site's current speed of 79.8 cm/sec was more than 50% greater

than both the lower creek and middle creek mud sites (23.5 cm/sec and 20.2 cm/sec). However, collections were made in the upper creek immediately after a major rain event, suggesting that typical current speeds are more similar to those of the middle and lower reaches of the creek. Canopy cover in the middle creek mud site was 45%, much greater than the lower creek mud site's 1% and the upper creek mud site's 6%.

Chironomid Community Structure Comparisons

Simpson's Diversity, Taxa Richness, and Abundance

A total of 46 chironomid taxa were identified in this study, 24 of which comprised more than 1% of at least one habitat/location unit (Appendix A). Differences in chironomid community structure were found among locations and habitats in Irondequoit Creek (Table 2). Simpson's diversity and taxa richness values were higher in the upper creek than in the lower creek, but chironomid abundance was highest in the middle creek. Simpson's diversity, taxa richness, and chironomid abundance values were all highest in the gravel habitats.

Differences by Location

Simpson's diversity and taxa richness values were different between the lower creek and upper creek locations (Table 2), but neither differed from the middle creek. The Kruskal-Wallis statistics were $H = 7.35$, $P = 0.0253$ for Simpson's diversity and $H = 7.73$, $P = 0.0209$) for taxa richness. Simpson's diversity and taxa richness values were both highest in the upper creek and lowest in the lower creek. Chironomid abundance was significantly higher in the middle creek (Kruskal-Wallis statistic $H = 13.58$, $P = 0.0011$), but there was no difference between the lower creek and the upper creek.

Differences by Habitat

Simpson's diversity, taxa richness, and abundance measures all were significantly different between the gravel and vegetation habitats (Table 2), whereas these measures for the mud habitats were never different than the other two habitats. The Kruskal-Wallis statistics were $H = 7.44$, $P = 0.0243$) for Simpson's diversity, $H = 7.56$, $P = 0.0228$ for taxa richness, and $H = 8.39$, $P = 0.0151$ for abundance. All the measures were found to be highest in the gravel habitats and lowest in the vegetation habitats.

Coefficient of Community and Percent Similarity of Community

For the tests of community similarity by location, the three habitat pairs of similarity values (mud/vegetation, mud/gravel, and vegetation/gravel) within each location and the three location pairs of similarity values (lower/middle, lower/upper, middle/upper) within each habitat type were compared (Table 3).

Differences by Location

There were no significant differences for either CC or PS_C for different locations of Irondequoit Creek (Table 3). The trends were the same for both sets of data, with the three habitat pairs in the upper creek showing the highest degree of similarity and the three habitat pairs in the lower creek showing the least.

Differences by Habitat

There were no significant differences for either CC or PS_C for different habitat types in Irondequoit Creek. The trend was for gravel habitats to be more similar than either the vegetation or mud habitats.

Sample Size Considerations

In this study, five replicate samples were collected in each habitat/location unit (n = 15 in the following analysis). Because of very high variability among replicates, Table 4 makes it clear that fifteen replicates provide enough information to detect a 50% difference in treatment means 90% of the time or a 30% difference 50% of the time (power = 0.9 and 0.5, respectively). To detect a 30% difference between treatment means with a Type II error probability of 30% (power = 0.7) would require at least 22 - 24 replicate samples, and to detect a 10% difference 90% of the time would require at least 331 - 352 replicates.

Chironomid Deformities Comparisons

No deformities were observed in chironomids collected in the upper creek (Table 5). Most deformities were observed in chironomids collected in the middle and lower creek mud habitats (range: 2.9-9.5% chironomids deformed). No Class III deformities were observed. The deformity rate of *Chironomus* in the lower creek mud habitat of Irondequoit Creek was 7.6%, with Class II and III frequency of 0.3% and a toxic score of 10.61 (Table 5).

Few *Chironomus* larvae (none of which was deformed) were found in Irondequoit Creek in sites other than the lower creek mud. Deformities were found in eight taxa other than *Chironomus* (Table 5). The deformity rate for all taxa known to be susceptible to

mentum deformities in the lower creek location was 5.3% (toxic score = 6.5). The middle creek location deformity rate was 4.5%, with a toxic score of 5.6 (Table 5).

Discussion

Habitat Comparability Comparisons

Comparison of important habitat criteria indicated that habitats in different creek locations were generally comparable. Although no mention of differences in biotic indices due to sample collection during different seasons was found in the literature, it is likely that habitat comparability criteria are based on the assumption that collection dates are close together. In this study, sample collection in the lower creek mud and lower creek vegetation sites was performed in September, 1996. Samples from all other sites were collected in May, 1997. Water temperatures were no different for the samples taken during the fall and the following spring, but complications may have arisen due to unknown emergence patterns of adult chironomids. There is no information available concerning the presence of particular chironomid taxa at a particular developmental stage (in this case, the fourth-instar larvae) at the particular time of year that sampling was carried out. It is assumed in this study that the relative proportions among taxa and numbers of chironomid larvae are similar during different seasons. This may not be the case.

Chironomid Community Structure Comparisons

Ecological Indicators of Community Differences

Simpson's diversity and taxa richness values were highest in the upper creek and lowest in the lower creek. Lower values in the lower creek could be an indication of organic or industrial pollution, both of which can cause decreases in abundance, taxa richness, and diversity (Wiederholm 1984a). This suggests that as Irondequoit Creek passes through

increasingly suburbanized and urbanized areas of its watershed, chironomid community diversity in similar habitats declines.

There were also differences in Simpson's diversity and taxa richness values among the mud, vegetation, and gravel habitats. Both measures were highest in gravel substrates and lowest in vegetation. The low values for vegetation were consistent despite differences in the nature of the vegetation and in the substrates above which vegetation samples were taken. In the lower creek, vegetation samples were taken in the same area as mud samples. The vegetation in this section consisted of beds of rooted submergent (mostly *Elodea*) and emergent macrophytes (mostly *Typha*). Vegetation samples from the middle and upper creek areas were taken in the same areas as gravel samples. In both of these areas, the vegetation consisted of drowned terrestrial vegetation and leaf litter. Despite these differences in vegetation types, *Cricotopus/Orthocladius* complex was the most abundant taxon in vegetation samples throughout the creek (Figure 6, Appendix D-5), and *Eukiefferiella* also showed its highest abundance in vegetation habitats (Appendix C-16).

Chironomid abundance was very high in the middle creek compared to other locations. The reason for the large number of chironomids in the middle creek sites is unknown. Little in the chironomid literature gives specific information relating feeding habits, food availability, habitat requirements, and chironomid numbers (Bass 1986). Pinder (1986) found that the nature of the substratum was an important factor in limiting the distribution of chironomid larvae, but that many species, even those with a distinct substrate preference, are capable of using a variety of substrates. To add to the confusion, Barber and Kevern (1973) stated that chironomid numbers are not related to substrate composition, but that they are related positively to the existence of macrophyte beds. This was not the case in this study, in

which macrophyte beds were found only in the lower creek (associated with mud substrate), the location in the creek with the lowest number of chironomid larvae. Mild eutrophication does favor organisms such as deposit-feeding chironomids, including many of the subfamily Chironominae, tribe Chironomini that were present in the middle creek mud site (Wiederholm 1984b). It is possible that there was enough organic enrichment in the middle creek sites to provide an adequate food supply for a variety of detritivorous chironomid taxa without displacing any taxa that prefer conditions that lean more toward oligotrophy.

In comparing community similarity values for habitat pairs, the higher similarity of the gravel sites in the three locations of Irondequoit Creek reflects the higher physical similarity of those sites. There were differences in the vegetation sites (macrophytes in the lower creek vs. leaf litter and submerged terrestrials in the middle and upper creek) and in the mud sites (depositional in the lower and middle creek vs. erosional in the upper creek). These differences probably were reflected in the higher community similarity values for the gravel sites than for the vegetation and mud sites.

Bass (1986) observed, "Differences in current and substrate which seem insignificant to humans become quite significant from the perspective of the invertebrates occupying the stream bottom," and this may account for differences observed in this study. For example, the middle creek mud site was different than the lower creek mud site in all measures (Simpson's diversity, taxa richness, and abundance). The phi values for substrate size for the two sites (Table 1) were within the three phi units difference that Bode *et al.* (1991) suggest for comparison of biotic indices. However, parts of the lower creek mud site were very muddy, while other sections of the lower creek and all of the middle creek mud site were mostly fine sand and silt mixed with decaying vegetation and leaf litter. In the upper creek

mud samples were collected in areas where the stream had eroded its banks, whereas samples were collected in depositional substrate in the lower and middle creek. Despite this difference, community similarity values were higher for the middle creek mud/upper creek mud than for the lower creek mud compared to either the middle or upper creek mud.

Differences in Chironomid Distributions

Differences in chironomid community distributions may be due to impacts of organic or toxic pollutants, but they may also be due to differing environmental requirements of individual taxa. While this study has attempted to account for chironomid habitat preferences by selecting gravel, mud, and vegetation habitats, there are also more subtle habitat considerations that may be responsible for variations in community structure.

The lower creek mud sample was dominated by *Chironomus* (Appendices D-1, D-4), and this was not unexpected. Many genera of subfamily Chironominae, tribe Chironomini are adapted to warm, standing water and some can even stand long periods of anaerobic conditions (Simpson and Bode 1980). *C. anthracinus* survives low oxygen levels and food shortages, although larval growth ceases (Butler 1984). *Chironomus*, although ecologically versatile in terms of water conditions, prefer depositional habitats (Hudson and Ciborowski 1996a), burrowing in soft sediments (Simpson and Bode 1980) where they live in or on bottom substrates in silk-lined tubes (Mason 1998). Warwick (1990b) described *Chironomus* as inhabitants of highly eutrophic waters and filter-feeding consumers of organic detritus (Dermott 1991; Warwick 1985; Wentsel *et al.* 1977). *Chironomus* represented a very small proportion of the chironomid populations in any of the gravel habitats and was a significant proportion of only the lower creek mud, lower creek

vegetation, and middle creek mud communities. Since the lower creek mud and vegetation substrate samples were taken at the same location in Irondequoit Creek, it is possible that the specimens of *Chironomus* found there were actually dislodged from the mud during sampling.

Cricotopus/Orthocladius complex was the most prevalent taxon found in this study (Figures 5, 6) and was the most abundant taxon in vegetation samples throughout the creek (Figure 6, Appendix D-5). *Cricotopus/Orthocladius* complex includes two genera and a large number of species with a wide range of tolerances for environmental conditions and pollution (Simpson and Bode 1980). *Cricotopus* is typically considered one of the taxa most tolerant of organic and inorganic contamination (Canfield *et al.* 1995a). Their preferred habitats in streams range from erosional to depositional conditions with clingers (those with behavioral adaptations for attachment to surfaces in stream riffles), sprawlers (those that inhabit the surface of floating leaves or fine sediments, with modifications for staying on top of the substrate), and burrowers (both miners in vascular hydrophytes and tube builders in substrates) represented (Merritt and Cummins 1996). Subfamily Orthocladiinae is the most diverse chironomid subfamily. From the perspective of feeding styles, Orthocladiinae include microphages, leaf miners, predators, and parasites (Simpson and Bode 1980). Many live closely associated with algae and aquatic vegetation (Mason 1998). *Cricotopus/Orthocladius* complex was virtually absent from any of the mud samples, but dominated the vegetation and gravel habitats in the lower, middle, and upper creek (Appendices D-1 through D-6).

Subfamily Diamesinae (represented here by *Diamesa* and *Pagastia*) was found to some extent in the gravel and vegetation samples, but was almost entirely lacking in the mud

samples (Figure 6). Simpson and Bode (1980) describe the Diamesinae as mostly clingers or burrowing tube builders that prefer cold, fast streams. Members of subfamily Diamesinae did not dominate any sample, but were responsible for some community structure differences, particularly the lower creek gravel site versus the lower creek mud and vegetation sites (Appendix D-1), the middle creek mud site versus the middle creek vegetation and gravel sites (Appendix D-2), and the middle creek vegetation site versus the lower and upper creek vegetation sites (Appendix D-5).

Subfamily Tanypodinae was represented almost entirely by *Procladius* (Appendix C-20) and was found almost exclusively in mud samples in the lower and upper creek locations (it was also found in the lower creek vegetation site, where it might have been dislodged from the underlying mud). *Procladius* are found in a wide range of environmental conditions (Simpson and Bode 1980), but their presence in the mud samples reflect their predacious nature and prey preference. *Procladius* use their ligulae, flexibly mounted, stabbing adaptations of the mentum (Warwick and Tisdale 1988), to spear soft-bodied prey (such as oligochaetes and early-instar chironomids) (Baker and McLachan 1979). It is more the presence or absence of prey that determine the distribution of Tanypodinae than water quality (Warwick 1980b). The substrate in the middle creek mud site was composed more of fine sand and silt than of organically rich mud. This may explain the absence of *Procladius* there.

In both the lower and middle creek mud sites, chironomid populations were composed primarily of members of subfamily Chironominae: tribe Chironomini. The lower creek mud's most abundant taxon was *Chironomus*, which was virtually absent from the middle creek mud site (Appendices C-1, D-4). The upper creek and middle creek mud sites shared

Paratendipes as the most abundant taxon (*Paratendipes* accounted for > 50% of the chironomids in the upper creek mud) (Appendices C-5, D-3). The rest of the middle creek mud sample was composed mainly of *Cryptochironomus*, *Phaenopsectra*, *Polypedilum*, and *Tribelos* (Appendix D-2). All these taxa are described by Simpson and Bode (1980) as tolerant of a wide range of ecological conditions.

Cryptochironomus larvae live within loose unconsolidated bottom sediments (Mason 1998) and, along with *Chironomus*, are commonly found in eutrophic conditions (Burt *et al.* 1991). *Paratendipes* exhibit their greatest abundance in areas of slack current where fine detritus (on which the larvae feed) accumulates (Simpson and Bode 1980). *Polypedilum* larvae are filter feeders whose occurrence is governed more by current speed and the amount of suspended food particles than by water quality (Simpson and Bode 1980). *Polypedilum* prefer mesotrophic conditions and are probably intolerant of heavy organic pollution (Burt *et al.* 1991). In a study of chironomid gut contents in a Pennsylvania stream, one species of *Polypedilum* contained 85% algae and 15% detritus (Cummins 1973). Dickman and Rygiel (1993) observed that *Polypedilum* live in dense stands of macrophytes, but that was not the case in this study. Both the lower creek and middle creek mud sites would seem to provide similar environmental conditions in terms of substrate particle size and current velocity (Table 1). The conditions present seem favorable to members of tribe Chironomini, so the differences in the chironomid communities between these two sites remain unexplained.

Sampling and Sample Size Considerations

It is clear from the data presented in Table 4 that the variability in the replicate samples collected in this study has important implications for the feasibility of using chironomids as

reliable indicators of water quality changes over time in Irondequoit Creek. Fifteen samples per treatment were collected (*i.e.*, 15 samples in each habitat across the upper, middle, and lower creek locations and 15 samples in each creek location across mud, vegetation, and gravel habitats). Standard benthic macroinvertebrate sampling protocols suggest four to six replicate samples per treatment, which in this data set would permit detection of only 50% differences in treatment means 50% of the time (i.e., power = 0.5; Table 4). In terms of biomonitoring, five replicates per treatment probably do not provide adequate resolution to make water quality management decisions. In this data set, to detect a 30% difference in treatment means 70% of the time would require 20 - 25 replicates per treatment; to detect a 10% difference 90% of the time would require over 300 replicates per treatment. The number of replicate samples suggested in Table 4 is the minimum number of samples necessary and is based on an assumption that the log-transformed taxa richness data had a perfect normal distribution. Since the distribution was not perfectly normal, the actual number of replicate samples required to achieve a given level of power and minimum level of detection is probably somewhat higher.

Clearly, given current sampling protocols, collecting and processing 300 replicate samples would be prohibitively expensive. A compromise can be reached between the need for statistical accuracy (small samples are statistically inaccurate due to large variations in the distributions of natural populations) and the reduction of labor (Elliott 1977). Smaller samples may be collected in order to increase sample size without increasing the time and effort involved in processing specimens. More, smaller samples in a given location help to minimize the influence of patchy benthic invertebrate distribution and produce a better

sample across any gradients of contamination concentrations and microhabitat types (Canfield *et al.* 1995a).

Chironomid Deformities Comparisons

Several questions arise when examining the chironomid deformity data that were collected. The first has to do with defining and recognizing the deformities. Included in the box below are types of deformities of the menta (for subfamilies Chironominae and Orthocladiinae) and the ligulae (for subfamily Tanypodinae) of chironomids (Warwick1991, 1989). Not included (and not used for this study) are deformities of the antennae, mandibles, and hypopharyngeal pecten. For the purposes of this study, the menta and ligulae deformities were determined to be the most clear-cut and most easily observed of the deformities known to be caused by exposure to organic and toxic contaminants.

menta	ligulae
number of teeth	number of teeth
asymmetry	asymmetry
massive disorganization of teeth	massive disorganization
absence of teeth	absence of teeth
overlapping teeth	overlapping teeth
reduction in size of teeth	reduction in size of teeth
super positioning of teeth	modifications to outer teeth
configuration of individual teeth	presence of accessory teeth
	presence of forked teeth
	fusing between ligula and paraligulae

Warwick (1991, 1990) observed that uneven wear (due to normal feeding and abrasion by coarse sediments) and breakage of the teeth of the menta and ligulae are easy to detect and easy to distinguish from morphological deformities. This is not necessarily true, particularly for the novice chironomid researcher. As part of the data collection and classification, a toxic score that included three levels of mouthparts deformity severity was

calculated. Lenat (1993) acknowledged that Class I deformities (the least severe of the three classes), "included slight deformities which were difficult to separate from 'chipped' teeth." Bird (1994) found deformity rates among chironomids as high as 16% in remote Canadian Shield Lakes (considered to be pristine sites, unimpacted by organic or toxic pollution) and considered these deformities to be natural abnormalities and to be of common occurrence. Identifying a deformed chironomid may not be as straightforward as it would seem after reading some of the published research.

Determining the level of chironomid deformities that actually signifies a response to pollution is another important question. *Chironomus* is generally acknowledged to be the taxon that most frequently shows deformities in response to environmental impacts (Diggins and Stewart 1993; Warwick 1990,1985; Warwick *et al.* 1987; Wiederholm 1984a). Other taxa that commonly demonstrate deformities include *Procladius*, *Micropsectra*, *Tanytarsus*, *Cryptochironomus*, *Polypedilum*, *Stictochironomus*, and *Phaenopsectra* (Diggins and Stewart 1993; Pettigrove 1989; Warwick 1989, 1988; Wiederholm 1984a). Pettigrove (1989) found that all chironomid taxa exhibiting deformities were subfamily Chironominae or Tanypodinae. This study found deformities in *Chironomus*, *Procladius*, *Microtendipes*, *Cricotopus/Orthocladius* complex, *Endochironomus*, *Polypedilum*, *Phaenopsectra*, *Tribelos*, and *Rheotanytarsus*. Of the taxa in which deformities were found, only deformed specimens of *Polypedilum* were found at more than one site (middle creek mud and middle creek gravel).

Studies that have compared deformity rates of chironomid larvae taken from unpolluted and polluted sites have compared rates only within taxa. Of the taxa that commonly display deformities, only *Cryptochironomus* (Appendix C-2), *Polypedilum* (Appendix C-7), and

Tanytarsus (Appendix C-14) were widely distributed through the Irondequoit Creek sampling sites, with only *Polypedilum* present in significant numbers. *Cryptochironomus* and *Tanytarsus* accounted for more than 5% of a sample site's total abundance in only one and two sites, respectively (Table 6), and no deformities were found in either taxon. The taxon that showed the highest rate of deformities in this study (*Phaenopsectra*) was found in significant numbers only in the middle creek mud site. The most abundant and most widely distributed taxon, *Cricotopus/Orthocladius* complex, does not commonly demonstrate deformities, and its rate of deformities in this study was 0.45%. It was not included in deformity rate calculations.

In addition, there is considerable variation in the estimation of background deformity rates that are a result of the natural variability of chironomid morphological structures. Estimates vary as to what incidence of deformities implies significant environmental degradation; this partly reflects the subjective nature of interpreting deformities in some structures (Ciborowski *et al.* 1995). Wiederholm (1984a) noted deformity rates for tribe Tanytarsini found at unpolluted sites of 0.3%. This number rose to 3.8% at slightly polluted sites and 17.5% at extremely polluted sites. The same study cited deformity rates for subfossil *Chironomus* (> 30 years) of 0.8% and present rates (two sites each) of 1.6% and 1.8% (unpolluted sites), 4.1% and 10.7% (slightly polluted sites), and 8.3% and 25% (at extremely polluted sites). Ciborowski *et al.* (1995) determined that baseline levels of mentum deformities in susceptible genera of 3% or less implied no significant degradation of water quality, while incidences of 6% or more could be expected at contaminated locations.

Using mentum deformity rates, none of the three locations of Irondequoit Creek exhibited evidence of toxic pollution or organic impact effects. The deformity rates for

susceptible taxa (lower creek: 5.3% for all deformities and 1.2% for Class II and III deformities; middle creek: 4.5% and 1.2%; and upper creek: no deformities) were similar to Lenat's (1993) figures for *Chironomus* from clean-water sites in North Carolina streams (5.4% for all deformities and 2.0% for Class II and III deformities). Toxic scores for susceptible taxa from the lower and middle creek were 6.5 and 5.6, respectively. Both scores were less than the 8.0 clean-water mean toxic score reported by Lenat (1993). . Lenat's observations indicated that deformity rates for stressed nontoxic streams (organic loading rather than toxic pollution) were 11%, and that nontoxic streams should be expected to have combined Class II and III deformity rates < 6% with a toxic score < 25.

Another consideration when using chironomid larvae deformities to determine water quality is sample size. Ciborowski et al. (1995) concluded that a sample size of at least 125 chironomid larvae per site was necessary to demonstrate that a doubling in the incidence of deformities of a genus over background levels would be significant 80% of the time. Lenat (1993), however, calculated statistics for sites if at least 15 *Chironomus* larvae were found. Studies of chironomid deformities are hindered by small sample sizes and/or the lack of adequate spatial scale (Hudson and Ciborowski 1996a). However, in this study, there were at least 330 specimens of larvae of taxa in which deformities were found in each sample site, with two exceptions. Only 35 specimens of *Procladius* were found in the lower creek mud site and 18 specimens of *Endochironomus* were found in the middle creek mud site. While the number of specimens found at each site is enough for analysis, a suitable taxon that is found in all habitats and stream locations is needed for a reliable comparison of deformity rates to be made.

Conclusions

This study was designed to answer four questions:

- Are there differences among upper, middle, and lower creek sampling locations, as evidenced by differences in chironomid community structure and mouthpart deformity rates?

Differences were found among the sampling locations in Irondequoit Creek using diversity indices. Simpson's diversity and taxa richness were highest in the upper creek and lowest in the lower creek. Chironomid abundance was highest in the middle creek.

- Are there differences among mud, vegetation, and gravel habitats, as evidenced by differences in chironomid community structure and mouthpart deformity rates?

Differences were also found among the sampled habitats using the same measures. Simpson's diversity, taxa richness, and chironomid abundance were all highest in the gravel habitats and lowest in the vegetation habitats. Some of the community structure differences (*e.g.*, the predominance of *Chironomus* in the lower creek mud and the high chironomid abundance in the middle creek location) might have been due to organic impacts.

- Is there evidence of pollution or degradation of water quality in the Irondequoit Creek watershed, and which chironomid taxa are the best indicators of such degradation?

Examination of chironomid mentum deformity data proved inconclusive for identifying differences among locations or habitats, due to the lack of shared deformed taxa across sites. Using deformity rates for all susceptible taxa, the Irondequoit Creek watershed showed no evidence of toxic or organic degradation. The non-uniform distribution of deformed taxa across sites made direct comparisons impossible. There was

no precedent found in chironomid deformity literature for comparing deformities in different taxa. *Cryptochironomus*, *Tanytarsus*, and *Polypedilum* were widely distributed in Irondequoit Creek and are among the taxa that commonly exhibit mouthpart deformities. Although no deformed *Cryptochironomus* or *Tanytarsus* were found in this study, deformed *Polypedilum* were found in two sites. One of these taxa may prove to be a better choice for deformity comparisons in Irondequoit Creek than *Chironomus*, which was found primarily in the lower creek mud habitat.

- Are current sampling designs adequate to obtain statistically reliable values for differences in chironomid communities in the watershed?

One of the goals of this study was to find ways to reduce the time and expense involved in collecting, sorting, preparing, identifying, and counting specimens. Although each of the habitats (mud, vegetation, and gravel) was found to have differences in chironomid community structure (Simpson's diversity, taxa richness, and abundance), 21 to 22 of the 24 taxa that comprised more than 1% of abundance at any one site were found in each of the three habitats. Thus, only one habitat needs to be sampled in the future to provide comparable indices of chironomid community structure. The gravel habitat had the greatest diversity and abundance and provides the broadest distribution of chironomid taxa across subfamilies and ecological requirements. The deformity-susceptible tribe Chironomini is more commonly found in the mud habitat. Thus, when comparing chironomid deformity rates, sampling in the mud habitats would be better. Because there is no evidence of toxic pollution in the Irondequoit Creek watershed, if only one habitat is to be sampled in the future, the gravel habitat is probably the best choice.

Also, the number of replicate samples needs to be increased in order to have sufficient power to validly recognize changes in chironomid communities over time. The number of replicates can be increased, without greatly increasing the time and effort of processing specimens, by reducing the spatial extent of samples by subsampling along standard transects (*e.g.*, multiple traveling kick samples in the gravel habitat could be taken every 2 to 5 feet along a standard 20 foot transect). Also, more caution during kick sampling would reduce the amount of gravel and detritus entering collecting nets, reduce sorting time, and may save time in identification of specimens by reducing damage to delicate structures.

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Table 1. Habitat Measurements for All Sampling Sites in Irondequoit Creek.

Physical habitat data for comparability of habitats sampled. Data presented as mean (std. dev., std. error)							
Site	Lower Creek			Middle Creek		Upper Creek	
	upper site mud, vegetation	lower site mud, vegetation	gravel	veg, gravel	mud	veg, gravel	mud
Depth (cm)	55 (8,4)	94 (6,3)	48.0 (8.9,4.0)	41.8 (8.5,3.8)	71.8 (7.1,3.2)	44.5 (12.1,5.4)	44.5 (12.1,5.4)
Width (m)	18 (3,1)	18 (4,2)	14.4 (1.6,0.7)	9.8 (2.2,1.0)	9.3 (1.6,0.7)	4.9 (0.9,0.4)	4.9 (0.9,0.4)
Current (cm/s)	29 (11,5)	18 (8,3)	81.0 (10.1,5.1)	52 (17.8,7.9)	20.2 (10.7,4.8)	79.8 (15.5,6.9)	79.8 (15.5,6.9)
Canopy (%)	2 (4,2)	0 (0,0)	60 (17.4,7.8)	45 (15.4,6.9)	45.2 (22.9,10.2)	6 (7.5,3.3)	6 (7.5,3.3)
Embeddedness (%)	92 (11,5)	96 (9,4)	43 (23.6,10.6)	24 (15.6,7.0)	85 (23.8,11.9)	30 (17.3,7.7)	80 (3.5,1.6)
Temperature (°C)	14.9 (0.5,0.2)	10.5 (0.2,0.1)	12.3 (0.4,0.3)	12.2 (0.3,0.2)	13 (0.1,0.1)	10.9 (1.3,0.9)	10.9 (1.3,0.9)
Conductivity (μmhos)	600 (0,0)	555 (51,23)	992 (208,147)	972 (200,142)	1099 (18,13)	353 (62,44)	353 (62,44)
DO (mg/L)	6.9 (0.1,0.1)	12.6 (0.7,0.3)	10.3 (0,0)	11.0 (0.1,0.1)	11.2 (0.1,0.1)	10.0 (0.4,0.3)	10.0 (0.4,0.3)
pH	8.1 (0.1,0)	7.8 (0.1,0)	7.9 (0.1,0.1)	7.0 (0.1,0)	8.2 (0.1,0.1)	7.5 (0.1,0)	7.5 (0.1,0)
Particle size (phi)	3.0 (1.3,0.6)	5.6 (1.3,0.6)	-4.6 (0.5,0.2)	-2.9 (1.3,0.6)	3.4 (1.3,0.6)	-1.2 (0.6,0.3)	4.8 (1.1,0.5)

Habitat Comparability Criteria (Bode *et al*, 1991):

Substrate Particle Size - phi not to differ by more than 3 units

Substrate Embedness - % not to differ by more than 50% (unless % values are w/in 20)

Current Speed - not to differ by more than 50% (unless w/in 20 cm/sec)

Canopy Cover - % not to differ by more than 50% (unless % values are w/in 20)

gravel	Lower Creek	Middle Creek	Upper Creek	
Particle size (phi)	-4.6	-2.9	-1.2	LC/UC differ by 3.4 phi units
Embeddedness (%)	43	24.0	30.0	all are within 20 percentage units
Current (cm/s)	81	52.0	79.8	all are within 50%
Canopy (%)	60	45.0	6.0	UC differs from other sites by more than 50%
Temperature (°C)	12.3	13	10.9	none differ by more than 50%

mud	Lower Creek	Middle Creek	Upper Creek	
Particle size (phi)	4.3	3.4	4.8	all are within 3 phi units
Embeddedness (%)	94	85.0	80	none differ by more than 50%
Current (cm/s)	23.5	20.2	79.8	UC differs from other sites by more than 50% *
Canopy (%)	1	45.2	6.0	MC differs from other sites by more than 50%
Temperature (°C)	12.65	12.2	10.9	none differ by more than 50%

* Upper Creek sampled after major rain event

Simpson's Diversity			
Kruskal-Wallis one-way nonparametric test for diversity by location			
location	mean rank	N	
lower	15.6	15	
middle	25.6	15	
upper	27.8	15	
total	23	45	
Kruskal-Wallis statistic			7.353
p-value using chi-squared approximation			0.0253
Kruskal-Wallis one-way nonparametric test for diversity by habitat			
habitat	mean rank	N	
mud	20.6	15	
vegetation	18	15	
gravel	30.4	15	
total	23	45	
Kruskal-Wallis statistic			7.4365
p-value using chi-squared approximation			0.0243
Taxa Richness			
Kruskal-Wallis one-way nonparametric test for taxa richness by location			
location	mean rank	N	
lower	15.5	15	
middle	25.6	15	
upper	28	15	
total	23	45	
Kruskal-Wallis statistic			7.7322
p-value using chi-squared approximation			0.0209
Kruskal-Wallis one-way nonparametric test for taxa richness by habitat			
habitat	mean rank	N	
mud	23.4	15	
vegetation	16.2	15	
gravel	29.3	15	
total	23	45	
Kruskal-Wallis statistic			7.5635
p-value using chi-squared approximation			0.0228
Abundance			
Kruskal-Wallis one-way nonparametric test for abundance by location			
location	mean rank	N	
lower	17.8	15	
middle	33.2	15	
upper	18	15	
total	23	45	
Kruskal-Wallis statistic			13.578
p-value using chi-squared approximation			0.0011
Kruskal-Wallis one-way nonparametric test for abundance by habitat			
habitat	mean rank	N	
mud	19.5	15	
vegetation	18.5	15	
gravel	31	15	
total	23	45	
Kruskal-Wallis statistic			8.3885
p-value using chi-squared approximation			0.0151

Table 2. Kruskal-Wallis Test Results for Simpson's Diversity, Taxa Richness, and Abundance.

Coefficient of Community (CC)			
Kruskal-Wallis one-way nonparametric ANOVA for CC by location			
location	mean rank	N	
lower	2.7	3	
middle	5.3	3	
upper	7	3	
total	5	9	
Kruskal-Wallis statistic			3.8222
p-value (Zar 1996)			> 0.1
Kruskal-Wallis one-way nonparametric ANOVA for CC by habitat			
habitat	mean rank	N	
mud	5	3	
vegetation	2.3	3	
gravel	7.7	3	
total	5	9	
Kruskal-Wallis statistic			5.6889
p-value (Zar 1996)			0.02 < p < 0.05

Percent Similarity of Community (PS_C)			
Kruskal-Wallis one-way nonparametric ANOVA for PS_C by location			
location	mean rank	N	
lower	3	3	
middle	5	3	
upper	7	3	
total	5	9	
Kruskal-Wallis statistic			3.2
p-value (Zar 1996)			> 0.1
Kruskal-Wallis one-way nonparametric ANOVA for PS_C by habitat			
habitat	mean rank	N	
mud	2.7	3	
vegetation	5.3	3	
gravel	7	3	
total	5	9	
Kruskal-Wallis statistic			3.822
p-value (Zar 1996)			> 0.1

Table 3. Kruskal-Wallis Test Results for Coefficient of Community and Percent Similarity of Community.

Taxa Richness By Location		minimum detectable difference		
		10%	30%	50%
power	0.5	121	14	5
	0.7	200	22	8
	0.9	331	37	14

Taxa Richness By Habitat		minimum detectable difference		
		10%	30%	50%
power	0.5	129	15	6
	0.7	212	24	9
	0.9	352	40	15

Table 4. Sample Sizes Required to Meet Defined Levels of Power and Minimum Detectable Differences.

Table 5. Summary of Chironomid Deformities for Susceptible Taxa at All Sampling Sites in Irondequoit Creek.

site	taxon	Class I	Class II	Class III	# organisms	% Class II & III deformities	% deformities	Toxic Score
Lower Creek Mud	*Chironomus* sp	15	10		330	0.30	7.58	10.61
	Procladius sp.		1		35	2.86	2.86	5.71
Lower Creek Vegetation	**no deformities**							
Lower Creek Gravel	*Microtendipes* sp.	23			556	0.00	4.14	4.14
Middle Creek Mud	*Endochironomus* sp.		1		18	5.56	5.56	11.11
	Polypedilum sp.	6			720	0.00	0.83	0.83
	Phaenopsectra sp.	64	6		736	0.82	9.51	10.33
	Tribelos sp.	31			349	0.00	8.88	8.88
Middle Creek Vegetation	*Rheotanytarsus* sp.		30		959	3.13	3.13	6.26
Middle Creek Gravel	*Polypedilum* sp.	4			404	0.00	0.99	0.99
Upper Creek Mud	**no deformities**							
Upper Creek Vegetation	**no deformities**							
Upper Creek Gravel	**no deformities**							
Lower Creek total		38	11		921	1.19	5.32	6.51
Middle Creek total		105	37		3186	1.16	4.46	5.62
Upper Creek total		0	0		0	-	-	0.00
Total		143	48		4107	1.17	4.65	5.82

	Site	LC Mud	LC Veg	LC Gravel	MC Mud	MC Veg	MC Gravel	UC Mud	UC Veg	UC Gravel
Chironominae	*Chironomus* sp.	■	■	▫	▫			▫		▫
Chironomini	*Cladopelma* sp.	▫	▫							
	Cryptochironomus sp.	▪	▫	▫	□	▫	▪	▪	▫	▪
	Cryptotendipes sp.			▫						
	Dicrotendipes sp.	▪		▫	▫			□	▪	▪
	Endochironomus sp.			▫	▫					
	Glyptotendipes sp.	▫			▫					
	Microtendipes sp.			■			▫	▫	▪	■
	Paracladopelma sp.	▫		▫	▫					
	Paratendipes sp.			▪	■	▫	▫	■	■	□
	Phaenopsectra sp.			▪	■		▫	▫		▫
	Polypedilum sp.	▪	▪	■	■	□	□	▪	▪	□
	Saetheria sp.			▫	▫					
	Stenochironomus sp.		▫							
	Stictochironomus sp.									▫
	Tribelos sp.				□					▫
Tanytarsini	*Cladotanytarsus* sp.			▪	■	▪	■	▫	▫	▪
	Micropsectra sp.	▪			▫			▪	▪	□
	Paratanytarsus sp.		▪				▫			□
	Rheotanytarsus sp.		■		▫	■	□	□	□	▫
	Stempellinella sp.							▫	▪	▫
	Sublettea sp.					▫				
	Tanytarsus sp.	▫		▫	▪	▪	▪	▪	□	■
Orthocladiinae	*Brillia* sp.					▫	▫		▫	
	Cric/Orth complex	▫	■	■	▪	■	■	■	■	■
	Eukiefferiella sp.		■	▫		□	▫		▪	▫
	Heterotrissocladius sp.					▫		▫	■	▪
	Nanocladius sp.			▪	▫		▫	▪	▪	▪
	Parametriocnemus sp.									▫
	Paraphaenocladius sp.		▫							
	Parorthocladius sp.								▫	
	Rheocricotopus sp.								▫	▫
	Smittia sp.									▫
	Thienemanniella sp.					▫			▫	
Tanypodinae	*Ablabesmyia* sp.								▫	
	Clinotanypus sp.		▪						▫	
	Natarsia sp.							▫	▫	
	Nilotanypus sp.									▫
	Procladius sp.	□	▪					▪	▫	
	Tanypus sp.	▪								
	Thienemannimyia sp.								▫	▪
Diamesinae	*Diamesa* sp.			■		□	■	▫		▫
	Pagastia sp.			▫		▪	▪	▪		▫

Legend: ▫ = < 1% of site total; ▪ = 1 - 5% of site total; □ = 5 - 10% of site total; ■ = > 10% of site total

Table 6. Chironomid Distribution in All Sampling Sites in Irondequoit Creek.

Figures

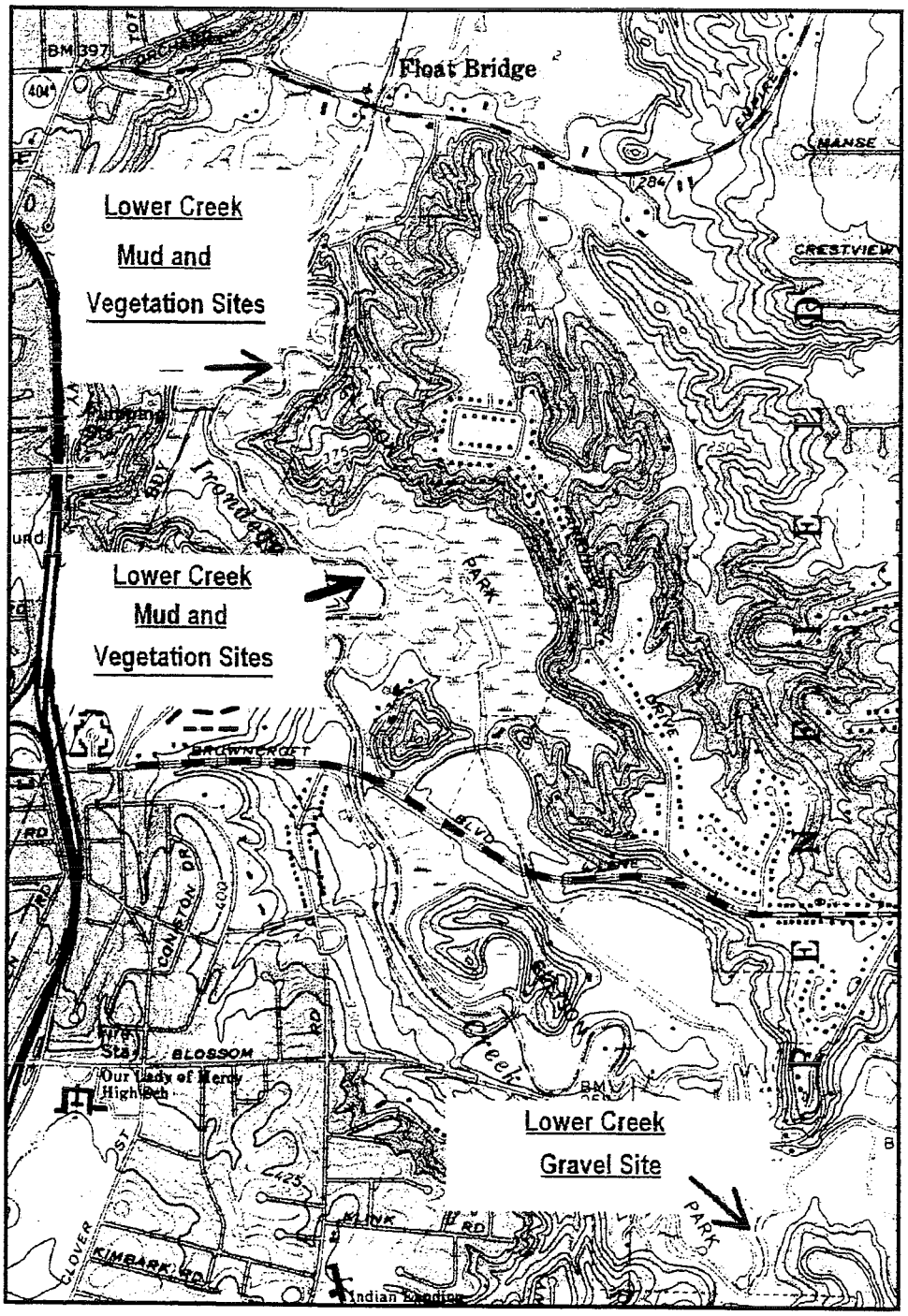


Figure 1. Lower Creek Sampling Sites in Irondequoit Creek.

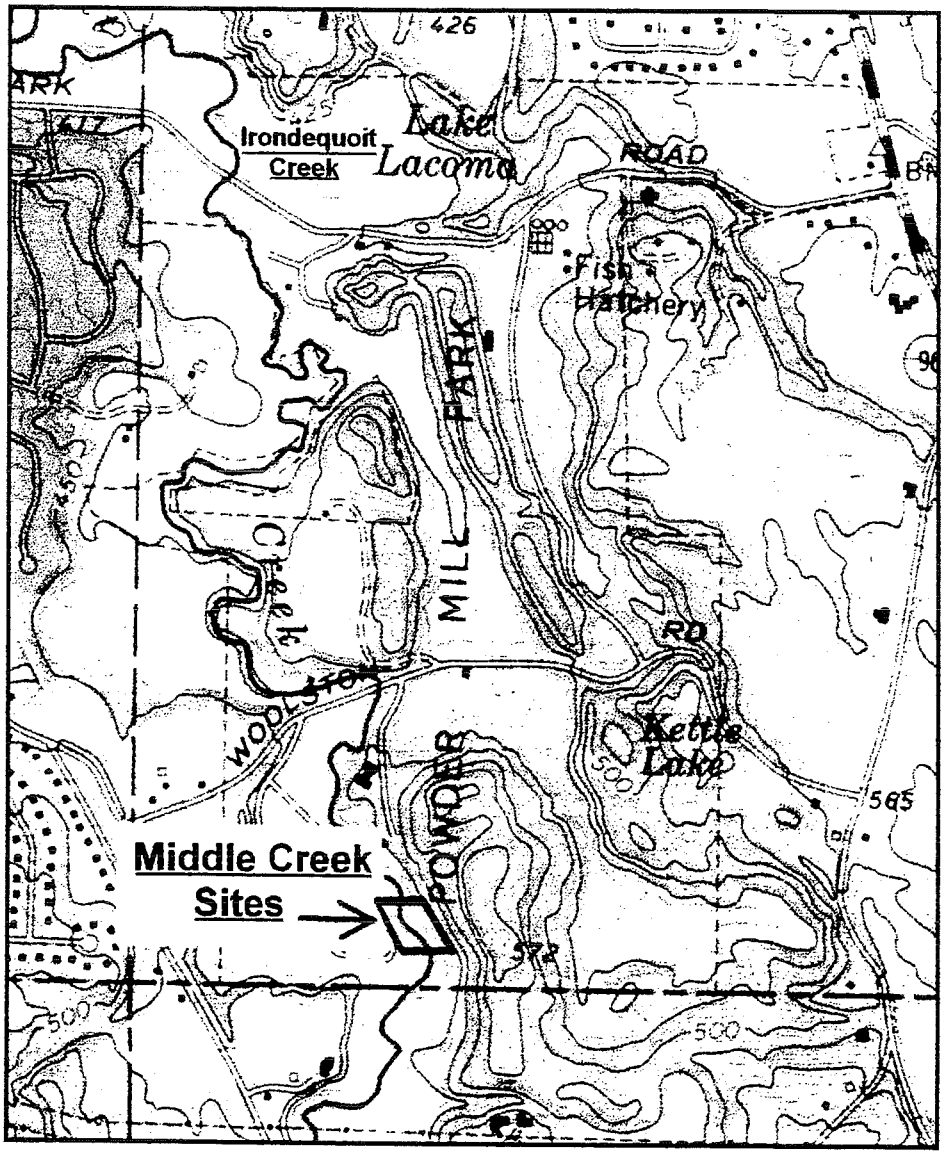


Figure 2. Middle Creek Sampling Sites in Irondequoit Creek.

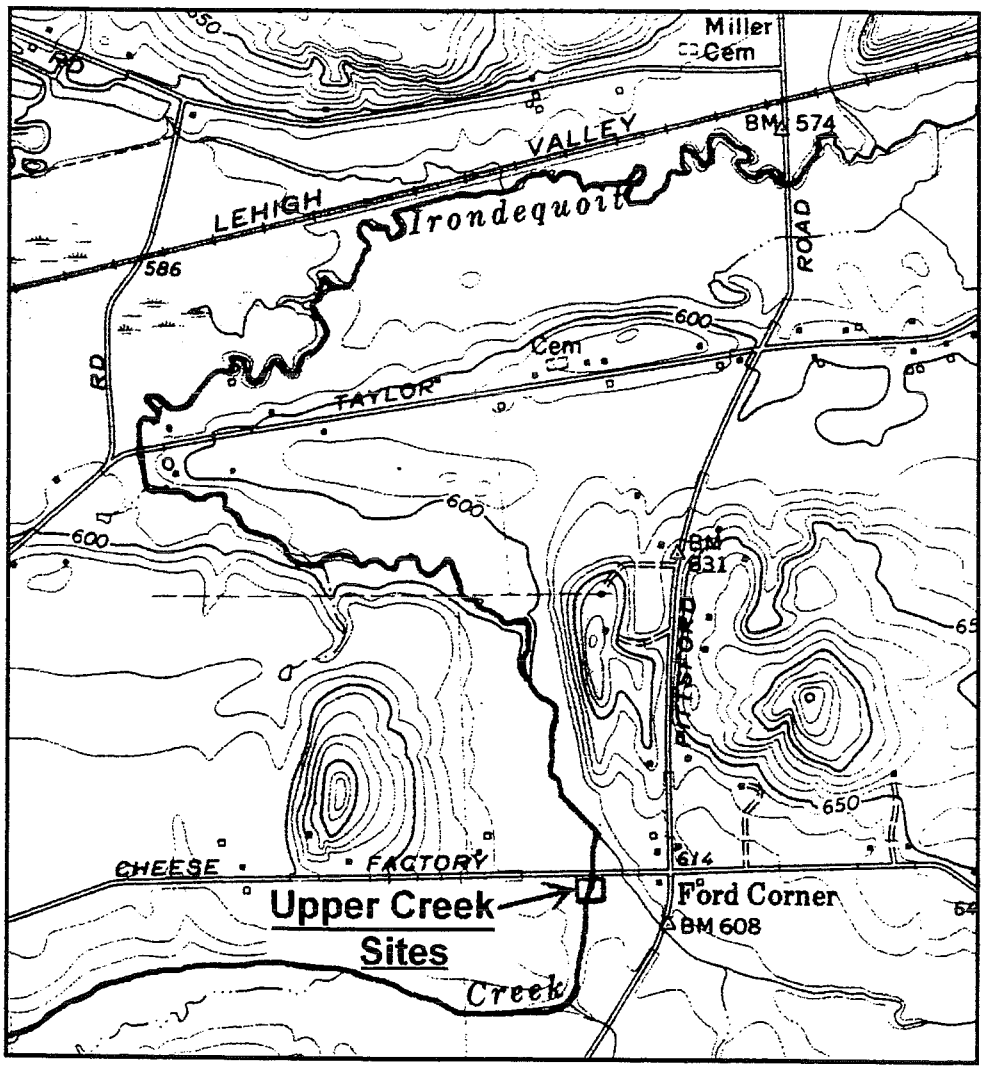


Figure 3. Upper Creek Sampling Sites in Irondequoit Creek.

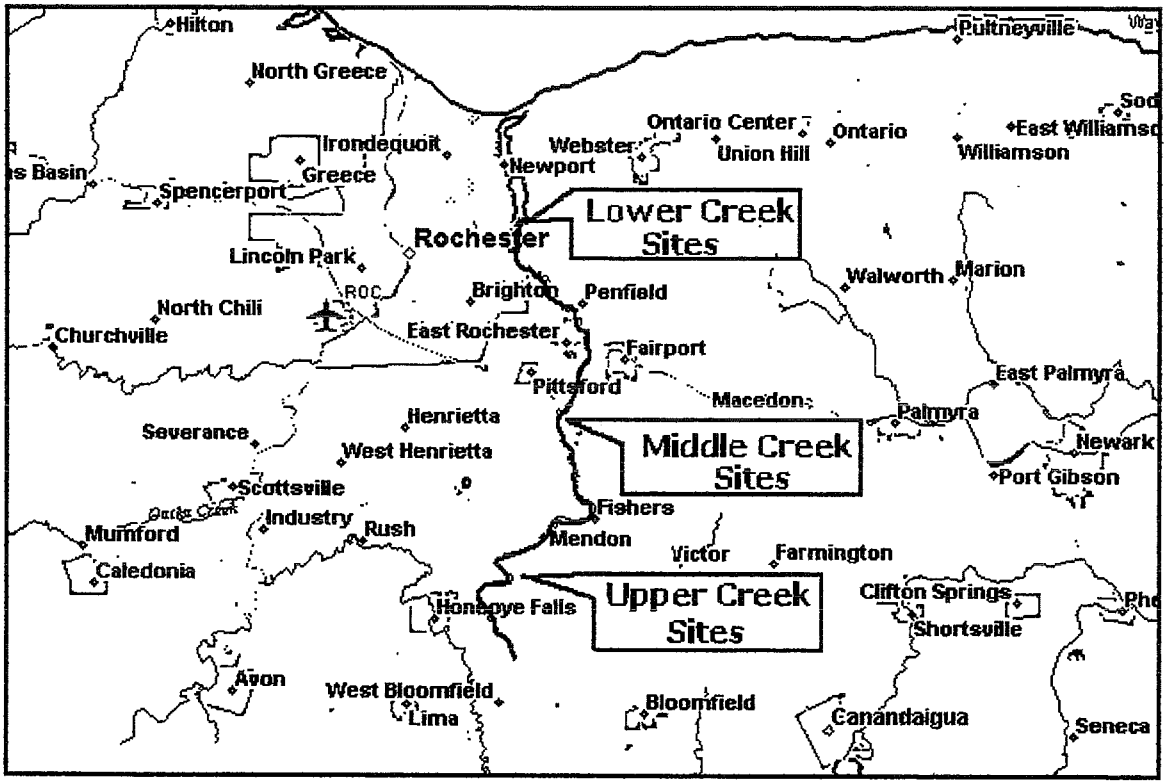


Figure 4. Relative Locations of Lower, Middle, and Upper Creek Sampling Sites in Irondequoit Creek.

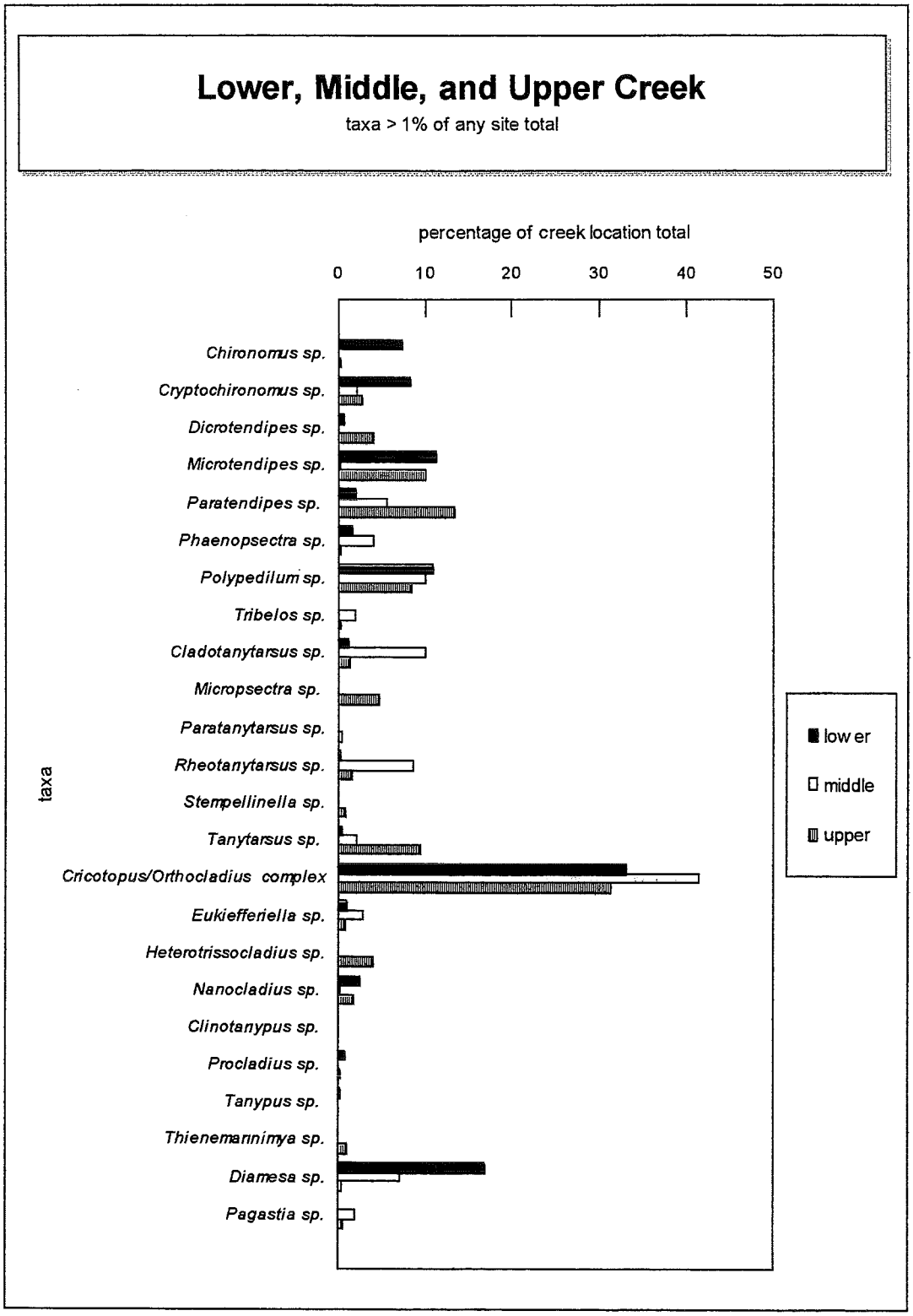


Figure 5. Chironomid Distribution in Lower, Middle, and Upper Creek Sites in Irondequoit Creek.

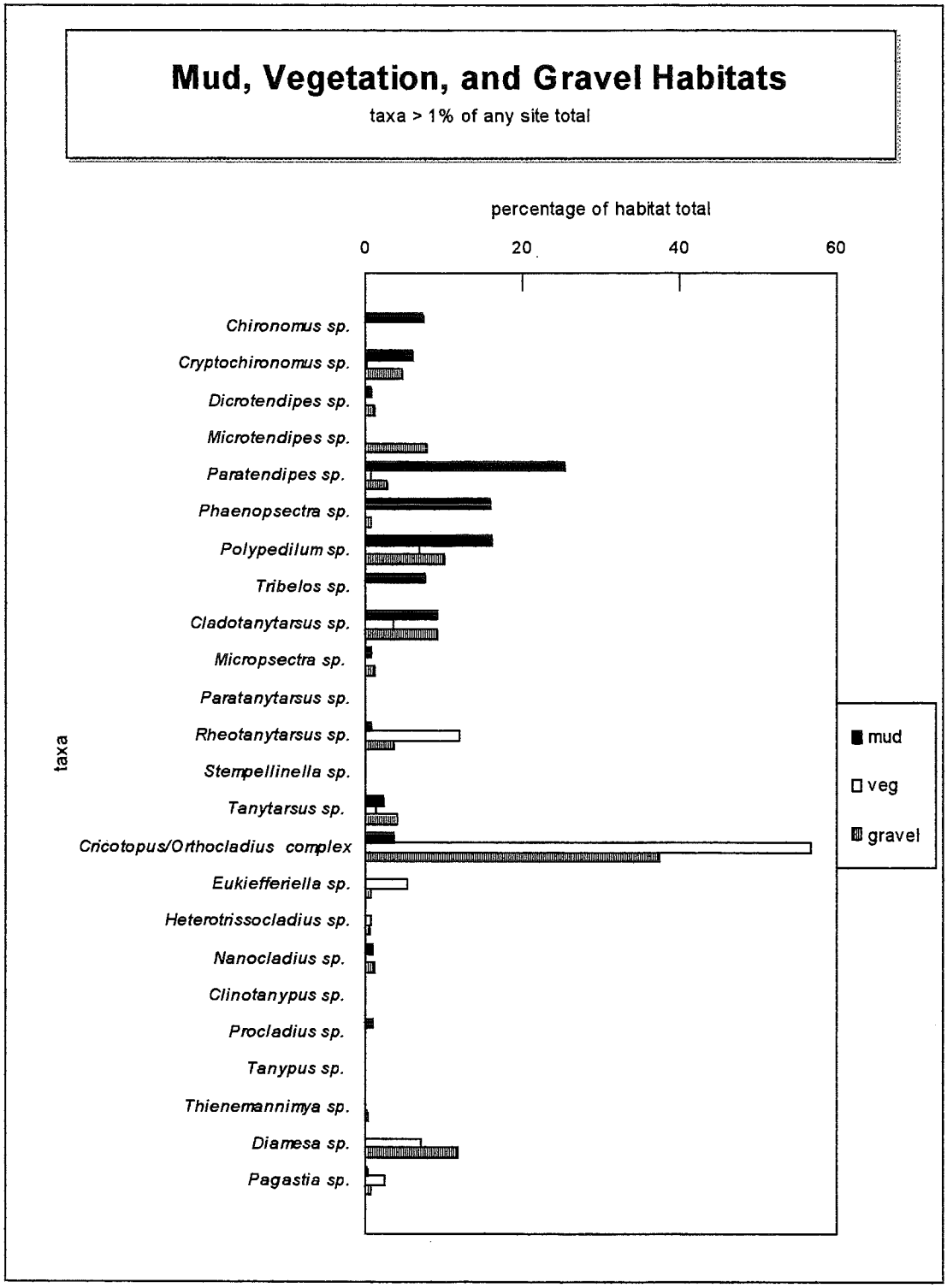


Figure 6. Chironomid Distribution in Mud, Vegetation, and Gravel Sites in Irondequoit Creek.

ɔendix A. Numbers of Chironomid Larvae Found by Site and Station in Irondequoit Creek.

	Page 1 Site	Lower Creek Mud					Lower Creek Vegetation				
	Taxon Station	1	2	3	4	5	1	2	3	4	5
ɔfamily	*Chironomus* sp.	100	16	31	127	56	11		1		7
ronominae	*Cladopelma* sp.				1		1				
ironomini)	*Cryptochironomus* sp.	10	1	2	3						1
	Cryptotendipes sp.										
	Dicrotendipes sp.	1	1		3	1					
	Einfeldia sp.										
	Endochironomus sp.										
	Glyptotendipes sp.	1									
	Microtendipes sp.										
	Parachironomus sp.										
	Paracladopelma sp.				1						
	Paratendipes sp.										
	Phaenopsectra sp.										
	Polypedilum sp.	4	1					4			
	Saetheria sp.										
	Stenochironomus sp.										1
	Stictochironomus sp.										
	Tribelos sp.										
ronominae	*Cladotanytarsus* sp.										
nytarsini)	*Micropsectra* sp.	1									
	Paratanytarsus sp.						1	3			
	Rheotanytarsus sp.							15			
	Stempellinella sp.										
	Sublettea sp.										
	Tanytarsus sp.			1	1						
hocladiinae	*Brillia* sp.										
	Cricotopus/Orthocladius complex				1			79			
	Eukiefferiella sp.							15			
	Heterotrissocladius sp.										
	Nanocladius sp.										
	Parametriocnemus sp.										
	Paraphaenocladius sp.							1			
	Parorthocladius sp.										
	Rheocricotopus sp.										
	Smittia sp.										
	Thienemanniella sp.										
ypodinae	*Ablabesmyia* sp.										
	Clinotanypus sp.									1	1
	Coelotanypus sp.										
	Natarsia sp.										
	Nilotanypus sp.										
	Procladius sp.	8	3	8	10	6				2	2
	Tanypus sp.	1	2		4						
	Thienemannimyia sp.										
mesinae	*Diamesa* sp.										
	Pagastia sp.										
	Unidentified Chironomidae			1	5	4		4		2	1
	Totals	126	24	43	156	67	13	121	1	5	13

Page 2	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5
Chironomus sp.	8		9			1			8						
Cladopelma sp.															
Cryptochironomus sp.	26	131	53	158	20	1	15	17	38	173		22			
Cryptotendipes sp.					6										
Dicrotendipes sp.		12	9					6							
Einfeldia sp.															
Endochironomus sp.	4			14		12		6							
Glyptotendipes sp.										31					
Microtendipes sp.	9	143	97	287	20										
Parachironomus sp.															
Paracladopelma sp.	2								8						
Paratendipes sp.	44	24		29		247	126	193	183	204	6				
Phaenopsectra sp.	6	24		43	7	2	75	134	23	502					
Polypedilum sp.	49	60	106	244	65	53	96	47	289	235	95	155	237	75	90
Saetheria sp.		36							8	16					
Stenochironomus sp.															
Stictochironomus sp.															
Tribelos sp.						1	5	6	7	330					
Cladotanytarsus sp.	6	12		43		12	146	70	152	47	19			6	329
Micropsectra sp.						10	5		7						
Paratanytarsus sp.															
Rheotanytarsus sp.								6	7		19	88	53	6	959
Stempellinella sp.															
Sublettea sp.											45			6	
Tanytarsus sp.				14	6	10	20	47	8		6				120
Brillia sp.															30
Cric/Orth complex	21	538	381	431	169	13	10	46	23	31	325	1677	1898	423	959
Eukiefferiella sp.		12			26						19	132	158	56	120
Heterotrissocladius sp.														6	
Nanocladius sp.	9	48	9	57		10	5	6							
Parametriocnemus sp.															
Paraphaenocladius sp.															
Parorthocladius sp.															
Rheocricotopus sp.															
Smittia sp.															
Thienemanniella sp.														6	
Ablabesmyia sp.															
Clinotanypus sp.															
Coelotanypus sp.															
Natarsia sp.															
Nilotanypus sp.															
Procladius sp.															
Tanypus sp.															
Thienemannimyia sp.															
Diamesa sp.	4	155	221	115	332						102	132	132	31	299
Pagastia sp.	2												158	6	90
Unidentified Chironomidae						1									
Totals	190	1195	885	1435	651	373	503	584	761	1569	636	2206	2636	621	2996

Appendix A Page 3	Middle Creek Gravel					Upper Creek Mud				
	1	2	3	4	5	1	2	3	4	5
Chironomus sp.									1	
Cladopelma sp.										
Cryptochironomus sp.	11		58	27	17	5			11	1
Cryptotendipes sp.										
Dicrotendipes sp.							20	1		1
Einfeldia sp.										
Endochironomus sp.										
Glyptotendipes sp.										
Microtendipes sp.	5	1	23		4	1				
Parachironomus sp.										
Paracladopelma sp.										
Paratendipes sp.	5		23		4	10	31	79	74	27
Phaenopsectra sp.					4		1			
Polypedilum sp.	44	21	127	107	105	2		1	14	2
Saetheria sp.										
Stenochironomus sp.										
Stictochironomus sp.										
Tribelos sp.										
Cladotanytarsus sp.	83	41	255	509	121	1		2		
Micropsectra sp.						1		1	1	10
Paratanytarsus sp.	6									
Rheotanytarsus sp.	44	3	185	161	21		2		20	
Stempellinella sp.								1	1	
Sublettea sp.										
Tanytarsus sp.	5	2	70	107		1	13	1	1	4
Brillia sp.					4					
Cric/Orth complex	259	12	347	1287	80	3		5	33	4
Eukiefferiella sp.	33									
Heterotrissocladius sp.								1		
Nanocladius sp.					4	10			10	1
Parametriocnemus sp.										
Paraphaenocladius sp.										
Parorthocladius sp.										
Rheocricotopus sp.										
Smittia sp.										
Thienemanniella sp.										
Ablabesmyia sp.										
Clinotanypus sp.										
Coelotanypus sp.										
Natarsia sp.								1	1	
Nilotanypus sp.										
Procladius sp.						1		5		
Tanypus sp.										
Thienemannimyia sp.										
Diamesa sp.	33		46	456	54	1				1
Pagastia sp.	22	10	23	27						10
Unidentified Chironomidae									10	
Totals	550	90	1157	2681	418	36	67	98	177	61

Appendix A Page 4	Upper Creek Vegetation					Upper Creek Gravel				
	1	2	3	4	5	1	2	3	4	5
Chironomus sp.							6			
Cladopelma sp.										
Cryptochironomus sp.		1		1		13	12		49	2
Cryptotendipes sp.										
Dicrotendipes sp.	2	2		1			31	1	88	1
Einfeldia sp.										
Endochironomus sp.										
Glyptotendipes sp.										
Microtendipes sp.	3	10				158		1	157	29
Parachironomus sp.										
Paracladopelma sp.										
Paratendipes sp.	30	11		15			125	20	49	
Phaenopsectra sp.									10	
Polypedilum sp.	3	4		1	5	112	44		98	18
Saetheria sp.										
Stenochironomus sp.										
Stictochironomus sp.									10	
Tribelos sp.							6			
Cladotanytarsus sp.	2			1				1	39	1
Micropsectra sp.	4	2		2			62	50	29	1
Paratanytarsus sp.						7	6			1
Rheotanytarsus sp.	2	13	2		1	13	6			
Stempellinella sp.				10			19			
Sublettea sp.										
Tanytarsus sp.	2	13	1	2		99	50		127	22
Brillia sp.		1								
Cric/Orth complex	25	48	1	13	4	389	143	50	284	102
Eukiefferiella sp.	10	1				6				12
Heterotrissocladius sp.	45	10	10	12			56		10	
Nanocladius sp.	2	13			1		19		10	
Parametriocnemus sp.							13			
Paraphaenocladius sp.										
Parorthocladius sp.					1					
Rheocricotopus sp.			1						10	
Smittia sp.							6			
Thienemanniella sp.		2								
Ablabesmyia sp.		1								
Clinotanypus sp.		1								
Coelotanypus sp.										
Natarsia sp.		2								
Nilotanypus sp.						7				
Procladius sp.		1								
Tanypus sp.										
Thienemannimyia sp.					1	13	13		10	
Diamesa sp.						7	6			
Pagastia sp.						13				
Unidentified Chironomidae										
Totals	130	136	15	58	13	837	623	123	980	189

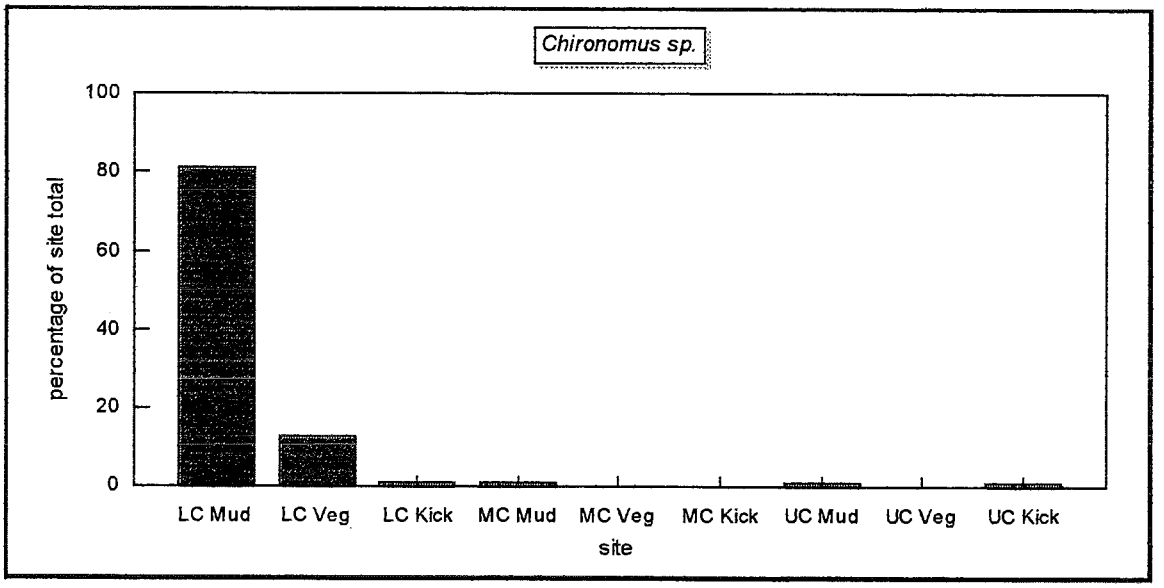
sites	Coefficient of Community (%)	Percentage Similarity of Community (%)
within lower creek		
LCM/LCV	50.0	18.2
LCM/LCK	46.7	6.8
LCV/LCK	33.3	40.0
within middle creek		
MCM/MCV	45.2	16.3
MCM/MCK	56.3	28.5
MCV/MCK	75.9	71.8
within upper creek		
UCM/UCV	71.4	51.1
UCM/UCK	75.6	41.6
UCV/UCK	65.3	56.6
3 mud sites		
LCM/MCM	62.1	7.0
LCM/UCM	51.6	9.3
MCM/UCM	66.7	41.8
3 vegetation sites		
LCV/MCV	38.5	72.7
LCV/UCV	40.0	38.0
MCV/UCV	59.5	40.8
3 gravel sites		
LCK/MCK	72.7	62.0
LCK/UCK	63.6	67.7
MCK/UCK	68.3	54.9

Sites Legend

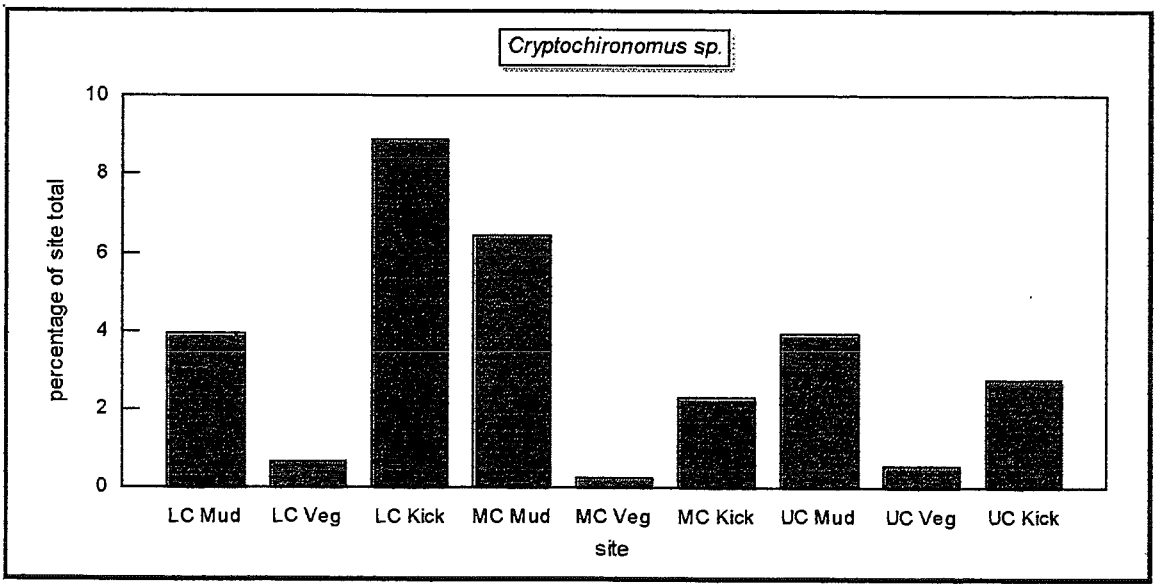
LCM: Lower Creek Mud
LCV: Lower Creek Vegetation
LCK: Lower Creek Gravel
MCM: Middle Creek Mud
MCV: Middle Creek Vegetation
MCK: Middle Creek Gravel
UCM: Upper Creek Mud
UCV: Upper Creek Vegetation
UCK: Upper Creek Gravel

site	replicate	Simpson's diversity	taxa richness	chironomid abundance
LCM	1	1.559	8	126
	2	2.118	6	24
	3	1.713	4	43
	4	1.402	9	156
	5	1.251	3	67
LCV	1	1.374	3	13
	2	2.038	6	121
	3	1.000	1	1
	4	1.800	2	5
	5	2.571	5	13
LCK	1	6.233	13	190
	2	3.968	12	1195
	3	3.598	8	885
	4	5.505	11	1435
	5	2.931	9	651
MCM	1	2.143	12	373
	2	4.789	10	503
	3	5.082	12	584
	4	4.049	13	761
	5	5.003	9	1569
MCV	1	3.154	9	636
	2	1.690	6	2206
	3	1.864	6	2636
	4	2.042	10	621
	5	4.309	9	2996
MCK	1	3.747	12	550
	2	3.403	7	90
	3	5.403	10	1157
	4	3.307	8	2681
	5	4.882	11	418
UCM	1	5.311	11	36
	2	2.924	5	67
	3	1.524	11	98
	4	3.775	11	177
	5	3.840	10	61
UCV	1	4.563	12	130
	2	5.835	18	136
	3	2.103	5	15
	4	5.175	10	58
	5	3.756	6	13
UCK	1	3.512	12	837
	2	7.783	18	623
	3	2.800	6	123
	4	6.554	15	980
	5	2.927	10	189

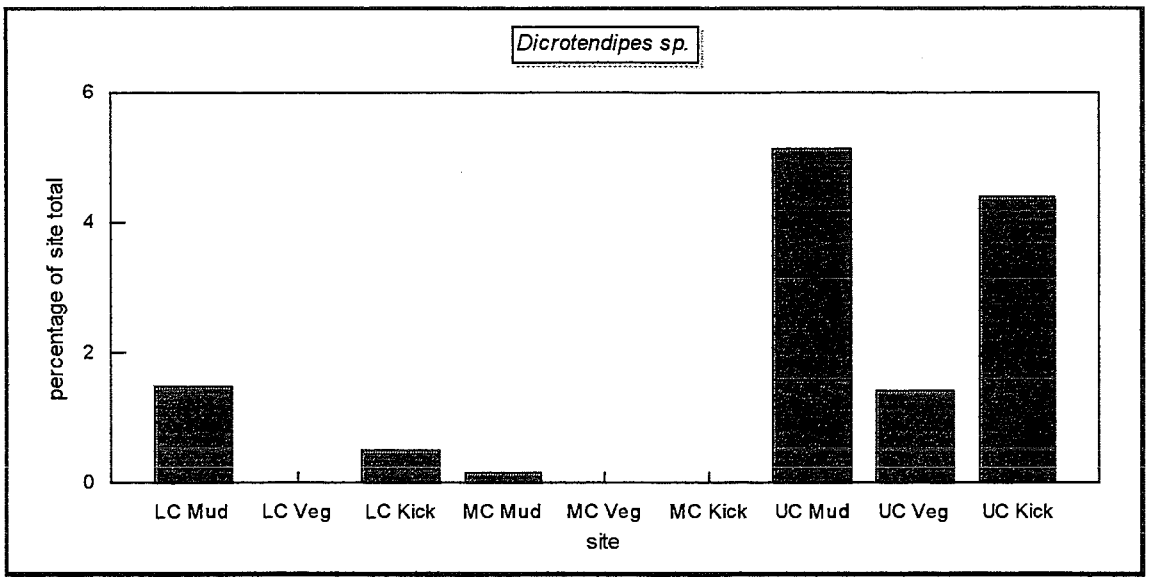
Appendix C. Distributions of Individual Chironomid Taxa in Irondequoit Creek.



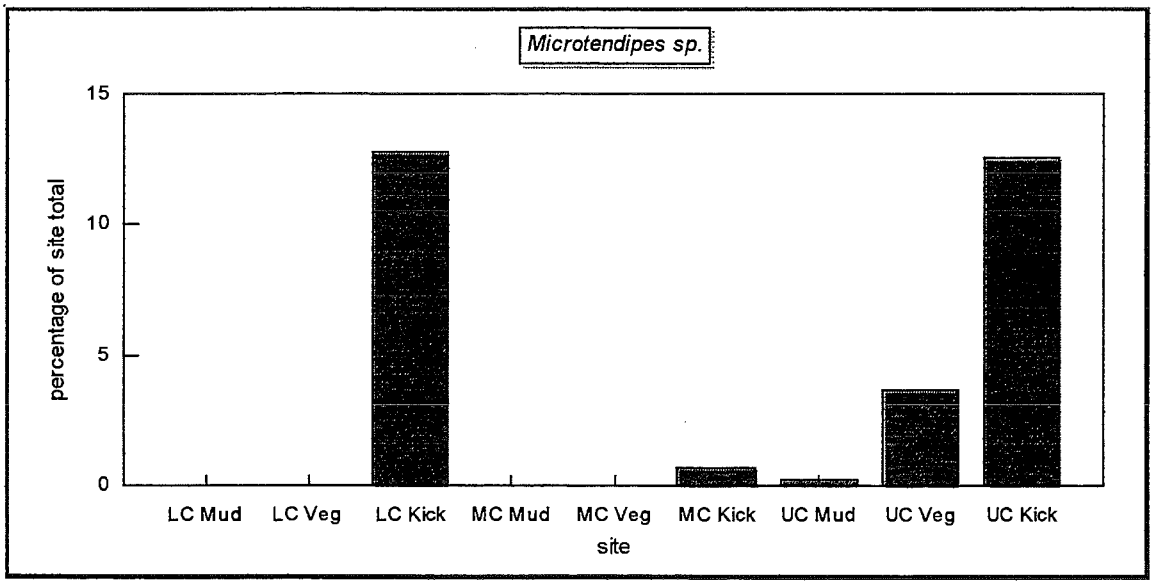
Appendix C-1. Distribution of *Chironomus* sp. in sampling sites.



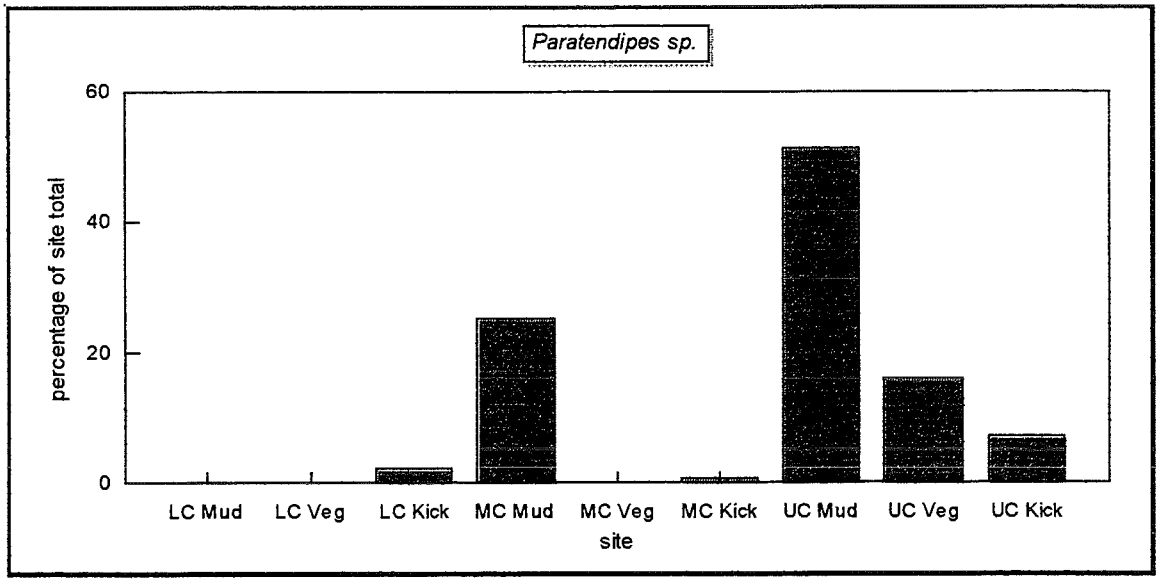
Appendix C-2. Distribution of *Cryptochironomus* sp. in sampling sites.



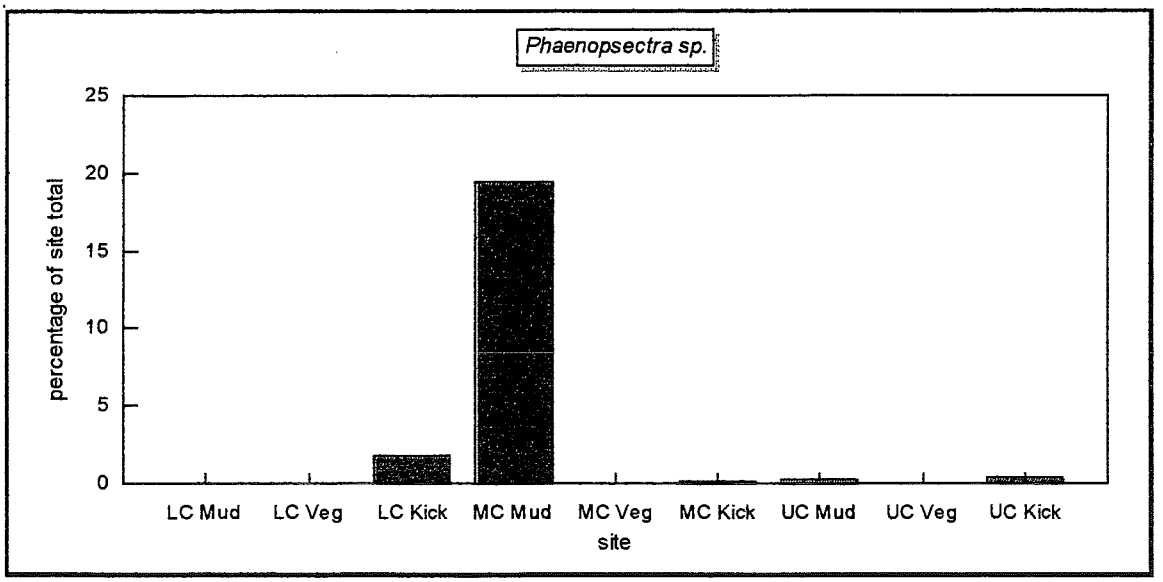
Appendix C-3. Distribution of *Dicrotendipes* sp. in sampling sites.



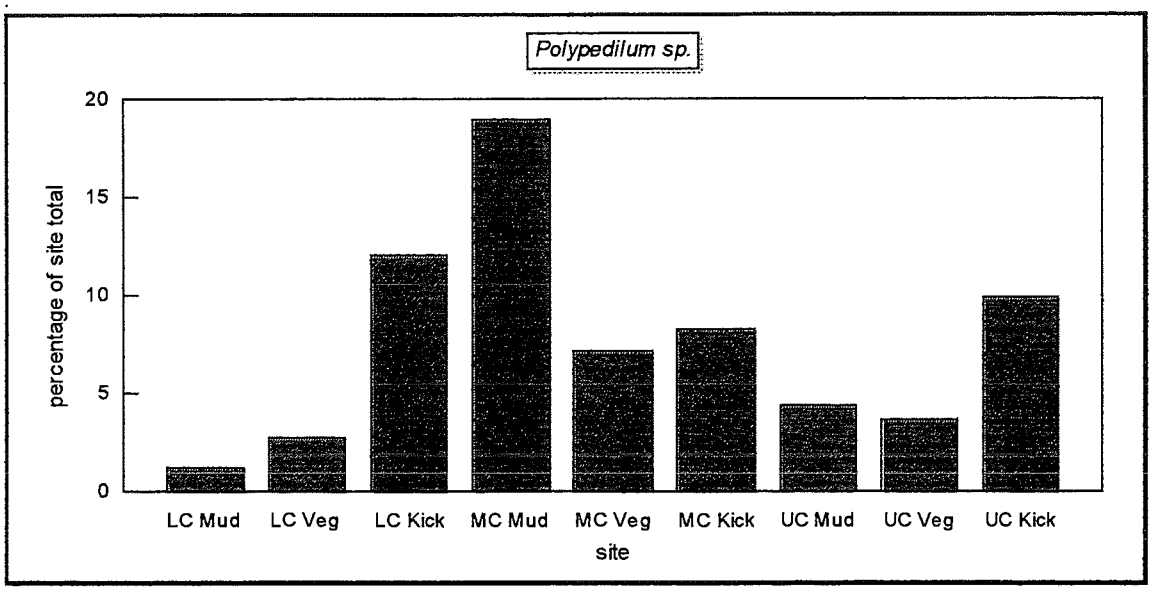
Appendix C-4. Distribution of *Microtendipes* sp. in sampling sites.



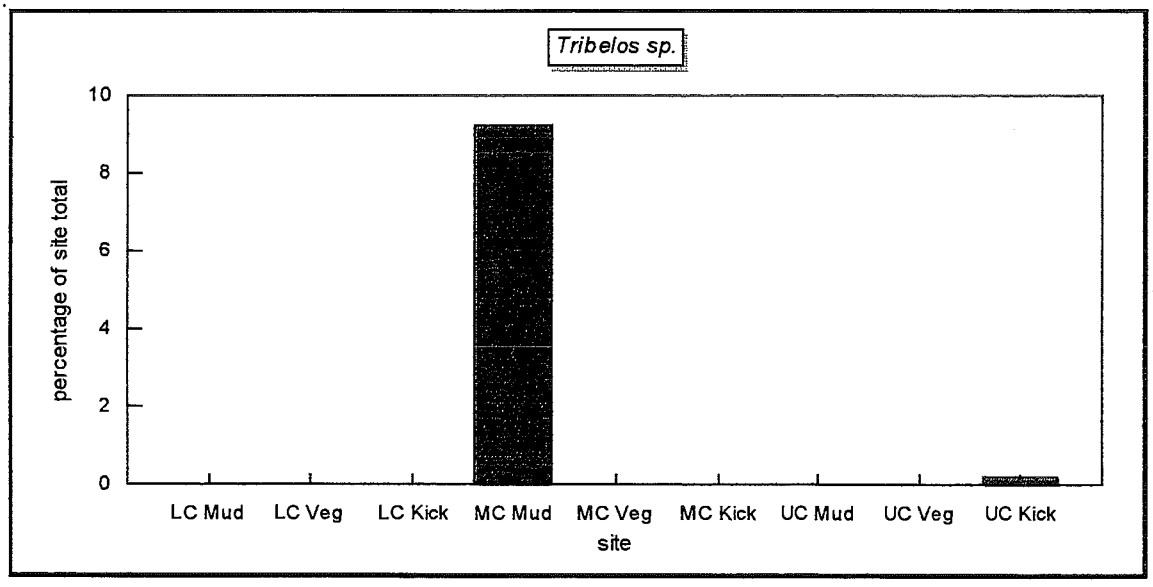
Appendix C-5. Distribution of *Paratendipes* sp. in sampling sites.



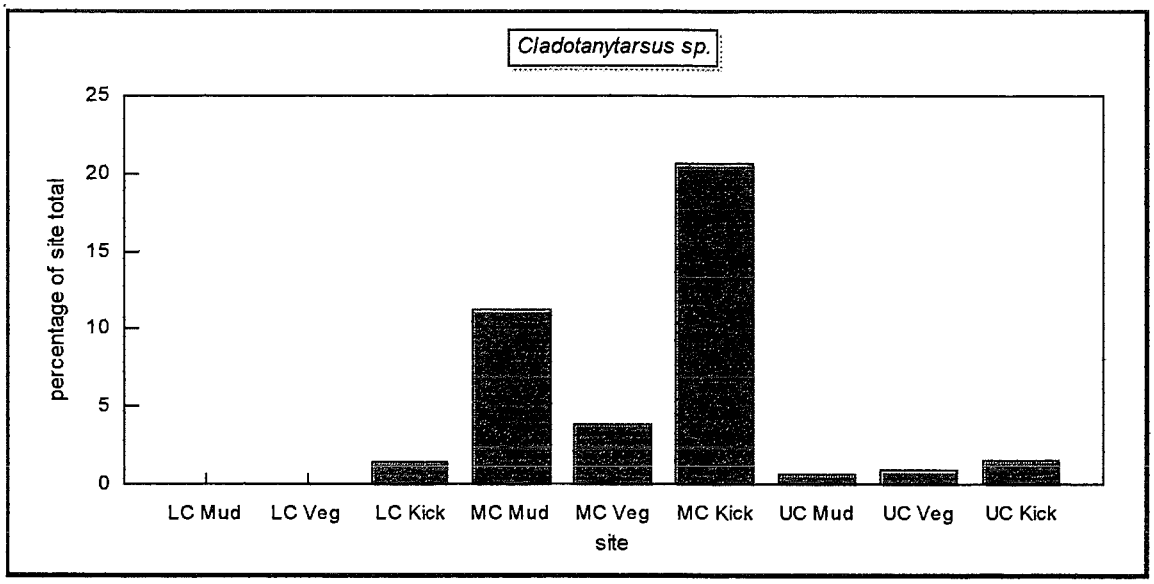
Appendix C-6. Distribution of *Phaenopsectra* sp. in sampling sites.



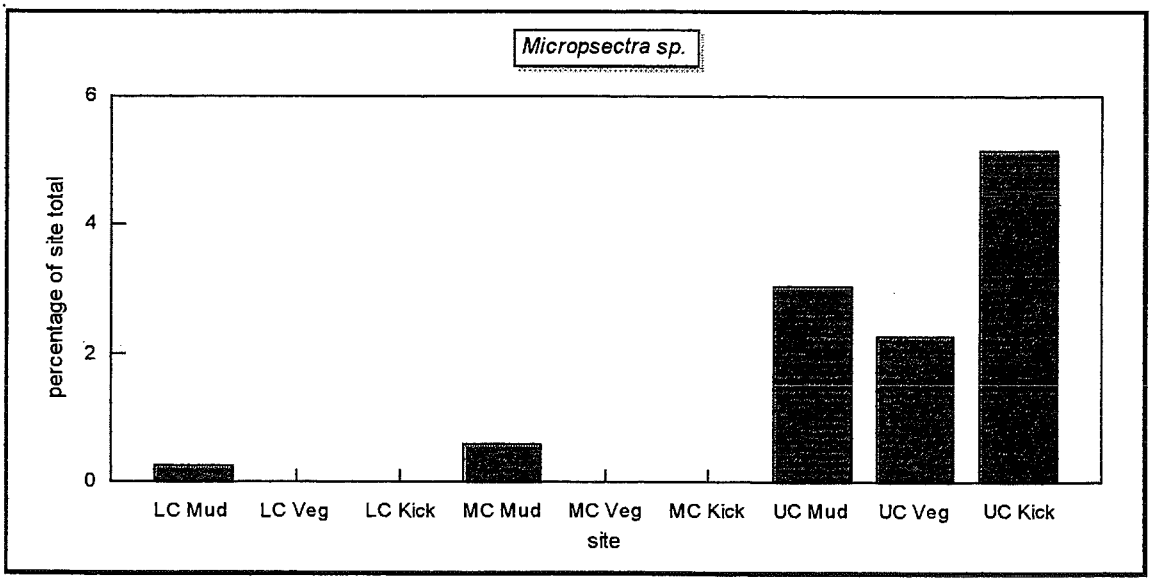
Appendix C-7. Distribution of *Polypedilum* sp. in sampling sites.



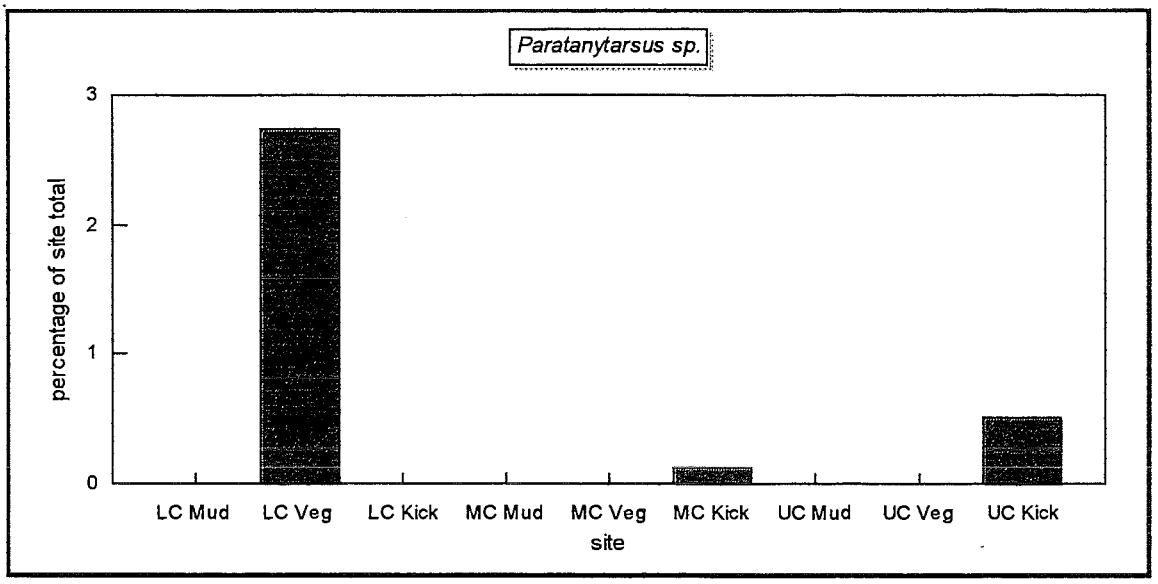
Appendix C-8. Distribution of *Tribelos* sp. in sampling sites.



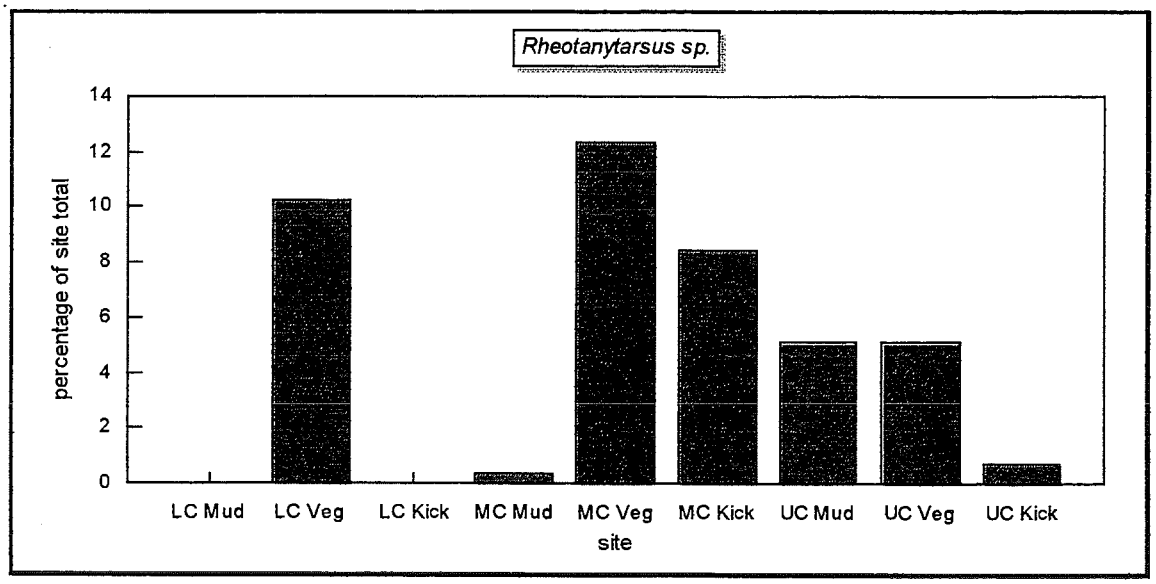
Appendix C-9. Distribution of *Cladotanytarsus* sp. in sampling sites.



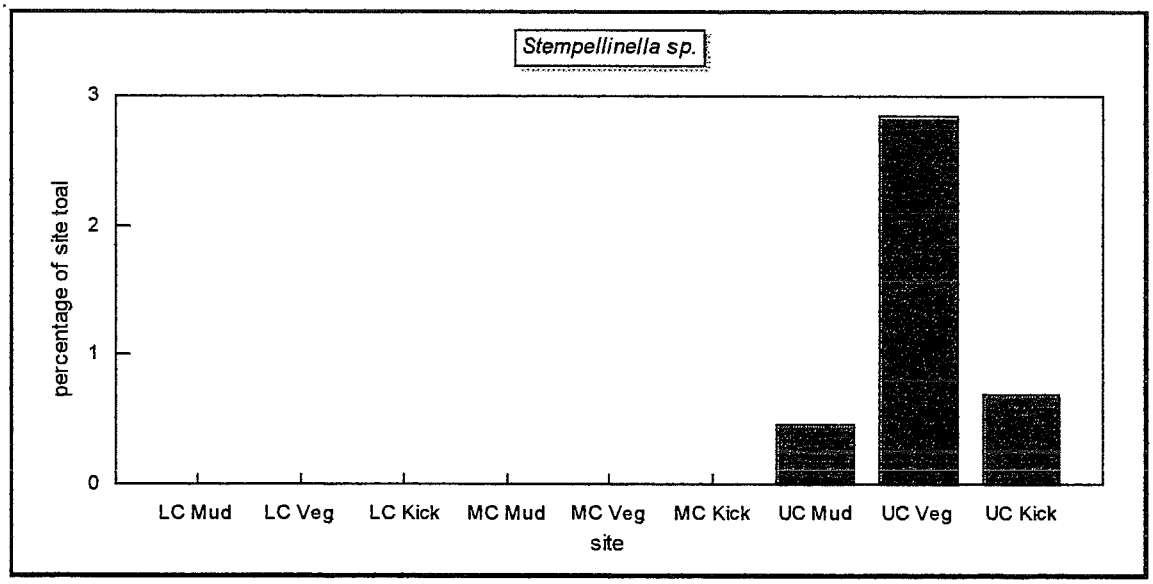
Appendix C-10. Distribution of *Micropsectra* sp. in sampling sites.



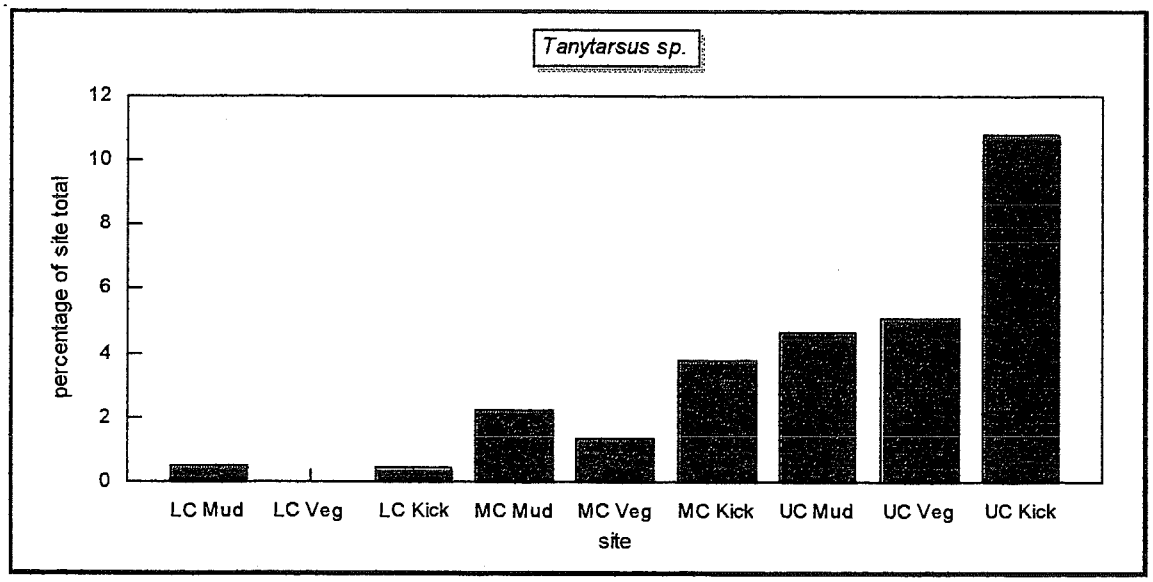
Appendix C-11. Distribution of *Paratanytarsus* sp. in sampling sites.



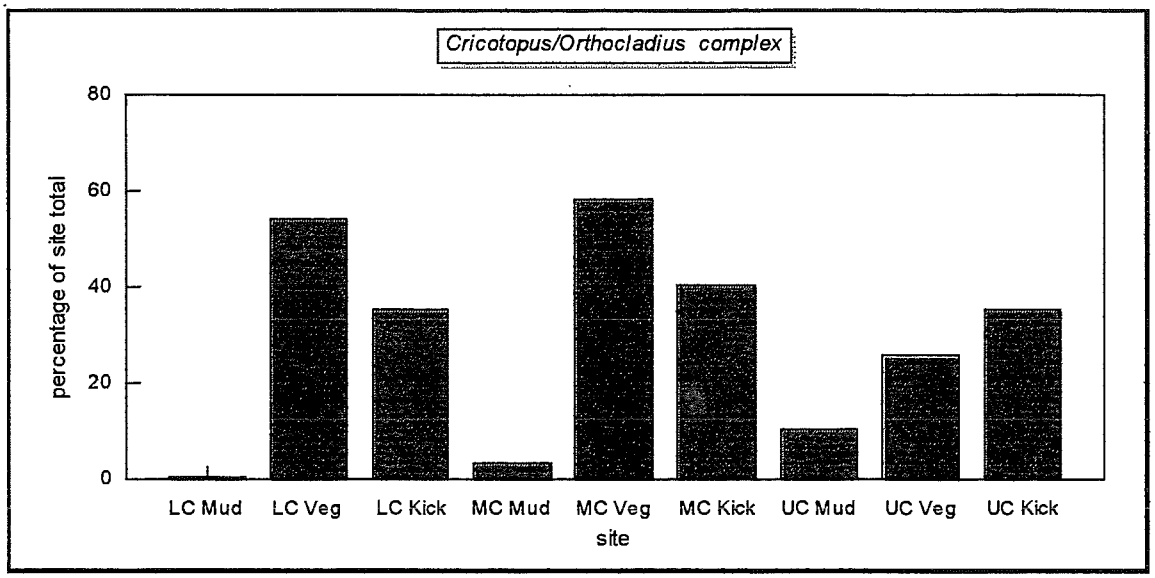
Appendix C-12. Distribution of *Rheotanytarsus* sp. in sampling sites.



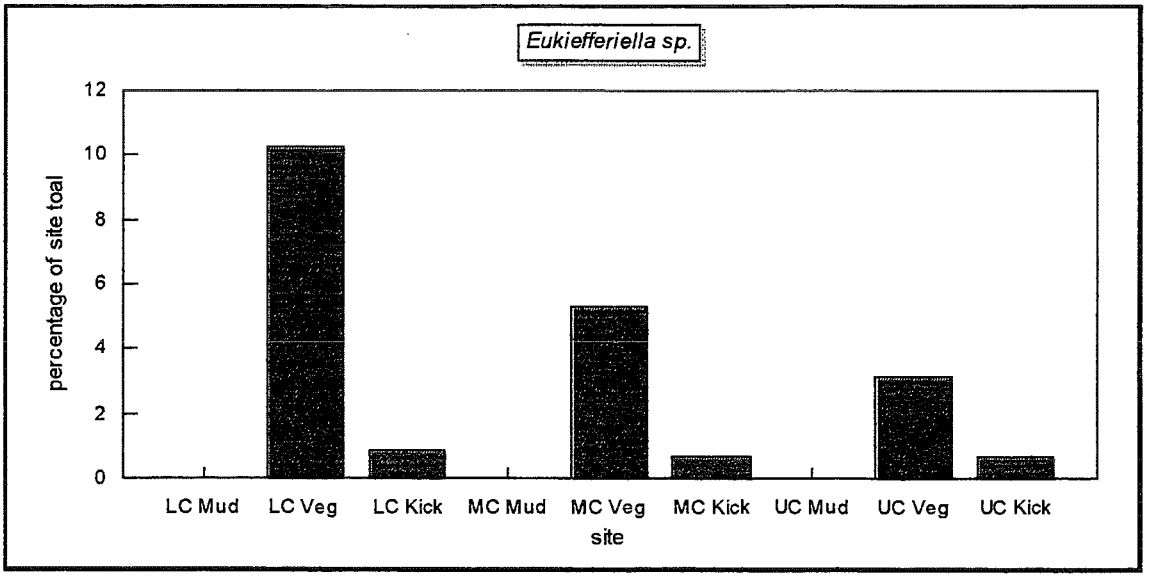
Appendix C-13. Distribution of *Stempellinella* sp. in sampling sites.



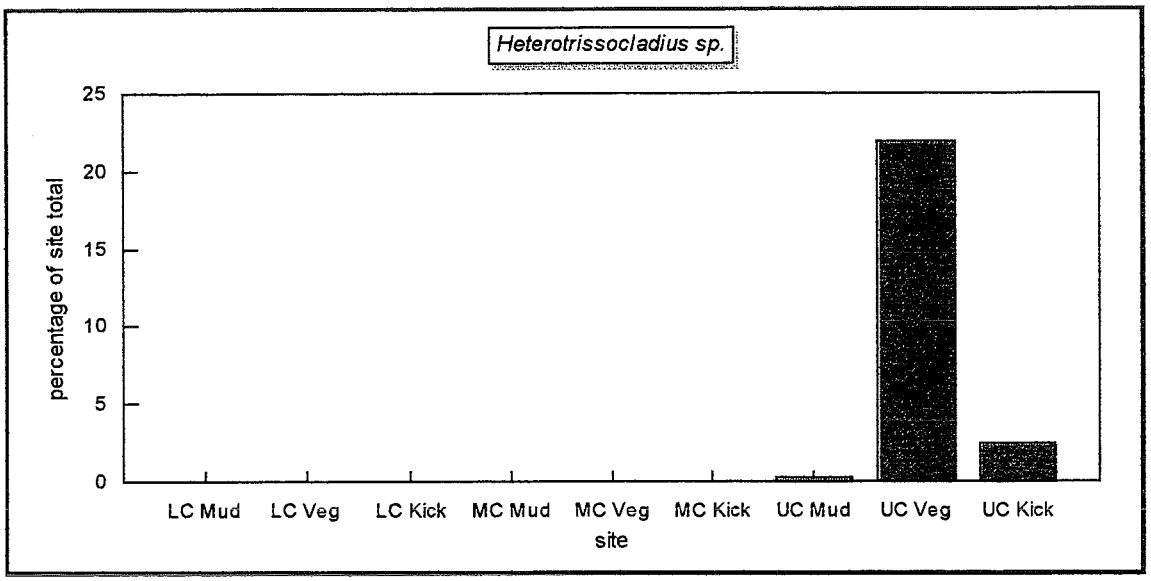
Appendix C-14. Distribution of *Tanytarsus* sp. in sampling sites.



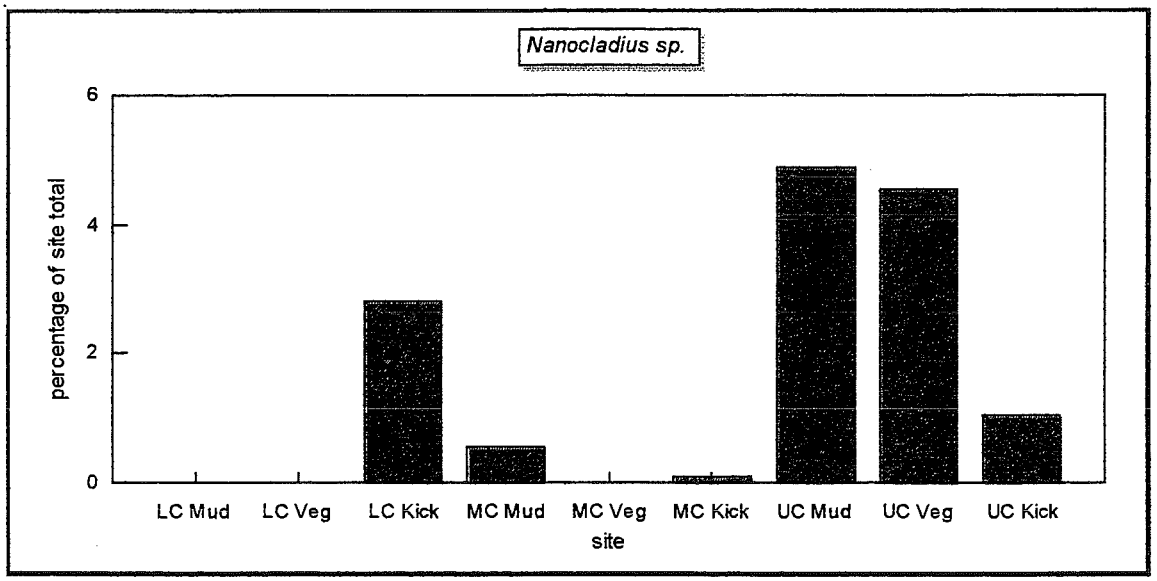
Appendix C-15. Distribution of *Cricotopus/Orthocladius* complex in sampling sites.



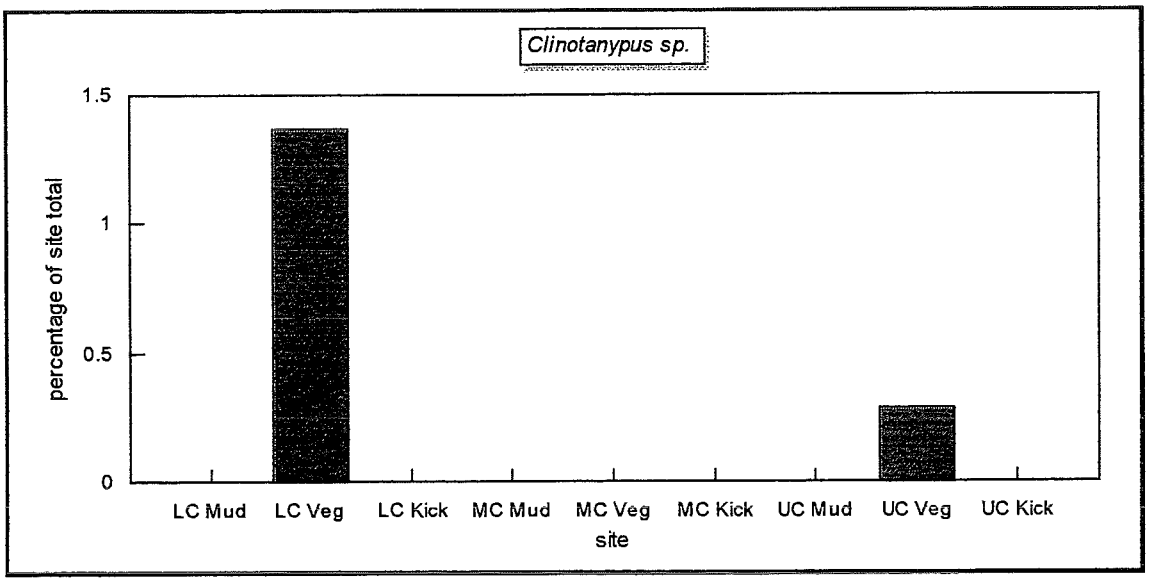
Appendix C-16. Distribution of *Eukiefferiella* sp. in sampling sites.



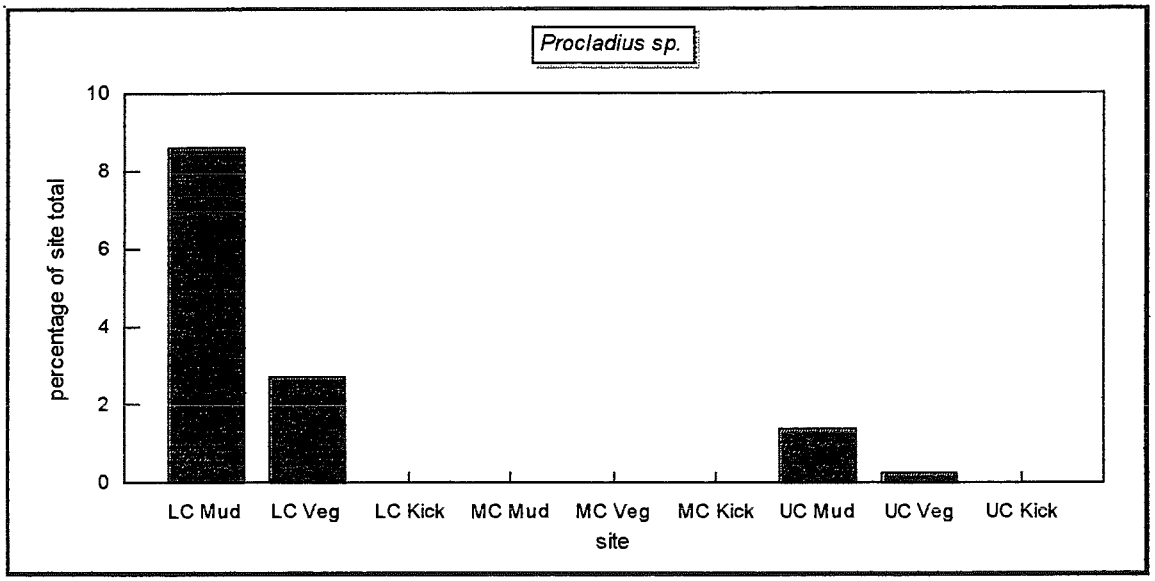
Appendix C-17. Distribution of *Heterotrissocladius* sp. in sampling sites.



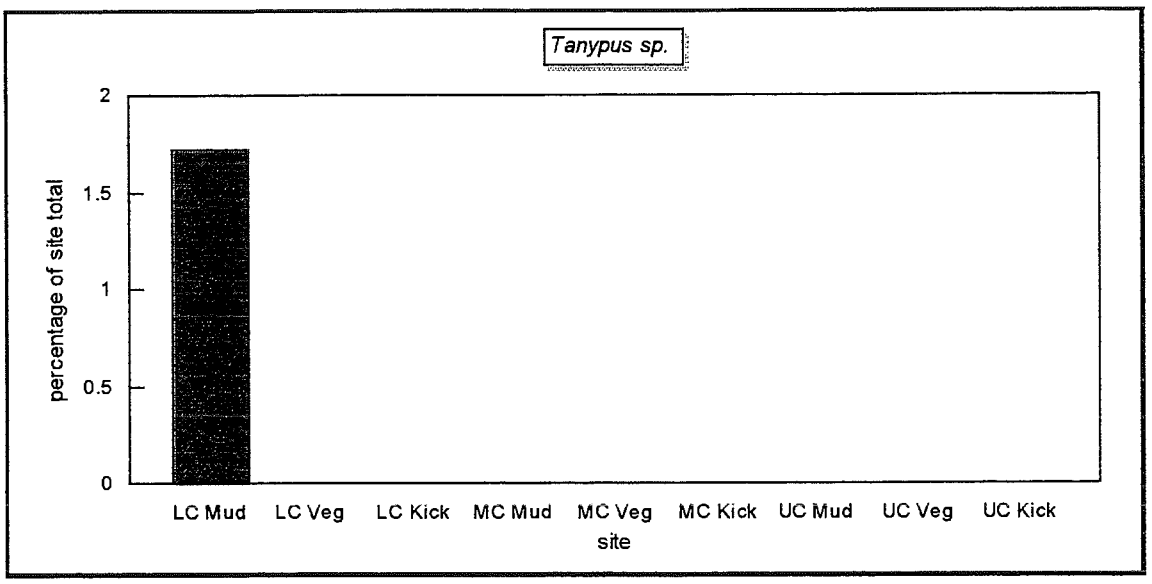
Appendix C-18. Distribution of *Nanocladius* sp. in sampling sites.



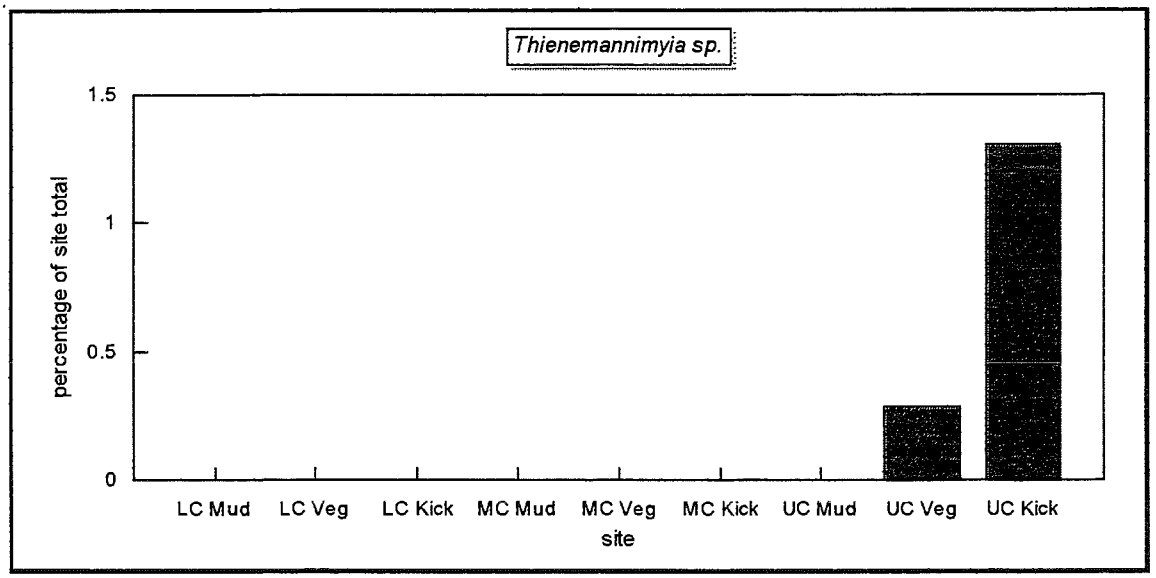
Appendix C-19. Distribution of *Clinotanypus* sp. in sampling sites.



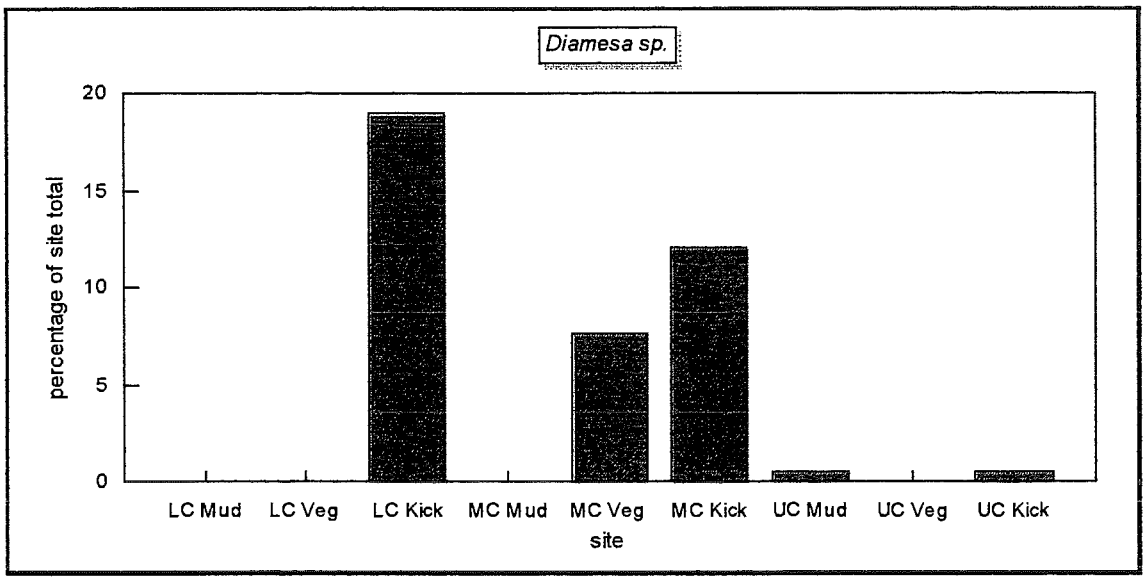
Appendix C-20. Distribution of *Procladius* sp. in sampling sites.



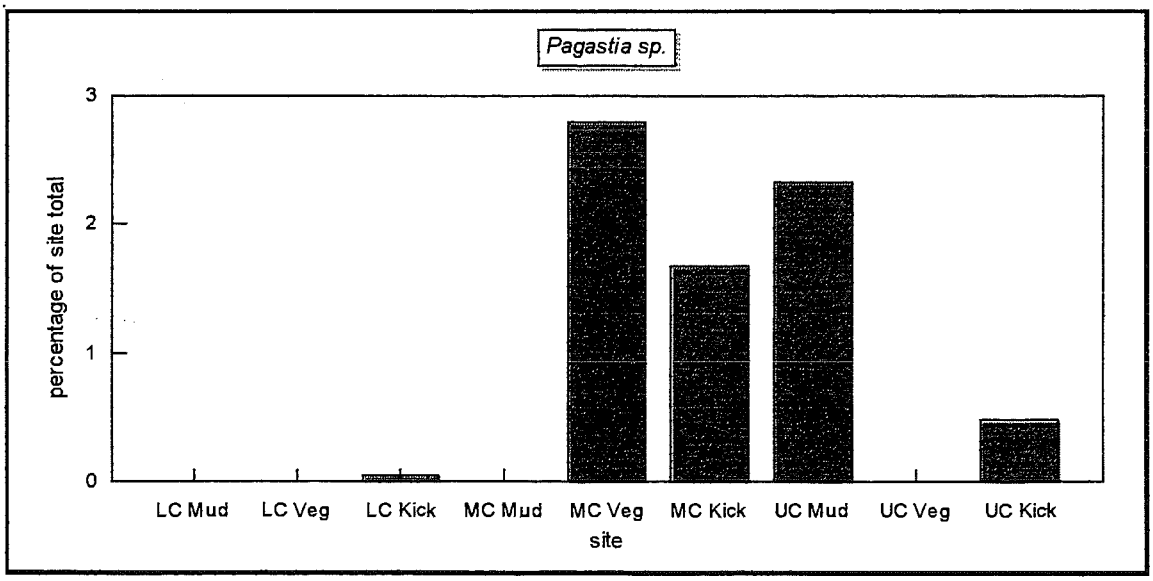
Appendix C-21. Distribution of *Tanypus* sp. in sampling sites.



Appendix C-22. Distribution of *Thienemannimyia* sp. in sampling sites.

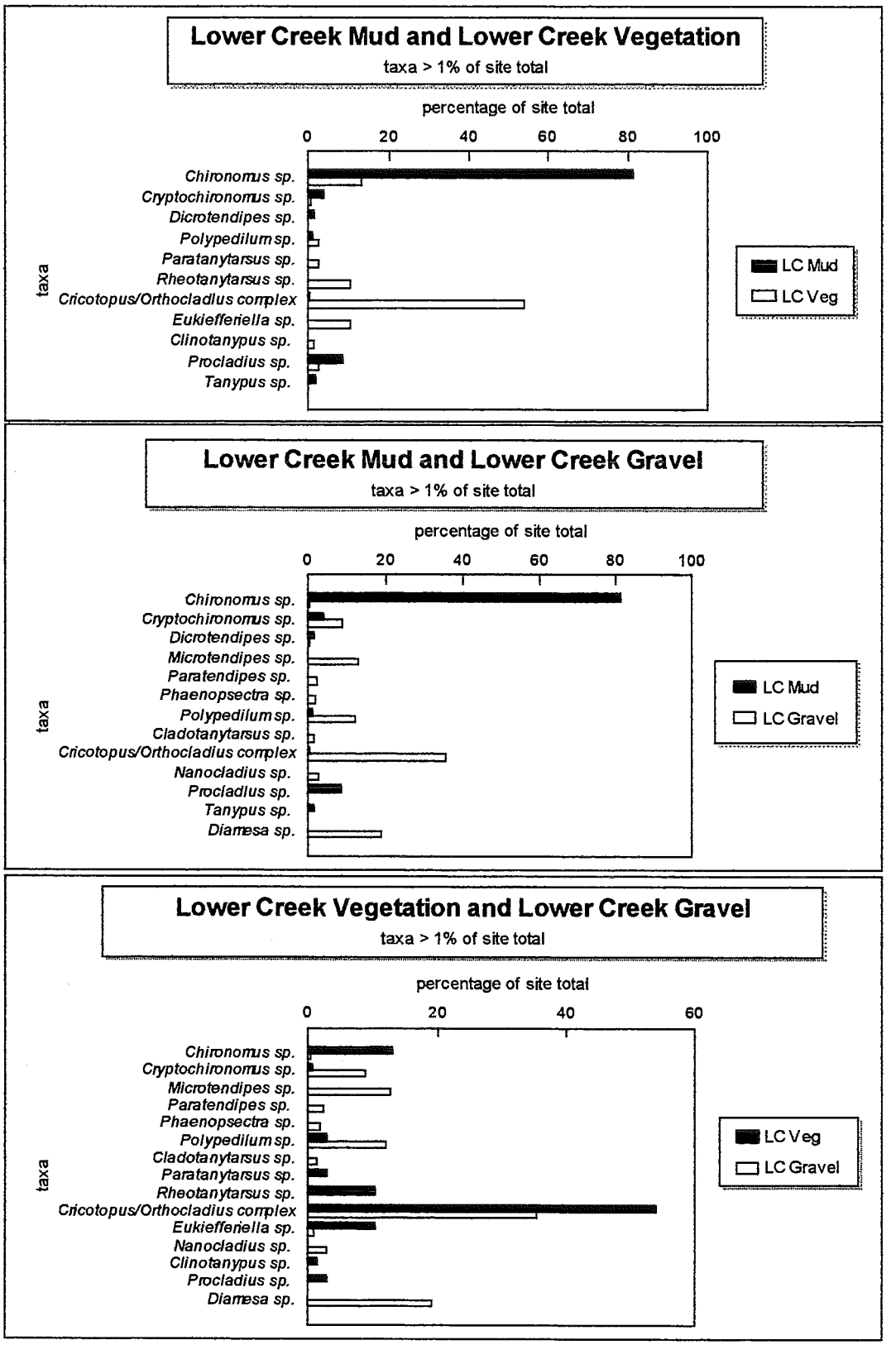


Appendix C-23. Distribution of *Diamesa* sp. in sampling sites.

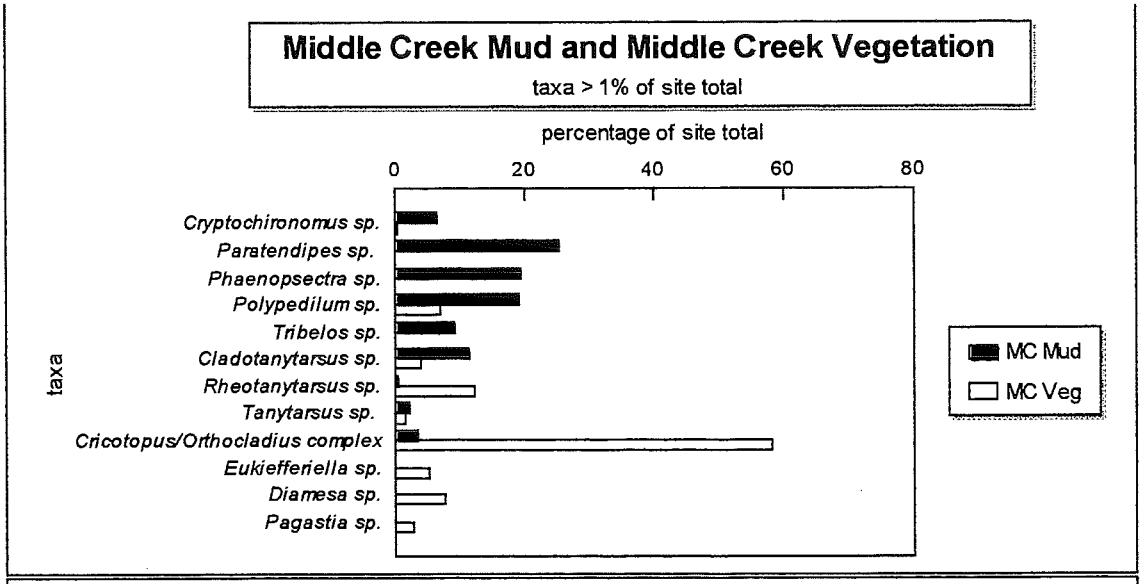


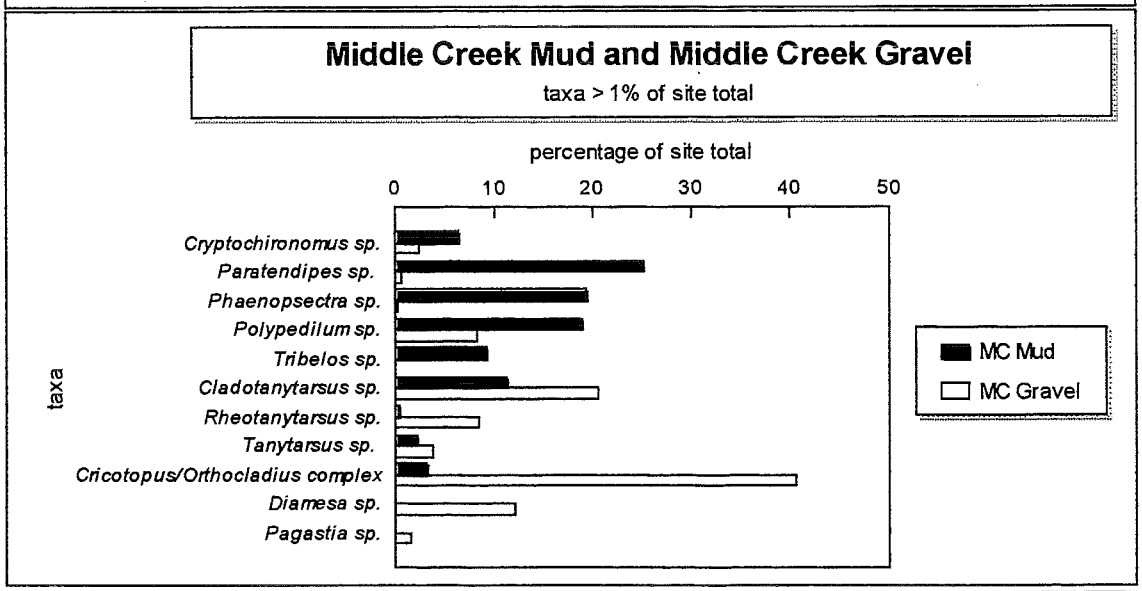
Appendix C-24. Distribution of *Pagastia* sp. in sampling sites.

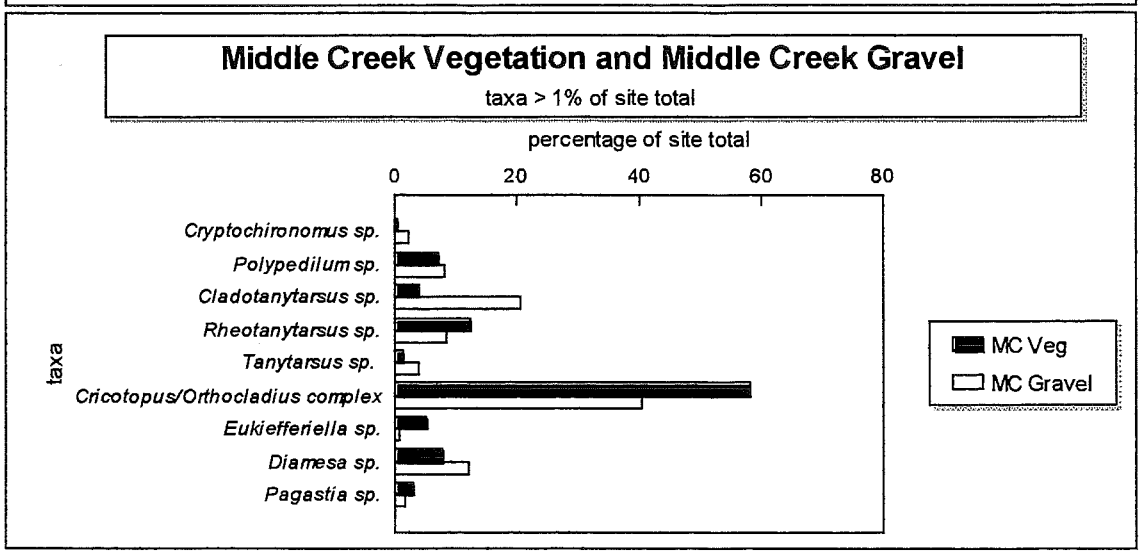
Appendix D. Chironomid Distributions in Irondequoit Creek by Location and Habitat.



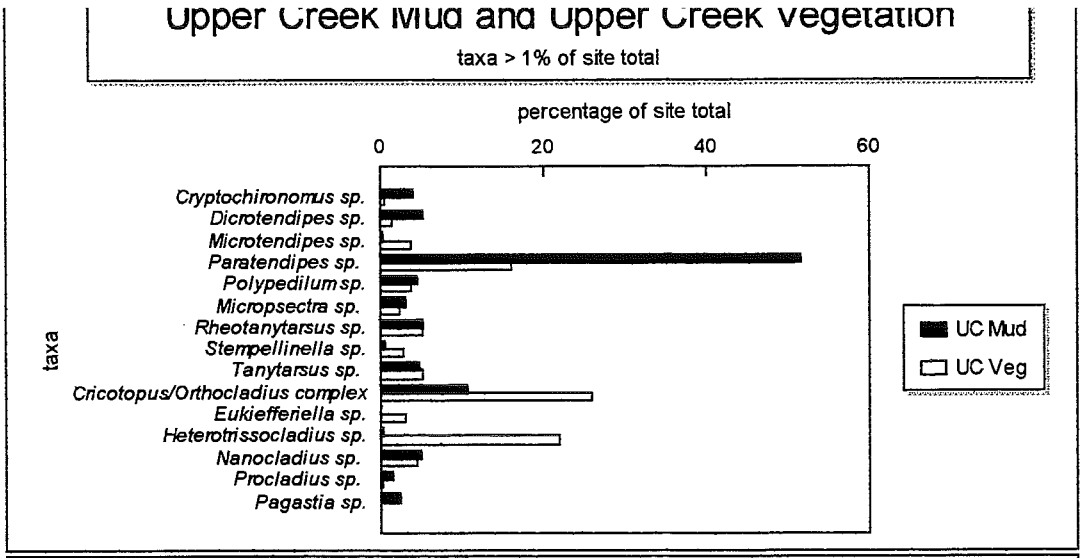
Appendix D-1. Chironomid Distribution in Lower Creek Sites.

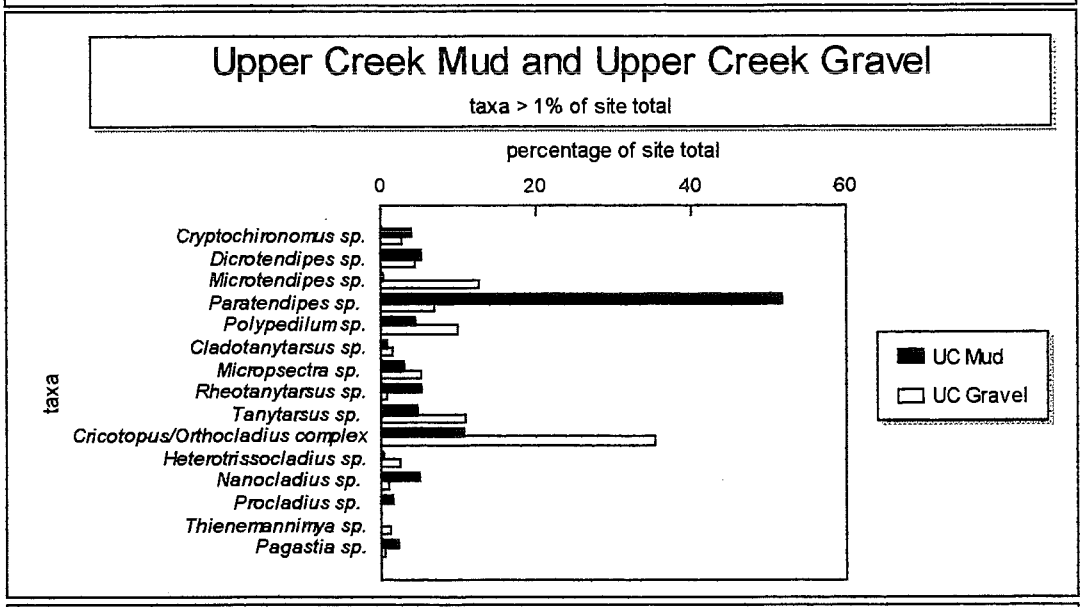


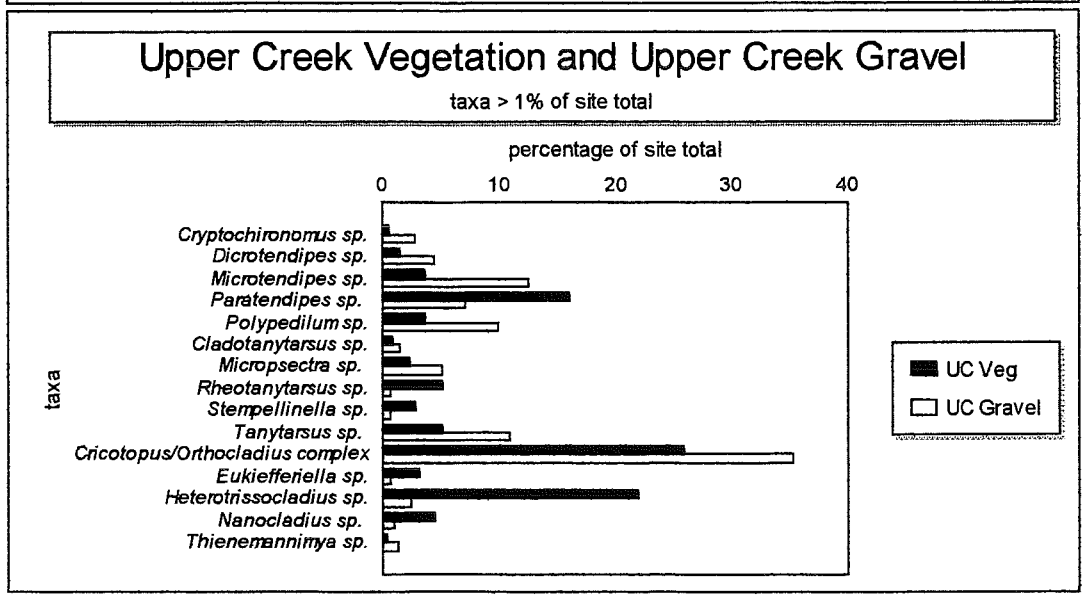




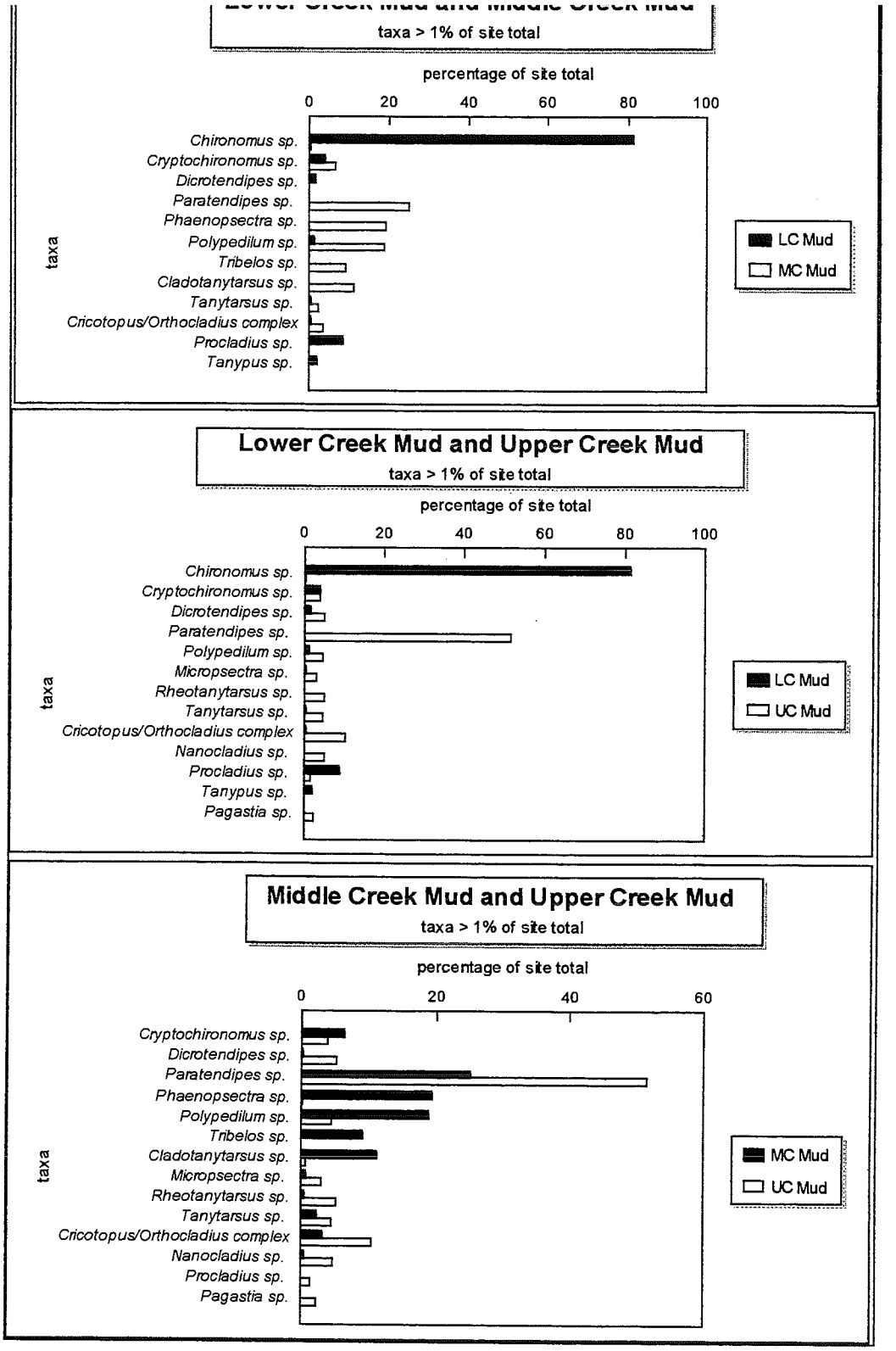
Appendix D-2. Chironomid Distribution in Middle Creek Sites.



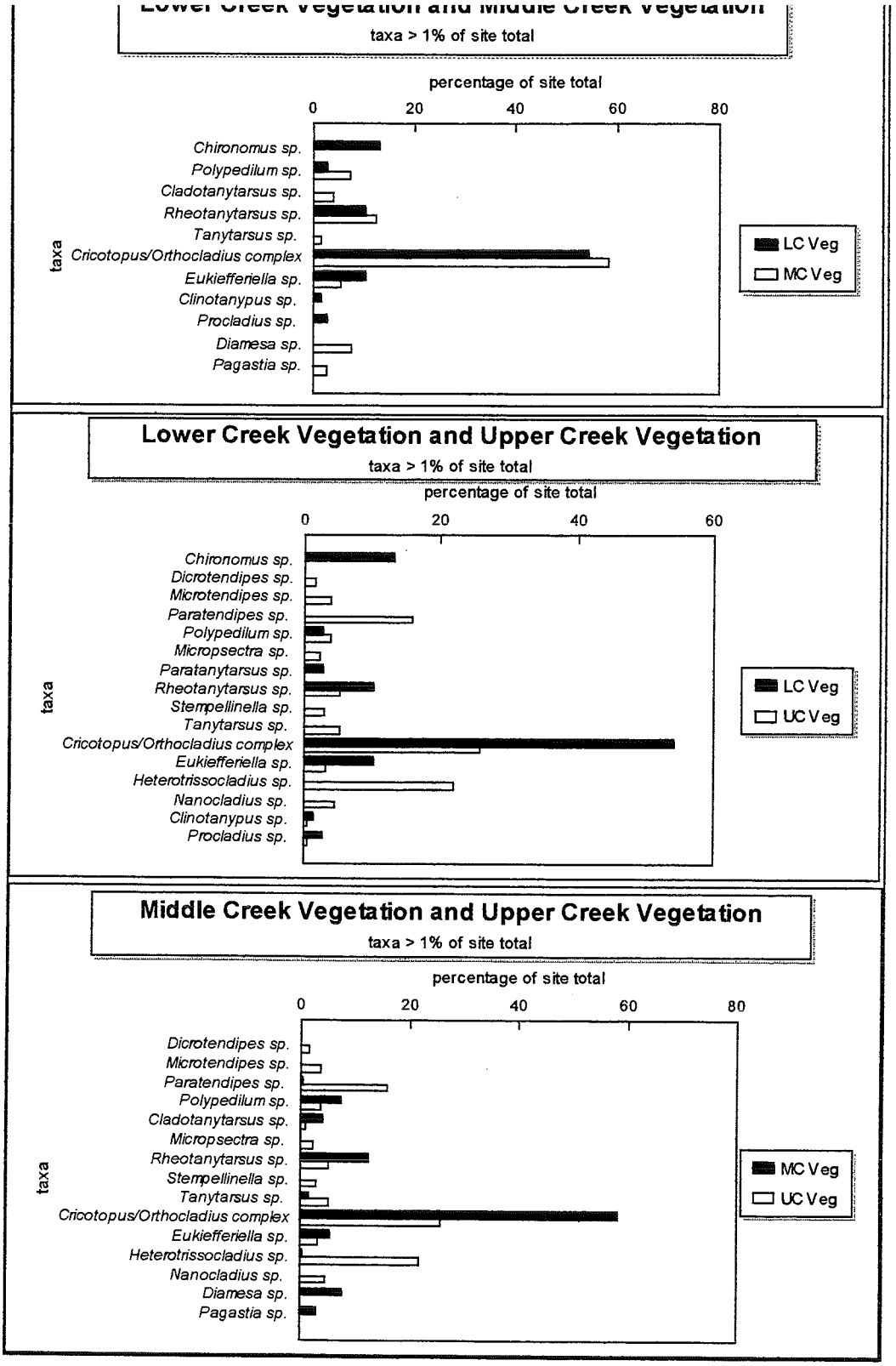




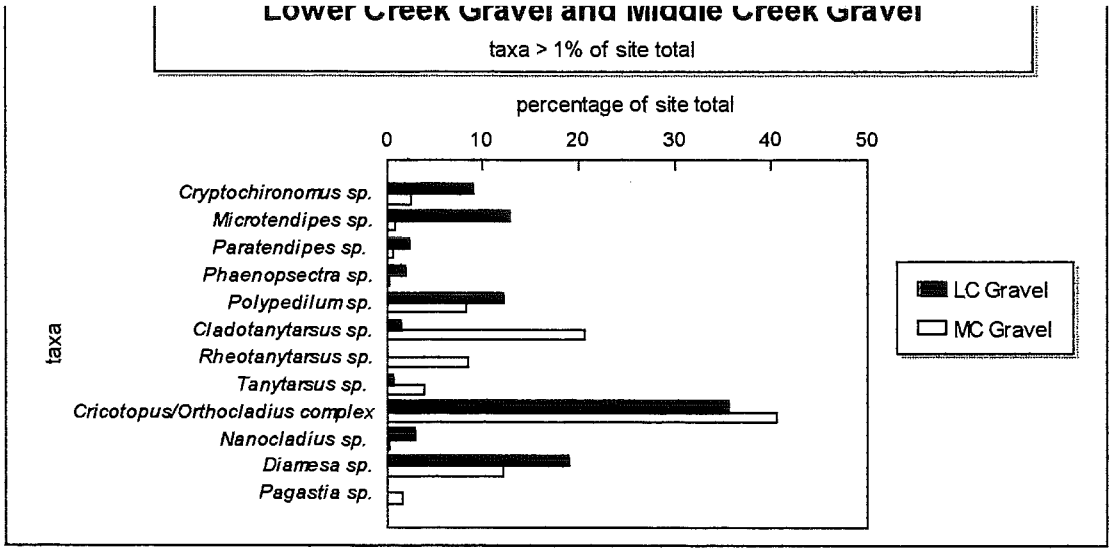
Appendix D-3. Chironomid Distribution in Upper Creek Sites.

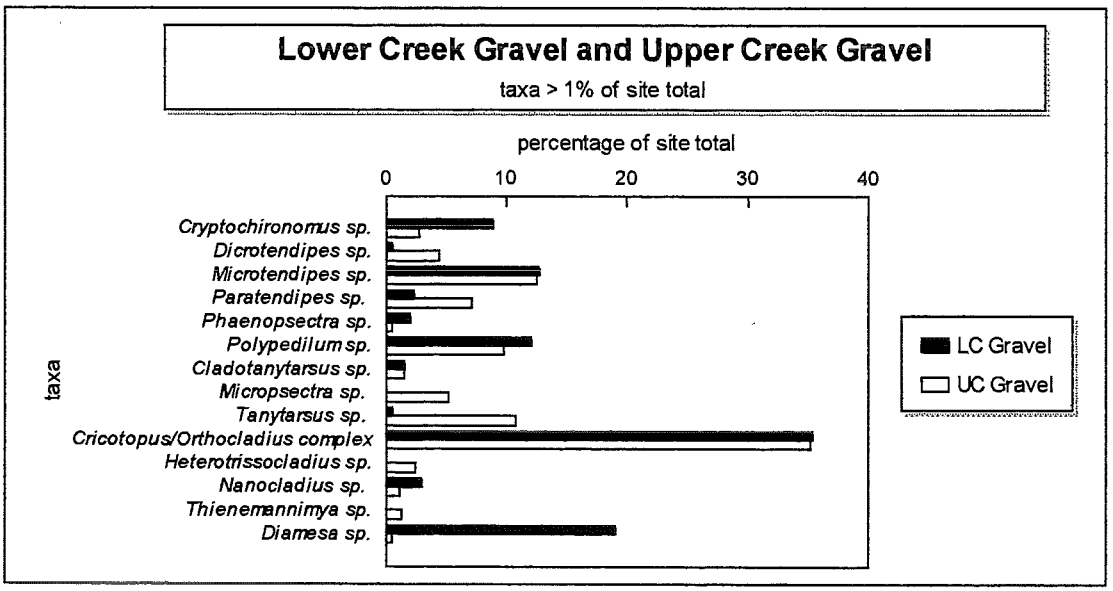


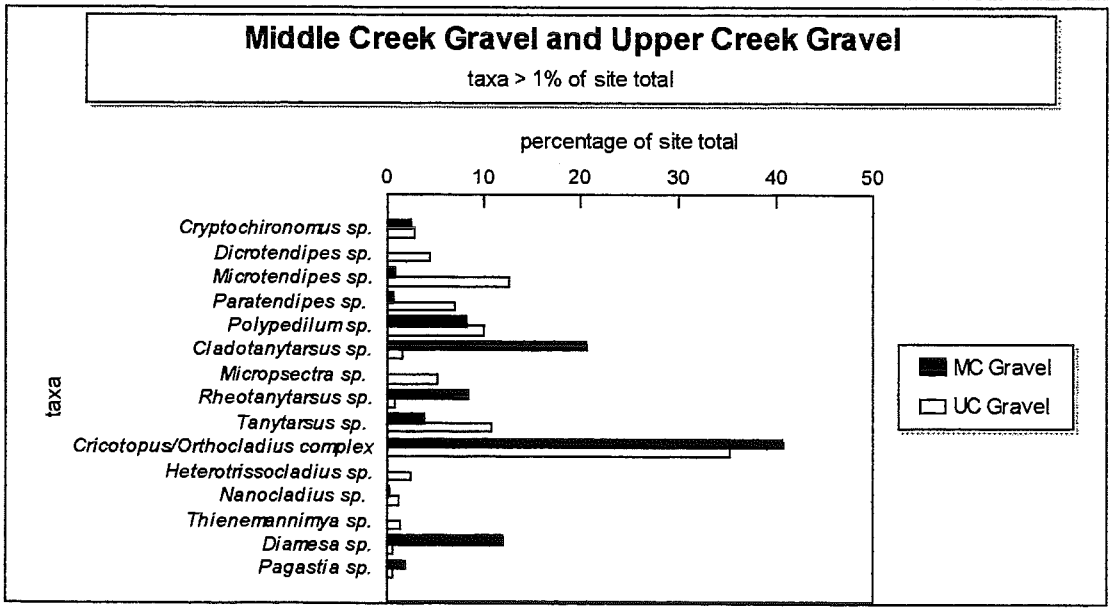
Appendix D-4. Chironomid Distribution in Mud Sites.



Appendix D-5. Chironomid Distribution in Vegetation Sites.







Appendix D-6. Chironomid Distribution in Gravel Sites.