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Benthic Macroinvertebrate Community Changes Following Zebra Mussel Colonization of Southwestern Lake Ontario

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BENTHIC MACROINVERTEBRATE COMMUNITY CHANGES FOLLOWING ZEBRA MUSSEL COLONIZATION OF SOUTHWESTERN LAKE ONTARIO

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Biographical Sketch

Mr. Stewart is a candidate for the Master of Science degree in Biological Sciences at the State University of New York College at Brockport. He obtained his Bachelor of Arts degree in Biological Sciences at Ithaca College, Ithaca, New York, in 1989. He also successfully completed coursework in 1988 at the University of Michigan Biological Station in Pellston, Michigan. He is a 1985 graduate of Brockport High School. He has been employed as a graduate teaching assistant at SUNY Brockport where he helped conduct undergraduate laboratory sessions in Ecology, Genetics, and Human Biology. He has lectured on the subject of benthic macroinvertebrate identification and ecology in Ecology and Environmental Impact Analysis. He has also provided schoolchildren of the Brockport Central School District with hands-on experience in fish and aquatic invertebrate sampling techniques, ecology, and identification. College-level courses have been completed in Animal and Plant Ecology, Limnology, Water Chemistry, Field Ornithology, Field Mammalogy, Parasitology, Woody Plant Identification, Aquatic Invertebrate Ecology and Identification, Fishery Techniques and Identification, and Fish Biology. He has served as a consultant, identifying aquatic invertebrates for Rochester, New York area businesses. He assisted with a New York State Sea Grant funded project examining uptake of mirex in pen-reared Lake Ontario fish. He has also cared for aquatic macrophytes while serving as a laboratory assistant at Ithaca College. As an intern at the Buffalo Zoo, he provided care for reptiles and amphibians. In addition to his current research in benthic macroinvertebrate ecology, he has conducted basic research on Downy Woodpecker home range size. His primary career interest concerns preservation and restoration of North

America's endangered vertebrate and invertebrate species. He will begin pursuit of a Ph.D. degree at Kent State University in the Fall of 1993.

Abstract

Changes in abundance and diversity of benthic macroinvertebrates inhabiting a natural cobble and artificial reef substrate in southwestern Lake Ontario were quantified following invasion of the zebra mussel, Dreissena polymorpha. Post-zebra mussel invasion data (1991-92) were statistically compared with pre-invasion data (1983) from the same sites. By 1991-92 zebra mussels comprised 73% and 90% of cobble and artificial reef macroinvertebrates, respectively, replacing the amphipod Gammarus fasciatus as the numerically dominant taxon at both sites. Overall abundance of non-zebra mussel taxa was significantly greater ($p < 0.05$) at cobble and artificial reef sites in 1991-92, than in 1983 before zebra mussels were present. Taxa exhibiting significant population increases at the cobble site during the time period separating the two studies were the annelids Manayunkia speciosa, Spirosperma ferox and unidentified tubificids; the gastropods Helisoma anceps, Physa heterostropha, Stagnicola catascopium, Valvata tricarinata, Goniobasis livescens and Amnicola limosa; and the arthropods Gammarus fasciatus and Orconectes propinquis. Significant population increases of Physa heterostropha, Goniobasis livescens, Amnicola limosa, Gammarus fasciatus and the trichopteran Polycentropus were observed at the artificial reef site. Although a few taxa sampled infrequently in 1983 were not collected in 1991-92, no taxa have decreased significantly since 1983. Comparisons of community composition in 1983 and 1991-92 suggest the cobble community has changed more than the artificial reef community. These changes are likely positive, as species richness was greater at cobble and artificial reef sites in 1991-92 relative to 1983, and Simpson's

Diversity showed no decline. Though other factors may have contributed to observed native macroinvertebrate community changes, my results support theories that zebra mussels are facilitating energy transfer to the benthos by filter-feeding, and that mussel shoals are providing additional habitat for native invertebrate taxa.

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(New York State Electric and Gas Corporation, Barker, New York) provided water temperature data. Annelid identifications were verified by Drs. Jarl K. Hiltunen (United States Environmental Protection Agency, Cincinnati, Ohio), David A. Strayer (Institute of Ecosystem Studies, Millbrook, New York), and Donald J. Klemm (United States Environmental Protection Agency, Cincinnati, Ohio). Dr. Bruce P. Smith (Department of Biology, Ithaca College) confirmed or corrected my identifications of water mites, while Mr. Andrew P. Bader (New York City Department of Environmental Protection, Grahamsville, New York) examined a wide array of organisms in order to confirm that the taxa identified in my study corresponded with those from his 1983 study. I am grateful to my parents, William and Bonita Stewart, for making my educational experience possible; to my future wife Susan, for her patience; and to my late canid friend James Henry Tanner, for companionship he provided throughout my graduate education.

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Introduction

Concern about the zebra mussel's (Dreissena polymorpha) impact on North American aquatic ecosystems (Hebert et al. 1991; Mackie 1991) has compelled Great Lakes scientists to investigate zebra mussel effects on algal assemblages (Holland Beeton 1990; Lowe et al. 1990; Nichols and Hopkins 1992), macrophyte communities (McNabb et al. 1991), and fish spawning, diet, growth and survival (Fitzsimons et al. 1991; Graham et al. 1991; Nepszy 1992; Leach 1993).

The purpose of my study was to characterize population changes of benthic macroinvertebrates indigenous to an artificial reef and natural cobble site in southwestern Lake Ontario, near Olcott, New York, between 1983 (pre-zebra mussel colonization) and 1991-92 (post-zebra mussel invasion). Like the adult zebra mussel, these "native" benthic macroinvertebrates are generally sessile, fairly large in size (retained on a sieve with 0.595 mm openings), and closely associated with bottom substrate (Clesceri et al. 1989). For convenience, non-zebra mussel invertebrate taxa will hereby be referred to as native benthic macroinvertebrates, despite arguments by Brinkhurst et al. (1968) and Cook and Johnson (1974) that some taxa have European origins.

Zebra mussels and other benthic macroinvertebrate taxa often occupy the same substrates (Sebestyen 1938; Conn et al. 1991), or consume similar foods (Hebert et al. 1991; Mackie 1991). These factors, coupled with the mussel's ability to reach adult densities as high as 448,970 individuals/m^2 (Piesik 1983), comprising 98% of benthic macroinvertebrates existing in some areas (Afanas'yev and Protasov 1987), suggest disruption of Great Lakes benthic macroinvertebrate communities is quite possible (Mackie et al. 1989; Reeders and Bij de Vaate 1990; Hebert et al. 1991; Marsden 1991). Deleterious effects of zebra mussels on Great Lakes populations of unionid mussels have already been documented (Mackie 1991; Gillis and Mackie 1992; Hunter and Bailey 1992). However, impacts on many other benthic macroinvertebrate taxa have not yet been quantified.

Many factors must be considered in predicting zebra mussel impacts on Great Lakes' benthic macroinvertebrate communities. Zebra mussels can attain high densities when hard substrates, such as rock material (Lyakhov and Mikheev 1964; Lewandowski and Stanczyckowska 1986; Bij de Vaate 1991) and the bodies of other benthic invertebrate taxa (Lamanova 1971; Lewandowski 1976; Arter 1989; Conn et al. 1991; Dermott and Barton 1991; Masteller and Schloesser 1991; Schloesser and Kovalak 1991) are abundant. It is not unusual for suitable substrates to be completely covered by zebra mussels (Lewandowski 1976; Hunter and Bailey 1992). According to Mackie (1991), and Schloesser and Kovalak (1991), removal of nutrients from the water column may adversely affect filter feeding organisms (e.g., unionid bivalves). Conversely, deposition of nutrient-rich feces and pseudofeces may enhance the fertility of benthic environments (Stanczyckowska et al. 1976; Stanczyckowska and Planter 1985; Reeders and Bij de Vaate 1990), perhaps facilitating population increases in benthic macroinvertebrate detritivores and their predators (Wiktor 1969; Izvekova and Lvova-Katchanova 1972; Stanczykowska 1977; Smit et al. 1990). Increased substrate heterogeneity manifested as zebra mussel colonies, empty shells, byssal threads, etc., may also benefit native benthic macroinvertebrates by providing them with additional habitat and shelter (Dermott and Barton 1991; Griffiths 1993).

Have zebra mussels competitively excluded any Southwestern Lake Ontario macroinvertebrate taxa from habitats they have traditionally inhabited, as mollusks introduced into other regions of the Great Lakes have in the past (Hebert et al. 1989), or have they filled an unoccupied ecological niche, resulting in neutral or positive changes in abundance and diversity of native taxa? Of the two sites investigated in this study, the rock-covered artificial reef provided zebra mussels with especially favorable habitat. Since only other epifaunal (Stanley 1972; Mackie 1991), or non-burrowing macroinvertebrates were formerly of numerical importance on the reef (Bader 1985), I believed that zebra mussels might compete with native taxa for living space at this site. I hypothesized that zebra mussels would displace some native taxa, inducing declines in native benthic macroinvertebrate abundance and species diversity on the artificial reef.

The second study site, the "cobble site", was comprised of a mixture of cobble, sand, and silt. This structurally heterogeneous site provided suitable habitat for infaunal (burrowing) taxa (Cook and Johnson 1974; Hynes 1974; Simpson and Bode 1980), in addition to many epifaunal taxa historically collected on the artificial reef (Bader 1985). I anticipated that competition between zebra mussels and native macroinvertebrate taxa for available hard structure would occur on cobble substrates. However, sand and silt substrates are suboptimal zebra mussel habitats (Lewandowski and Stanczyckowska 1986; Stanczyckowska 1977), and mussel densities in these microhabitats were expected to remain low. Free from competition for space, many native macroinvertebrates inhabiting these softer substrates were expected to benefit through utilization of empty mussel shells as shelter, and by consuming feces and pseudofeces produced in adjacent areas supporting larger zebra mussel populations (Dermott and Barton 1991; Griffiths 1993).

I hypothesized that overall native macroinvertebrate abundance at the cobble site would increase following zebra mussel invasion. Positive changes in numbers of detritivores occupying sand and silt substrates were expected to offset any population declines observed in taxa stressed by competition with zebra mussels for living space or food. Due to potential competitive exclusion of some native taxa, I believed cobble site species diversity would decline. Regardless of how native macroinvertebrate abundance and diversity were affected, zebra mussel activities were expected to cause changes in native artificial reef and cobble site benthic macroinvertebrate communities (Hebert et al. 1989; Hunter and Bailey 1992).

Study Area

The study area was situated approximately 1.6 km west and 0.8 km offshore of Olcott, New York, in the southwestern region of Lake Ontario (Figure 1). The artificial reef (latitude=43° 20' 9" N; longitude=78° 45' 30" W; Figure 2) was constructed in 1982 of siltstone and shale. Particle sizes on this structure ranged from small pebbles to boulders approximately 0.5 m in diameter. Several discrete piles of material were placed in the area. However, all samples were collected from one of two mounds of rubble, each approximately 30 meters in length. These reef sections were easily identified by the pile of cinderblocks which now connects them (Figure 2). Reef sampling depths ranged from 5 - 7 m below the water surface.

The cobble site was located approximately 0.5 km east of the artificial reef. Physical characteristics of the cobble site (latitude=43° 20' 9" N; longitude=78° 44' 48" W) were representative of the benthic environment naturally found along this nearshore region of Lake Ontario. The flat lake bed was covered with particles ranging from silt to rocks at least 25 cm in diameter. Depth of sampling at the cobble site approximated sampling depth at the artificial reef site.

Materials and Methods

This study was designed to replicate that of Bader (1985) who quantified benthic macroinvertebrate densities on the same artificial reef and cobble sites in 1983 before establishment of zebra mussel populations (Bader's data served as the "control" data for my study). In 1991-92, SCUBA divers established transects at both artificial reef and cobble sites by extending a 100 ft. tape on the two substrates to be sampled. Before sampling, five locations along each transect were selected from a random numbers table (Beyer 1978). Samples were collected from these randomly designated locations. This procedure was repeated on four dates in 1991-92 (July 12 and September 21, 1991, and May 15 and August 20-23, 1992). Samples were not collected on more than one occasion from the same location along a transect.

Two distinct sampling methods were used to estimate benthic macroinvertebrate abundance. Native taxa were collected exclusively by a dome suction sampler (Gale and Thompson 1975), while zebra mussel densities were estimated by both dome suction and plot sampling. Components of the dome suction sampler included a stainless steel housing enclosing an area of 0.164 m^2, and a plexiglass cover with two armholes. Attached to this cover was a 12 volt lawnmower battery equipped with a vent overflow plug to prevent water contamination of battery contents, and a bilge pump (5,682 L/hr). Attached to the pump were a hose used to vacuum the substrate, and a collecting bag that retained particles equal to or larger than 0.500 mm × 0.500 mm in size. Affixed to the vacuum hose was a nozzle equipped with steel rods spaced 1.27 cm × 1.27 cm apart. Although this screening made collection of large unionid bivalves impossible (all other native invertebrates were small enough to pass through the screening), its presence was required to prevent the pump from clogging. In cases of occasional clogging, pump casing was removed and the impeller cleaned. A complete description and accompanying diagram of the dome suction sampler is available in Bader (1985), Clesceri et al. (1989), and Gale and Thompson (1975).

With one exception, five replicate dome suction samples were collected on a transect at both artificial reef and cobble sites on each of the four sampling dates (one of five replicate samples from the artificial reef was lost during transport to the water surface on July 12, 1991). Dome suction samples were collected by placing the sampling device on the substrate, then operating the pump for a three minute period (Bader 1985). While the pump was activated, the vacuum hose intake nozzle was maneuvered so that the entire area enclosed by the steel housing was cleaned. Stones and other objects were overturned, and their entire surfaces vacuumed.

Following transport of samples to the boat at the water surface, collecting bag contents were rinsed thoroughly into five gallon buckets. Bucket contents were poured through aquarium dip nets having mesh sizes equal to or finer than that of the sample collecting bag (0.5 mm). Sample components were then carefully transferred to plastic bottles. A solution containing 2-5% formalin and rose bengal dye (200 mg/L) (Clesceri et al. 1989) was then added to the sample contents. The dilute formalin fixed most soft-bodied organisms in a relaxed state, while rose bengal imparted a red color to freshly killed organisms, thereby easing separation of macroinvertebrates from other debris. Within 24 hours, the formalin-rose bengal solution was replaced with 70% ethanol, a preferable long-term preservative (Clesceri et al. 1989).

While the dome suction sampler appeared to clean substrates of all native macroinvertebrates, save large unionids, byssally attached zebra mussels were difficult to remove completely from substrates. Plot sampling (Stanczyckowska 1977; Lewandowski and Stanczyckowska 1986; Hebert et al. 1991) was utilized to compensate for dome suction sampler limitations. A square frame enclosing an area of 0.185 m^2 was placed on both artificial reef and cobble substrates, adjacent to the dome suction sampler, at three of the five randomly selected sampling locations. Plot sampling involved transferring rocks found within the frame and comprising the benthic substrate surface to a pillowcase (mesh size < 0.5 mm x 0.5 mm). At the water surface, zebra mussels were removed from rocks by scraping with a hard-bristle brush (Piesik 1983). Plot sample processing was similar to processing of dome suction samples. Zebra mussels were collected in five gallon buckets, passed through the aquarium dip net used for recovering dome suction samples (Hunter and Bailey 1992), then placed in plastic bottles prior to fixation and preservation.

In the laboratory, benthic macroinvertebrates were separated from other debris while carefully examining samples under a stereoscopic microscope (5 × power). Native mollusk individuals were counted and considered in abundance estimates if the shell aperture was intact. To avoid overestimating abundances of other native taxa, mutilated and torn individuals were only counted if the animal's head was still attached to the body. Very rarely were damaged native mollusks observed in samples. Damaged individuals of other taxa were more common, yet posterior body regions lacking heads were easily recognized and removed from samples.

Zebra mussels were easily fragmented during removal from substrates, resulting in high frequencies of damaged individuals in samples. In an attempt to increase the accuracy of zebra mussel abundance estimates, fragmented living individuals (e.g., tissue attached to shells) were considered along with whole organisms in abundance estimations. Because of their high numbers, subsampling (Elliott 1971) was employed to obtain zebra mussel abundance estimates. Following removal of native invertebrates, empty zebra mussel shells and other debris, zebra mussels from the same replicate sample were mixed together thoroughly in a dissecting pan. The objective of this was to increase the probability that mussels of all size ranges would be evenly distributed throughout the container. A mass of zebra mussels was then removed from the pan with a spoon, and transferred to a petri dish. Beginning at the top of the microscope field and proceeding from left to right, the assemblage was scanned. Whole, undamaged zebra mussels were removed as they were encountered until a count of 500 individuals was attained. These mussels were blotted dry and weighed. The average mass/individual was then calculated. Remaining undamaged and damaged individuals were then blotted dry and weighed. Abundance estimates were determined based on the average mass/individual and the total mass of zebra mussels in the replicate sample. Because use of both dome and plot sampling in estimating zebra mussel densities had limitations (inability of the dome suction sampler to remove all mussels from substrate; the variability in surface area of rocks removed from within the square frame during plot sampling), mussel abundance estimates from both methods were given equal consideration in data analysis. In general, dome suction samples provided lower, less variable estimates of zebra mussel abundance than plot samples.

Abundance estimates of native taxa were usually derived from direct counts of all organisms within each replicate sample. Occasionally (one cobble site replicate sample on 7/12/91 and three cobble site replicate samples on 8/20/92) oligochaetes were excessively abundant and subsampling of replicate samples was necessary. A decision to subsample was made after all macroinvertebrates were separated from debris, then further separated into their taxonomic classes. An oligochaete assemblage was subsampled by alternatively choosing in a consistent manner to identify or reject individuals as the group was scanned (e.g., identifying every second individual lying in a petri dish, beginning at the uppermost region of the microscope field and scanning from left to right). This method was designed to allow for equal probability of selecting each individual for identification, regardless of size or other physical characteristics (Elliott 1971). If subsampling by one-half the number of animals in the original sample occurred, counts for all oligochaete taxa were doubled after identifications were made.

Macroinvertebrates were identified to the lowest taxonomic level possible, depending on condition of preserved specimens and available publications (Brinkhurst and Jamieson 1971; Harman and Berg 1971; Hobbs 1972; Holsinger 1972; Burch 1975a; Burch 1975b; Edmunds et al. 1976; Wiggins 1977; Mackie et al. 1980; Simpson and Bode 1980; Clarke 1981; Klemm 1985; Merritt and Cummins 1984; Pennak 1989; Bode 1990; Peckarsky et al. 1990; Klemm 1990; Smith 1990; Strayer 1990; and Klemm 1991). Transparency of organisms (Oligochaeta, Arachnoidea, Chironomidae) requiring examination under a compound microscope (450×) was increased by clearing animals in glacial acetic acid for at least 24 hours (personal observation). A stereoscopic microscope (45×) was used for identification of other taxa which required no special preparation. Identifications were verified or corrected by Drs. Jarl K. Hiltunen, David A. Strayer (Oligochaeta), Donald J. Klemm (Oligochaeta and Hirudinea), Bruce P. Smith (Arachnoidea) and Mr. Andrew Bader.

Sample mean abundance estimates (# individuals/m^2), standard errors of those means, and ranges of abundance estimates (95% confidence limits) were calculated for all artificial reef and cobble site taxa on each sampling date. Two-sample T-tests (Elliott 1971; Dr. James McNamara, Department of Mathematics, State University of New York College at Brockport, personal communication) were used to compare native macroinvertebrate abundance estimates from identical months but different years (July 12, 1983 and July 12, 1991; September 10, 1983 and September 21, 1991; May 11, 1983 and

May 15, 1992; August 31, 1983 and August 20-23, 1992) at cobble and artificial reef sites. Taxa whose abundances were not quantified in 1983 (Unionidae and Arachnoidea), or those that Bader (1985) did not distinguish from closely related taxa (Nais sp., Oligochaeta cocoons, unidentified Heptageniidae, Trichoptera pupae, Orthocladius-Cricotopus, unidentified Chironomidae, and Chironomidae pupae), were not considered in pre- and post-zebra mussel invasion comparisons of macroinvertebrate abundance, species diversity, or community similarity. Their abundances in 1991-92 were estimated for documentation purposes and future reference.

Changes in native benthic macroinvertebrate community composition between 1983 and 1991-92 were further analyzed by Morisita's Community Similarity Index (Horn 1966 and Morisita 1959 in Brower and Zar 1977; Eckblad 1984). This index is based on the probability that two individuals, randomly selected from two different communities, will belong to the same taxon. Thus communities having similar taxa comprising nearly equal percentages of their respective communities will have high Morisita's Index values. Mean abundance estimates for each native taxon on each 1983 and 1991-92 sampling date were used to calculate the degree of similarity between cobble site communities (1983 and 1991-92), artificial reef communities (1983 and 1991-92), cobble site and artificial reef communities (1983), and cobble site and artificial reef communities (1991-92).

Native macroinvertebrate species diversity was analyzed by "species" (taxa) richness (Bode et al. 1990) and Simpson's Diversity (Simpson 1949 in Brower and Zar 1977; Eckblad 1984). Species richness was measured by recording the number of distinct native taxa collected at each site on each date. With exception of July 1991 (artificial reef site), when only four replicate samples were collected (the total area sampled was 0.66 m^2), the same benthic area (0.82 m^2) was sampled at both sites in 1983 and 1991-92. Like Morisita's Community Similarity Index, the number of different native taxa collected and the equitability of their population sizes are both important determinants of Simpson's Diversity (Brower and Zar 1977). Communities having many taxa with similar population sizes have greater Simpson's Diversity than those with a few numerically dominant taxa. Mean abundance estimates for each taxon were used to determine Simpson's Diversity at cobble and artificial reef sites on each 1983 and 1991-92 sampling date. A Mann-Whitney test (Elliott 1971) was used to analyze for differences in species richness and Simpson's Diversity between 1983 and 1991-92.

Results

Relative Abundance of Zebra Mussels and Native Benthic Macroinvertebrate Taxa

A complete list of native benthic macroinvertebrate taxa collected at cobble and artificial reef sites in 1983 and 1991-92 is provided in Table 1. Relative abundance estimates of zebra mussels and these native cobble and artificial reef site inhabitants throughout 1983 and 1991-92 are shown in Figures 3 and 4, respectively. Taxa whose abundance estimates comprised at least 1% of all benthic macroinvertebrates collected at cobble or artificial reef sites in 1983 or 1991-92 are included. Based on an average of dome and plot sampling abundance estimates, zebra mussels dominated cobble and artificial reef macroinvertebrate communities in 1991-92. Zebra mussels comprised 73% and 90% (Figures 3a and 4a), respectively, of macroinvertebrates recovered at these sites. These results contrast strongly with those from 1983, when the amphipod Gammarus fasciatus was numerically dominant on both cobble (55%) and artificial reef (78%) sites (Figures 3c and 4c), and abundance of numerically important taxa was more evenly distributed. Although I refer to all individuals of the genus Dreissena as zebra mussels, approximately 1% of dreissenids collected in 1991-92 were actually closely related quagga mussels, Dreissena sp. (Marsden 1992; L. Ben Motten, State University of New York College at Brockport, unpublished data).

If zebra mussel counts from 1991-92 are disregarded and relative abundance of native taxa is considered alone (Figures 3b and 4b), it is evident that the evenness of numerically abundant taxa remained high and may have increased since 1983 at both cobble and artificial reef sites. Native taxa appearing to be of increased relative abundance at the cobble site in 1991-92 were the gastropods Amnicola limosa (11.4% and < 1% of native benthic macroinvertebrates collected in 1991-92 and 1983, respectively; Figures 3b and 3c) and Physa heterostropha (6.6% and < 1%), and the oligochaetes Stylaria lacustris (3.8% and < 1%), Potamothrix vejdovskyi (2.4% and < 1%), Spirosperma ferox (1.4% and < 1%) and unidentified tubificids (11.7% and 3.1%). Gammarus fasciatus (32.5% and 54.9%), the sphaeriacean bivalve Musculium partumeium (1.8% and 7.4%), turbellarians (< 1% and 2.2%), and the insect larvae Chironomus (<1% and 2.5%) and Polycentropus (<1% and 1.7%) comprised a smaller percentage of the cobble site native benthic macroinvertebrate community in 1991-92 than 1983. Relative abundance of the gastropods Goniobasis livescens (14.8% and 11.2%) and Stagnicola catascopium (6.1% and 10.1%) appeared similar in 1983 and 1991-92. Relative abundance estimates of native benthic macroinvertebrate taxa inhabiting the cobble site on each 1983 and 1991-92 sampling date are shown in Appendix 1. Monthly abundance estimates of native taxa comprising at least 5% of the cobble site community composition on one or more sampling dates (1983 or 1991-92) are provided in Appendix 3.

While relative abundance of Gammarus fasciatus at the artificial reef site remained greater than that of any other native taxon in 1991-92 (73.2%; Figure 4b), Amnicola limosa, (8.8% and < 1%; Figures 4b and 4c, respectively), turbellarians (1.4% and < 1%) and unidentified tubificids (1.5% and < 1%) comprised a greater percentage of artificial reef native macroinvertebrate community composition in 1991-92 than 1983. Despite increased prominence of these taxa, the gastropods Goniobasis livescens (6.9% and 11.8%), Physa heterostropha (2.7% and 4.1%), and Stagnicola catascopium (2.1 and 2.9%) continued to be important constituents of the artificial reef site native community ten years after initial sampling of this site. Relative abundance estimates of native artificial reef site taxa are provided by sampling date in Appendix 2. Monthly changes in abundance of native taxa comprising at least 5% of the artificial reef site community composition on any 1983 or 1991-92 sampling date are shown in Appendix 4.

Changes in Total Benthic Macroinvertebrate Abundance

Monthly abundance estimates of zebra mussels (1991-92) and native benthic macroinvertebrates (1983 and 1991-92) are shown in Figures 5 (cobble site) and 6 (artificial reef site). Zebra mussel abundance estimates at the cobble site ranged from 1,283 ± 743 $\{\bar{x} \pm 1.96(\frac{s}{\sqrt{n}})\}$ (Lewis 1984) individuals/m^2 on July 12, 1991, to 20,773 ± 618 individuals/m^2 on August 23, 1992. Despite the presence of zebra mussels in 1991-92, total abundance of native benthic macroinvertebrates at the cobble site was significantly greater ($p < 0.05$) on three of the four sampling dates in 1991-92 than in 1983 (September, May and August). Abundance estimates in my first month of sampling (July 1991) were nearly significantly greater ($p < 0.10$) than 1983 estimates (the procedure I used to calculate p-values is given in Appendix 5). While no significant differences between abundance of zebra mussels and 1991-92 native macroinvertebrates were observed based on dome suction sampling (Figure 5), abundance estimates obtained by plot sampling suggested that zebra mussels were actually more abundant than all other macroinvertebrate taxa combined in 1991-92 (replicate sample and mean zebra mussel abundance and wet biomass estimates are provided in Appendices 6 and 7).

Zebra mussel abundance estimates at the artificial reef site ranged from 9,184 ± 3,610 individuals/m^2 on July 12, 1991, to 55,508 ± 22,790 individuals/m^2, also obtained on July 12, 1991. Regardless of the sampling method used, zebra mussels were significantly more abundant ($p < 0.05$) at the artificial reef than native macroinvertebrates on all four 1991-92 sampling dates. Likewise, native macroinvertebrates as a group were significantly more abundant ($p < 0.05$) on all 1991-92 sampling dates, than on similar dates in 1983.

Changes in Abundance of Individual Native Benthic Macroinvertebrate Taxa

Included with the list of native benthic macroinvertebrate taxa collected at cobble and artificial reef sites in 1983 and 1991-92 (Table 1), but noted separately, are taxa collected in 1983 on a date other than July 12, September 10, May 11, or August 31 (-*), and taxa whose abundances were estimated in 1991-92 but not in 1983 (?) (Mr. Andrew P. Bader, New York City Department of Environmental Protection, personal communication). Excluding taxa collected in 1983 during a time of year not sampled in 1991-92 (n = 7 and n = 11 at cobble and artificial reef sites, respectively), or those whose abundances were not quantified in 1983 (n = 14 and n = 14), 35 taxa were collected at the cobble site in 1983, and 44 in 1991-92. At the artificial reef site, 23 taxa were identified in 1983 and 39 in 1991-92. Four phyla and eight classes were found. In terms of taxonomic diversity, gastropods, oligochaetes and insects were particularly well represented at both artificial reef and cobble sites.

Taxa collected at cobble or artificial reef sites in 1983 but not in 1991-92 included enchytraeid oligochaetes, the sphaeriacean bivalve Musculium partumeium (absent at artificial reef site only), the gastropod Ferrissia rivularis, the isopod Caecidotea racovitzai, and the chironomids Cricotopus (absent at cobble site only), Endochironomus, Parachironomus, Micropsectra and Paratanytarsus. Documented as present for the first time in 1991-92 were oligochaetes Lumbriculus variegatus, Chaetogaster limnaei, Pristinella osborni, Nais pardalis and Vejdovskyella intermedia; the hirudinean Desserobdella phalera, the unionacean bivalve Ligumia nasuta, the gastropod Valvata tricarinata, the ephemeropteran Eurylophella and the chironomids Eukiefferiella and Polypedilum.

Replicate sample counts of all native taxa collected in 1991-92 are provided by sampling date in Appendices 8 (cobble site) and 9 (artificial reef site). Mean abundance estimates of each taxon (1983 and 1991-92), and p-values derived from comparisons of each taxon's abundance in 1983 and 1991-92, are given by date in Appendices 10 (cobble site) and 11 (artificial reef site). Mean abundance estimates of each taxon on all sampling dates are summarized in Appendices 12 (cobble site) and 13 (artificial reef site). Statistically significant differences in abundance (95% CI or 99% CI) between samples collected during the same months but different years are indicated in Appendices 10-13.

Monthly abundance estimates of taxa significantly more abundant ($p < 0.05$) on two or more sampling dates in 1991-92 than in 1983 are given in Tables 2 (cobble site) and 3 (artificial reef site). While populations of several taxa were significantly more abundant in 1991-92 than in 1983, no taxon exhibited a significant population decline on more than one sampling date at either cobble or artificial reef sites. At the cobble site, the tubificid Spirosperma ferox and the gastropods Physa heterostropha, Valvata tricarinata, and Amnicola limosa were more abundant on all four 1991-92 sampling dates than on similar sampling dates in 1983. The polychaete Manayunkia speciosa, unidentified tubificids, the gastropods Helisoma anceps, Stagnicola catascopium, Goniobasis livescens; the amphipod Gammarus fasciatus and the decapod Orconectes propinquis were more abundant at the cobble site on three 1991-92 sampling dates than they were almost ten years ago. At the artificial reef site, Amnicola limosa and Gammarus fasciatus exhibited significant population increases, relative to 1983, on all four 1991-92 sampling dates. Physa heterostropha, Goniobasis livescens and the trichopteran Polycentropus were more numerous on two 1991-92 sampling dates than on similar dates in 1983.

Community Similarity Comparisons and Changes in Native Macroinvertebrate Diversity

Degrees of similarity between native macroinvertebrate communities inhabiting the same sites during different years, or different sites during the same years, are shown by month in Figure 7. Morisita's Index (MI) values obtained from community composition comparisons are provided in Appendix 14. With the possible exception of cobble site communities in July 1983 and July 1991 (MI = 0.5), cobble site community composition in 1991-92 showed little change from 1983 (MI range = 0.7 - 0.9). Increased populations of gastropods such as Physa heterostropha, Valvata tricarinata, and Amnicola limosa (Table 2) contributed to the community change observed at the cobble site. The artificial reef site community changed even less than the cobble site community (MI range = 0.7 - 1.0). Notable change in artificial reef community composition was suggested only when data from May 1983 and 1992 were compared (MI = 0.7; Figure 7). Increased prominence of Amnicola limosa probably caused some of the community change that was observed at the artificial reef site between 1983 and 1991-92 (Table 3).

Same year comparisons between cobble and artificial reef site communities suggested that communities at the two sites were less similar to each other in 1991-92 (MI range = 0.4 - 0.8) than 1983 (MI range = 0.9 - 1.0; Figure 7). It appears that increasingly diverse (Table 1) and large (Table 2) populations of oligochaetes at the cobble site are largely responsible for increased differences in cobble and artificial reef site community compositions.

Monthly estimates of native species richness at cobble and artificial reef sites are shown in Figures 8 and 9, respectively, and Appendix 15. Species richness was greater at both sites ($p < 0.05$) throughout 1991-92 than in 1983. Cobble site species richness in 1991-92 ranged from 26 taxa/0.82 m^2 in September 1991 to 31 taxa/0.82 m^2 in July 1991 and August 1992 (Figure 8). In contrast, species richness at the cobble site in 1983 never exceeded 22 taxa/0.82 m^2. A similar pattern was observed on the artificial reef. While diversity of taxa ranged from 18 taxa/0.656 m^2 in July to 25 taxa/0.82 m^2 in August 1991-92, species richness never exceeded 15 taxa/0.82 m^2 in 1983 (Figure 9).

Simpson's Diversity also appeared to be higher ($p < 0.01$) at the cobble site in 1991-92 than in 1983. While such increases in Simpson's Diversity were not observed at the artificial reef site, results indicated that equitability of native macroinvertebrate population sizes has not diminished since 1983 (Figure 11) despite recent establishment of zebra mussel populations at this site. Disproportionately high populations of _Gammarus fasciatus_ at the artificial reef site in May 1992 (Table 3; Appendices 11 and 13) resulted in low Simpson's Diversity at that time, relative to other sampling dates.

Discussion

My data suggest the zebra mussel's short-term impact on native benthic macroinvertebrate communities at cobble and artificial reef sites has been largely positive. Results and theories derived from other studies may help explain mechanisms behind observed changes in macroinvertebrate abundance and diversity between 1983 and 1991-92. Factors possibly contributing to increased native benthic macroinvertebrate abundance and diversity will be discussed below.

Transfer of Energy to Benthic Environments

Zebra mussels may be facilitating transfer of nutrients to southwestern Lake Ontario's benthos by filter-feeding and subsequently depositing feces and pseudofeces (Wiktor 1963; Stanczykowksa et al. 1976; Reeders and Bij de Vaate 1990; Leach 1993). Many authors (Wiktor 1969; Izvekova and Lvova-Katchanova 1972; Smirnova and Vinogradov 1990) have discussed the importance of zebra mussel feces and pseudofeces (partially digested material) in diets of detritivorous benthic macroinvertebrates. Laden with bacteria and the digestive enzyme acid phosphatase, pseudofeces not only has high nutritive value, but may be easily digested and assimilated by organisms consuming it (Izvekova and Lvova-Katchanova 1972). Among facultative or obligatory detritivores showing population increases at cobble or artificial reef sites were Spirosperma ferox, other (unidentified) tubificids, Physa heterostropha, Valvata tricarinata, Gammarus fasciatus and Polycentropus (Harman and Berg 1971; Hynes 1974; Caspers 1980; Klemm 1985). Griffiths (1993) suspected that deposition of organic material by zebra mussels caused recently documented population increases in Potamothrix moldaviensis and

Spirosperma ferox in Lake St. Clair, while Lewandowski (1976) concluded that oligochaete and chironomid densities in a European aquatic system were typically higher in environments having accumulations of mussel feces and pseudofeces than in waters lacking zebra mussels.

Direct Use of Zebra Mussels as a Food Source

It is possible that some native macroinvertebrate taxa of cobble and artificial reef sites benefit by consuming or parasitizing zebra mussels. Orconectes limosus consumed large numbers of small zebra mussels under ideal water temperature conditions in Poland (Piesik 1974). Though not yet documented to consume zebra mussels, the species of crayfish I collected (Orconectes propinquis) exhibited population increases at the cobble site in 1991-92 relative to 1983 (Table 2; Appendix 12). Beedham (1970) observed and described a parasitic or commensalate relationship between chironomid larvae (Metriocnemus) and zebra mussels, in which chironomids resided within and upon shells of living zebra mussels; possibly subsisting upon body secretions or pseudofeces agglutinated with enzyme-rich mucus. European-based zebra mussel populations have also been preyed upon by leeches (Lewandowski 1976; Smit et. al. 1990) and the oligochaete Chaetogaster (Piesik 1983). It is interesting that Chaetogaster limnaei, a commensalate of the snails Helisoma anceps (Fernandez et al. 1991) and Physa gyrina (Sankwathri and Holmes 1976), was not collected at Olcott until after zebra mussels became established. Is it possible that appearances of Chaetogaster and other taxa, absent in 1983 but found in 1991-92, are linked to the present-day occurrence of zebra mussels? Studies examining potential predator-prey or symbiotic relationships between zebra mussels and benthic macroinvertebrate taxa native to the Great Lakes could yield valuable information, and should be conducted in the near future.

Increased Substrate Complexity and Creation of New Microhabitats

Enhanced substrate complexity may be most responsible for increased native macroinvertebrate abundance at cobble and artificial reef sites, as well as for trends suggesting increased species diversity. Mussel colonies provide new forms of physical structure on the lake bottom, and interstices between individual mussels offer shelter to other taxa (Dermott and Barton 1991). Even byssal threads are known to be utilized by many European benthic macroinvertebrate taxa for substrate and protection (Lewandowski 1976). Dusoge (1966) and Wiktor (1969) observed abundance and biomass of European benthic macroinvertebrates to be greater among clumps of zebra mussels than in adjacent areas lacking mussels. Dermott and Barton (1991) and Griffiths (1993) hypothesized that structural shifts in benthic substrates following zebra mussel colonization of southwestern Lake Ontario (near the Niagara River) and Lake St. Clair contributed to recent increases in native benthic macroinvertebrate abundance and species richness in these areas. Hirudineans, gastropods, Gammarus, Polycentropus, and the chironomid Polypedilum were considered by these investigators to benefit from physical structure created by zebra mussels. These taxa, and closely related taxa, exhibited significant population increases in

1991-92 relative to 1983 at southwestern Lake Ontario cobble and artificial reef study sites, or were collected at one of these sites for the first time in 1991-92.

Zebra mussels indirectly create habitat as well. Filter-feeding not only accelerates rates of nutrient transfer to benthic habitats, but also improves water clarity (Stanczyckowska 1984; Hebert et al. 1991). Growth of benthic algae may be promoted by increased light penetration to the benthos (Lowe et al. 1990) in combination with higher benthic nutrient levels than existed a few years ago. Strong relationships between abundant benthic algae and high Great Lakes populations of nematodes, naidid oligochaetes, hirudineans, gastropods (Amnicola, Goniobasis, Gyraulus, Helisoma, Physa, Valvata), Hydrachnidia, Gammarus, ephemeropterans and Chironomus have been observed in the past (Nicholson 1873 as cited in Cook and Johnson 1974; Cook and Johnson 1974; Barton and Hynes 1978). Although present, benthic algae did not appear to be especially abundant at cobble or artificial reef sites in 1991-92. Studies examining potential zebra mussel induced changes in abundance of benthic algae in the Great Lakes are needed.

Factors Possibly Contributing to Changes in Diversity and Community Composition

Population ecologists have long recognized the importance of biotic interactions (cf. Nicholson 1933 in Begon and Mortimer 1986) and structural heterogeneity (MacArthur 1969) in determining abundance and diversity of species within a community. The zebra mussel is a prime example of an organism having the ability to induce changes in biological communities. Zebra mussels appear to benefit macroinvertebrates of artificial reef and cobble sites in southwestern Lake Ontario, although communities at each of these two sites have been affected differently. Cobble site substrate heterogeneity is greater than at the artificial reef, providing a probable explanation for the greater species richness observed at the cobble site (Cook and Johnson 1974). Silty and sandy areas, lacking on the reef, are especially favorable habitats for burrowing oligochaetes (Brinkhurst et al. 1968). Populations of soft substrate organisms have increased greatly at the cobble site, causing some change in the native macroinvertebrate community composition and increasing dissimilarities between cobble and reef faunal assemblages.

Factors Possibly Contributing to Declines of Some Native Benthic Macroinvertebrate Taxa

If zebra mussels have accelerated energy transfer to the benthos, and have improved habitat for so many taxa, why have some taxa apparently declined (not significantly) in abundance at cobble and artificial reef sites? Potential causes for declines include: (1) zebra mussels functioning as exploitive or interference competitors with other taxa (Hebert et al. 1991), and (2) changes in trophic status of the Lake Ontario ecosystem by mussel biofiltration.

(1) While zebra mussel filter-feeding may benefit many benthic organisms, there is concern that zebra mussel induced reductions in suspended food particle concentrations is threatening unionid bivalves dependent upon this food source (Hebert et al. 1991). Zebra mussels are known to be impacting North American species of unionids by settling on their shells and inhibiting their ability to feed, respire, and reproduce (Hebert et al. 1989;

Hebert et al. 1991; Mackie 1991; Masteller and Schloesser 1991; Schloesser and Kovalak 1991; Gillis and Mackie 1992; Hunter and Bailey 1992). Crayfish have also been found covered with zebra mussels (Sebestyen 1938), whose byssal fibers can pierce the animals' protective exoskeletons (Lamanova 1971). Sphaeriid bivalves (Dermott and Barton 1991), the gastropod Goniobasis livescens (personal observation), and other mollusks are also colonized. Fortunately, crayfish discard mussels upon molting, and most other non-unionid taxa are too small and short-lived to become heavily colonized.

It is unfortunate that the dome suction sampler was unable to collect large unionids, thus restricting my ability to measure impacts upon them. However, both large and small unionid individuals were observed at the cobble site in 1991-92, and few zebra mussels were attached to them. Unionids collected by hand from sand and silt regions of the cobble site included Elliptio complanata, Lampsilis radiata and Ligumia nasuta. Long-term effects of zebra mussels on populations of southwestern Lake Ontario crayfish and unionid taxa should be studied in the future.

(2) Just as increased transfer of nutrients to benthic environments appear to have benefitted most native cobble and artificial reef taxa, it is possible that trophic requirements of some taxa recovered in 1983, but not in 1991-92, may no longer be met (Griffiths 1993). Since taxa exhibiting population declines (taxa sampled in 1983 but not in 1991-92) tolerate a diverse array of trophic conditions (Bode 1990), exclusion of native taxa by zebra mussel effects on water quality or trophic state was not evident.

Other Factors Possibly Contributing to Changes in Macroinvertebrate Abundance

It is likely that factors independent of zebra mussel activities have influenced cobble and artificial reef site native benthic macroinvertebrate populations during the past ten years. Anthropogenic effects on water quality (Cook and Johnson 1974; Sly 1991), thermal regimes (Barton 1986) and habitat change (Haynes and Makarewicz 1982; Ricklefs 1983) are just a few of the environmental parameters known to impact macroinvertebrate populations.

Phosphorus abatement programs have facilitated declines in total phosphorus concentrations throughout Lake Ontario since the mid-1970s (Barton 1986, Stevens and Neilson 1987). These declines continued between 1983 and 1991-92; from 11-12 μgP/L in March, 1983 to 9.5-10.5 μgP/L in March, 1990 (Hugh H.F. Dobson, 1990, Canadian Center for Inland Waters, unpublished data; Great Lakes Fishery Commission 1992). Assessing the effects that phosphorus abatement has had and will continue to have on benthic macroinvertebrate populations is problematic. According to Johnson and MacNeil (1986 in Sly 1991), declines in abundance of some oligochaete, sphaeriid bivalve and isopod taxa were observed in the Bay of Quinte following reductions in phosphorous loading to Lake Ontario and prior to establishment of zebra mussel populations within the lake. Perhaps disappearance of Caecidotea racovitzai from the cobble site by 1991-92 was related to this phenomenon. Barton (1986) observed declines in total benthic macroinvertebrate abundance in areas undergoing rapid deeutrophication, though other taxa likely benefitted as benthic macroinvertebrate species diversity is typically lower in highly enriched environments than in more oligotrophic waters (Barton and Hynes 1978; Barton 1986). Increases in water clarity resulting from phosphorus reductions may facilitate temperature increases in benthic environments by allowing light to reach greater depths. Consequently, primary production in benthic environments may actually increase under such conditions (Mazumder 1990 in Sly 1991). When one considers this factor in combination with previously discussed favorable effects of zebra mussels on benthic fauna (especially nutrient transfer, increase in water clarity via filter-feeding), positive changes in cobble and artificial reef site macroinvertebrate abundance and diversity between 1983 and 1991-92 are understandable. Since both zebra mussels and reduced nutrient loadings are suspected of having profound influences on the Lake Ontario ecosystem, determining the extent in which cobble and artificial reef taxa have truly been affected by zebra mussels is not possible at this time.

Reduced discharge of many contaminants into Lake Ontario in recent years may have allowed for population resurgences of pollution sensitive taxa (Sly 1991). Though cobble and artificial reef site populations of chironomids changed little between 1983 and 1991-92, studies by Warwick (1985), Warwick et al. (1987) and Dickman et al. (1992) have shown populations of chironomid larvae to be particularly sensitive to toxic compounds. Information regarding sensitivity of other cobble and reef site taxa to specific toxic compounds is lacking (Sly 1991).

Though seasonal water temperatures in the vicinity of cobble and artificial reef sites appeared similar throughout 1983 and 1991-92 studies (Bader 1985; Gerry Morgan, New York State Electric and Gas Corporation, unpublished data), frequent seiching is known to occur in the study area (Dr. James M. Haynes, Department of Biological Sciences, State University of New York, personal communication). Many macroinvertebrate taxa, including ephemeropterans and decapods, are sensitive to rapid water temperature changes (Emery 1970). Samples collected following an upwelling event could therefore be expected to exhibit reduced abundance of some taxa than would normally be the case.

Dissolved oxygen is one environmental parameter that can probably be excluded from consideration in terms of effects on macroinvertebrate population changes. Sly (1991) reports that dissolved oxygen concentrations remain high in nearshore regions of Lake Ontario throughout the year.

Since the artificial reef was only a year old when its macroinvertebrate fauna was first sampled in 1983 (Bader 1985), many taxa may not have had sufficient opportunity to colonize this site and attain their maximum population densities by that time. It is also conceivable that natural processes of primary succession (Ricklefs 1983) have altered physical characteristics of the artificial reef, making the structure more or less favorable over time for certain taxa. Despite these possibilities, community changes at the long established cobble site appeared more extensive than at the artificial reef, suggesting that age of study site cannot explain all changes measured in my study.

Finally, most benthic macroinvertebrate populations fluctuate considerably throughout the year (Tables 2-3; Appendices 3-4, 10-13), suggesting that taxa infrequently encountered in 1983 but absent in 1991-92 (enchytraeid oligochaetes, Ferrissia rivularis Caecidotea racovitzai, Oecetis, Endochironomus, Parachironomus, Micropsectra and Paratanytarsus) may have been collected had we sampled on different dates. Absence of the mud-loving Musculium partumeium at the artificial reef site in 1991-92 may be attributed to the predominance of hard substrate on this structure (Clarke 1981), and the resulting difficulty of this species maintaining viable populations at this site. Since several taxa (Caecidotea, Chironomus, Cricotopus) showing possible declines in my study (Table 1 and Appendices 10-13) have coexisted with zebra mussels in other instances (Wolnomiejski and Gizinski 1976; Dermott and Barton 1991), further studies are needed to determine which of the observed population declines are attributable to zebra mussels and not other factors.

Assessments of Zebra Mussel Impacts on other Great Lakes Organisms

It seems pertinent to apply results from my study and others to analyze potential effects of zebra mussels on other Great Lakes organisms. Reduction of phytoplankton biomass (Leach 1993) may adversely affect populations of zooplankton and fishes (e.g., yellow perch) dependent upon this food resource (Graham et al. 1991). Although the tiny zebra mussel larva is probably of little food value to most vertebrates (Dr. Joseph C. Makarewicz, Department of Biological Sciences, State University of New York College at Brockport, personal communication), a few scientists (Wiktor 1958; Zhdanova and Gusynkaya 1986) have speculated that some planktivorous fish species might survive by consuming veligers as zooplankton substitutes. In contrast to veligers, adult zebra mussels have high caloric contents (Birger and Malyarevskaya 1977 and Walz 1979 in Mackie et al. 1989). Fish species inhabiting southwestern Lake Ontario and known to feed on adult zebra mussels include freshwater drum (French and Bur 1993), whose populations may be increasing (Dr. James M. Haynes, Department of Biological Sciences, State University of New York College at Brockport, personal communication), and carp (Botnauric et al. 1964 in Stanczykowska 1977). Based on European studies (DeNie 1982), the American eel may also prey on zebra mussels.

Change in physical structure of spawning beds may curtail reproductive success in some fish species. However, Fitzsimons et al. (1991), Nepszy (1992), and Leach (1993) have observed no ill effects of zebra mussel colonization on walleye reproduction in Lake Erie. It is possible that increased densities of aquatic macrophytes in Lake Ontario wetlands likely resulting from water clarification by zebra mussels will increase available spawning and nursery habitat for certain fish species (McNabb et al. 1991).

Shifts in abundance of fish species will undoubtedly affect benthic macroinvertebrate community assemblages. Christie et al. (1987) observed population increases in the deepwater amphipod Pontoporeia following declines in Lake Ontario slimy sculpin (Cottus cognatus) populations brought about by intense salmonid predation. Zebra mussel induced changes in populations of fish species may have contributed to macroinvertebrate population changes observed in 1991-92 relative to 1983, though further investigations regarding recent fish population changes are needed.

A variety of waterfowl are known to consume zebra mussels. Of these, species congregating along the south shore of Lake Ontario include mallards, goldeneyes, common and red-breasted mergansers, herring gulls, and gadwalls (numerous authors cited in Stanczykowska 1977). Some waterfowl populations in parts of Europe have increased substantially following zebra mussel invasion of previously uncolonized systems (numerous authors in Stanczykowska 1977). Zebra mussel effects on Lake Ontario waterfowl populations are presently unknown and merit study.

Summary

By 1991-92, the zebra mussel was the numerically dominant benthic macroinvertebrate taxon at southwestern Lake Ontario cobble and artificial reef sites. Nevertheless, overall abundance of native benthic macroinvertebrates was greater in both habitats following establishment of zebra mussel populations than in 1983 before the zebra mussel invasion. Native macroinvertebrate species richness was also higher at cobble and artificial reef sites in 1991-92, than in 1983.

By occurring in large clumps and filter-feeding intensively, zebra mussels may benefit other macroinvertebrate taxa by increasing the complexity of substrate available to those taxa and by increasing the flow of energy to benthic environments. This study failed to provide evidence that zebra mussels have induced population declines in any taxon found at either cobble or artificial reef sites in 1983. Though factors independent of zebra mussel activities likely contributed to these community changes, my data suggest that zebra mussels may not have the disastrous effects on Great Lakes ecosystems predicted only a few years ago.

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Table I. Native Benthic Macroinvertebrate Taxa of Cobble and Artificial Reef Sites, 1983 and 1991-92

	cobble site		artificial reef site	
taxon	1983	1991-92	1983	1991-92
Nematoda	+	+	-	+
Platyhelminthes				
Turbellaria	+	-	+	+
Annelida				
Polychaeta				
Sabellidae				
Manayunkia speciosa	-	+	-	+
Oligochaeta				
Lumbriculida				
Lumbriculidae				
Lumbriculus variegatus	-	+	-	-
unidentified Lumbriculidae	+	+	-*	-
Haplotaxida				
Enchytraeidae	+	-	-	-
Naididae				
Chaetogaster limnaei	-	+	-	+
Pristinella osborni	-	+	-	+
Nais communis	-	+	-*	+
Nais pardalis	-	+	-	+
Nais sp.	?	+	?	+
Stylaria lacustris	-	+	-*	+
Vejdovskyella intermedia	-	+	-	-
Tubificidae				
Potamothrix moldaviensis	+	+	-	-
Potamothrix vejdovskyi	+	+	-	+
Spirosperma ferox	+	+	-	+
unidentified Tubificidae	+	+	-*	+
Oligochaeta cocoons	?	+	?	-
Hirudinea				
Rhynchobdellida				
Glossiphoniidae				
Desserobdella phalera	-	-	-	+
Piscicolidae				
Piscicola punctata	-	+	-*	-
Mollusca				
Bivalvia				
Sphaeriidae				
Musculium partumeium	+	+	+	-
Unionidae				
Ligumia nasuta	?	+	?	-
unidentified Unionidae	?	+	?	-
Gastropoda				
Pulmonata				
Ancylidae				
Ferrissia rivularis	+	-	-*	-
Planorbidae				
Gyraulus parvus	+	+	+	+
Helisoma anceps	-	+	-*	+
Physidae				
Physa heterostropha	+	+	+	+
Lymnaeidae				
Stagnicola catascopium	+	+	+	+
Prosobranchia				
Valvatidae				
Valvata tricarinata	-	+	-	+
Bithyniidae				
Bithynia tentaculata	+	+	+	+
Pleuroceridae				
Goniobasis livescens	+	+	+	+
Hydrobiidae				
Amnicola limosa	+	+	+	+

1983 sampling dates (5/11, 7/12, 9/10, 8/31).
1991-92 sampling dates (7/12/91, 9/21/91, 5/15/92, 8/20/92-8/23/92).
(+) collected at specified site during year and sampling dates indicated.
(-) not collected at specified site during year and sampling dates indicated.
(-*) collected in 1983 at specified site, but on a date other than those listed above.
(?) if collected in 1983, not identified and abundances not quantified (Bader, personal communication).

Table 1. Native Benthic Macroinvertebrate Taxa of Cobble and Artificial Reef Sites, 1983 and 1991-92.

taxon	cobble site 1983	cobble site 1991-92	artificial reef site 1983	artificial reef site 1991-92
Arthropoda				
Crustacea				
Isopoda				
Asellidae				
Caecidotea racovitzai	+	-	-	-
Amphipoda				
Gammaridae				
Gammarus fasciatus	+	+	+	+
Decapoda				
Cambaridae				
Orconectes propinquus	+	+	+	+
Arachnoidea				
Acarina				
Hygrobatidae				
Hygrobates	?	+	?	+
Lebertiidae				
Lebertia	?	+	?	+
Pionidae				
Forelia	?	+	?	-
Wettina	?	+	?	-
unidentified Acarina	?	+	?	+
Insecta				
Ephemeroptera				
Ephemerellidae				
Eurylophella	-	-	-	+
Heptageniidae				
Stenacron	+	+	+	+
Stenonema	+	+	+	+
unidentified Heptageniidae	?	-	?	+
Trichoptera				
Hydroptilidae				
Agraylea	-*	+	-	+
Leptoceridae				
Ceraclea	+	+	+	+
Oecetis	-*	-	-	-
Polycentropidae				
Polycentropus	+	+	+	+
Trichoptera pupae	?	+	?	+
Diptera				
Chironomidae				
Procladius	+	+	-*	+
Theinnemannimyia	-*	+	-*	+
Cricotopus	+	-	+	+
Eukiefferiella	-	+	-	+
Heterotrissocladius	+	+	+	+
Orthocladius	+	+	+	+
Orthocladius-Cricotopus	?	+	?	+
Psectrocladius	+	+	+	+
Chironomus	+	+	+	+
Endochironomus	+	-	+	-
Parachironomus	+	-	+	-
Dicrotendipes	-*	-	-	-
Microtendipes	-*	-	-	-
Paratendipes	+	+	+	-
Phaenopsectra	-*	+	-*	+
Polypedilum	-	-	-	+
Micropsectra	+	-	-	-
Paratanytarsus	+	-	-*	-
Rheotanytarsus	-*	+	-	-
Tanytarsus	+	+	+	+
unidentified Chironomidae	?	+	?	+
Chironomidae pupae	?	+	?	+

1983 sampling dates (5/11, 7/12, 9/10, 8/31).
1991-92 sampling dates (7/12/91, 9/21/91, 5/15/92, 8/20/92-8/23/92).
(+) collected at specified site during year and sampling dates indicated.
(-) not collected at specified site during year and sampling dates indicated.
(-*) collected in 1983 at specified site, but on a date other than those listed above.
(?) if collected in 1983, not identified and abundances not quantified (Bader, personal communication).

Table 2. Abundance Estimates of Selected Native Cobble Site Benthic Macroinvertebrate Taxa (included are taxa significantly more abundant on two or more 1991-92 sampling dates, relative to similar sampling dates from the same month in 1983).

mean # individuals/square meter (standard error in parentheses)

taxon	7/12/83	7/12/91	9/10/83	9/21/91	5/11/83	5/15/92	8/31/83	8/20/92
Annelida								
Polychaeta								
Sabellidae								
Manayunkia speciosa	0.0	13.4 (8.2)*	0.0	31.7 (11.2)**	0.0	3.7 (1.3)	0.0	7.3 (4.0)*
Oligochaeta								
Tubificidae								
Spirosperma ferox	0.0	22.0 (14.3)*	1.2 (1.2)	12.2 (4.6)*	0.0	76.8 (30.7)**	0.0	68.3 (20.9)**
unidentified Tubificidae	22.9 (9.8)	102.4 (51.9)	13.2 (11.8)	151.2 (88.7)	20.5 (14.8)	174.4 (83.1)**	19.3 (4.8)	1130.5 (702.4)**
Mollusca								
Gastropoda								
Pulmonata								
Planorbidae								
Helisoma anceps	0.0	1.2 (1.1)	0.0	6.1 (3.0)*	0.0	8.5 (4.1)*	0.0	59.8 (9.7)**
Physidae								
Physa heterostropha	0.0	56.1 (25.1)**	7.2 (4.4)	152.4 (18.9)**	2.4 (1.5)	25.6 (9.2)*	8.4 (1.5)	645.1 (36.8)**
Lymnaeidae								
Stagnicola catascopium	219.3 (48.3)	495.1 (155.8)	20.5 (6.2)	159.8 (29.5)**	0.0	8.5 (5.1)*	6.0 (3.3)	150.0 (15.4)**
Prosobranchia								
Valvatidae								
Valvata tricarinata	0.0	4.9 (2.0)*	0.0	68.3 (21.0)**	0.0	14.6 (5.1)**	0.0	25.6 (9.7)**
Pleuroceridae								
Goniobasis livescens	102.4 (13.7)	148.8 (49.7)	104.8 (21.9)	1180.5 (200.8)**	39.8 (16.9)	357.3 (34.4)**	25.3 (10.5)	276.8 (30.4)**
Hydrobiidae								
Amnicola limosa	0.0	332.9 (57.8)**	3.6 (2.4)	943.9 (202.8)**	0.0	107.3 (21.2)**	1.2 (1.2)	135.4 (27.0)**
Arthropoda								
Crustacea								
Amphipoda								
Gammaridae								
Gammarus fasciatus	657.8 (66.8)	335.4 (73.9)	232.5 (72.0)	1669.5 (253.7)**	84.3 (29.6)	218.3 (32.5)*	357.8 (66.6)	2095.1 (134.2)**
Decapoda								
Cambaridae								
Orconectes propinquus	3.6 (1.5)	57.3 (15.7)*	0.0	17.1 (3.2)**	2.4 (1.5)	9.8 (3.3)	1.2 (1.2)	32.9 (6.8)**
total	1159.0 (106.8)	2390.2 (507.6)	475.9 (84.5)	4595.1 (745.2)**	261.4 (90.9)	1315.8 (169.5)*	531.3 (64.2)	4970.7 (924.3)**

*significantly more abundant (95% CI) in 1991-92, than on a date from the same month in 1983.

**significantly more abundant (99% CI) in 1991-92, than on a date from the same month in 1983.

Table 3. Abundance Estimates of Selected Native Artificial Reef Site Benthic Macroinvertebrate Taxa (included are taxa significantly more abundant on two or more 1991-92 sampling dates, relative to similar sampling dates from the same month in 1983).

	mean # individuals/square meter (standard error in parentheses)							
taxon	7/12/83	7/12/91	9/10/83	9/21/91	5/11/83	5/15/92	8/31/83	8/20/92
Mollusca								
Gastropoda								
Pulmonata								
Physidae								
Physa heterostropha	1.2 (1.2)	108.2 (33.2)**	60.2 (27.5)	112.2 (12.5)	2.4 (2.4)	19.5 (7.2)*	91.6 (12.8)	61.0 (20.0)
Prosobranchia								
Pleuroceridae								
Goniobasis livescens	162.6 (27.8)	96.0 (19.3)	179.5 (65.3)	461.0 (133.0)*	19.3 (12.3)	74.4 (23.0)*	83.1 (22.2)	141.5 (16.8)
Hydrobiidae								
Amnicola limosa	0.0	144.8 (66.8)**	0.0	648.8 (80.9)**	0.0	79.3 (32.9)**	2.4 (2.4)	113.4 (24.2)**
Arthropoda								
Crustacea								
Amphipoda								
Gammaridae								
Gammarus fasciatus	669.9 (195.5)	1714.9 (341.4)*	1543.4 (517.2)	3865.8 (374.9)*	44.6 (43.1)	1136.6 (250.4)*	669.9 (225.8)	1524.4 (201.1)*
Insecta								
Trichoptera								
Polycentropidae								
Polycentropus	0.0	21.3 (5.1)**	2.4 (2.4)	85.4 (18.2)**	0.0	1.2 (1.1)	0.0	4.9 (3.2)
total	878.3 (194.4)	2510.7 (326.7)*	1866.3 (577.4)	5267.1 (522.8)*	126.5 (41.2)	1373.2 (306.9)**	881.9 (250.5)	2115.8 (319.4)*

*significantly more abundant (95% CI) in 1991-92, than on a date from the same month in 1983.
**significantly more abundant (99% CI) in 1991-92, than on a date from the same month in 1983.

Figure 1.

Map of Lake Ontario Showing Approximate Location of Study Area (Olcott, NY).

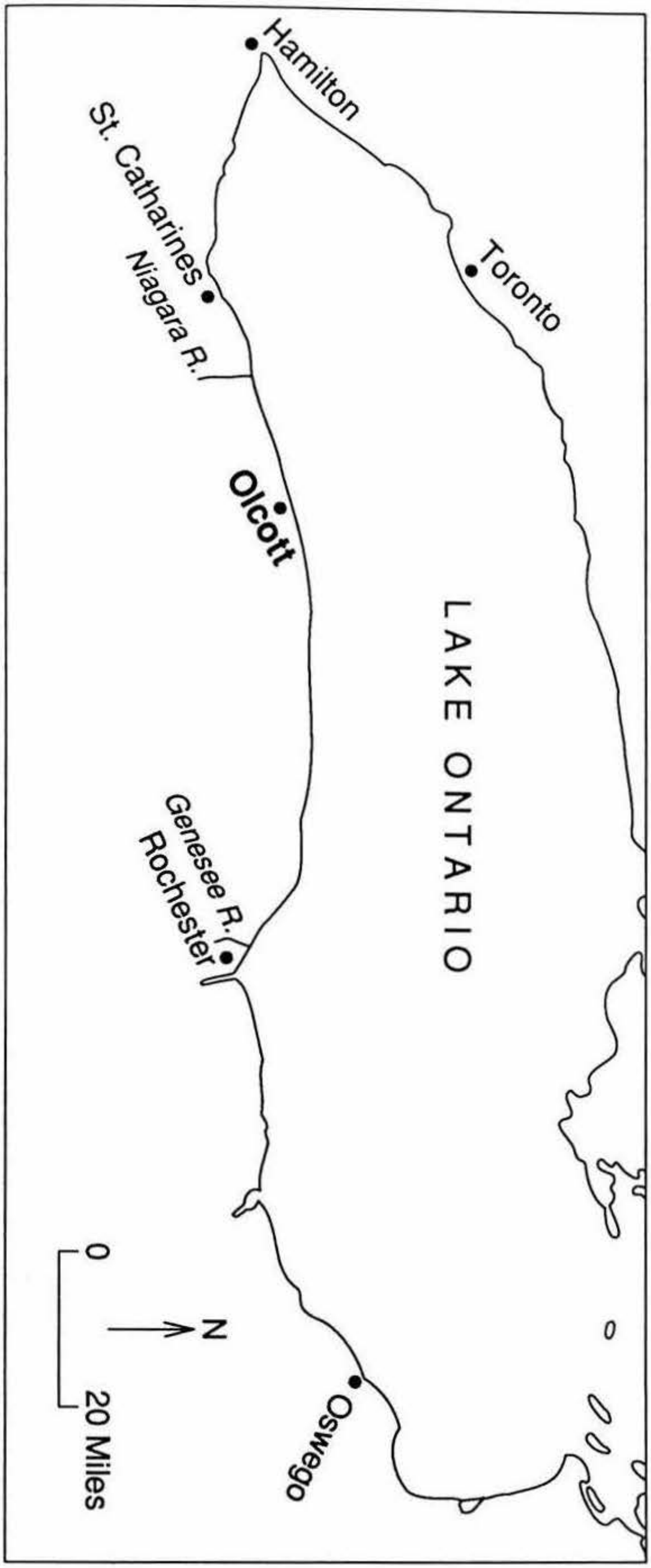

Hamilton
St. Catharines
Niagara R.
Toronto
Olcott
LAKE ONTARIO
Genesee R.
Rochester
Oswego
0
N
20 Miles

Figure 2.

Topographic Map of the Artificial Reef, Southwestern Lake Ontario, near Olcott, New York.

source: redrawn from Bader (1985) by N.J. Frisch, State University of New York College at Brockport.

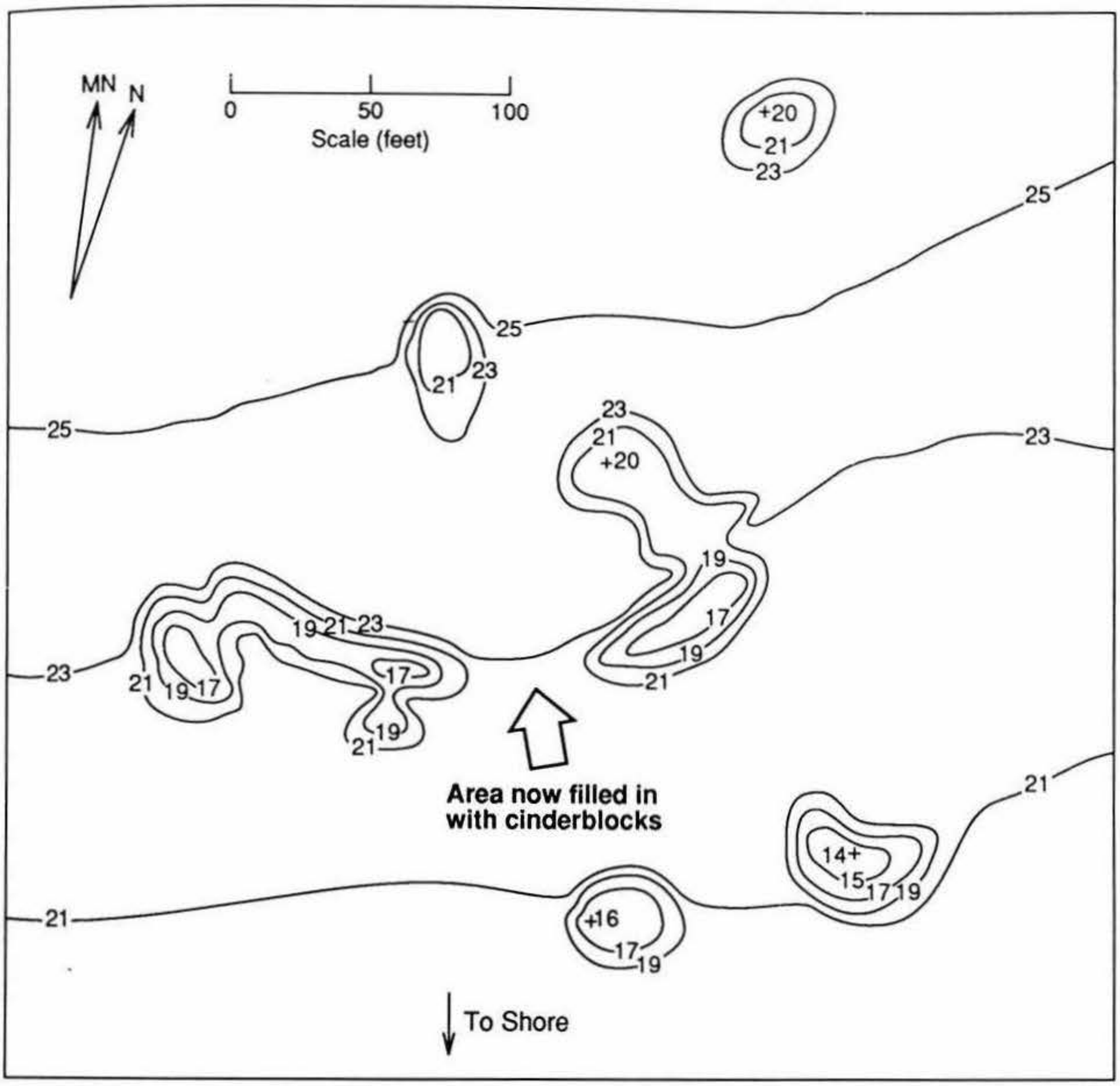

MN
N
0
50
100
Scale (feet)
+20
21
23
25
25
21
23
25
23
21
+20
23
19
17
19
21
19
21
23
23
21
19
17
17
21
19
Area now filled in with cinderblocks
21
14+
15
17
19
21
+16
17
19
To Shore

Figure 3.

Relative Abundance of Benthic Macroinvertebrate Taxa at the Cobble Site, 1983 and 1991-92.

Figure 3a. 1991-92 (zebra mussels included).
Figure 3b. 1991-92 (zebra mussels not included).
Figure 3c. 1983.

Taxa whose populations comprised at least 1.0% of all macroinvertebrates recovered during a year's sampling are included.

Figure 3a.

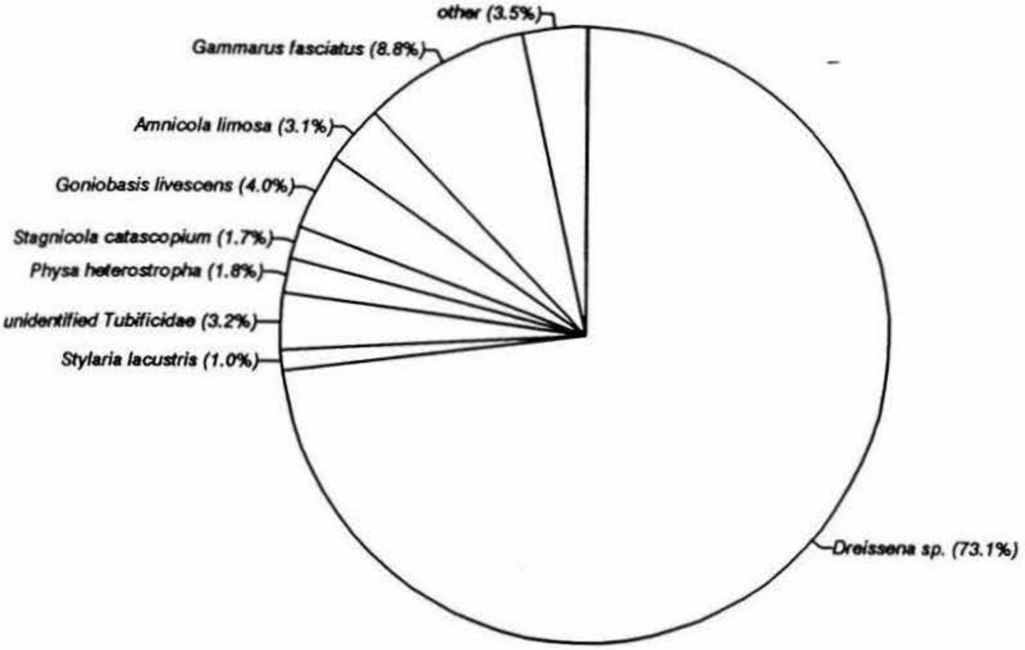

other (3.5%)
Gammarus fasciatus (8.8%)
Amnicola limosa (3.1%)
Goniobasis livescens (4.0%)
Stagnicola catascopium (1.7%)
Physa heterostropha (1.8%)
unidentified Tubificidae (3.2%)
Stylaria lacustris (1.0%)
Dreissena sp. (73.1%)

Figure 3b.

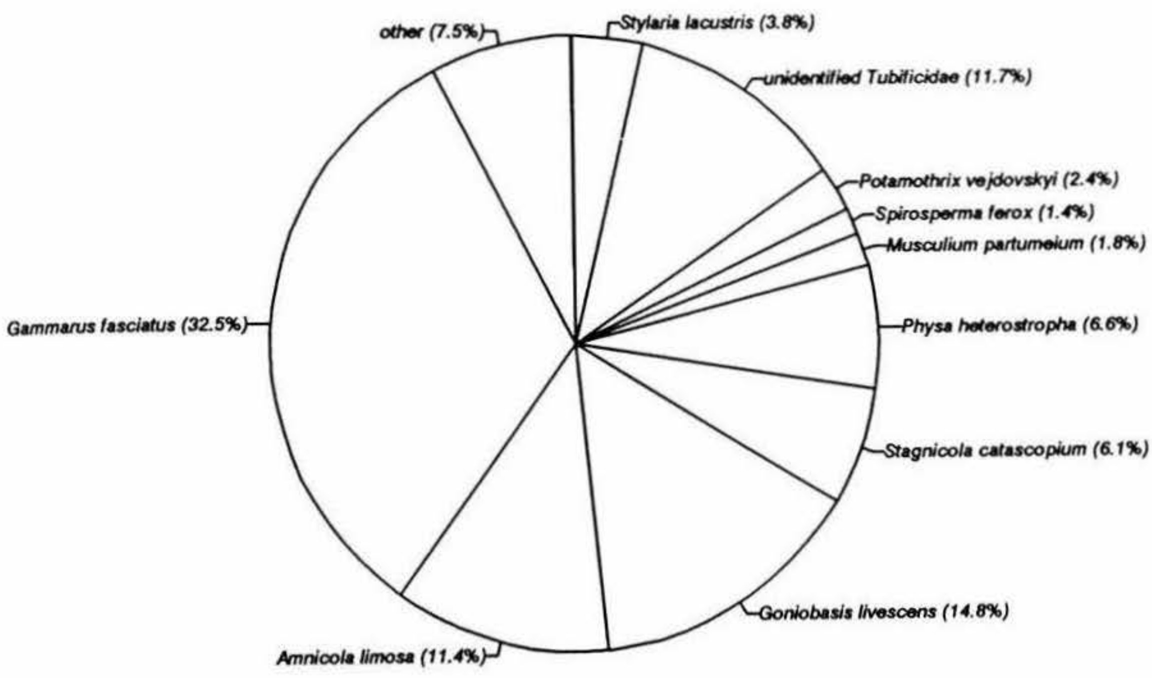

other (7.5%)
Stylaria lacustris (3.8%)
unidentified Tubificidae (11.7%)
Potamothrix vejdovskyi (2.4%)
Spirosperma ferox (1.4%)
Musculium partumeium (1.8%)
Physa heterostropha (6.6%)
Stagnicola catascopium (6.1%)
Goniobasis livescens (14.8%)
Amnicola limosa (11.4%)
Gammarus fasciatus (32.5%)

Figure 3c.

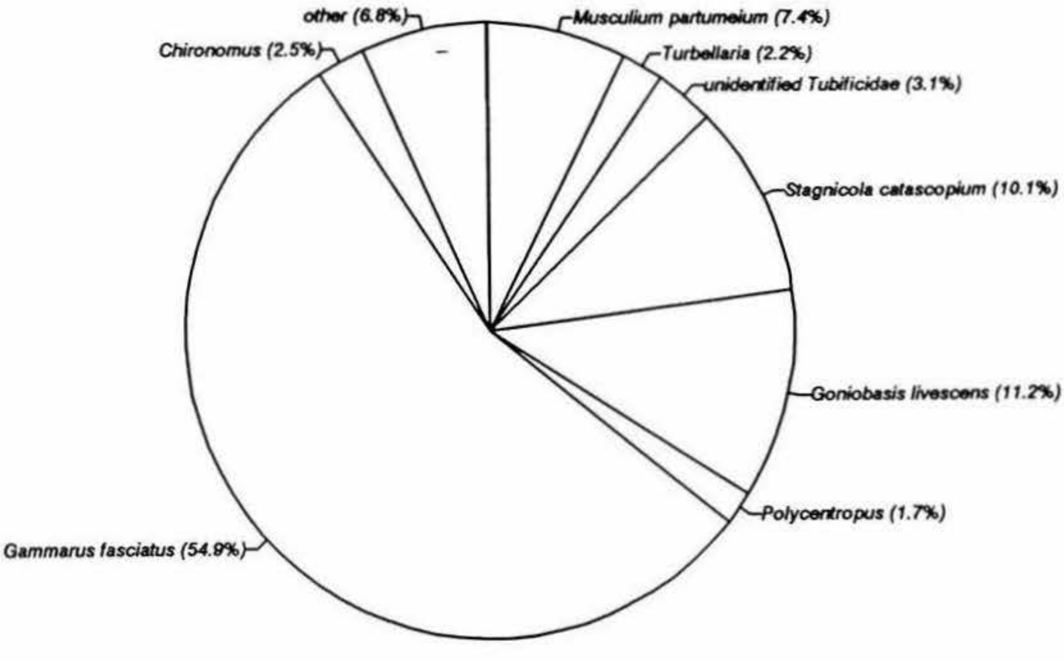

other (6.8%)
Chironomus (2.5%)
Musculium partumeium (7.4%)
Turbellaria (2.2%)
unidentified Tubificidae (3.1%)
Stagnicola catascopium (10.1%)
Goniobasis livescens (11.2%)
Polycentropus (1.7%)
Gammarus fasciatus (54.9%)

Figure 4.

Relative Abundance of Benthic Macroinvertebrate Taxa at the Artificial Reef Site, 1983 and 1991-92.

Figure 4a. 1991-92 (zebra mussels included).
Figure 4b. 1991-92 (zebra mussels not included).
Figure 4c. 1983.

Taxa whose populations comprised at least 1.0% of all macroinvertebrates recovered during a year's sampling are included.

Figure 4a.

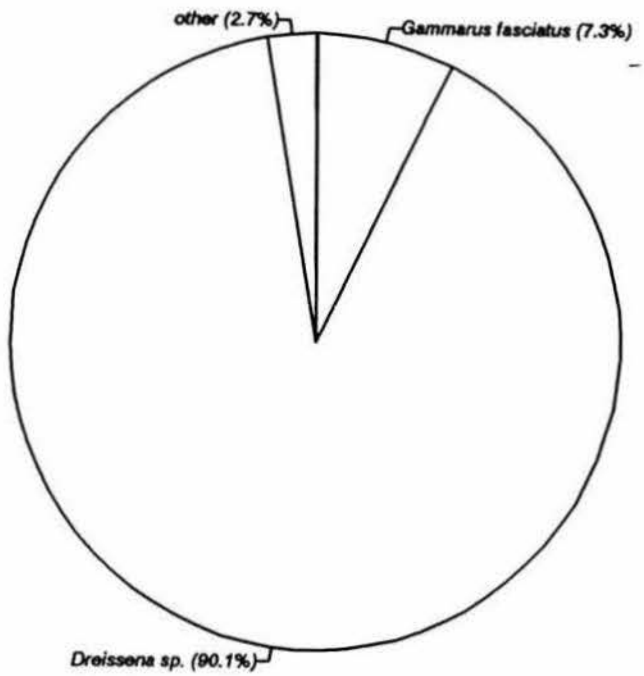
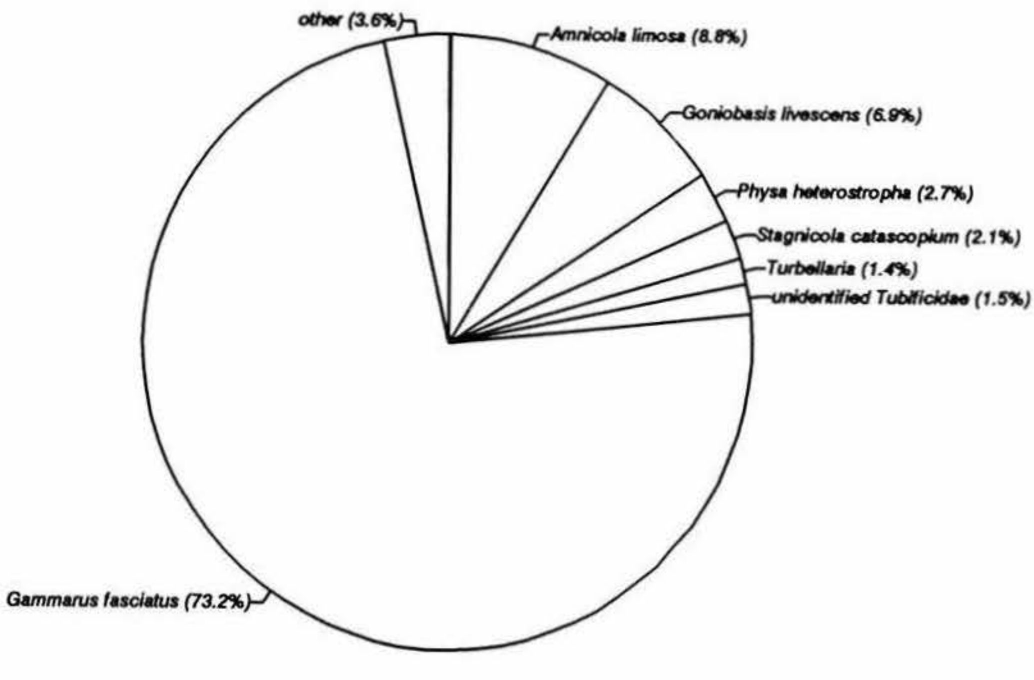
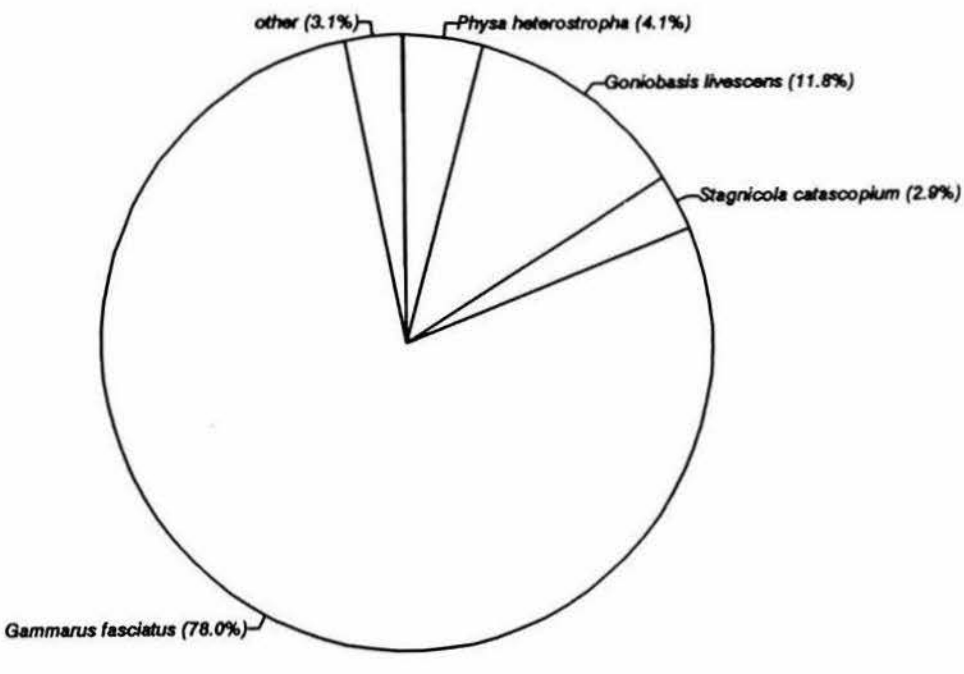


Figure 4b.



other (3.6%)
Amnicola limosa (8.8%)
Goniobasis livescens (6.9%)
Physa heterostropha (2.7%)
Stagnicola catascopium (2.1%)
Turbellaria (1.4%)
unidentified Tubificidae (1.5%)
Gammarus fasciatus (73.2%)

Figure 4c.



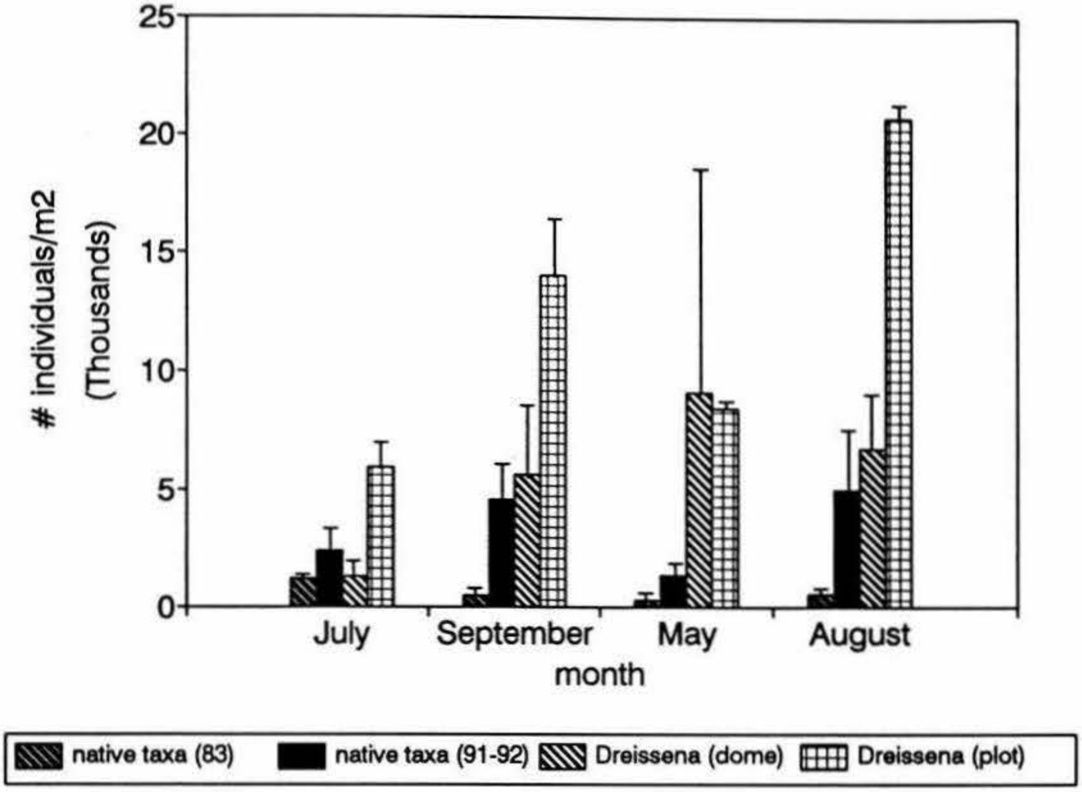
other (3.1%)
Physa heterostropha (4.1%)
Goniobasis livescens (11.8%)
Stagnicola catascopium (2.9%)
Gammarus fasciatus (78.0%)

Figure 5.

Monthly Abundance Estimates of Benthic Macroinvertebrates at the Cobble Site, 1983 and 1991-92.

error bars = $\pm (1.96 \times \frac{s}{\sqrt{n}})$.

Figure 5.



25
20
15
10
5
0
individuals/m2
(Thousands)
July
September
May
August
month
native taxa (83)
native taxa (91-92)
Dreissena (dome)
Dreissena (plot)

Figure 6.

Monthly Abundance Estimates of Benthic Macroinvertebrates at the Artificial Reef Site, 1983 and 1991-92.

error bars = $\pm (1.96 \times \frac{s}{\sqrt{n}})$.

Figure 6.

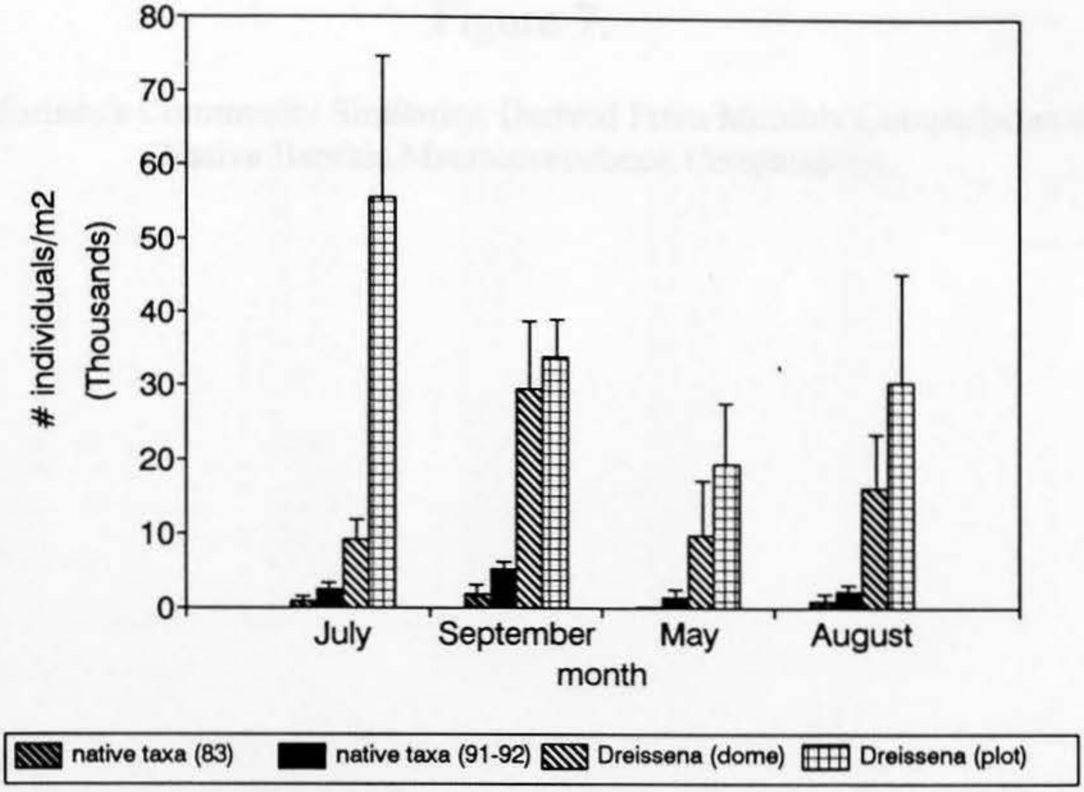
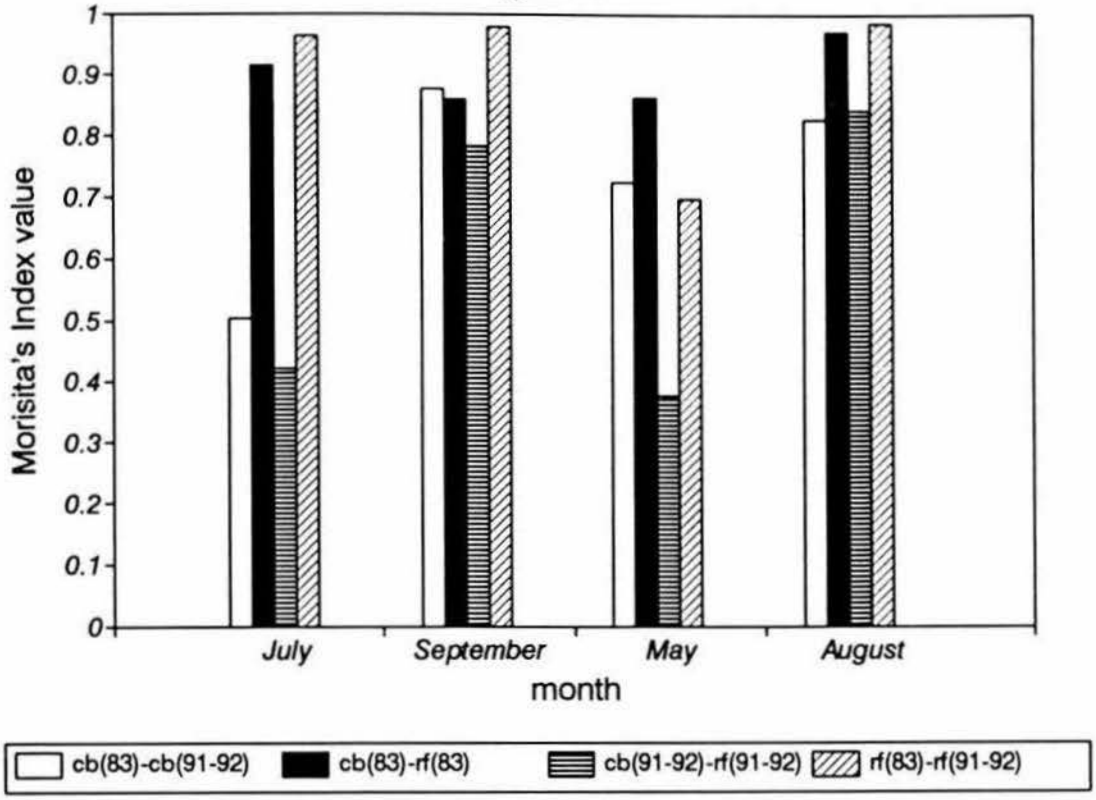

80
70
60
50
40
30
20
10
0
individuals/m2
(Thousands)
July
September
May
August
month
native taxa (83)
native taxa (91-92)
Dreissena (dome)
Dreissena (plot)

Figure 7.

Morisita's Community Similarity, Derived From Monthly Comparisons of Native Benthic Macroinvertebrate Communities.

Figure 7.

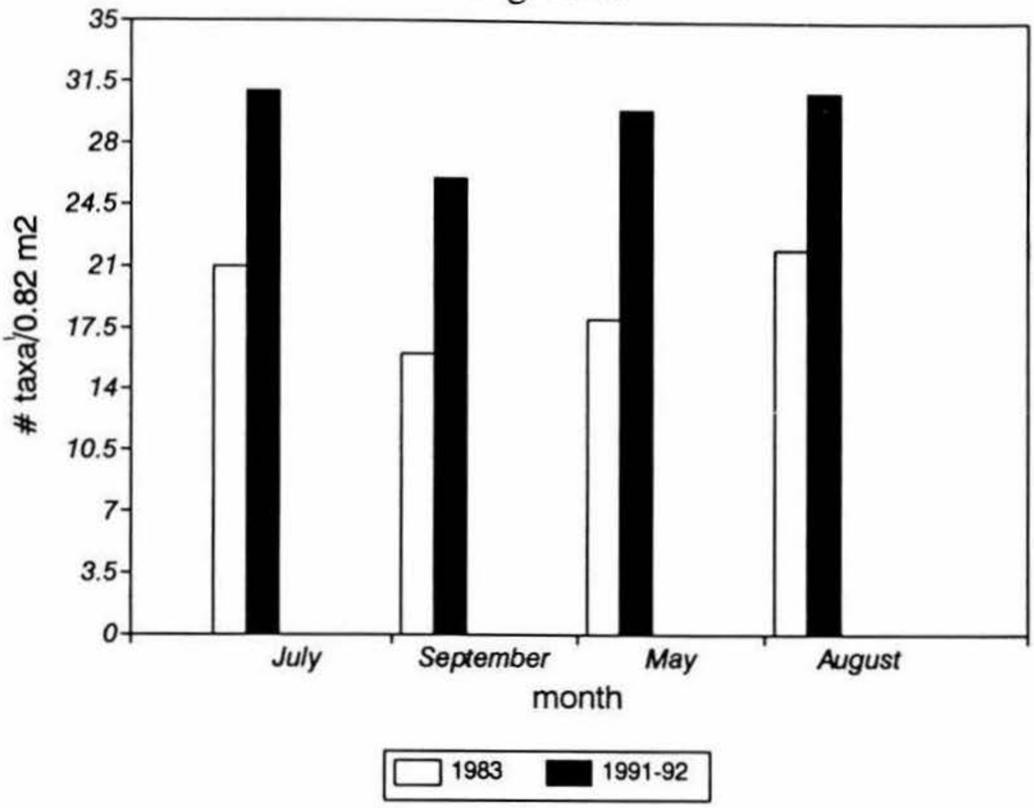


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Morisita's Index value
July
September
May
August
month
cb(83)-cb(91-92)
cb(83)-rf(83)
cb(91-92)-rf(91-92)
rf(83)-rf(91-92)

Figure 8.

Native Benthic Macroinvertebrate Species Richness at the Cobble Site, by Month, 1983 and 1991-92.

Figure 8.



35
31.5
28
24.5
21
17.5
14
10.5
7
3.5
0
taxa/0.82 m2
July
September
May
August
month
1983
1991-92

Figure 9.

Native Benthic Macroinvertebrate Species Richness at the Artificial Reef Site, by Month, 1983 and 1991-92.

*# taxa/0.82 m^2 on all sampling dates with exception of July 12, 1991 (# taxa/0.66 m^2).

Figure 9.

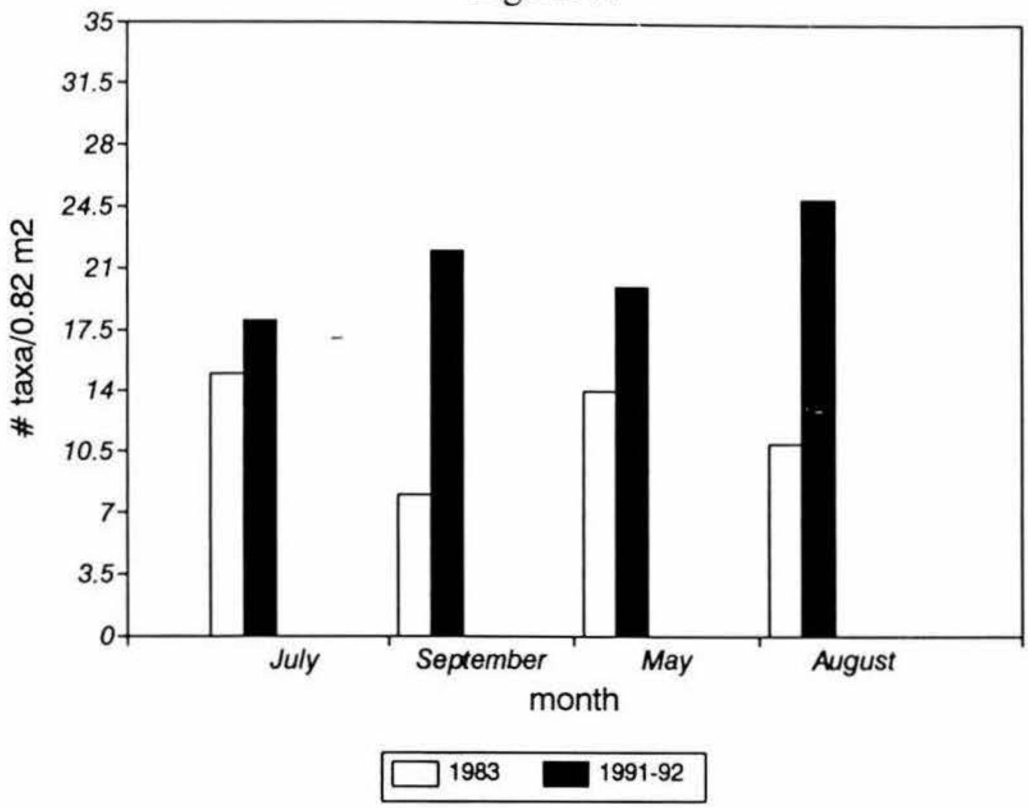

35
31.5
28
24.5
21
17.5
14
10.5
7
3.5
0
taxa/0.82 m2
July
September
May
August
month
1983
1991-92

Figure 10.

Simpson's Diversity of Native Benthic Macroinvertebrates at the Cobble Site, by Month, 1983 and 1991-92.

Figure 10.

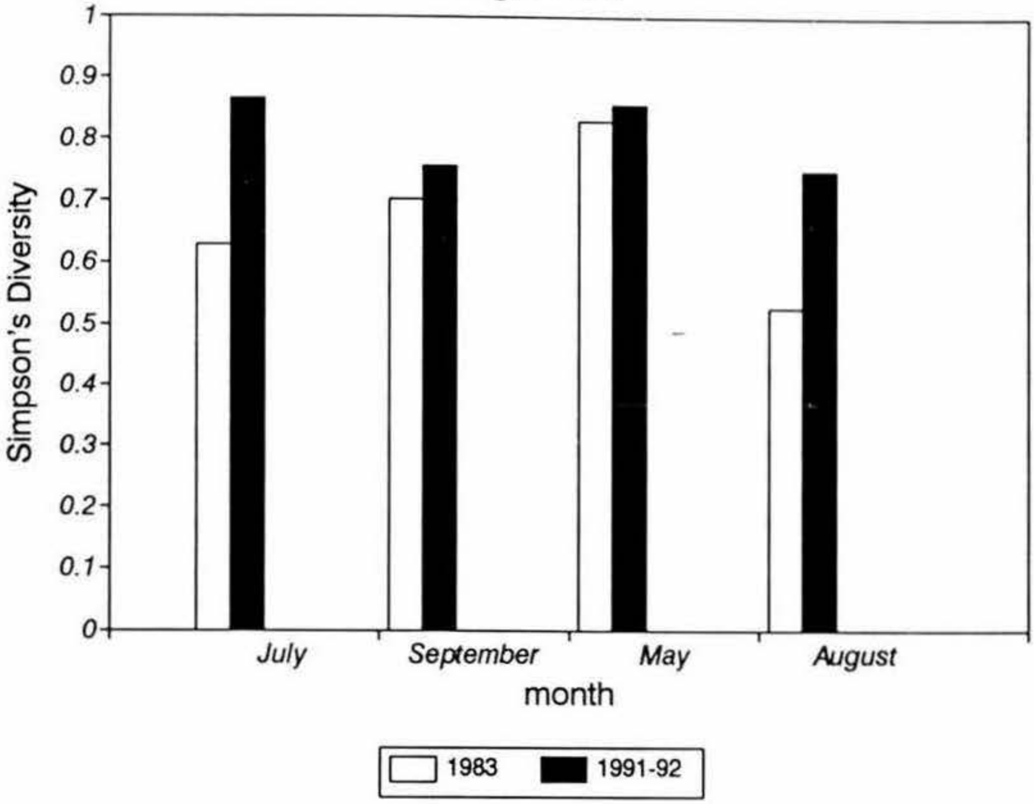
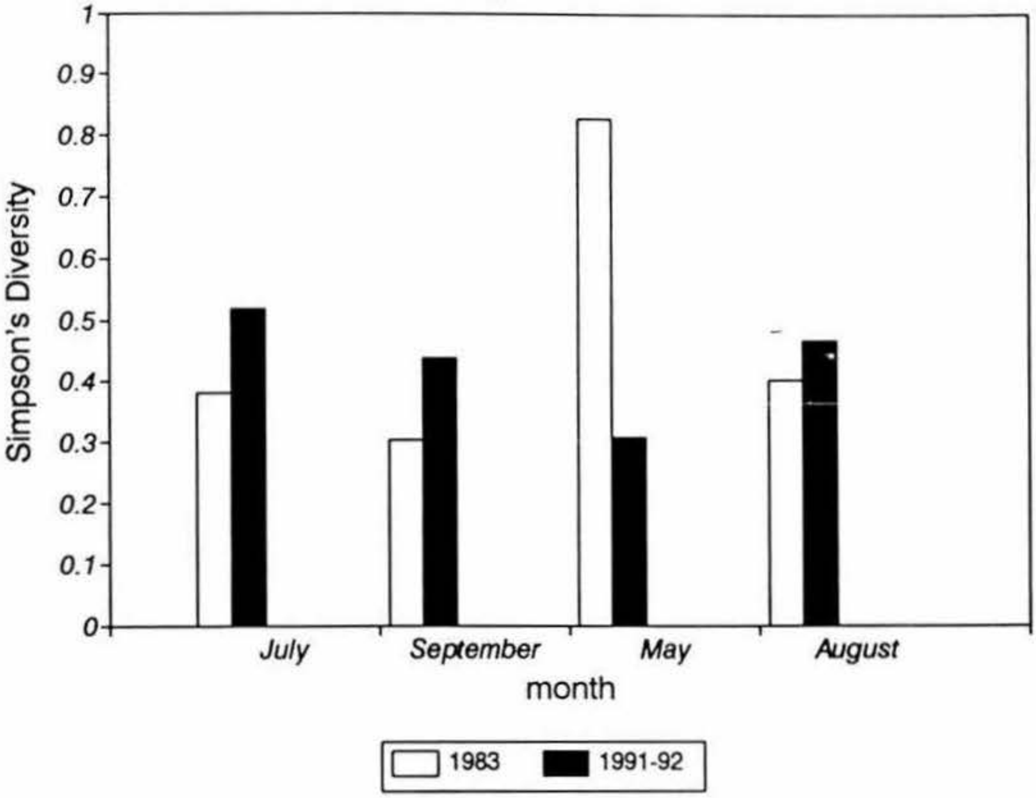

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Simpson's Diversity
July
September
May
August
month
1983
1991-92

Figure 11.

Simpson's Diversity of Native Benthic Macroinvertebrates at the Artificial Reef Site, by Month, 1983 and 1991-92.

Figure 11.



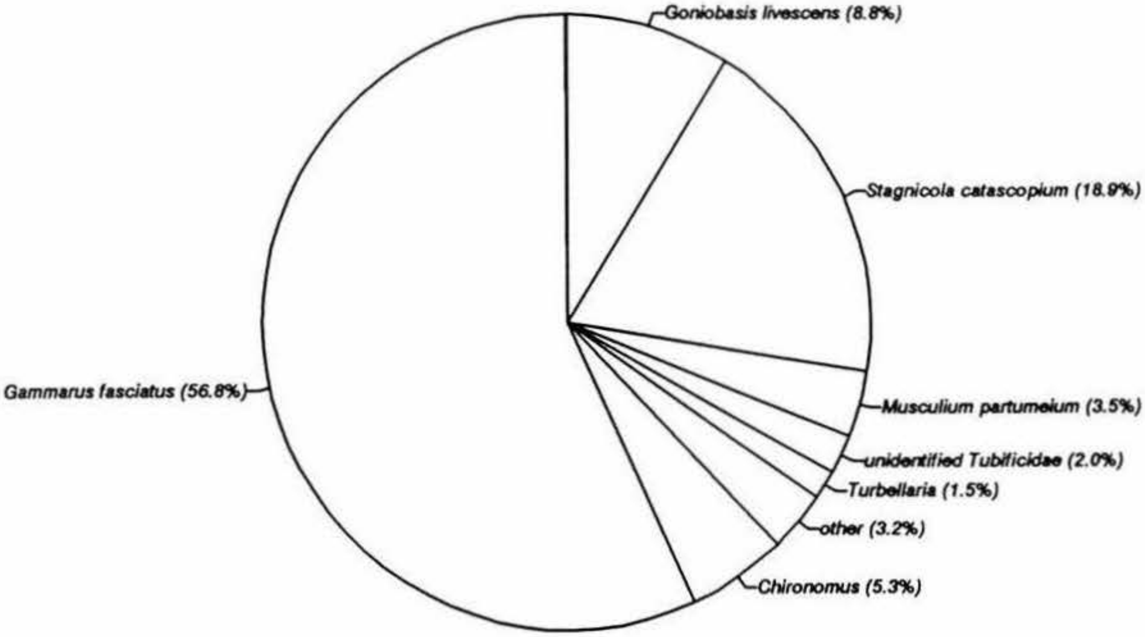
Simpson's Diversity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
July
September
May
August
month
1983
1991-92

Appendix 1.

Relative Abundance Estimates of Native Benthic Macroinvertebrate Taxa at the Cobble Site, by Sampling Date, 1983 and 1991-92.

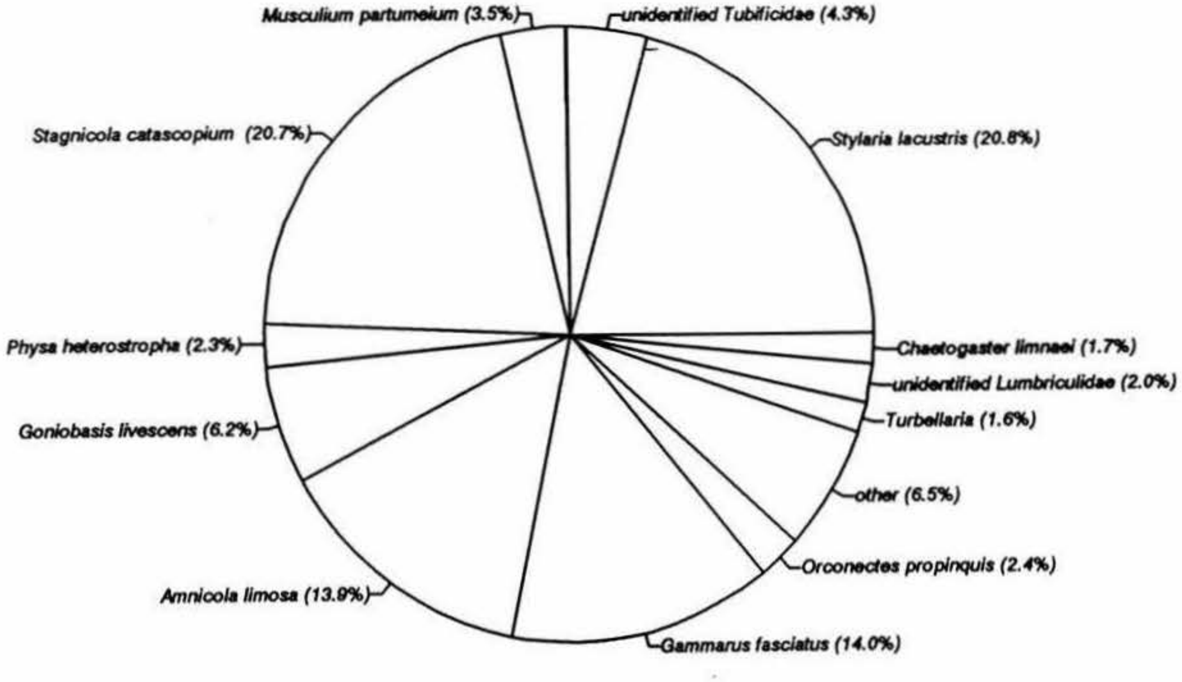
Taxa comprising at least 1.0% of the total benthic macroinvertebrate population on a particular sampling date are included.

Appendix 1a.



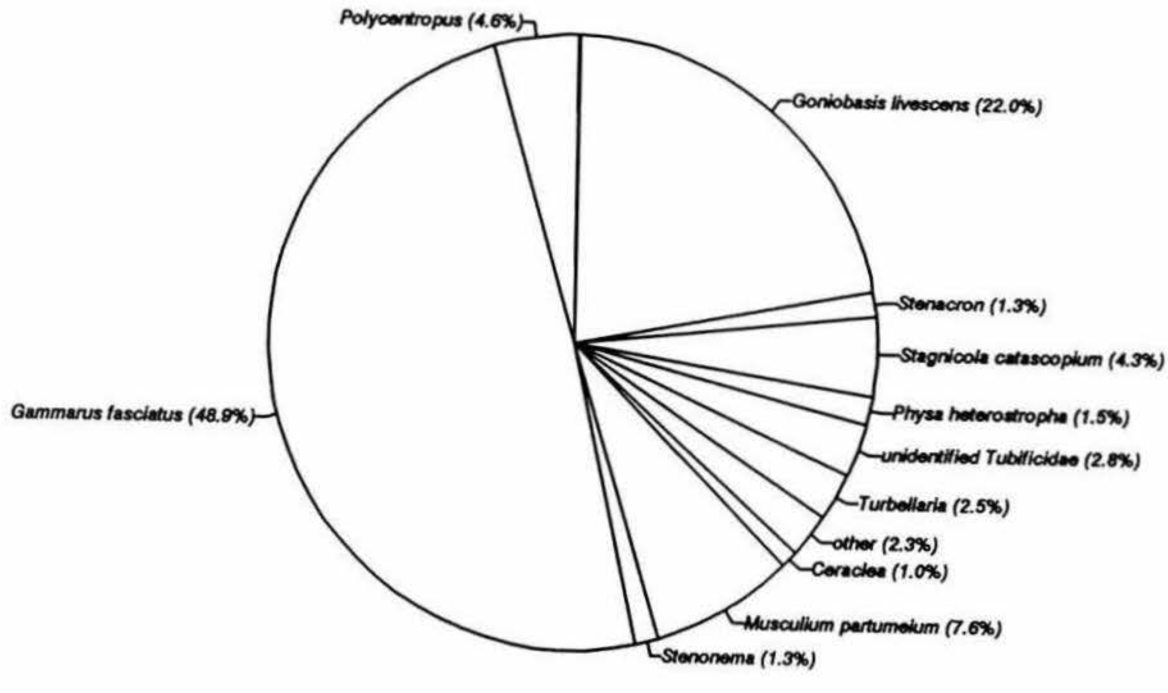
Goniobasis livescens (8.8%)
Stagnicola catascopium (18.9%)
Gammarus fasciatus (56.8%)
Musculium partumeium (3.5%)
unidentified Tubificidae (2.0%)
Turbellaria (1.5%)
other (3.2%)
Chironomus (5.3%)

Appendix 1b.



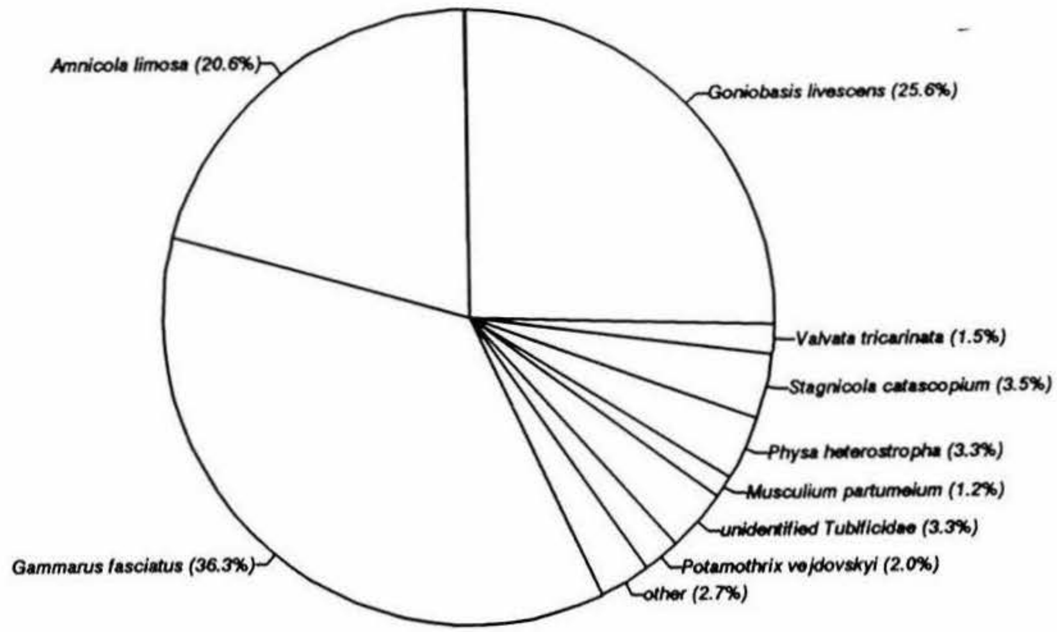
Musculium partumeium (3.5%)
unidentified Tubificidae (4.3%)
Stagnicola catascopium (20.7%)
Stylaria lacustris (20.8%)
Physa heterostropha (2.3%)
Chaetogaster limnaei (1.7%)
unidentified Lumbriculidae (2.0%)
Goniobasis livescens (6.2%)
Turbellaria (1.6%)
other (6.5%)
Orconectes propinquis (2.4%)
Amnicola limosa (13.9%)
Gammarus fasciatus (14.0%)

Appendix 1c.

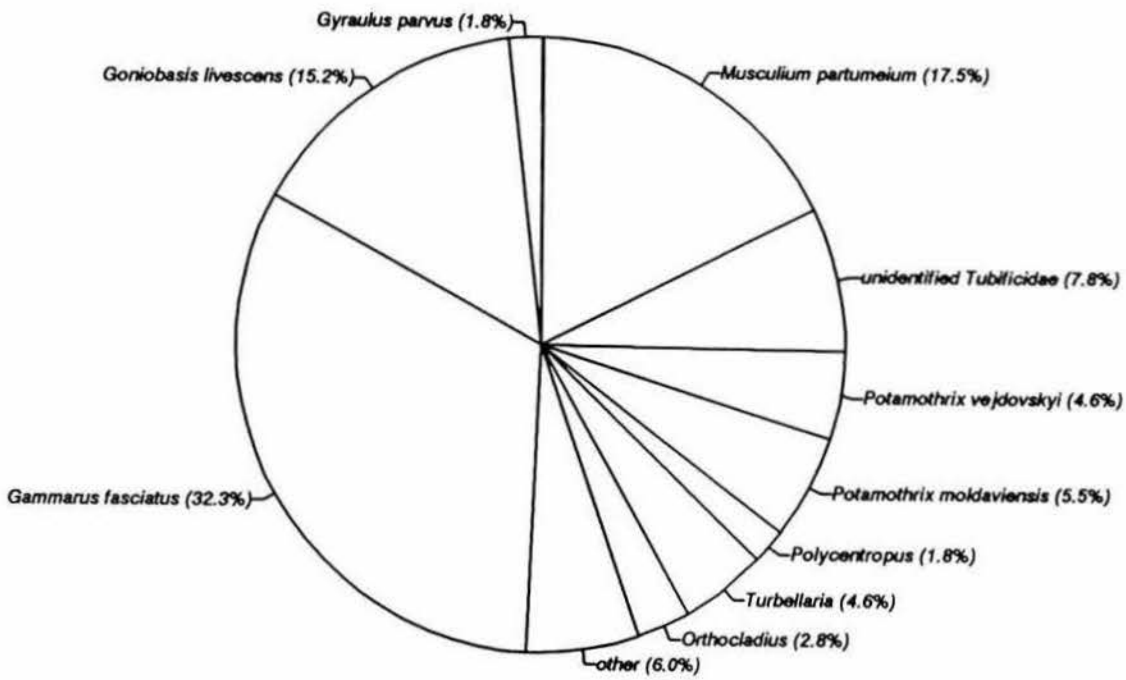


Polycentropus (4.6%)
Goniobasis livescens (22.0%)
Stenacron (1.3%)
Stagnicola catascopium (4.3%)
Physa heterostropha (1.5%)
unidentified Tubificidae (2.8%)
Turbellaria (2.5%)
other (2.3%)
Ceraclea (1.0%)
Musculium partumeium (7.6%)
Stenonema (1.3%)
Gammarus fasciatus (48.9%)

Appendix 1d.

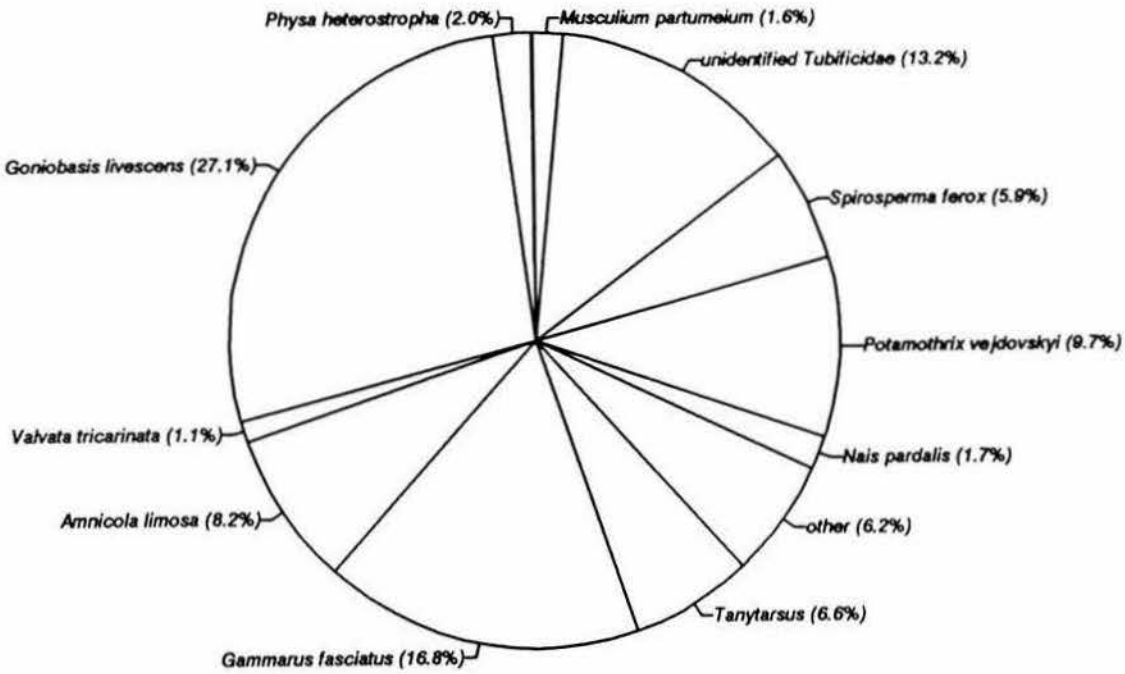

Amnicola limosa (20.6%)
Goniobasis livescens (25.6%)
Valvata tricarinata (1.5%)
Stagnicola catascopium (3.5%)
Physa heterostropha (3.3%)
Musculium partumeium (1.2%)
unidentified Tubificidae (3.3%)
Potamothrix vejdovskyi (2.0%)
other (2.7%)
Gammarus fasciatus (36.3%)

Appendix 1e.

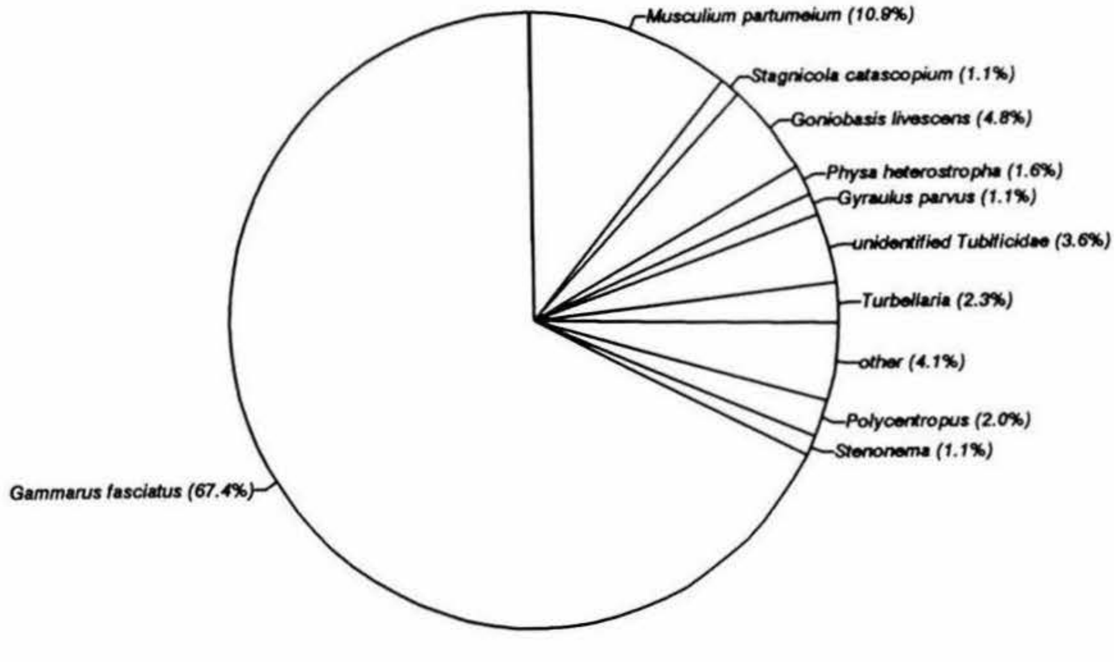


Gyraulus parvus (1.8%)
Goniobasis livescens (15.2%)
Musculium partumeium (17.5%)
unidentified Tubificidae (7.8%)
Potamothrix vejdovskyi (4.6%)
Potamothrix moldaviensis (5.5%)
Polycentropus (1.8%)
Turbellaria (4.6%)
Orthocladius (2.8%)
other (6.0%)
Gammarus fasciatus (32.3%)

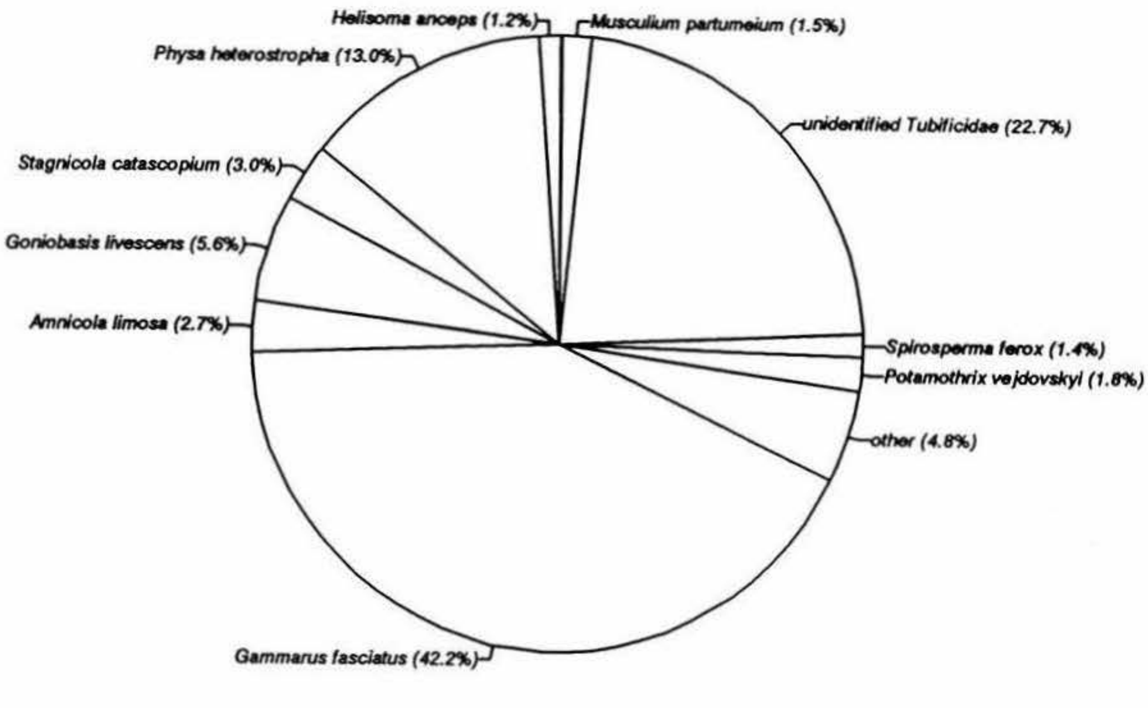
Appendix 1f.


Physa heterostropha (2.0%)
Musculium partumeium (1.6%)
unidentified Tubificidae (13.2%)
Goniobasis livescens (27.1%)
Spirosperma ferox (5.9%)
Potamothrix vejdovskyi (9.7%)
Valvata tricarinata (1.1%)
Nais pardalis (1.7%)
Amnicola limosa (8.2%)
other (6.2%)
Tanytarsus (6.6%)
Gammarus fasciatus (16.8%)

Appendix 1g.


Musculium partumeium (10.9%)
Stagnicola catascopium (1.1%)
Goniobasis livescens (4.8%)
Physa heterostropha (1.6%)
Gyraulus parvus (1.1%)
unidentified Tubificidae (3.6%)
Turbellaria (2.3%)
other (4.1%)
Polycentropus (2.0%)
Stenonema (1.1%)
Gammarus fasciatus (67.4%)

Appendix 1h.



Helisoma anceps (1.2%)
Musculium partumeium (1.5%)
Physa heterostropha (13.0%)
unidentified Tubificidae (22.7%)
Stagnicola catascopium (3.0%)
Goniobasis livescens (5.6%)
Amnicola limosa (2.7%)
Spirosperma ferox (1.4%)
Potamothrix vejdovskyi (1.8%)
other (4.8%)
Gammarus fasciatus (42.2%)

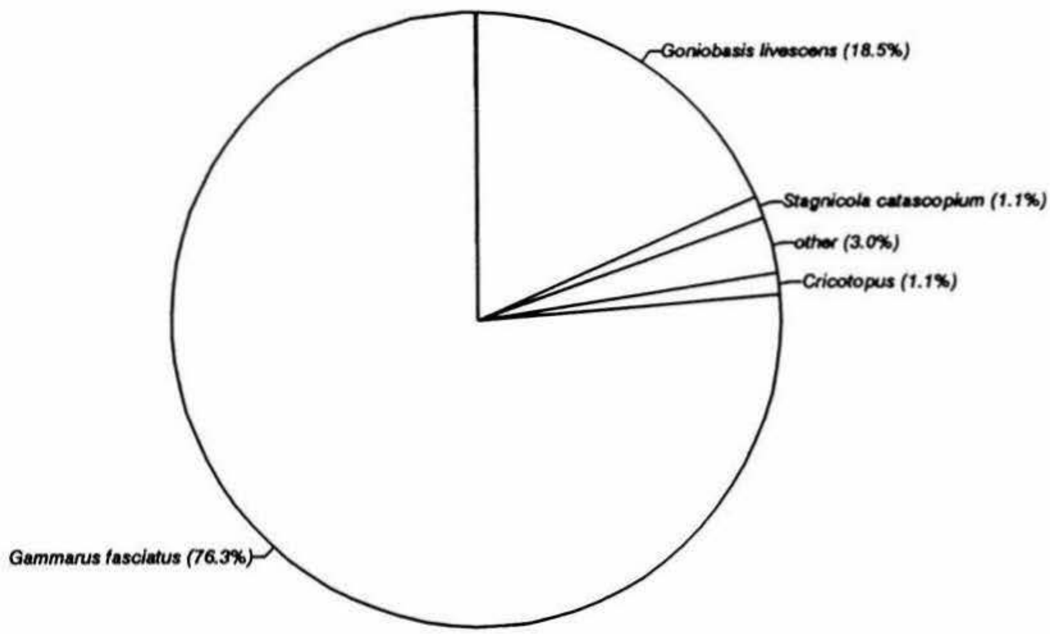
Appendix 2.

Relative Abundance Estimates of Native Benthic Macroinvertebrate Taxa at the Artificial Reef Site, by Sampling Date, 1983 and 1991-92.

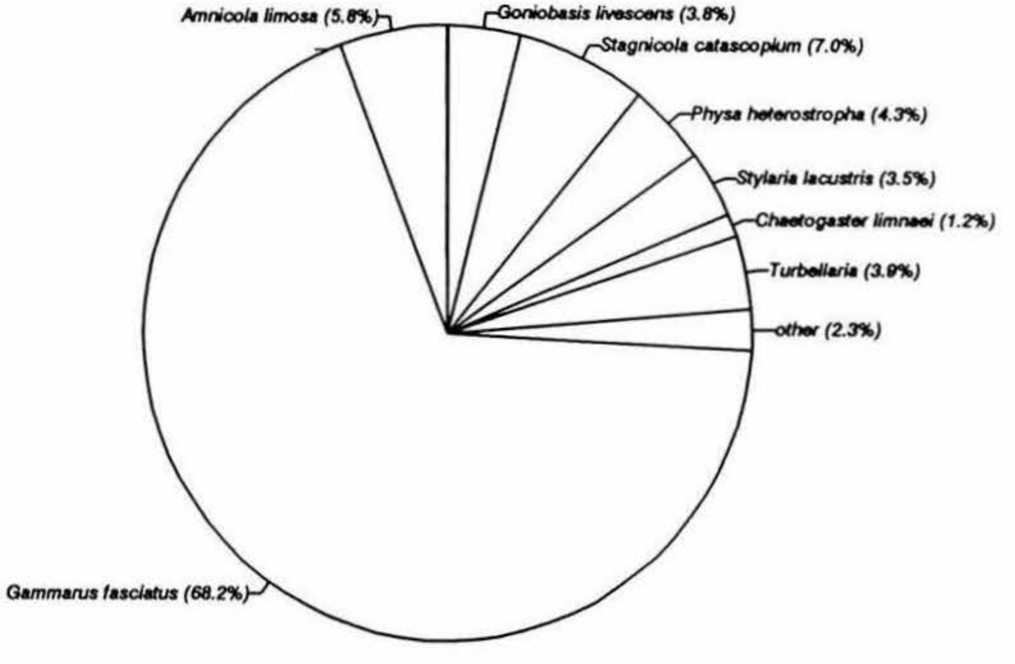
Appendix 2a. July 12, 1983.
Appendix 2b. July 12, 1991.
Appendix 2c. September 10, 1983.
Appendix 2d. September 21, 1991.
Appendix 2e. May 11, 1983.
Appendix 2f. May 15, 1992.
Appendix 2g. August 31, 1983.
Appendix 2h. August 20, 1992.

Taxa comprising at least 1.0% of the total benthic macroinvertebrate population on a particular sampling date are included.

Appendix 2a.

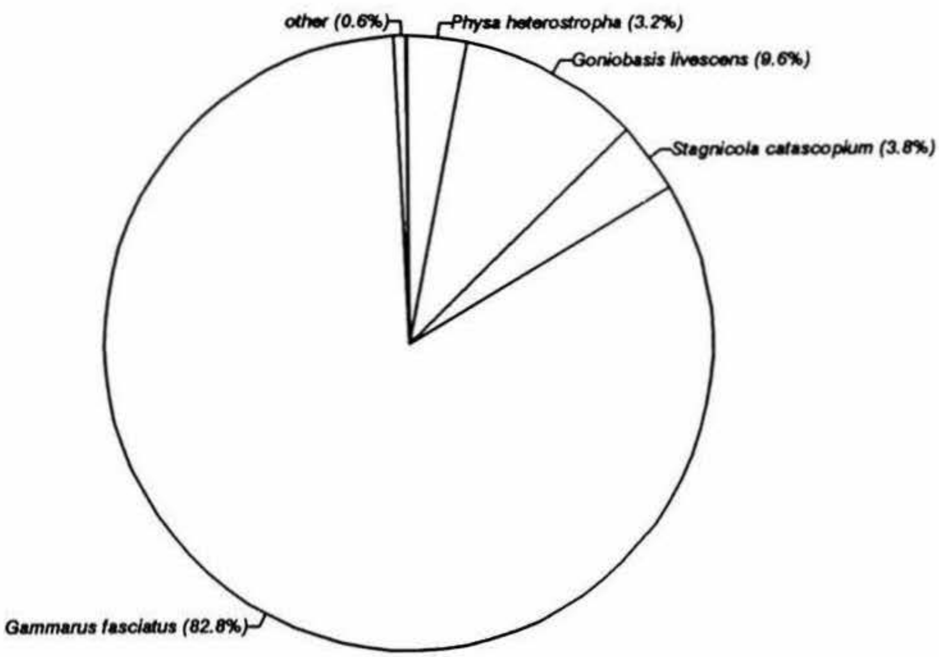

Goniobasis livescens (18.5%)
Stagnicola catascopium (1.1%)
other (3.0%)
Cricotopus (1.1%)
Gammarus fasciatus (76.3%)

Appendix 2b.



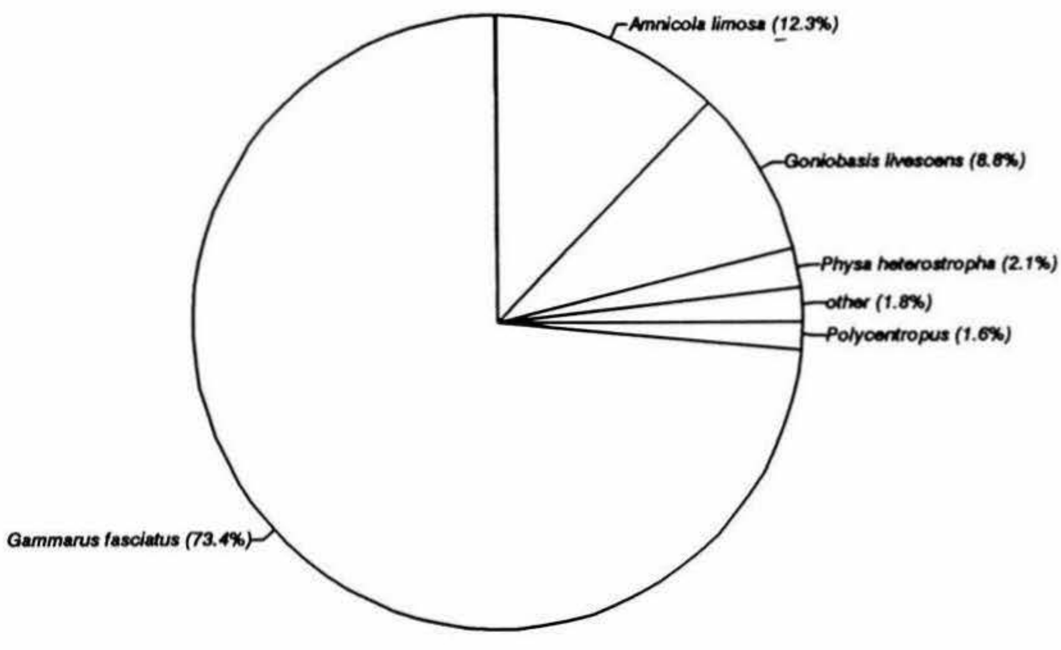
Amnicola limosa (5.8%)
Goniobasis livescens (3.8%)
Stagnicola catascopium (7.0%)
Physa heterostropha (4.3%)
Stylaria lacustris (3.5%)
Chaetogaster limnaei (1.2%)
Turbellaria (3.9%)
other (2.3%)
Gammarus fasciatus (68.2%)

Appendix 2c.

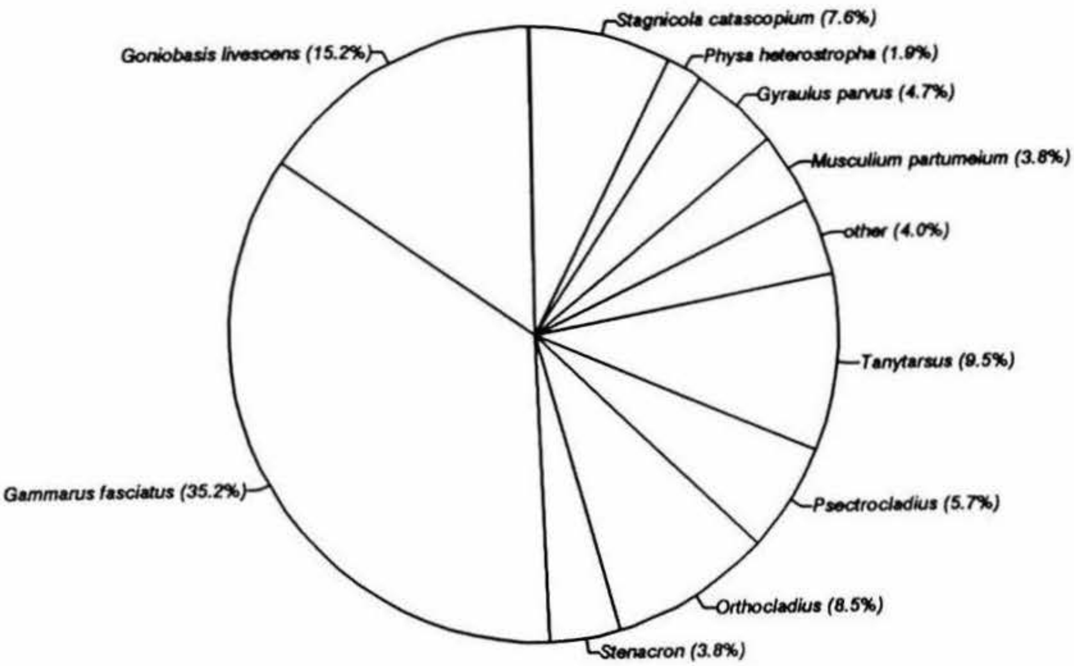


other (0.6%)
Physa heterostropha (3.2%)
Goniobasis livescens (9.6%)
Stagnicola catascopium (3.8%)
Gammarus fasciatus (82.8%)

Appendix 2d.

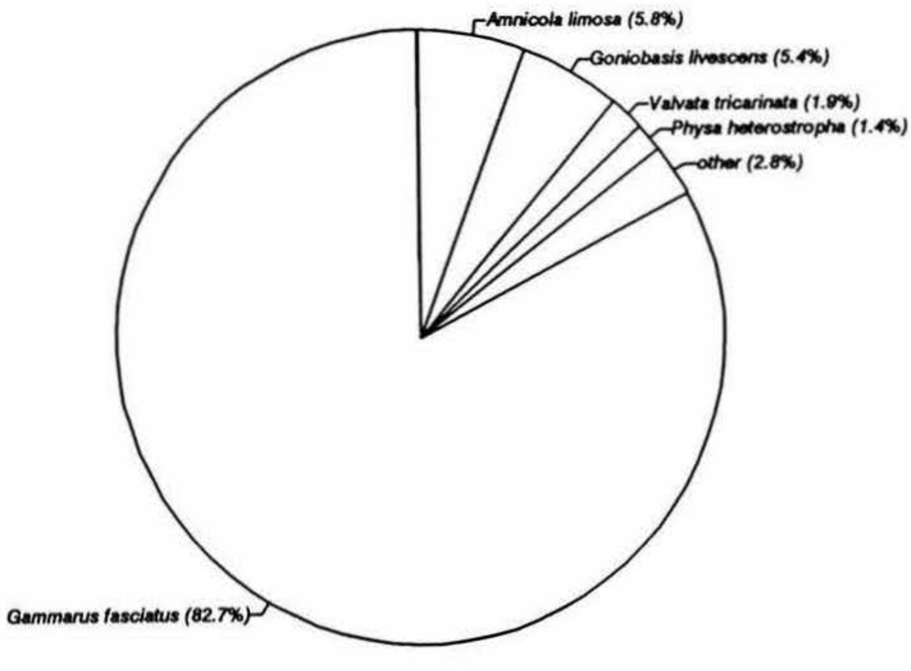

Amnicola limosa (12.3%)
Goniobasis livescens (8.8%)
Physa heterostropha (2.1%)
other (1.8%)
Polycentropus (1.6%)
Gammarus fasciatus (73.4%)

Appendix 2e.

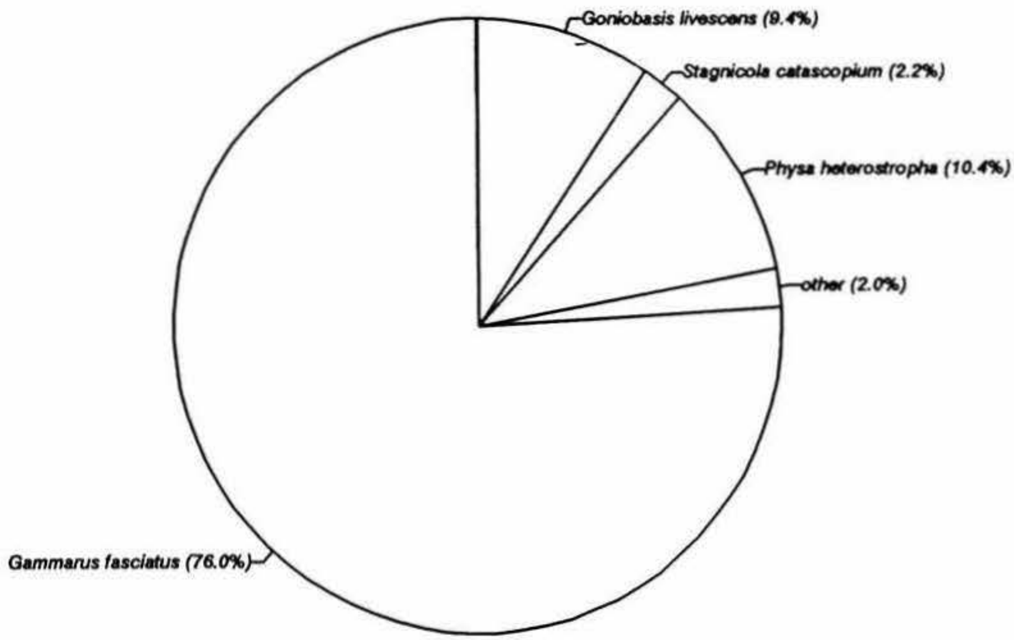


Stagnicola catascopium (7.6%)
Physa heterostropha (1.9%)
Gyraulus parvus (4.7%)
Musculium partumeium (3.8%)
other (4.0%)
Tanytarsus (9.5%)
Psectrocladius (5.7%)
Orthocladius (8.5%)
Stenacron (3.8%)
Gammarus fasciatus (35.2%)
Goniobasis livescens (15.2%)

Appendix 2f.

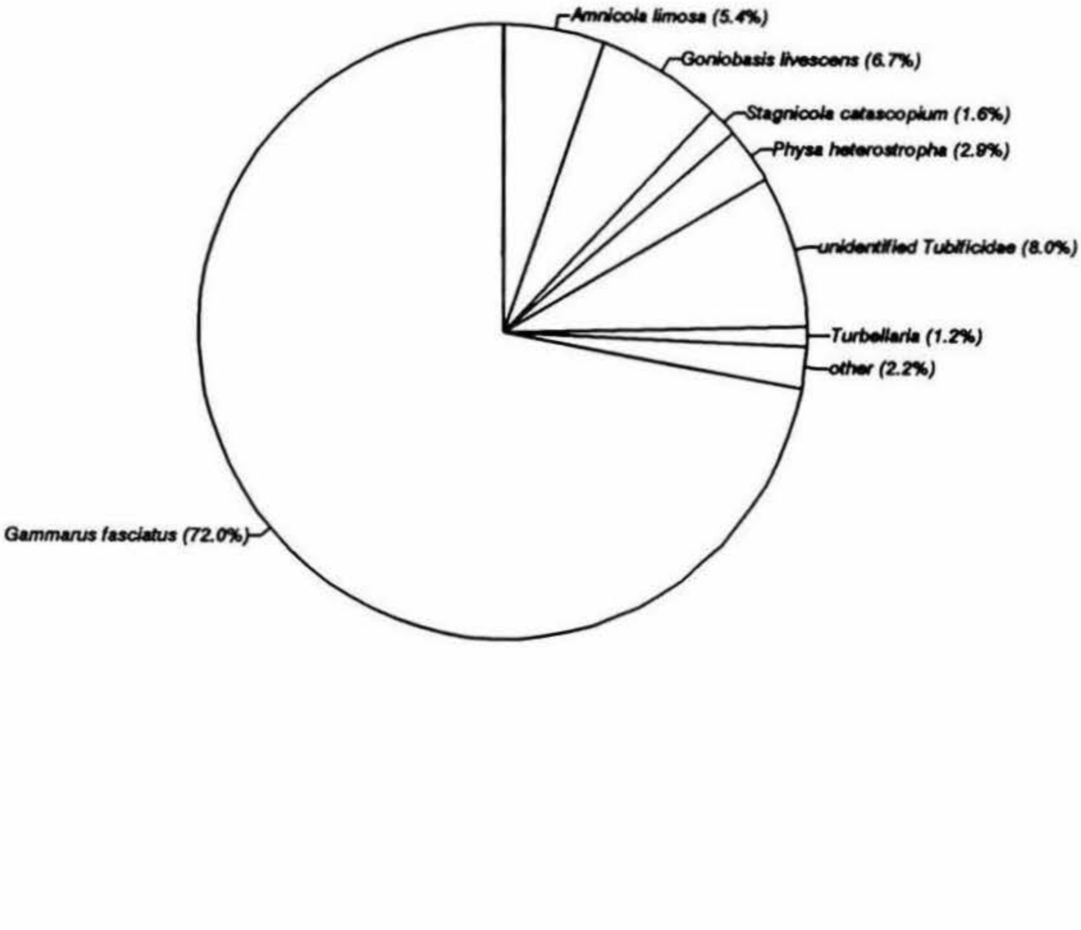

Amnicola limosa (5.8%)
Goniobasis livescens (5.4%)
Valvata tricarinata (1.9%)
Physa heterostropha (1.4%)
other (2.8%)
Gammarus fasciatus (82.7%)

Appendix 2g.



Goniobasis livescens (9.4%)
Stagnicola catascopium (2.2%)
Physa heterostropha (10.4%)
other (2.0%)
Gammarus fasciatus (76.0%)

Appendix 2h.



Amnicola limosa (5.4%)
Goniobasis livescens (6.7%)
Stagnicola catascopium (1.6%)
Physa heterostropha (2.9%)
unidentified Tubificidae (8.0%)
Turbellaria (1.2%)
other (2.2%)
Gammarus fasciatus (72.0%)

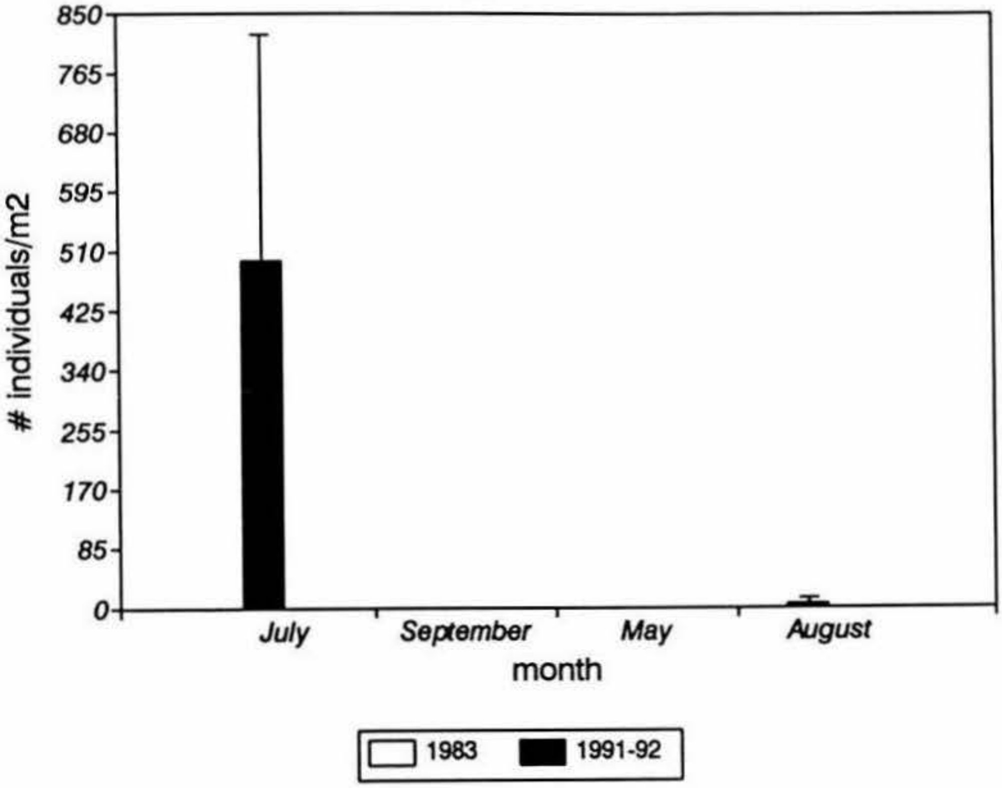
Appendix 3.

Changes in Abundance of Selected Native Benthic Macroinvertebrate Taxa at the Cobble Site, by Month, 1983 and 1991-92.

Taxa whose populations comprised at least 5.0% of the total native macroinvertebrate population on one or more sampling dates are included.

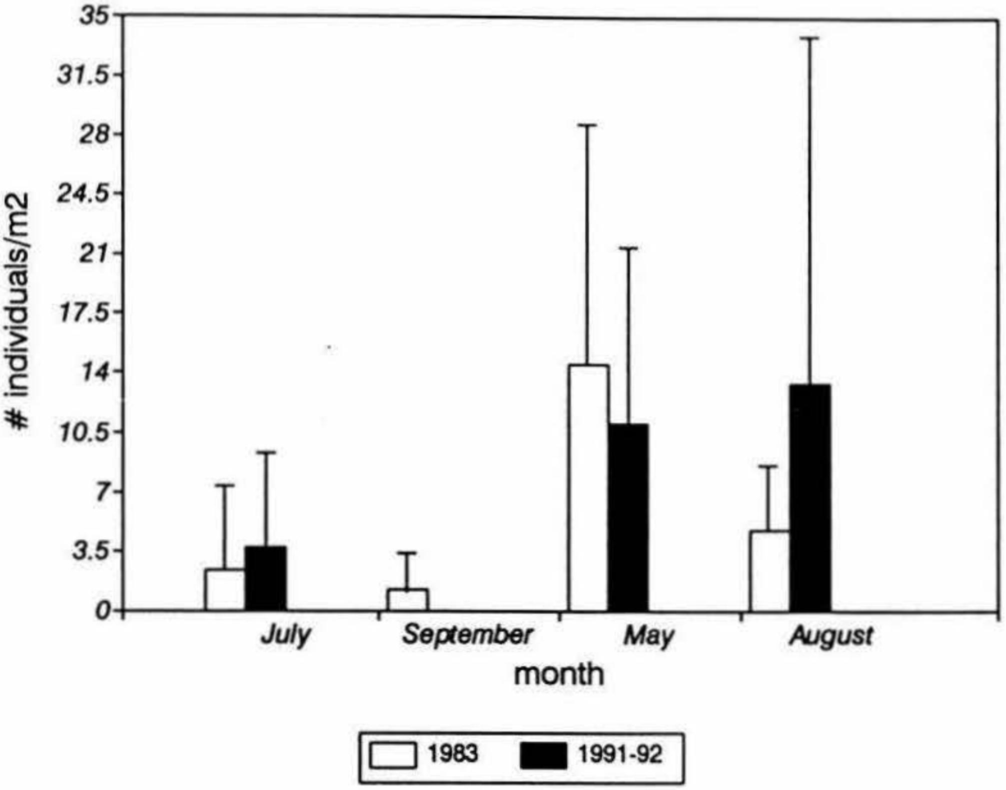
error bars = $\pm\ (1.96 \times \frac{s}{\sqrt{n}})$.

Appendix 3a.

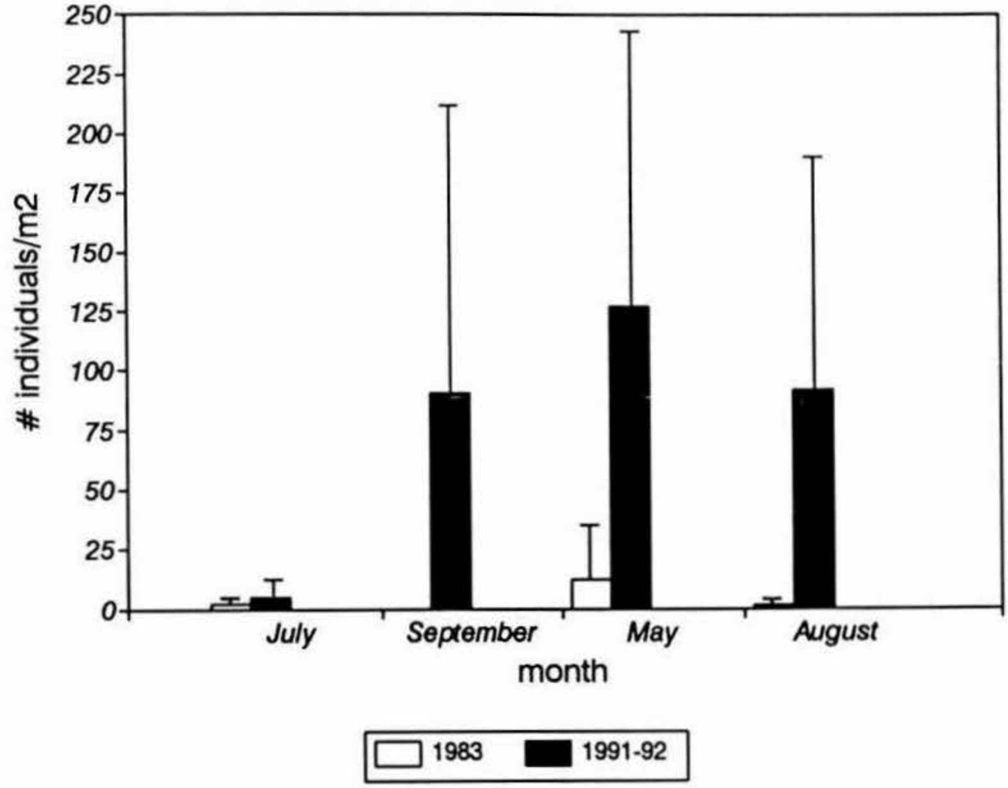


850
765
680
595
510
425
340
255
170
85
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3b.

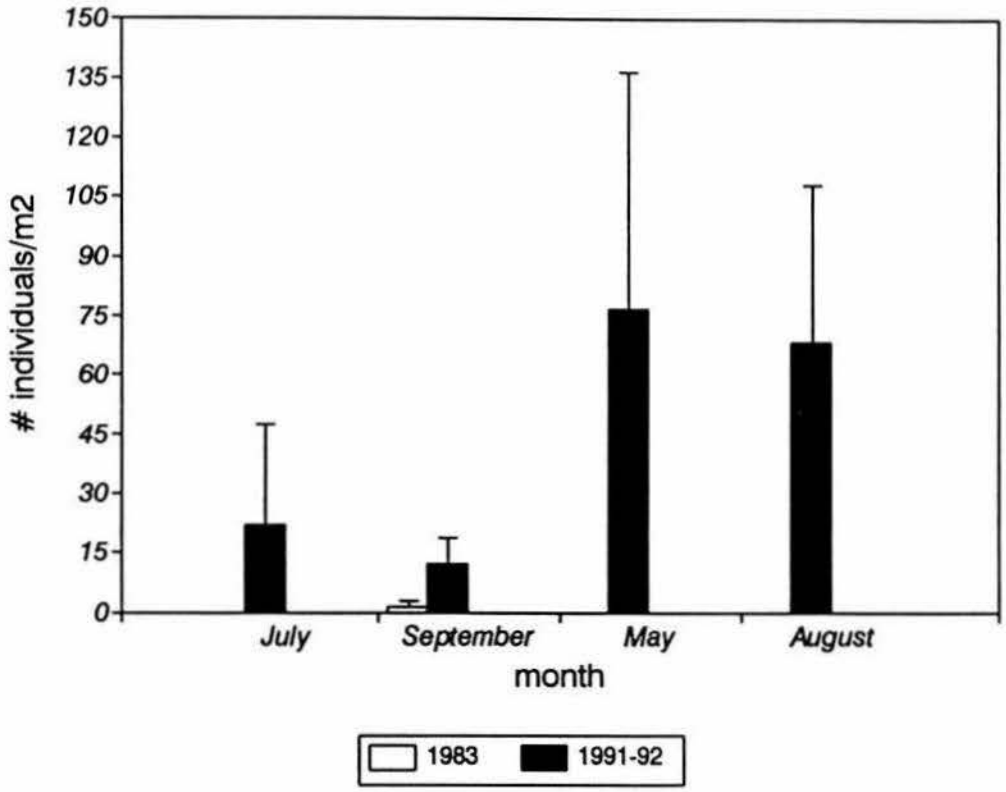

35
31.5
28
24.5
21
17.5
14
10.5
7
3.5
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3c.

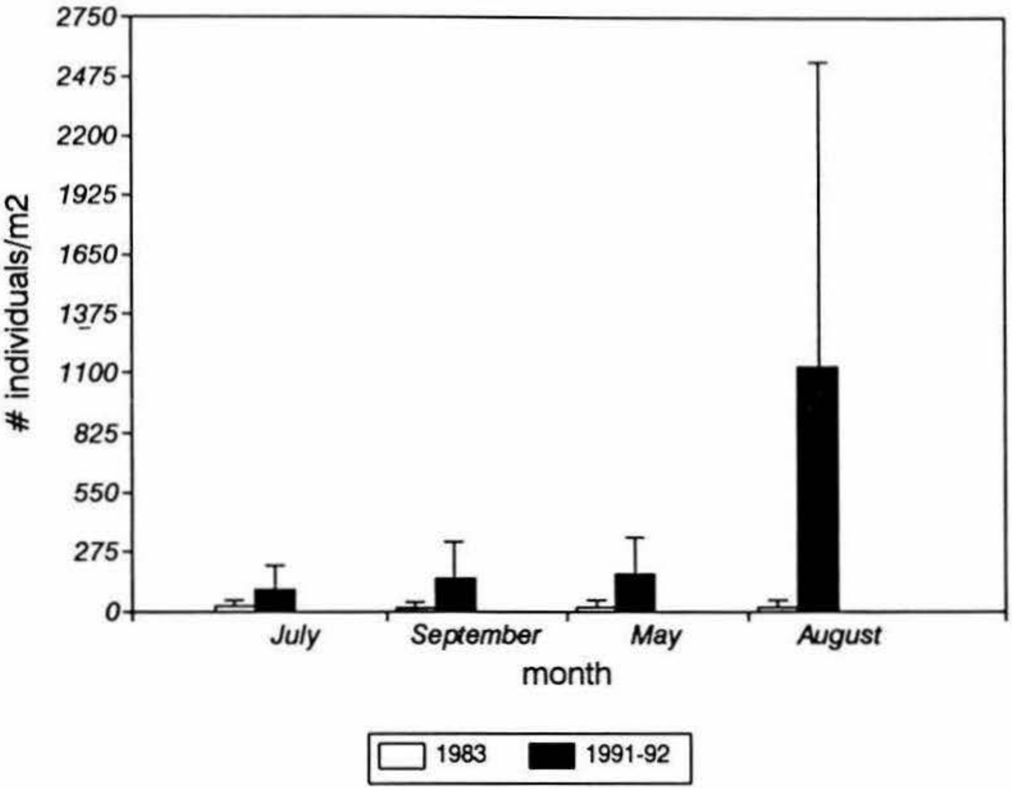


250
225
200
175
150
125
100
75
50
25
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3d.

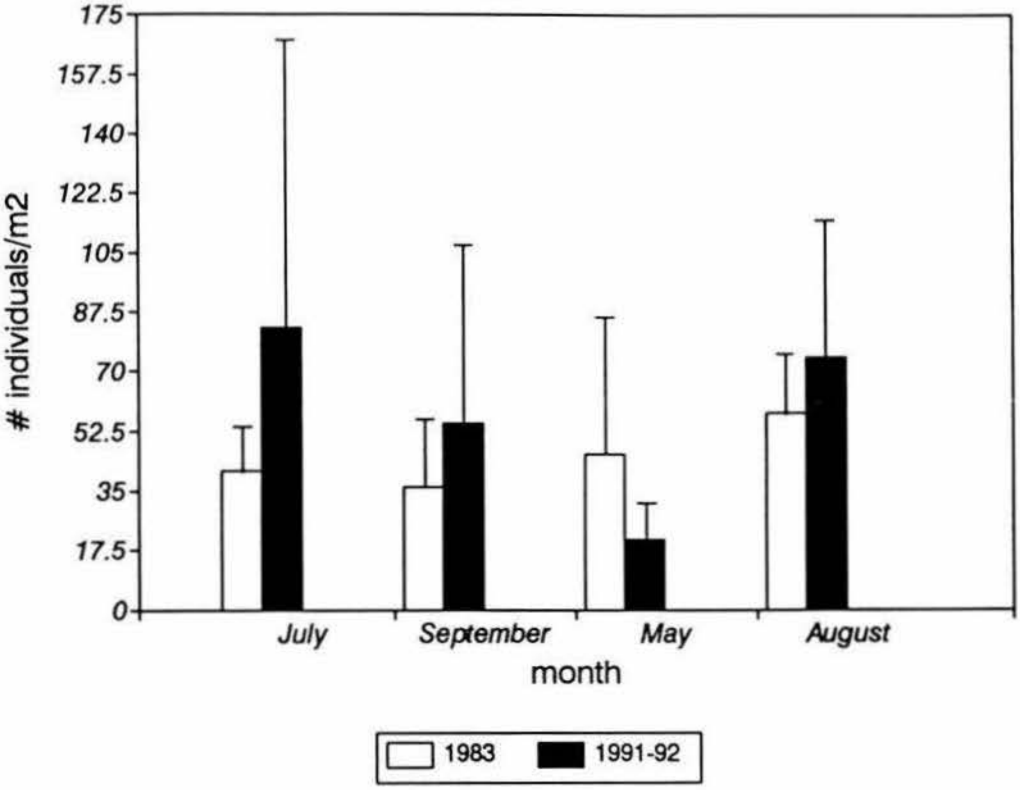

150
135
120
105
90
75
60
45
30
15
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3e.



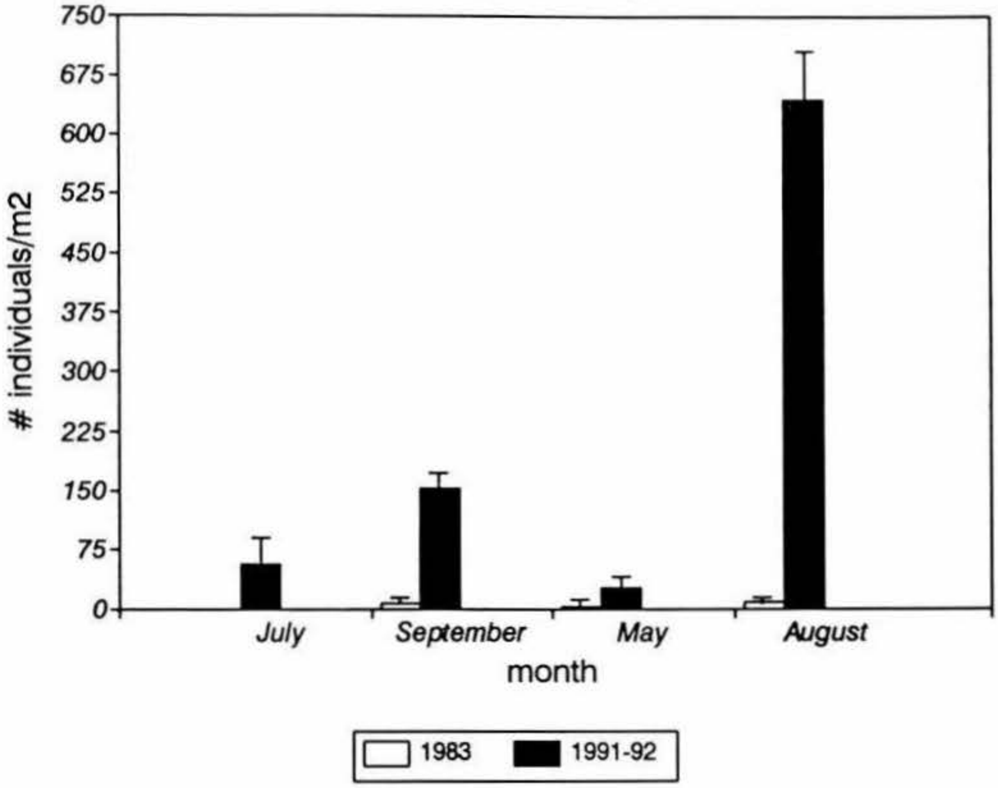
2750
2475
2200
1925
1650
1375
1100
825
550
275
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3f.



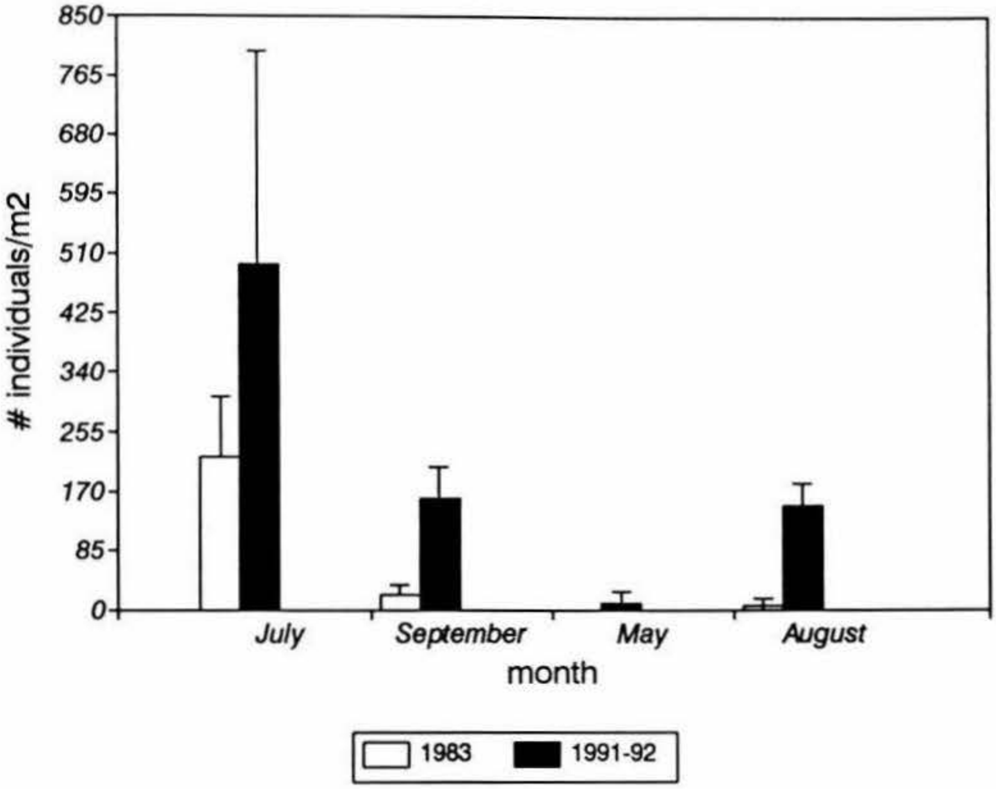
175
157.5
140
122.5
105
87.5
70
52.5
35
17.5
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3g.



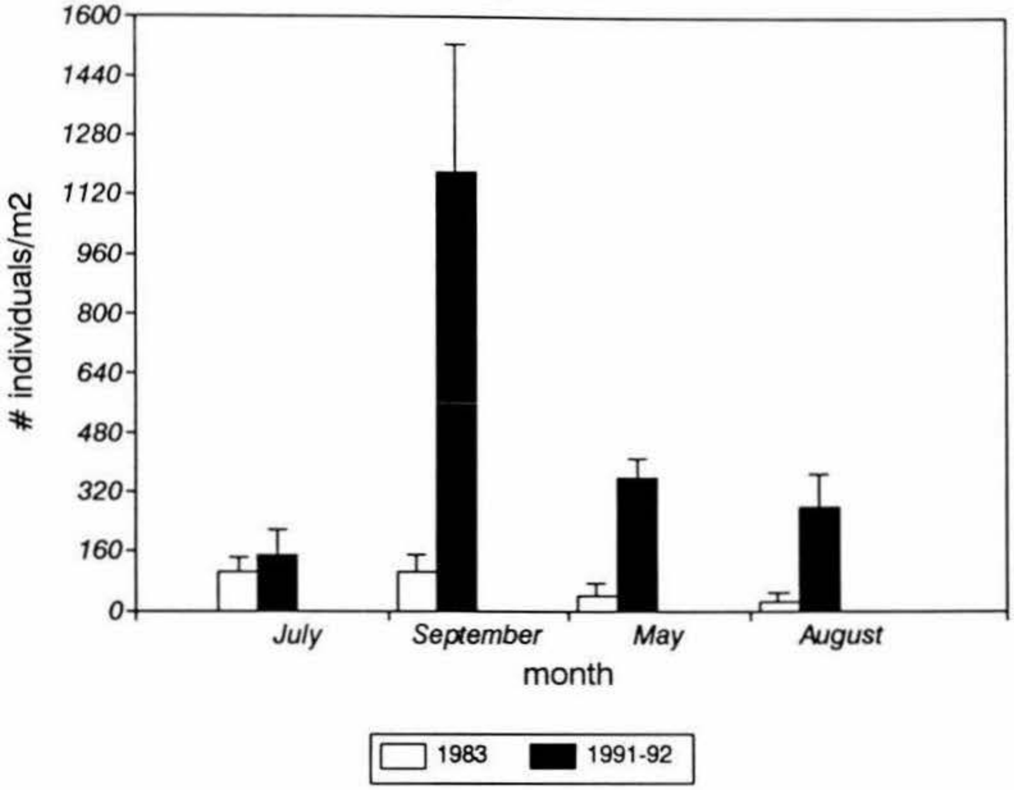
750
675
600
525
450
375
300
225
150
75
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3h.



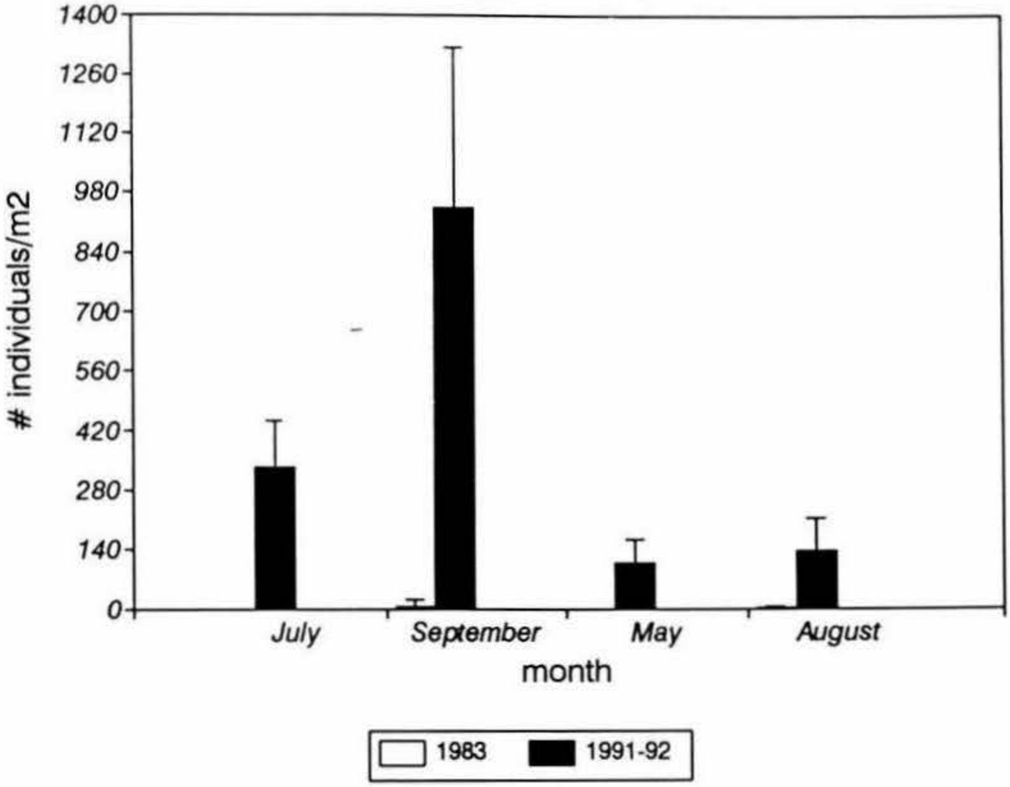
850
765
680
595
510
425
340
255
170
85
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3i.

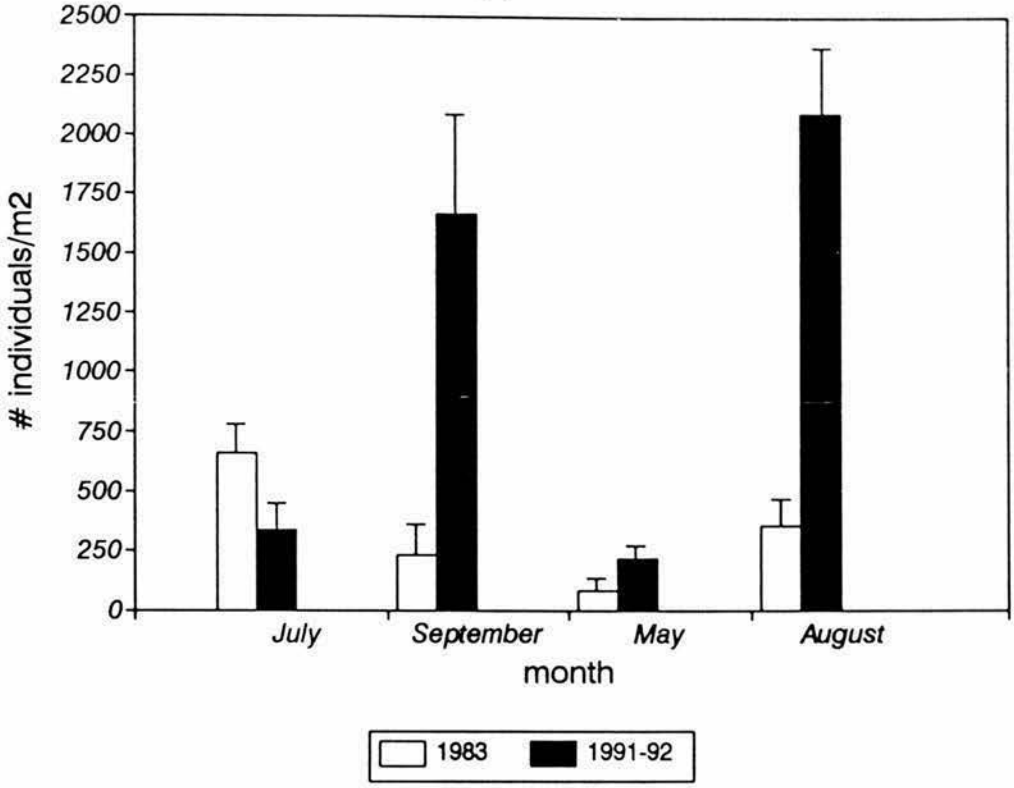


1600
1440
1280
1120
960
800
640
480
320
160
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3j.

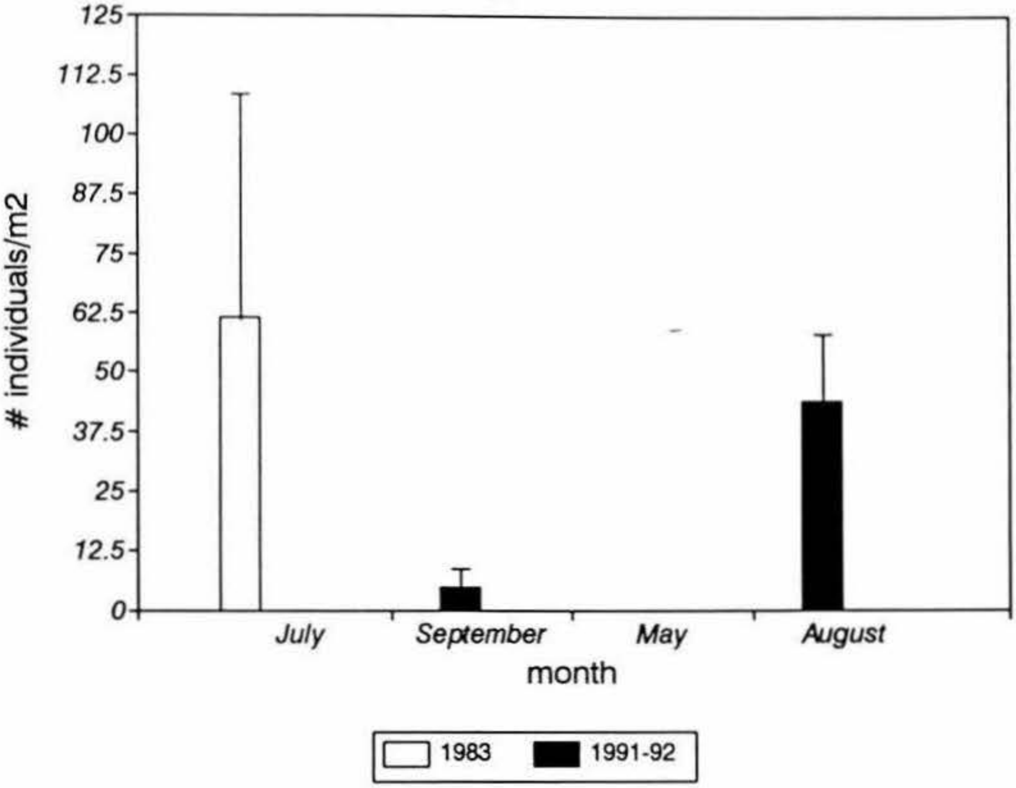

1400
1260
1120
980
840
700
560
420
280
140
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3k.



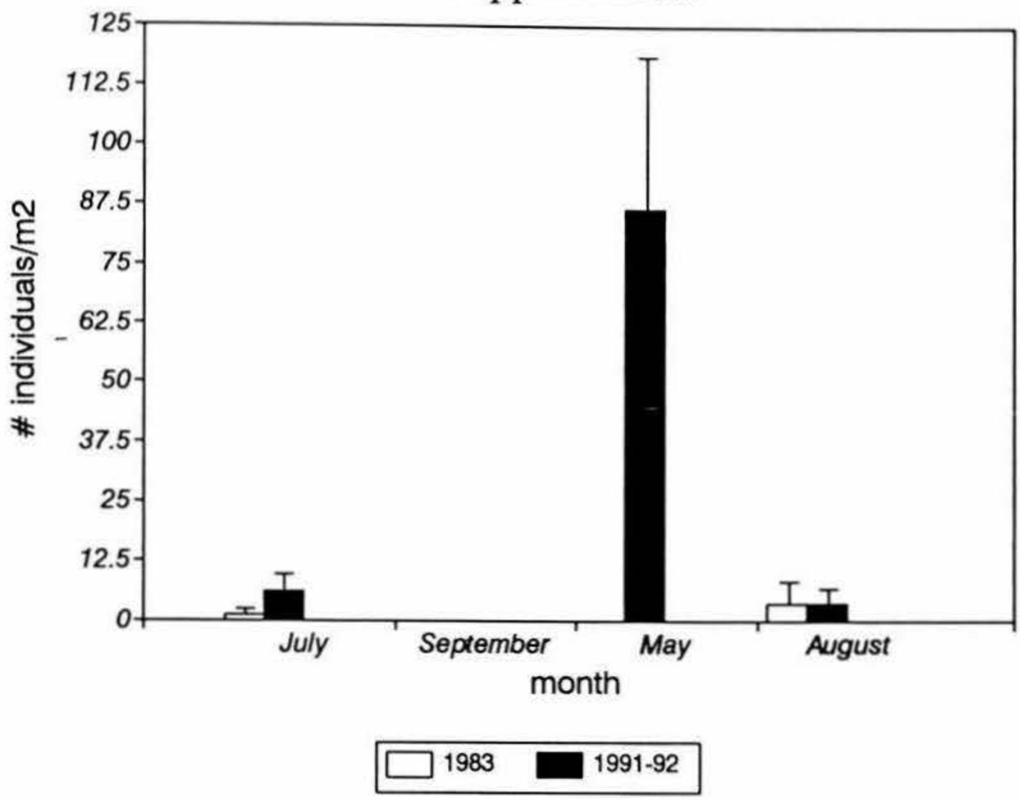
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3l.



125
112.5
100
87.5
75
62.5
50
37.5
25
12.5
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 3m.


125
112.5
100
87.5
75
62.5
50
37.5
25
12.5
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4.

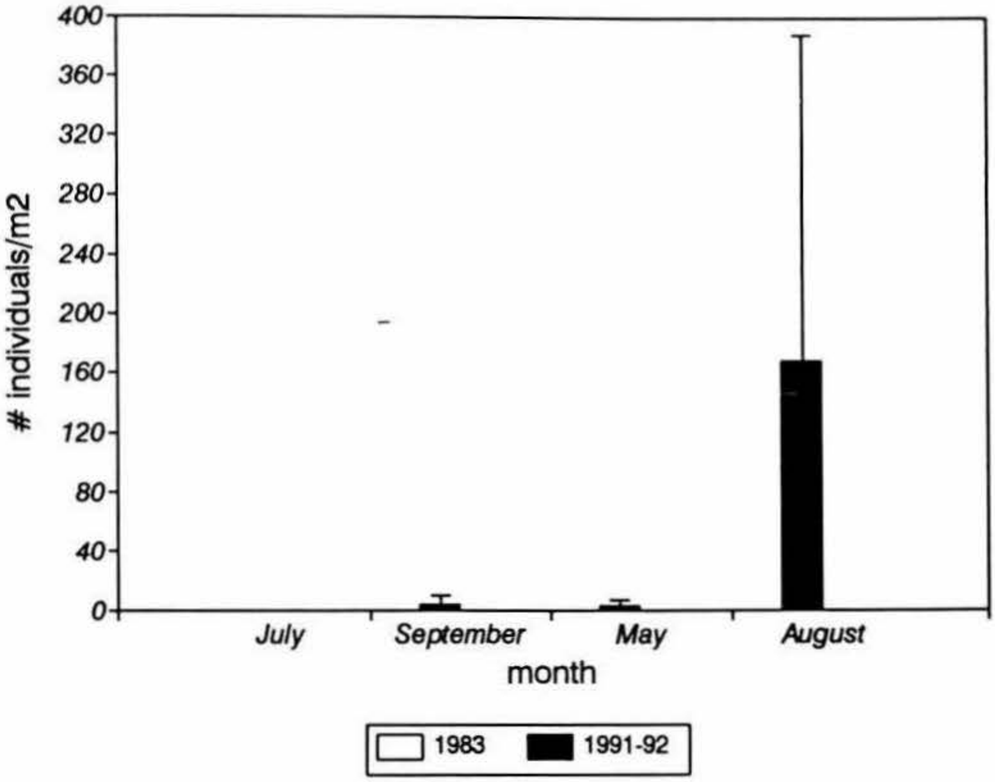
Changes in Abundance of Selected Native Benthic Macroinvertebrate Taxa at the Artificial Reef Site, by Month, 1983 and 1991-92.

Appendix 4a. unidentified Tubificidae.
Appendix 4b. Physa heterostropha.
Appendix 4c. Stagnicola catascopium.
Appendix 4d. Goniobasis livescens.
Appendix 4e. Amnicola limosa.
Appendix 4f. Gammarus fasciatus.
Appendix 4g. Orthocladius.
Appendix 4h. Psectrocladius.
Appendix 4i. Tanytarsus.

Taxa whose populations comprised at least 5.0% of the total native macroinvertebrate population on one or more sampling dates are included.

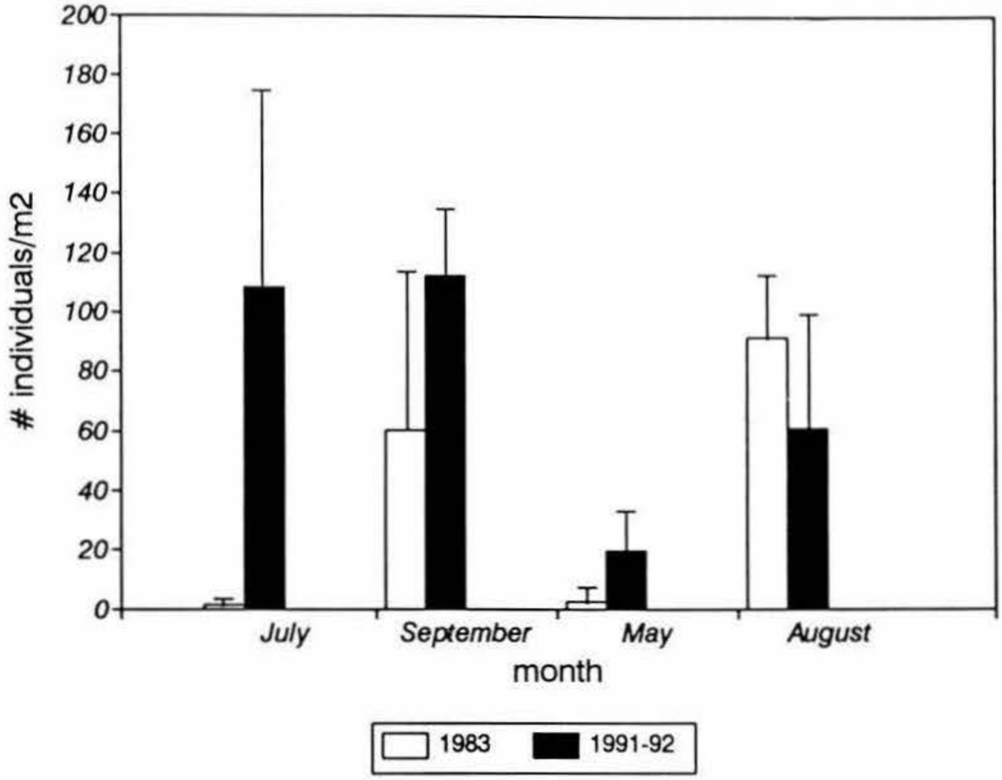
error bars = $\pm (1.96 \times \frac{s}{\sqrt{n}})$.

Appendix 4a.



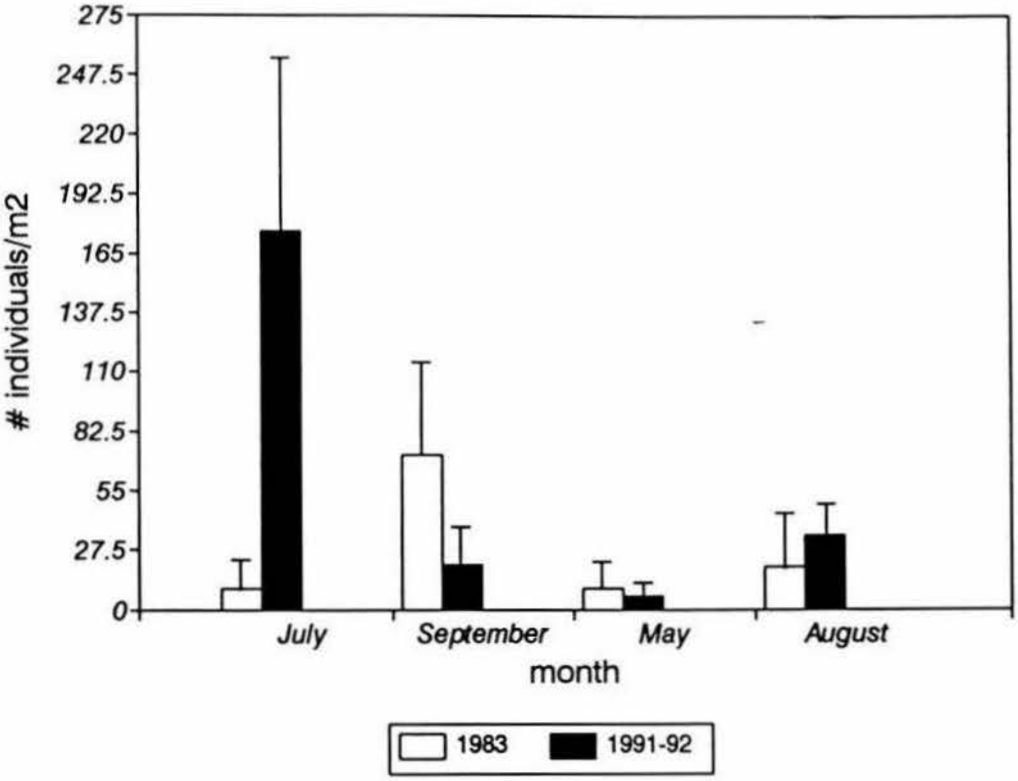
400
360
320
280
240
200
160
120
80
40
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4b.



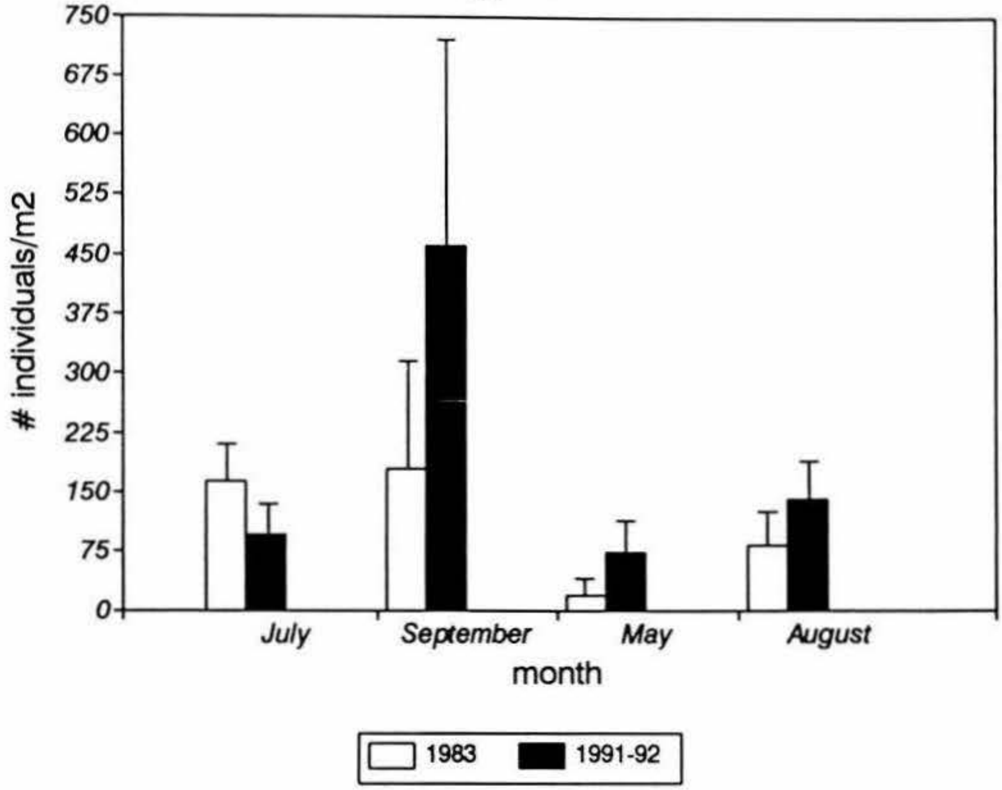
200
180
160
140
120
100
80
60
40
20
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4c.



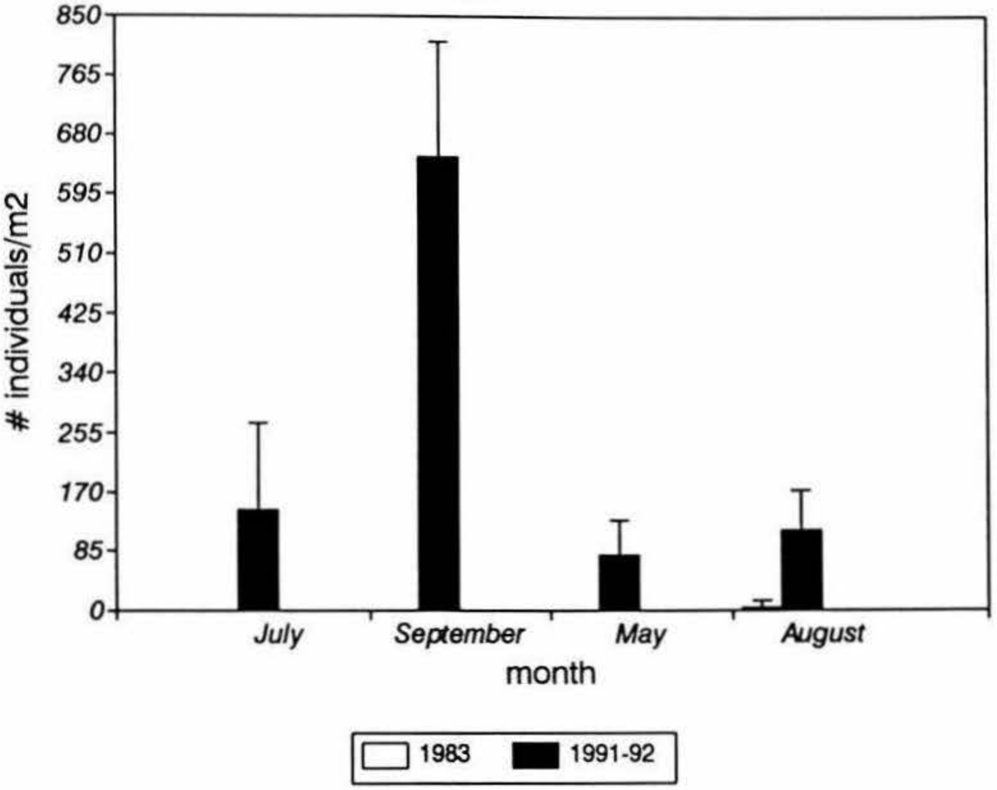
275
247.5
220
192.5
165
137.5
110
82.5
55
27.5
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4d.



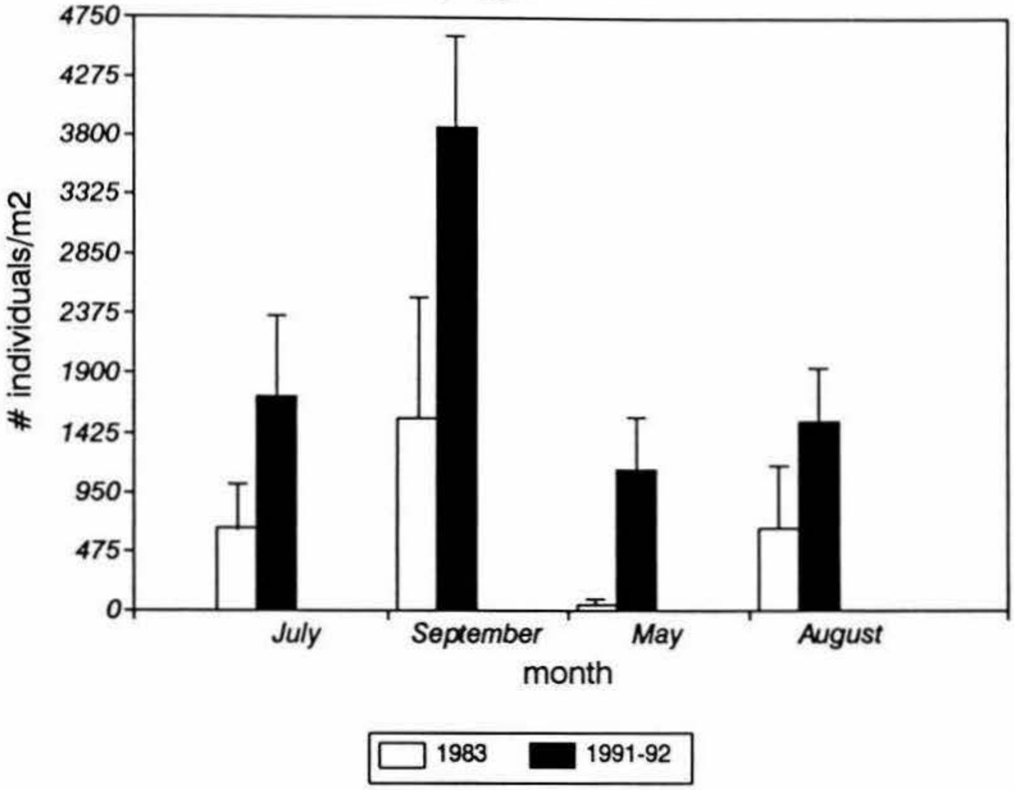
750
675
600
525
450
375
300
225
150
75
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4e.

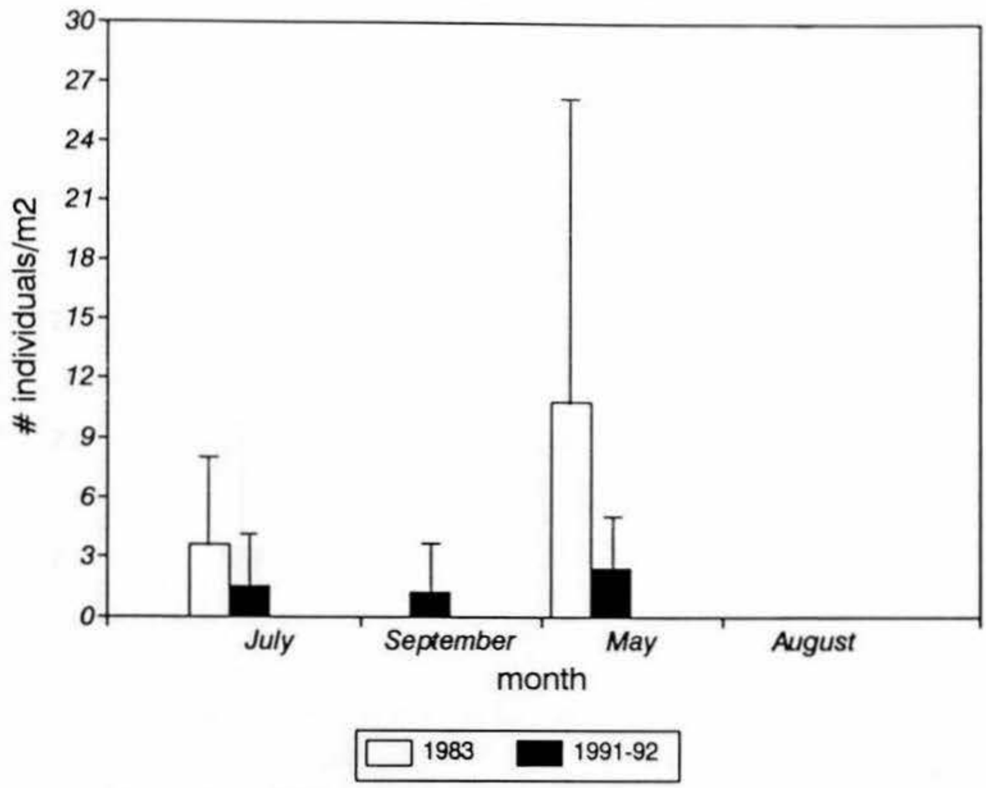


850
765
680
595
510
425
340
255
170
85
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4f.

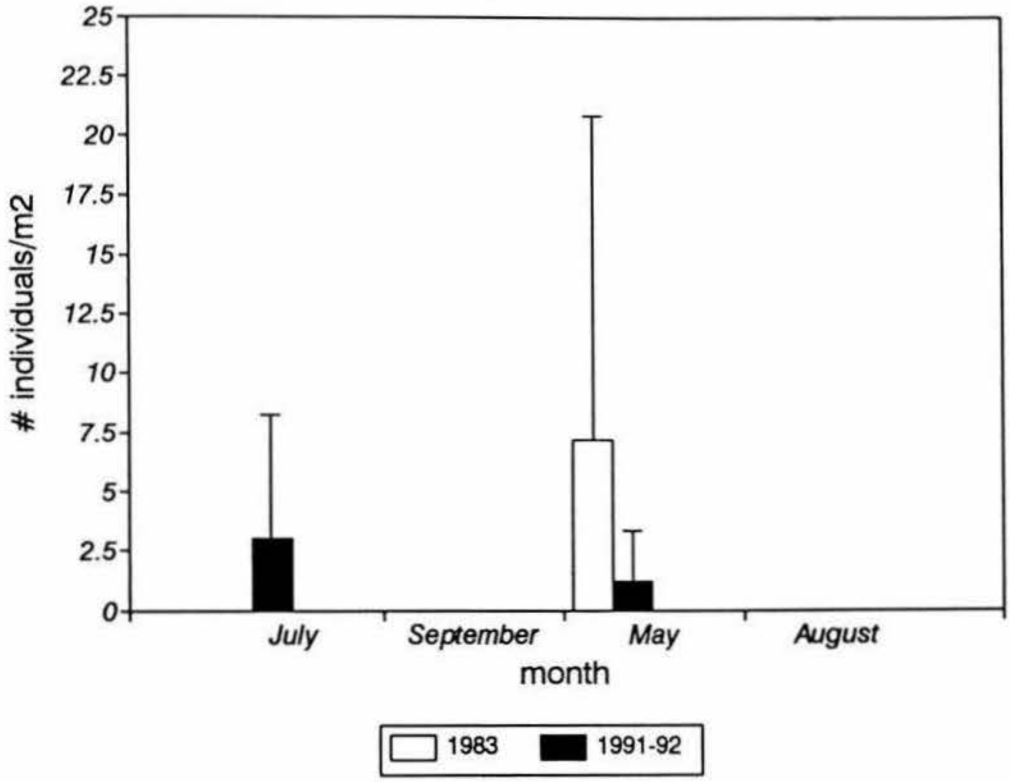

4750
4275
3800
3325
2850
2375
1900
1425
950
475
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4g.



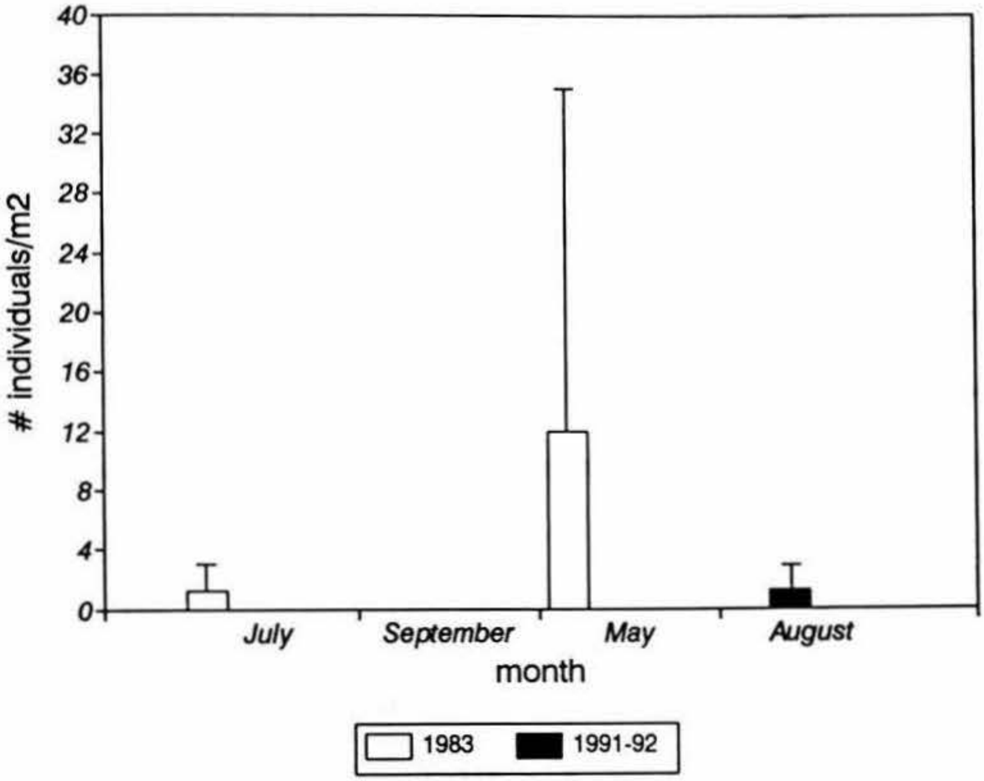
30
27
24
21
18
15
12
9
6
3
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4h.



25
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 4i.



40
36
32
28
24
20
16
12
8
4
0
individuals/m2
July
September
May
August
month
1983
1991-92

Appendix 5. Sample Calculations: Logarithmic Conversions of Sample Means and Statistical Comparison of 1983 and 1991-92 Monthly Native Benthic Macroinvertebrate Abundance Estimates by T-test.

According to Elliott (1971) and others, a T-test cannot be applied without risk of error unless several conditions are met: 1) the data must follow a normal distribution, 2) the variance of the sample must be independent of the mean, and 3) the components of the variance should be additive. Since my replicate sample macroinvertebrate counts were rarely distributed normally around a mean abundance estimate, and variance and mean values tended to increase together, these conditions were never fulfilled. By substituting each replicate sample count with a mathematical function that normalized the frequency distribution of replicate counts and eliminated dependence of variance on the mean, these conditions were met.

Replicate sample counts from 1991-92 were transformed by using the formula $\log(X + 1)$, where X = # individuals/m^2 in each replicate sample. Mean abundance and variance estimates from 1983 were also transformed. Since replicate sample counts from 1983 were not available, normalized mean and variance estimates were derived through a series of backcalculations. Each taxon's 1991-92 abundance estimates were then compared statistically to 1983 abundance estimates from the same month. An example follows.

Appendix 5. (continued).

<u>To be compared</u>: abundance of Turbellaria at the cobble site on July 12, 1983 (mean # individuals/m^2 = X83) and July 12, 1991 (mean # individuals/m^2 = X91).

<u>conversion of X91 to U91 = ln(X91 + 1)</u>

X91 data = (36.59, 79.27, 30.49, 0, 48.78); U91 data = (3.63, 4.39, 3.45, 0, 3.91)

mean (U91) estimate = 3.07

variance (U91) estimate = 1.57

<u>conversion of X83 to U83</u>

sample mean = X83 = 16.87

std. error of mean = 2.25 (5 data points)

std. error of popn. = standard error of mean (2.25) × $\sqrt{5}$ = 5.03

sample variance (X83) = (std. error of popn.)^2 = $(5.03)^2$ = 25.3

variance (U83) estimate = ln(variance(X83) ÷ $(X83+1)^2$ + 1) = ln(0.0793 + 1) = 0.0763

mean (U83) estimate = ln(X83 + 1) - 1/2(variance(U83) estimate) = ln(17.87) - 0.03815 = 2.84

<u>T-test formulas and calculations</u>

test statistic (T.S.) = U83 - U91 = 2.84 - 3.07 = -0.23

variance (T.S.) = (variance (U83) estimate ÷ N) + (variance (U91) estimate ÷ N) = (0.076 ÷ 5) + (1.57 ÷ 5) = 0.329

std. error (T.S.) = $\sqrt{variance(T.S.)}$ = 0.574

T = (T.S.) ÷ (std. error(T.S.)) = -0.23 ÷ 0.574 = -0.40

deg. fr. = ((N -1) × (variance(U83) + variance $(U91))^2$) ÷ (variance$(U83)^2$ + variance$(U91)^2$ = (5-1 × $(0.0763 + 1.57)^2$) ÷ (0.0763^2 + 1.57^2) = 4.37 (round down to 4)

Appendix 5. (continued).

conclusion: $T = -0.40$ with 4 degrees of freedom (p-value > 0.50). Therefore, there was no statistically significant difference between abundance of Turbellaria at the cobble site in July 1983 and July 1991.

sources: Elliott (1971) and Dr. James N. McNamara, Department of Mathematics, State University of New York, College at Brockport, personal communication, 1992.

Appendix 6. Sample and Mean Zebra Mussel Abundance Estimates at Cobble and Artificial Reef Sites, 1991-92.

cobble site (dome suction sampling)

	# individuals/square meter						
date	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5	mean	st. error
7/12/91	2718.9	1787.8	737.8	605.5	563.4	1282.7	379.0
9/21/91	2119.2	9506.1	3333.5	2492.7	10654.9	5621.3	1645.8
5/15/92	1930.5	31240.2	2620.7	4610.4	5109.8	9102.3	4978.7
8/23/92	7670.1	3944.5	10325.0	7854.3	3967.1	6752.2	1103.9

cobble site (plot sampling)

	# individuals/square meter				
date	rep. 1	rep. 2	rep. 3	mean	st. error
7/12/91	5021.6	5680.0	7054.0	5918.5	488.9
9/21/91	10405.4	15856.8	15942.2	14068.1	1495.5
5/15/92	8278.9	8488.6	8588.6	8452.0	74.5
8/23/92	20675.7	20157.3	21484.9	20772.6	315.4

artificial reef site (dome suction sampling)

	# individuals/square meter						
date	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5	mean	st. error
7/12/91	7718.9	10248.8	14431.1	4338.4	no data	9184.3	1842.1
9/21/91	20632.9	35111.0	34133.5	14186.6	44132.9	29639.4	4817.2
5/15/92	3878.0	8765.2	6881.1	590.2	29581.7	9939.2	4563.9
8/20/92	4039.6	18928.0	20129.9	10718.9	27533.5	16270.0	3629.0

artificial reef site (plot sampling)

	# individuals/square meter				
date	rep. 1	rep. 2	rep. 3	mean	st. error
7/12/91	75289.7	27872.4	63360.5	55507.5	11627.4
9/21/91	41183.2	33682.2	26992.4	33952.6	3346.7
5/15/92	28071.9	22923.2	7463.2	19486.1	5056.3
8/20/92	21045.4	20294.0	50450.8	30596.7	8107.6

Appendix 7. Sample and Mean Zebra Mussel Biomass Estimates at Cobble and Artificial Reef Sites, 1991-92.

cobble site (dome suction sampling)

	grams/square meter						
date	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5	mean	st. error
7/12/91	142.7	82.9	41.5	25.6	29.9	11.1	6.1
9/21/91	780.5	709.1	289.6	243.9	734.8	195.7	127.7
5/15/92	111.0	1531.1	136.6	262.8	255.5	459.4	241.2
8/23/92	725.6	346.3	1065.2	906.7	345.1	677.8	130.4

cobble site (plot sampling)

	grams/square meter				
date	rep. 1	rep. 2	rep. 3	mean	st. error
7/12/91	381.6	5680.0	7054.0	4371.9	1660.9
9/21/91	749.2	1335.1	1195.7	1093.3	144.3
5/15/92	680.5	590.8	695.7	655.7	26.7
8/23/92	2245.4	2358.4	2127.0	2243.6	54.5

artificial reef site (dome suction sampling)

	grams/square meter						
date	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5	mean	st. error
7/12/91	517.1	656.1	1019.5	309.8	no data	625.6	129.3
9/21/91	3161.0	1917.1	2232.3	990.2	2524.4	2165.0	320.5
5/15/92	299.4	547.0	498.2	39.6	2189.0	714.6	339.2
8/20/92	482.3	1961.0	2238.4	814.6	2136.6	1526.6	326.5

artificial reef site (plot sampling)

	grams/square meter				
date	rep. 1	rep. 2	rep. 3	mean	st. error
7/12/91	5902.7	2174.0	4371.9	4149.5	883.6
9/21/91	3739.4	3220.0	2127.0	3028.8	388.0
5/15/92	2919.4	2122.7	788.1	1943.4	507.7
8/20/92	2091.9	2232.4	5418.4	3247.6	886.9

Appendix 8a. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, by Replicate Sample (July 12, 1991).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Nematoda	6.1	0.0	12.2	0.0	0.0
Platyhelminthes					
Turbellaria	36.6	79.3	30.5	0.0	48.8
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	0.0	6.1	48.8	12.2
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0	0.0	0.0	0.0
unidentified Lumbriculidae	109.8	109.8	0.0	12.2	12.2
Haplotaxida					
Naididae					
Chaetogaster limnaei	30.5	12.2	61.0	85.4	12.2
Pristinella osborni	0.0	0.0	0.0	0.0	0.0
Nais communis	6.1	0.0	0.0	0.0	0.0
Nais pardalis	0.0	0.0	0.0	0.0	0.0
Nais sp.	0.0	0.0	0.0	12.2	0.0
Stylaria lacustris	158.5	1256.1	372.0	280.5	414.6
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	0.0
Tubificidae					
Potamothrix moldaviensis	18.3	0.0	0.0	0.0	0.0
Potamothrix vejdovskyi	18.3	0.0	6.1	0.0	0.0
Spirosperma ferox	6.1	85.4	6.1	12.2	0.0
unidentified Tubificidae	317.1	134.2	24.4	24.4	12.2
Oligochaeta cocoons	0.0	0.0	0.0	0.0	0.0
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0	0.0	0.0	0.0
Piscicolidae					
Piscicola punctata	6.1	0.0	0.0	0.0	0.0
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	231.7	158.5	12.2	6.1	6.1
Unionidae					
Ligumia nasuta	6.1	0.0	0.0	0.0	0.0
unidentified Unionidae	6.1	6.1	0.0	0.0	0.0
Gastropoda					
Pulmonata					
Planorbidae					
Gyraulus parvus	0.0	0.0	0.0	0.0	0.0
Helisoma anceps	0.0	0.0	0.0	6.1	0.0
Physidae					
Physa heterostropha	158.5	73.2	18.3	24.4	6.1
Lymnaeidae					
Stagnicola catascopium	274.4	1134.2	140.2	567.1	359.8
Prosobranchia					
Valvatidae					
Valvata tricarinata	6.1	12.2	0.0	0.0	6.1
Bithyniidae					
Bithynia tentaculata	0.0	0.0	0.0	0.0	0.0
Pleuroceridae					
Goniobasis livescens	323.2	213.4	140.2	48.8	18.3

Appendix 8a. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, by Replicate Sample (July 12, 1991).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Prosobranchia (continued)					
Hydrobiidae					
Amnicola limosa	512.2	420.7	329.3	268.3	134.2
Arthropoda					
Crustacea					
Amphipoda					
Gammaridae					
Gammarus fasciatus	542.7	475.6	195.1	359.8	103.7
Decapoda					
Cambaridae					
Orconectes propinquis	109.8	54.9	54.9	67.1	0.0
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	0.0	0.0	0.0	0.0	0.0
Lebertiidae					
Lebertia	0.0	0.0	0.0	0.0	0.0
Pionidae					
Forelia	0.0	0.0	0.0	0.0	0.0
Wettina	0.0	0.0	0.0	0.0	0.0
unidentified Acarina	0.0	0.0	0.0	0.0	0.0
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0	0.0	0.0	0.0
Heptageniidae					
Stenacron	73.2	0.0	6.1	6.1	0.0
Stenonema	0.0	0.0	0.0	0.0	0.0
unidentified Heptageniidae	0.0	0.0	0.0	0.0	0.0
Trichoptera					
Hydroptilidae					
Agraylea	24.4	12.2	6.1	6.1	12.2
Leptoceridae					
Ceraclea	6.1	6.1	18.3	6.1	18.3
Polycentropidae					
Polycentropus	18.3	18.3	24.4	6.1	6.1
Trichoptera pupae	0.0	0.0	0.0	6.1	0.0
Diptera					
Chironomidae					
Procladius	0.0	0.0	0.0	0.0	0.0
Theinnemannimyia	6.1	0.0	0.0	12.2	0.0
Cricotopus	0.0	0.0	0.0	0.0	0.0
Eukieferriella	0.0	0.0	0.0	0.0	0.0
Heterotrissocladius	0.0	0.0	0.0	0.0	0.0
Orthocladius	12.2	18.3	6.1	24.4	6.1
Orthocladius-Cricotopus	0.0	6.1	12.2	0.0	0.0
Psectrocladius	18.3	6.1	0.0	61.0	12.2
Chironomus	0.0	0.0	0.0	0.0	0.0
Paratendipes	6.1	0.0	0.0	12.2	0.0
Phaenopsectra	0.0	0.0	0.0	0.0	0.0
Polypedilum	0.0	0.0	0.0	0.0	0.0
Rheotanytarsus	0.0	0.0	0.0	0.0	6.1
Tanytarsus	12.2	0.0	0.0	12.2	6.1
unidentified Chironomidae	0.0	0.0	0.0	12.2	0.0
Chironomidae pupae	6.1	12.2	0.0	0.0	6.1
total	3067.3	4305.1	1481.8	1988.1	1219.7

Appendix 8b. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, by Replicate Sample (September 21, 1991).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Nematoda	0.0	6.1	0.0	0.0	6.1
Platyhelminthes					
Turbellaria	0.0	0.0	6.1	0.0	12.2
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	30.5	42.7	6.1	6.1	73.2
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	6.1	0.0	0.0	18.3
unidentified Lumbriculidae	6.1	0.0	0.0	0.0	0.0
Haplotaxida					
Naididae					
Chaetogaster limnaei	0.0	0.0	0.0	0.0	0.0
Pristinella osborni	6.1	0.0	0.0	0.0	0.0
Nais communis	0.0	0.0	0.0	0.0	0.0
Nais pardalis	0.0	0.0	0.0	0.0	18.3
Nais sp.	0.0	0.0	0.0	0.0	0.0
Stylaria lacustris	0.0	0.0	0.0	0.0	0.0
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	0.0
Tubificidae					
Potamothrix moldaviensis	0.0	0.0	0.0	0.0	0.0
Potamothrix vejdovskyi	67.1	6.1	6.1	0.0	372.0
Spirosperma ferox	12.2	12.2	6.1	0.0	30.5
unidentified Tubificidae	219.5	18.3	0.0	6.1	512.2
Oligochaeta cocoons	48.8	0.0	12.2	0.0	18.3
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0	0.0	0.0	0.0
Piscicolidae					
Piscicola punctata	0.0	0.0	0.0	0.0	0.0
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	30.5	0.0	36.6	36.6	170.7
Unionidae					
Ligumia nasuta	6.1	0.0	0.0	0.0	0.0
unidentified Unionidae	0.0	0.0	0.0	0.0	0.0
Gastropoda					
Pulmonata					
Planorbidae					
Gyraulus parvus	12.2	0.0	6.1	18.3	18.3
Helisoma anceps	0.0	0.0	6.1	6.1	18.3
Physidae					
Physa heterostropha	219.5	170.7	134.2	91.5	146.3
Lymnaeidae					
Stagnicola catascopium	268.3	158.5	146.3	61.0	164.6
Prosobranchia					
Valvatidae					
Valvata tricarinata	122.0	42.7	30.5	18.3	128.0
Bithyniidae					
Bithynia tentaculata	0.0	0.0	0.0	6.1	0.0
Pleuroceridae					
Goniobasis livescens	1420.7	1262.2	756.1	615.8	1847.6

Appendix 8b. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, by Replicate Sample (September 21, 1991).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Prosobranchia (continued)					
Hydrobiidae					
Amnicola limosa	1396.3	707.3	493.9	542.7	1579.3
Arthropoda					
Crustacea					
Amphipoda					
Gammaridae					
Gammarus fasciatus	2323.2	2378.0	1170.7	1067.1	1408.5
Decapoda					
Cambaridae					
Orconectes propinquis	18.3	24.4	24.4	12.2	6.1
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	36.6	12.2	6.1	12.2	0.0
Lebertiidae					
Lebertia	12.2	6.1	0.0	0.0	0.0
Pionidae					
Forelia	0.0	0.0	0.0	0.0	0.0
Wettina	0.0	0.0	0.0	0.0	0.0
unidentified Acarina	0.0	0.0	0.0	6.1	0.0
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0	0.0	0.0	0.0
Heptageniidae					
Stenacron	6.1	0.0	0.0	0.0	0.0
Stenonema	0.0	6.1	0.0	0.0	12.2
unidentified Heptageniidae	0.0	0.0	0.0	0.0	0.0
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0	0.0	0.0	0.0
Leptoceridae					
Ceraclea	0.0	6.1	6.1	0.0	0.0
Polycentropidae					
Polycentropus	6.1	42.7	0.0	18.3	12.2
Trichoptera pupae	0.0	0.0	0.0	0.0	0.0
Diptera					
Chironomidae					
Procladius	0.0	0.0	0.0	0.0	0.0
Theinnemannimyia	0.0	0.0	0.0	0.0	0.0
Cricotopus	0.0	0.0	0.0	0.0	0.0
Eukieferriella	0.0	0.0	0.0	0.0	0.0
Heterotrissocladius	0.0	0.0	0.0	0.0	0.0
Orthocladius	0.0	0.0	0.0	0.0	0.0
Orthocladius-Cricotopus	0.0	0.0	0.0	0.0	0.0
Psectrocladius	0.0	0.0	0.0	0.0	0.0
Chironomus	0.0	6.1	6.1	0.0	12.2
Paratendipes	0.0	0.0	0.0	0.0	0.0
Phaenopsectra	0.0	0.0	0.0	0.0	0.0
Polypedilum	0.0	0.0	0.0	0.0	0.0
Rheotanytarsus	0.0	0.0	0.0	0.0	0.0
Tanytarsus	0.0	0.0	0.0	0.0	0.0
unidentified Chironomidae	0.0	0.0	0.0	0.0	6.1
Chironomidae pupae	0.0	0.0	0.0	0.0	0.0
total	6268.4	4914.6	2859.8	2524.5	6591.5

Appendix 8c. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, by Replicate Sample (May 15, 1992).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Nematoda	6.1	6.1	6.1	0.0	0.0
Platyhelminthes					
Turbellaria	0.0	0.0	24.4	12.2	0.0
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	0.0	6.1	6.1	6.1
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0	0.0	0.0	0.0
unidentified Lumbriculidae	0.0	0.0	0.0	18.3	0.0
Haplotaxida					
Naididae					
Chaetogaster limnaei	0.0	18.3	0.0	0.0	0.0
Pristinella osborni	0.0	0.0	0.0	0.0	0.0
Nais communis	0.0	0.0	0.0	0.0	0.0
Nais pardalis	18.3	36.6	12.2	18.3	24.4
Nais sp.	0.0	0.0	0.0	0.0	0.0
Stylaria lacustris	0.0	0.0	0.0	0.0	0.0
Vejdovskyella intermedia	0.0	6.1	12.2	0.0	0.0
Tubificidae					
Potamothrix moldaviensis	6.1	0.0	0.0	30.5	18.3
Potamothrix vejdovskyi	85.4	0.0	0.0	201.2	347.6
Spirosperma ferox	201.2	97.6	24.4	12.2	48.8
unidentified Tubificidae	122.0	42.7	79.3	85.4	542.7
Oligochaeta cocoons	6.1	6.1	0.0	0.0	0.0
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0	0.0	0.0	0.0
Piscicolidae					
Piscicola punctata	0.0	0.0	0.0	0.0	0.0
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	36.6	0.0	12.2	18.3	36.6
Unionidae					
Ligumia nasuta	0.0	0.0	6.1	0.0	0.0
unidentified Unionidae	0.0	0.0	0.0	0.0	0.0
Gastropoda					
Pulmonata					
Planorbidae					
Gyraulus parvus	12.2	0.0	0.0	0.0	0.0
Helisoma anceps	0.0	12.2	0.0	24.4	6.1
Physidae					
Physa heterostropha	24.4	0.0	30.5	12.2	61.0
Lymnaeidae					
Stagnicola catascopium	30.5	6.1	0.0	6.1	0.0
Prosobranchia					
Valvatidae					
Valvata tricarinata	36.6	12.2	6.1	12.2	6.1
Bithyniidae					
Bithynia tentaculata	12.2	0.0	0.0	6.1	6.1
Pleuroceridae					
Goniobasis livescens	420.7	311.0	280.5	298.8	475.6

Appendix 8c. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, by Replicate Sample (May 15, 1992).

taxon	# individuals/square meter				
	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Prosobranchia (continued)					
Hydrobiidae					
Amnicola limosa	164.6	85.4	146.3	109.8	30.5
Arthropoda					
Crustacea					
Amphipoda					
Gammaridae					
Gammarus fasciatus	268.3	134.1	329.3	152.4	207.3
Decapoda					
Cambaridae					
Orconectes propinquis	6.1	0.0	6.1	18.3	18.3
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	6.1	6.1	24.4	18.3	18.3
Lebertiidae					
Lebertia	0.0	0.0	0.0	0.0	0.0
Pionidae					
Forelia	0.0	0.0	0.0	6.1	0.0
Wettina	6.1	18.3	0.0	0.0	0.0
unidentified Acarina	0.0	0.0	6.1	0.0	0.0
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0	0.0	0.0	0.0
Heptageniidae					
Stenacron	6.1	0.0	0.0	0.0	0.0
Stenonema	0.0	0.0	0.0	0.0	0.0
unidentified Heptageniidae	0.0	0.0	0.0	0.0	0.0
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0	0.0	0.0	0.0
Leptoceridae					
Ceraclea	0.0	0.0	6.1	0.0	0.0
Polycentropidae					
Polycentropus	0.0	0.0	6.1	0.0	6.1
Trichoptera pupae	0.0	0.0	0.0	0.0	0.0
Diptera					
Chironomidae					
Procladius	12.2	6.1	0.0	0.0	0.0
Theinnemannimyia	0.0	0.0	0.0	0.0	0.0
Cricotopus	0.0	0.0	0.0	0.0	0.0
Eukieferriella	0.0	0.0	0.0	6.1	0.0
Heterotrissocladius	0.0	0.0	0.0	0.0	0.0
Orthocladius	0.0	0.0	6.1	0.0	0.0
Orthocladius-Cricotopus	12.2	0.0	12.2	6.1	18.3
Psectrocladius	0.0	0.0	0.0	0.0	0.0
Chironomus	0.0	0.0	0.0	0.0	0.0
Paratendipes	0.0	0.0	0.0	0.0	0.0
Phaenopsectra	0.0	0.0	0.0	6.1	12.2
Polypedilum	0.0	0.0	0.0	0.0	0.0
Rheotanytarsus	0.0	0.0	0.0	0.0	0.0
Tanytarsus	146.3	103.7	73.2	67.1	42.7
unidentified Chironomidae	0.0	0.0	0.0	0.0	0.0
Chironomidae pupae	6.1	6.1	12.2	6.1	0.0
total	1652.5	914.8	1128.2	1158.7	1933.1

Appendix 8d. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, by Replicate Sample (August 23, 1992).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Nematoda	0.0	6.1	0.0	0.0	24.4
Platyhelminthes					
Turbellaria	67.1	12.2	18.3	0.0	48.8
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	6.1	0.0	6.1	0.0	24.4
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0	0.0	0.0	0.0
unidentified Lumbriculidae	6.1	0.0	0.0	0.0	134.2
Haplotaxida					
Naididae					
Chaetogaster limnaei	0.0	0.0	0.0	0.0	0.0
Pristinella osborni	0.0	0.0	24.4	0.0	0.0
Nais communis	0.0	0.0	0.0	0.0	0.0
Nais pardalis	0.0	0.0	0.0	0.0	0.0
Nais sp.	0.0	0.0	0.0	0.0	0.0
Stylaria lacustris	0.0	0.0	0.0	0.0	24.4
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	0.0
Tubificidae					
Potamothrix moldaviensis	6.1	0.0	0.0	0.0	61.0
Potamothrix vejdovskyi	182.9	0.0	0.0	0.0	274.4
Spirosperma ferox	6.1	85.4	30.5	79.3	140.2
unidentified Tubificidae	926.8	286.6	146.3	79.3	4213.4
Oligochaeta cocoons	6.1	54.9	12.2	79.3	158.5
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0	0.0	0.0	0.0
Piscicolidae					
Piscicola punctata	0.0	0.0	0.0	0.0	0.0
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	67.1	36.6	61.0	36.6	170.7
Unionidae					
Ligumia nasuta	0.0	0.0	0.0	0.0	0.0
unidentified Unionidae	0.0	0.0	0.0	0.0	0.0
Gastropoda					
Pulmonata					
Planorbidae					
Gyraulus parvus	12.2	6.1	24.4	6.1	6.1
Helisoma anceps	24.4	91.5	61.0	67.1	54.9
Physidae					
Physa heterostropha	731.7	676.8	719.5	524.4	573.2
Lymnaeidae					
Stagnicola catascopium	134.2	213.4	109.8	146.3	146.3
Prosobranchia					
Valvatidae					
Valvata tricarinata	18.3	24.4	67.1	12.2	6.1
Bithyniidae					
Bithynia tentaculata	30.5	0.0	6.1	0.0	0.0
Pleuroceridae					
Goniobasis livescens	323.2	152.4	256.1	317.1	335.4

Appendix 8d. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, by Replicate Sample (August 23, 1992).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Prosobranchia (continued)					
Hydrobiidae					
Amnicola limosa	122.0	54.9	213.4	195.1	91.5
Arthropoda					
Crustacea					
Amphipoda					
Gammaridae					
Gammarus fasciatus	1975.6	1920.7	1707.3	2329.3	2542.7
Decapoda					
Cambaridae					
Orconectes propinquis	36.6	18.3	12.2	48.8	48.8
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	48.8	18.3	24.4	30.5	6.1
Lebertiidae					
Lebertia	0.0	0.0	6.1	0.0	0.0
Pionidae					
Forelia	0.0	0.0	0.0	0.0	0.0
Wettina	0.0	0.0	0.0	0.0	0.0
unidentified Acarina	0.0	0.0	6.1	6.1	0.0
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0	0.0	0.0	0.0
Heptageniidae					
Stenacron	0.0	0.0	0.0	0.0	6.1
Stenonema	0.0	0.0	0.0	0.0	0.0
unidentified Heptageniidae	0.0	0.0	0.0	0.0	0.0
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0	0.0	0.0	6.1
Leptoceridae					
Ceraclea	0.0	0.0	0.0	0.0	0.0
Polycentropidae					
Polycentropus	0.0	0.0	0.0	12.2	6.1
Trichoptera pupae	0.0	0.0	0.0	0.0	0.0
Diptera					
Chironomidae					
Procladius	0.0	6.1	0.0	0.0	0.0
Theinnemannimyia	0.0	0.0	0.0	0.0	12.2
Cricotopus	0.0	0.0	0.0	0.0	0.0
Eukieferriella	0.0	0.0	0.0	0.0	0.0
Heterotrissocladius	24.4	18.3	6.1	12.2	0.0
Orthocladius	0.0	0.0	0.0	0.0	0.0
Orthocladius-Cricotopus	0.0	0.0	0.0	0.0	0.0
Psectrocladius	6.1	0.0	0.0	0.0	0.0
Chironomus	79.3	30.5	24.4	42.7	42.7
Paratendipes	0.0	0.0	0.0	12.2	0.0
Phaenopsectra	0.0	0.0	0.0	0.0	0.0
Polypedilum	0.0	0.0	0.0	0.0	0.0
Rheotanytarsus	0.0	0.0	0.0	0.0	0.0
Tanytarsus	0.0	6.1	0.0	0.0	12.2
unidentified Chironomidae	0.0	6.1	0.0	0.0	12.2
Chironomidae pupae	0.0	12.2	6.1	18.3	6.1
total	4841.7	3737.9	3548.9	4055.1	9189.2

Appendix 9a. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, by Replicate Sample (July 12, 1991).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Nematoda	0.0	0.0	0.0	0.0	no data
Platyhelminthes					
Turbellaria	85.4	79.3	91.5	134.1	no data
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	0.0	0.0	0.0	no data
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0	0.0	0.0	no data
unidentified Lumbriculidae	0.0	0.0	0.0	0.0	no data
Haplotaxida					
Naididae					
Chaetogaster limnaei	12.2	61.0	36.6	6.1	no data
Pristinella osborni	0.0	0.0	0.0	0.0	no data
Nais communis	12.2	6.1	0.0	0.0	no data
Nais pardalis	0.0	0.0	0.0	0.0	no data
Nais sp.	6.1	18.3	6.1	0.0	no data
Stylaria lacustris	0.0	243.9	36.6	73.2	no data
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	no data
Tubificidae					
Potamothrix moldaviensis	0.0	0.0	0.0	0.0	no data
Potamothrix vejdovskyi	0.0	0.0	0.0	0.0	no data
Spirosperma ferox	0.0	0.0	0.0	0.0	no data
unidentified Tubificidae	0.0	0.0	0.0	0.0	no data
Oligochaeta cocoons	0.0	0.0	0.0	0.0	no data
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0	0.0	0.0	no data
Piscicolidae					
Piscicola punctata	0.0	0.0	0.0	0.0	no data
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	0.0	0.0	0.0	0.0	no data
Unionidae					
Ligumia nasuta	0.0	0.0	0.0	0.0	no data
unidentified Unionidae	0.0	0.0	0.0	0.0	no data
Gastropoda					
Pulmonata					
Planorbidae					
Gyraulus parvus	0.0	0.0	0.0	0.0	no data
Helisoma anceps	0.0	0.0	0.0	6.1	no data
Physidae					
Physa heterostropha	30.5	213.4	85.4	103.7	no data
Lymnaeidae					
Stagnicola catascopium	67.1	304.9	134.1	195.1	no data
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	0.0	0.0	0.0	no data
Bithyniidae					
Bithynia tentaculata	0.0	6.1	0.0	0.0	no data
Pleuroceridae					
Goniobasis livescens	158.5	97.6	67.1	61.0	no data

Appendix 9a. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, by Replicate Sample (July 12, 1991).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Prosobranchia (continued)					
Hydrobiidae					
Amnicola limosa	30.5	372.0	103.7	73.2	no data
Arthropoda					
Crustacea					
Amphipoda					
Gammaridae					
Gammarus fasciatus	1237.8	1030.5	1798.8	2792.7	no data
Decapoda					
Cambaridae					
Orconectes propinquis	12.2	6.1	0.0	6.1	no data
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	0.0	0.0	0.0	0.0	no data
Lebertiidae					
Lebertia	0.0	0.0	0.0	0.0	no data
Pionidae					
Forelia	0.0	0.0	0.0	0.0	no data
Wettina	0.0	0.0	0.0	0.0	no data
unidentified Acarina	0.0	0.0	0.0	0.0	no data
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0	0.0	0.0	no data
Heptageniidae					
Stenacron	0.0	0.0	0.0	0.0	no data
Stenonema	0.0	0.0	0.0	0.0	no data
unidentified Heptageniidae	0.0	0.0	0.0	0.0	no data
Trichoptera					
Hydroptilidae					
Agraylea	12.2	0.0	12.2	30.5	no data
Leptoceridae					
Ceraclea	0.0	0.0	6.1	0.0	no data
Polycentropidae					
Polycentropus	6.1	30.5	30.5	18.3	no data
Trichoptera pupae	0.0	0.0	6.1	0.0	no data
Diptera					
Chironomidae					
Procladius	0.0	0.0	0.0	0.0	no data
Theinnemannimyia	0.0	0.0	0.0	0.0	no data
Cricotopus	0.0	6.1	0.0	0.0	no data
Eukiefferiella	0.0	0.0	0.0	0.0	no data
Heterotrissocladius	0.0	0.0	0.0	0.0	no data
Orthocladius	0.0	6.1	0.0	0.0	no data
Orthocladius-Cricotopus	0.0	0.0	0.0	0.0	no data
Psectrocladius	0.0	12.2	0.0	0.0	no data
Chironomus	0.0	0.0	0.0	0.0	no data
Paratendipes	0.0	0.0	0.0	0.0	no data
Phaenopsectra	0.0	0.0	0.0	0.0	no data
Polypedilum	0.0	0.0	0.0	0.0	no data
Rheotanytarsus	0.0	0.0	0.0	0.0	no data
Tanytarsus	0.0	0.0	0.0	0.0	no data
unidentified Chironomidae	0.0	0.0	0.0	0.0	no data
Chironomidae pupae	0.0	6.1	0.0	0.0	no data
total	1670.8	2500.2	2414.8	3500.1	no data

Appendix 9b. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, by Replicate Sample (September 21, 1991).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Nematoda	0.0	0.0	0.0	0.0	0.0
Platyhelminthes					
Turbellaria	85.4	6.1	18.3	12.2	0.0
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	6.1	0.0	0.0	6.1	0.0
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0	0.0	0.0	0.0
unidentified Lumbriculidae	0.0	0.0	0.0	0.0	0.0
Haplotaxida					
Naididae					
Chaetogaster limnaei	6.1	0.0	0.0	0.0	0.0
Pristinella osborni	0.0	0.0	0.0	6.1	0.0
Nais communis	12.2	0.0	0.0	0.0	0.0
Nais pardalis	0.0	0.0	0.0	0.0	0.0
Nais sp.	6.1	0.0	0.0	0.0	0.0
Stylaria lacustris	18.3	0.0	0.0	0.0	0.0
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	0.0
Tubificidae					
Potamothrix moldaviensis	0.0	0.0	0.0	0.0	0.0
Potamothrix vejdovskyi	6.1	0.0	0.0	0.0	0.0
Spirosperma ferox	0.0	0.0	0.0	0.0	0.0
Oligochaeta cocoons	0.0	0.0	0.0	0.0	0.0
unidentified Tubificidae	0.0	12.2	0.0	6.1	0.0
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0	0.0	0.0	6.1
Piscicolidae					
Piscicola punctata	0.0	0.0	0.0	0.0	0.0
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	0.0	0.0	0.0	0.0	0.0
Unionidae					
Ligumia nasuta	0.0	0.0	0.0	0.0	0.0
unidentified Unionidae	0.0	0.0	0.0	0.0	0.0
Gastropoda					
Pulmonata					
Planorbidae					
Gyraulus parvus	0.0	12.2	0.0	12.2	0.0
Helisoma anceps	0.0	6.1	6.1	12.2	6.1
Physidae					
Physa heterostropha	128.0	85.4	128.0	146.3	73.2
Lymnaeidae					
Stagnicola catascopium	12.2	18.3	18.3	42.7	12.2
Prosobranchia					
Valvatidae					
Valvata tricarinata	6.1	6.1	6.1	6.1	0.0
Bithyniidae					
Bithynia tentaculata	0.0	0.0	0.0	6.1	0.0
Pleuroceridae					
Goniobasis livescens	329.3	311.0	286.6	1054.9	323.2

Appendix 9b. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, by Replicate Sample (September 21, 1991).

taxon	# individuals/square meter				
	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Prosobranchia (continued)					
Hydrobiidae					
Amnicola limosa	658.5	792.7	579.3	865.8	347.6
Arthropoda					
Crustacea					
Amphipoda					
Gammaridae					
Gammarus fasciatus	5146.3	3243.9	3347.6	4573.2	3018.3
Decapoda					
Cambaridae					
Orconectes propinquis	0.0	0.0	0.0	0.0	0.0
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	0.0	18.3	0.0	30.5	0.0
Lebertiidae					
Lebertia	0.0	6.1	0.0	0.0	0.0
Pionidae					
Forelia	0.0	0.0	0.0	0.0	0.0
Wettina	0.0	0.0	0.0	0.0	0.0
unidentified Acarina	0.0	0.0	0.0	0.0	0.0
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0	0.0	0.0	0.0
Heptageniidae					
Stenacron	12.2	0.0	6.1	0.0	0.0
Stenonema	6.1	6.1	12.2	12.2	12.2
unidentified Heptageniidae	0.0	0.0	0.0	6.1	0.0
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0	0.0	0.0	0.0
Leptoceridae					
Ceraclea	0.0	0.0	0.0	0.0	0.0
Polycentropidae					
Polycentropus	73.2	36.6	91.5	67.1	158.5
Trichoptera pupae	0.0	0.0	0.0	0.0	0.0
Diptera					
Chironomidae					
Procladius	0.0	0.0	0.0	0.0	0.0
Theinnemannimyia	0.0	0.0	0.0	0.0	0.0
Cricotopus	0.0	0.0	0.0	0.0	0.0
Eukiefferiella	0.0	0.0	0.0	0.0	0.0
Heterotrissocladius	0.0	0.0	0.0	0.0	0.0
Orthocladius	0.0	0.0	0.0	6.1	0.0
Orthocladius-Cricotopus	0.0	0.0	0.0	0.0	0.0
Psectrocladius	0.0	0.0	0.0	0.0	0.0
Chironomus	0.0	0.0	0.0	0.0	0.0
Paratendipes	0.0	0.0	0.0	0.0	0.0
Phaenopsectra	0.0	0.0	0.0	0.0	0.0
Polypedilum	0.0	0.0	0.0	0.0	0.0
Rheotanytarsus	0.0	0.0	0.0	0.0	0.0
Tanytarsus	0.0	0.0	0.0	0.0	0.0
unidentified Chironomidae	0.0	0.0	0.0	0.0	0.0
Chironomidae pupae	0.0	0.0	0.0	0.0	0.0
total	6512.2	4561.1	4500.1	6872.0	3957.4

Appendix 9c. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, by Replicate Sample (May 15, 1992).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Nematoda	0.0	0.0	0.0	0.0	0.0
Platyhelminthes					
Turbellaria	30.5	0.0	0.0	0.0	0.0
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	0.0	0.0	0.0	0.0
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0	0.0	0.0	0.0
unidentified Lumbriculidae	0.0	0.0	0.0	0.0	0.0
Haplotaxida					
Naididae					
Chaetogaster limnaei	0.0	0.0	0.0	0.0	0.0
Pristinella osborni	0.0	0.0	0.0	0.0	0.0
Nais communis	0.0	0.0	0.0	0.0	0.0
Nais pardalis	0.0	0.0	0.0	6.1	0.0
Nais sp.	0.0	0.0	0.0	0.0	0.0
Stylaria lacustris	0.0	0.0	0.0	0.0	0.0
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	0.0
Tubificidae					
Potamothrix moldaviensis	0.0	0.0	0.0	0.0	0.0
Potamothrix vejdovskyi	0.0	0.0	0.0	0.0	6.1
Spirosperma ferox	0.0	0.0	0.0	0.0	0.0
unidentified Tubificidae	12.2	0.0	0.0	0.0	0.0
Oligochaeta cocoons	0.0	0.0	0.0	0.0	0.0
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0	0.0	0.0	0.0
Piscicolidae					
Piscicola punctata	0.0	0.0	0.0	0.0	0.0
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	0.0	0.0	0.0	0.0	0.0
Unionidae					
Ligumia nasuta	0.0	0.0	0.0	0.0	0.0
unidentified Unionidae	0.0	0.0	0.0	0.0	0.0
Gastropoda					
Pulmonata					
Planorbidae					
Gyraulus parvus	6.1	0.0	6.1	0.0	0.0
Helisoma anceps	0.0	0.0	0.0	0.0	0.0
Physidae					
Physa heterostropha	48.8	0.0	18.3	18.3	12.2
Lymnaeidae					
Stagnicola catascopium	6.1	12.2	6.1	6.1	0.0
Prosobranchia					
Valvatidae					
Valvata tricarinata	54.9	6.1	42.7	12.2	12.2
Bithyniidae					
Bithynia tentaculata	0.0	0.0	0.0	0.0	0.0
Pleuroceridae					
Goniobasis livescens	158.5	36.6	109.8	24.4	42.7

Appendix 9c. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, by Replicate Sample (May 15, 1992).

	# individuals/square meter				
taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Prosobranchia (continued)					
Hydrobiidae					
Amnicola limosa	219.5	18.3	24.4	79.3	54.9
Arthropoda					
Crustacea					
Amphipoda					
Gammaridae					
Gammarus fasciatus	1975.6	670.7	384.2	1390.2	1262.2
Decapoda					
Cambaridae					
Orconectes propinquis	0.0	0.0	0.0	0.0	0.0
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	6.1	18.3	12.2	42.7	0.0
Lebertiidae					
Lebertia	0.0	0.0	0.0	0.0	6.1
Pionidae					
Forelia	0.0	0.0	0.0	0.0	0.0
Wettina	0.0	0.0	0.0	0.0	0.0
unidentified Acarina	0.0	0.0	0.0	6.1	0.0
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0	0.0	6.1	6.1
Heptageniidae					
Stenacron	0.0	0.0	0.0	0.0	0.0
Stenonema	0.0	6.1	0.0	12.2	0.0
unidentified Heptageniidae	0.0	0.0	0.0	6.1	0.0
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0	0.0	6.1	0.0
Leptoceridae					
Ceraclea	0.0	0.0	0.0	6.1	0.0
Polycentropidae					
Polycentropus	0.0	0.0	0.0	6.1	0.0
Trichoptera pupae	0.0	0.0	0.0	0.0	0.0
Diptera					
Chironomidae					
Procladius	0.0	0.0	0.0	0.0	0.0
Theinnemannimyia	0.0	0.0	0.0	0.0	0.0
Cricotopus	0.0	0.0	6.1	0.0	0.0
Eukiefferiella	12.2	0.0	0.0	6.1	0.0
Heterotrissocladius	0.0	0.0	0.0	0.0	0.0
Orthocladius	0.0	0.0	6.1	6.1	0.0
Orthocladius-Cricotopus	0.0	12.2	0.0	0.0	0.0
Psectrocladius	0.0	0.0	0.0	6.1	0.0
Chironomus	0.0	0.0	0.0	0.0	0.0
Paratendipes	0.0	0.0	0.0	0.0	0.0
Phaenopsectra	0.0	0.0	0.0	0.0	0.0
Polypedilum	0.0	0.0	0.0	0.0	0.0
Rheotanytarsus	0.0	0.0	0.0	0.0	0.0
Tanytarsus	0.0	0.0	0.0	0.0	0.0
unidentified Chironomidae	0.0	0.0	0.0	6.1	0.0
Chironomidae pupae	6.1	0.0	0.0	6.1	12.2
total	2536.6	780.5	616.0	1658.6	1414.7

Appendix 9d. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, by Replicate Sample (August 20, 1992).

taxon	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
	# individuals/square meter				
Nematoda	0.0	6.1	0.0	0.0	0.0
Platyhelminthes					
Turbellaria	18.3	67.1	36.6	0.0	6.1
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	0.0	0.0	0.0	0.0
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0	0.0	0.0	0.0
unidentified Lumbriculidae	0.0	0.0	0.0	0.0	0.0
Haplotaxida					
Naididae					
Chaetogaster limnaei	0.0	0.0	0.0	0.0	0.0
Pristinella osborni	0.0	0.0	0.0	0.0	0.0
Nais communis	0.0	0.0	0.0	0.0	0.0
Nais pardalis	0.0	18.3	0.0	6.1	0.0
Nais sp.	0.0	0.0	0.0	0.0	0.0
Stylaria lacustris	0.0	0.0	0.0	0.0	0.0
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	0.0
Tubificidae					
Potamothrix moldaviensis	0.0	0.0	0.0	0.0	0.0
Potamothrix vejdovskyi	0.0	0.0	12.2	0.0	0.0
Spirosperma ferox	6.1	0.0	6.1	0.0	0.0
unidentified Tubificidae	6.1	164.6	670.7	0.0	0.0
Oligochaeta cocoons	0.0	0.0	0.0	0.0	0.0
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0	0.0	0.0	24.4
Piscicolidae					
Piscicola punctata	0.0	0.0	0.0	0.0	0.0
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	0.0	0.0	0.0	0.0	0.0
Unionidae					
Ligumia nasuta	0.0	0.0	0.0	0.0	0.0
unidentified Unionidae	0.0	0.0	0.0	0.0	0.0
Gastropoda					
Pulmonata					
Planorbidae					
Gyraulus parvus	6.1	6.1	0.0	0.0	0.0
Helisoma anceps	6.1	30.5	0.0	0.0	0.0
Physidae					
Physa heterostropha	79.3	30.5	36.6	18.3	140.2
Lymnaeidae					
Stagnicola catascopium	18.3	42.7	42.7	12.2	54.9
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	6.1	6.1	0.0	0.0
Bithyniidae					
Bithynia tentaculata	6.1	0.0	0.0	0.0	0.0
Pleuroceridae					
Goniobasis livescens	103.7	128.0	189.0	103.7	182.9

Appendix 9d. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, by Replicate Sample (August 20, 1992).

taxon	# individuals/square meter				
	rep. 1	rep. 2	rep. 3	rep. 4	rep. 5
Prosobranchia (continued)					
Hydrobiidae					
Amnicola limosa	24.4	152.4	170.7	79.3	140.2
Arthropoda					
Crustacea					
Amphipoda					
Gammaridae					
Gammarus fasciatus	878.0	2213.4	1676.8	1231.7	1622.0
Decapoda					
Cambaridae					
Orconectes propinquis	0.0	0.0	6.1	0.0	0.0
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	54.9	73.2	18.3	67.1	36.6
Lebertiidae					
Lebertia	0.0	0.0	0.0	0.0	0.0
Pionidae					
Forelia	0.0	0.0	0.0	0.0	0.0
Wettina	0.0	0.0	0.0	0.0	0.0
unidentified Acarina	0.0	0.0	0.0	0.0	0.0
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0	0.0	0.0	0.0
Heptageniidae					
Stenacron	0.0	0.0	0.0	0.0	0.0
Stenonema	0.0	0.0	0.0	0.0	0.0
unidentified Heptageniidae	0.0	0.0	0.0	0.0	0.0
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0	0.0	0.0	0.0
Leptoceridae					
Ceraclea	0.0	0.0	0.0	0.0	0.0
Polycentropidae					
Polycentropus	0.0	6.1	0.0	0.0	18.3
Trichoptera pupae	0.0	0.0	0.0	0.0	0.0
Diptera					
Chironomidae					
Procladius	0.0	0.0	6.1	0.0	0.0
Theinnemannimyia	0.0	0.0	0.0	0.0	6.1
Cricotopus	0.0	0.0	0.0	0.0	0.0
Eukiefferiella	0.0	0.0	0.0	0.0	0.0
Heterotrissocladius	0.0	6.1	12.2	0.0	0.0
Orthocladius	0.0	0.0	0.0	0.0	0.0
Orthocladius-Cricotopus	0.0	0.0	0.0	0.0	0.0
Psectrocladius	0.0	0.0	0.0	0.0	0.0
Chironomus	0.0	0.0	6.1	0.0	6.1
Paratendipes	0.0	0.0	0.0	0.0	0.0
Phaenopsectra	0.0	0.0	6.1	0.0	0.0
Polypedilum	0.0	0.0	6.1	0.0	0.0
Rheotanytarsus	0.0	0.0	0.0	0.0	0.0
Tanytarsus	0.0	0.0	0.0	6.1	0.0
unidentified Chironomidae	0.0	6.1	0.0	0.0	0.0
Chironomidae pupae	0.0	0.0	6.1	0.0	0.0
total	1207.4	2957.3	2914.6	1524.5	2237.8

Appendix 10a. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (July 12, 1983 and July 12, 1991).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Nematoda	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Platyhelminthes					
Turbellaria	16.9 (2.2)	39.0 (11.5)	-0.393	4.4	> 0.50
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	13.4 (8.2)	-3.068	4.0	< 0.05*
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0			
unidentified Lumbriculidae	6.0 (4.7)	48.8 (22.4)	-2.040	7.7	< 0.10
Haplotaxida					
Enchytraeidae	0.0	0.0			
Naididae					
Chaetogaster limnaei	0.0	40.2 (12.9)	-8.745	4.0	< 0.001**
Pristinella osborni	0.0	0.0			
Nais communis	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Nais pardalis	0.0	0.0			
Nais sp.	no data	2.4 (2.2)			
Stylaria lacustris	0.0	496.3 (174.4)	-16.216	4.0	< 0.001**
Vejdovskyella intermedia	0.0	0.0			
Tubificidae					
Potamothrix moldaviensis	2.4 (2.4)	3.7 (3.3)	0.010	8.0	> 0.50
Potamothrix vejdovskyi	2.4 (1.5)	4.9 (3.2)	-0.161	7.4	> 0.50
Spirosperma ferox	0.0	22.0 (14.3)	-4.100	4.0	< 0.02*
unidentified Tubificidae	22.9 (9.8)	102.4 (51.9)	-1.790	7.2	< 0.20
Oligochaeta cocoons	no data	0.0			
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0			
Piscicolidae					
Piscicola punctata	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	41.0 (6.7)	82.9 (42.3)	0.475	4.6	> 0.50
Unionidae					
Ligumia nasuta	no data	1.2 (1.1)			
unidentified Unionidae	no data	2.4 (1.3)			
Pulmonata					
Ancylidae					
Ferrissia rivularis	0.0	0.0			
Planorbidae					
Gyraulus parvus	0.0	0.0			
Helisoma anceps	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Physidae					
Physa heterostropha	0.0	56.1 (25.1)	-7.537	4.0	<0.002**

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10a. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (July 12, 1983 and July 12, 1991).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Pulmonata (continued)					
Lymnaeidae					
Stagnicola catascopium	219.3 (48.3)	495.1 (155.8)	-1.589	6.2	< 0.20
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	4.9 (2.0)	-2.790	4.0	< 0.05*
Bithyniidae					
Bithynia tentaculata	0.0	0.0			
Pleuroceridae					
Goniobasis livescens	102.4 (13.7)	148.8 (49.7)	0.007	4.6	> 0.50
Hydrobiidae					
Amnicola limosa	0.0	332.9 (57.8)	-18.840	4.0	< 0.001**
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea racovitzai	0.0	0.0			
Amphipoda					
Gammaridae					
Gammarus fasciatus	657.8 (66.8)	335.4 (73.9)	2.221	4.6	< 0.10
Decapoda					
Cambaridae					
Orconectes propinquis	3.6 (1.5)	57.3 (15.7)	-3.181	5.9	< 0.05*
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	no data	0.0			
Lebertiidae					
Lebertia	no data	0.0			
Pionidae					
Forelia	no data	0.0			
Wettina	no data	0.0			
unidentified Acarina	no data	0.0			
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0			
Heptageniidae					
Stenacron	0.0	17.1 (12.6)	-2.914	4.0	< 0.05*
Stenonema	0.0	0.0			
unidentified Heptageniidae	no data	0.0			
Trichoptera					
Hydroptilidae					
Agraylea	0.0	12.2 (3.0)	-7.989	4.0	< 0.002**
Leptoceridae					
Ceraclea	4.8 (3.0)	11.0 (2.7)	-1.983	7.5	< 0.10
Polycentropidae					
Polycentropus	4.8 (2.2)	14.6 (3.3)	-2.420	8.0	< 0.05*
Trichoptera pupae	no data	1.2 (1.1)			

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10a. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (July 12, 1983 and July 12, 1991).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Diptera					
Chironomidae					
Procladius	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Theinnemannimyia	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Cricotopus	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Eukiefferiella	0.0	0.0			
Heterotrissocladius	0.0	0.0			
Orthocladius	2.4 (2.4)	13.4 (3.2)	-3.264	6.8	< 0.02*
Orthocladius-Cricotopus	no data	3.7 (2.2)			
Psectrocladius	1.2 (1.2)	19.5 (9.7)	-2.956	7.7	< 0.05*
Chironomus	61.4 (24.9)	0.0	11.223	4.0	< 0.001****
Endochironomus	2.4 (1.5)	0.0	2.398	4.0	< 0.10
Parachironomus	2.4 (2.4)	0.0	1.197	4.0	< 0.50
Paratendipes	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Phaenopsectra	0.0	0.0			
Polypedilum	0.0	0.0			
Micropsectra	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Paratanytarsus	0.0	0.0			
Rheotanytarsus	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Tanytarsus	1.2 (1.2)	6.1 (2.4)	-1.685	7.9	< 0.20
unidentified Chironomidae	no data	2.4 (2.2)			
Chironomidae pupae	no data	4.9 (2.0)			
corrected total	1159.0 (106.8)	2390.2 (507.6)	-1.966	6.2	< 0.10
actual total	1159.0 (106.8)	2412.4 (509.1)			

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983.
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10b. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (September 10, 1983 and September 21, 1991).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Nematoda	0.0	2.4 (1.3)	-1.789	4.0	< 0.20
Platyhelminthes					
Turbellaria	12.0 (3.3)	3.7 (2.2)	2.859	5.9	< 0.05***
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	31.7 (11.2)	-7.042	4.0	< 0.005**
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	4.9 (3.2)	-1.971	4.0	< 0.20
unidentified Lumbriculidae	3.6 (2.4)	1.2 (1.1)	1.229	8.0	< 0.50
Haplotaxida					
Enchytraeidae	0.0	0.0			
Naididae					
Chaetogaster limnaei	0.0	0.0			
Pristinella osborni	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Nais communis	0.0	0.0			
Nais pardalis	0.0	3.7 (3.3)	-1.216	4.0	< 0.50
Nais sp.	no data	0.0			
Stylaria lacustris	0.0	0.0			
Vejdovskyella intermedia	0.0	0.0			
Tubificidae					
Potamothrix moldaviensis	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Potamothrix vejdovskyi	0.0	90.2 (63.9)	-4.392	4.0	< 0.02*
Spirosperma ferox	1.2 (1.2)	12.2 (4.6)	-2.768	7.9	< 0.05*
unidentified Tubificidae	13.2 (11.8)	151.2 (88.7)	-1.618	7.7	< 0.20
Oligochaeta cocoons	no data	15.9 (8.0)			
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0			
Piscicolidae					
Piscicola punctata	0.0	0.0			
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	36.1 (9.5)	54.9 (26.6)	0.480	5.3	> 0.50
Unionidae					
Ligumia nasuta	no data	1.2 (1.1)			
unidentified Unionidae	no data	0.0			
Pulmonata					
Ancylidae					
Ferrissia rivularis	0.0	0.0			
Planorbidae					
Gyraulus parvus	0.0	11.0 (3.2)	-4.444	4.0	< 0.02*
Helisoma anceps	0.0	6.1 (3.0)	-2.831	4.0	< 0.05*
Physidae					
Physa heterostropha	7.2 (4.4)	152.4 (18.9)	-6.870	6.3	< 0.001**

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10b. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (September 10, 1983 and September 21, 1991).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Pulmonata (continued)					
Lymnaeidae					
Stagnicola catascopium	20.5 (6.2)	159.8 (29.5)	-5.138	7.8	< 0.002**
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	68.3 (21.0)	-10.239	4.0	< 0.001**
Bithyniidae					
Bithynia tentaculata	1.2 (1.2)	1.2 (1.1)	-0.102	9.0	> 0.50
Pleuroceridae					
Goniobasis livescens	104.8 (21.9)	1180.5 (200.8)	-7.011	7.1	< 0.001**
Hydrobiidae					
Amnicola limosa	3.6 (2.4)	943.9 (202.8)	-10.891	7.4	< 0.001**
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea racovitzai	0.0	0.0			
Amphipoda					
Gammaridae					
Gammarus fasciatus	232.5 (72.0)	1669.5 (253.7)	-5.519	8.0	< 0.001**
Decapoda					
Cambaridae					
Orconectes propinquis	0.0	17.1 (3.2)	-9.006	4.0	< 0.001**
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	no data	13.4 (5.6)			
Lebertiidae					
Lebertia	no data	3.7 (2.2)			
Pionidae					
Forelia	no data	0.0			
Wettina	no data	0.0			
unidentified Acarina	no data	1.2 (1.1)			
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0			
Heptageniidae					
Stenacron	6.0 (3.3)	1.2 (1.1)	2.133	8.0	< 0.10
Stenonema	6.0 (1.9)	3.7 (2.2)	1.640	6.1	< 0.20
unidentified Heptageniidae	no data	0.0			
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0			
Leptoceridae					
Ceraclea	4.8 (3.5)	2.4 (1.3)	0.721	8.0	< 0.50
Polycentropidae					
Polycentropus	21.7 (7.0)	15.9 (6.6)	1.167	6.2	< 0.50
Trichoptera pupae	no data	0.0			

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10b. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (September 10, 1983 and September 21, 1991).

	mean # individuals/square meter (std. error)		T-statistics		
taxon	1983	1991-92	T	deg. free	p-value
Diptera					
Chironomidae					
Procladius	0.0	0.0			
Theinnemannimyia	0.0	0.0			
Cricotopus	0.0	0.0			
Eukieferriella	0.0	0.0			
Heterotrissocladius	0.0	0.0			
Orthocladius	0.0	0.0			
Orthocladius-Cricotopus	no data	0.0			
Psectrocladius	0.0	0.0			
Chironomus	0.0	4.9 (2.0)	-2.790	4.0	< 0.05*
Endochironomus	0.0	0.0			
Parachironomus	0.0	0.0			
Paratendipes	0.0	0.0			
Phaenopsectra	0.0	0.0			
Polypedilum	0.0	0.0			
Micropsectra	0.0	0.0			
Paratanytarsus	0.0	0.0			
Rheotanytarsus	0.0	0.0			
Tanytarsus	0.0	0.0			
unidentified Chironomidae	no data	1.2 (1.1)			
Chironomidae pupae	no data	0.0			
corrected total	475.9 (84.5)	4595.1 (745.2)	-5.950	8.0	< 0.001**
actual total	475.9 (84.5)	4631.8 (753.1)			

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983.
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10c. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (May 11, 1983 and May 15, 1992).

	mean # individuals/square meter (std. error)		T-statistics		
taxon	1983	1991-92	T	deg. free.	p-value
Nematoda	0.0	3.7 (1.3)	-2.683	4.0	< 0.10
Platyhelminthes					
Turbellaria	12.0 (5.0)	7.3 (4.4)	1.782	6.7	< 0.20
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	3.7 (1.3)	-2.683	4.0	< 0.10
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0			
unidentified Lumbriculidae	0.0	3.7 (3.3)	-1.216	4.0	< 0.50
Haplotaxida					
Enchytraeidae	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Naididae					
Chaetogaster limnaei	0.0	3.7 (3.3)	-1.216	4.0	< 0.50
Pristinella osborni	0.0	0.0			
Nais communis	0.0	0.0			
Nais pardalis	0.0	22.0 (3.7)	-11.665	4.0	< 0.001**
Nais sp.	no data	0.0			
Stylaria lacustris	0.0	0.0			
Vejdovskyella intermedia	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Tubificidae					
Potamothrix moldaviensis	14.5 (7.8)	11.0 (5.3)	0.977	7.4	< 0.50
Potamothrix vejdovskyi	12.0 (12.0)	126.8 (59.4)	-1.507	7.6	< 0.20
Spirosperma ferox	0.0	76.8 (30.7)	-8.938	4.0	< 0.001**
unidentified Tubificidae	20.5 (14.8)	174.4 (83.1)	-3.561	7.8	< 0.01**
Oligochaeta cocoons	no data	2.4 (1.3)			
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0			
Piscicolidae					
Piscicola punctata	0.0	0.0			
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	45.8 (21.6)	20.7 (6.4)	1.439	7.4	< 0.20
Unionidae					
Ligumia nasuta	no data	1.2 (1.1)			
unidentified Unionidae	no data	0.0			
Pulmonata					
Ancylidae					
Ferrissia rivularis	0.0	0.0			
Planorbidae					
Gyraulus parvus	4.8 (4.8)	2.4 (2.2)	0.702	7.8	> 0.50
Helisoma anceps	0.0	8.5 (4.1)	-3.012	4.0	< 0.05*
Physidae					
Physa heterostropha	2.4 (1.5)	25.6 (9.2)	-2.764	7.1	< 0.05*

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10c. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (May 11, 1983 and May 15, 1992).

	mean # individuals/square meter (std. error)		T-statistics		
taxon	1983	1991-92	T	deg. free.	p-value
Pulmonata (continued)					
Lymnaeidae					
Stagnicola catascopium	0.0	8.5 (5.1)	-2.868	4.0	< 0.05*
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	14.6 (5.1)	-7.278	4.0	< 0.002**
Bithyniidae					
Bithynia tentaculata	2.4 (2.4)	4.9 (2.0)	-1.026	8.0	< 0.50
Pleuroceridae					
Goniobasis livescens	39.8 (16.9)	357.3 (34.4)	-6.051	6.4	< 0.001**
Hydrobiidae					
Amnicola limosa	0.0	107.3 (21.2)	-13.203	4.0	< 0.001**
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea racovitzai	0.0	0.0			
Amphipoda					
Gammaridae					
Gammarus fasciatus	84.3 (29.6)	218.3 (32.5)	-2.801	7.8	< 0.05*
Decapoda					
Cambaridae					
Orconectes propinquis	2.4 (1.5)	9.8 (3.3)	-1.827	7.6	< 0.20
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	no data	14.6 (3.3)			
Lebertiidae					
Lebertia	no data	0.0			
Pionidae					
Forelia	no data	1.2 (1.1)			
Wettina	no data	4.9 (3.2)			
unidentified Acarina	no data	1.2 (1.1)			
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0			
Heptageniidae					
Stenacron	1.2 (1.2)	1.2 (1.1)	-0.102	8.0	> 0.50
Stenonema	2.4 (1.5)	0.0	2.398	4.0	< 0.10
unidentified Heptageniidae	no data	0.0			
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0			
Leptoceridae					
Ceraclea	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Polycentropidae					
Polycentropus	4.8 (3.5)	2.4 (1.3)	0.721	8.0	< 0.50
Trichoptera pupae	no data	0.0			

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10c. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (May 11, 1983 and May 15, 1992).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Diptera					
Chironomidae					
Procladius	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Theinnemannimyia	0.0	0.0			
Cricotopus	0.0	0.0			
Eukieferriella	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Heterotrissocladius	0.0	0.0			
Orthocladius	7.2 (3.5)	1.2 (1.1)	2.595	7.9	< 0.05***
Orthocladius-Cricotopus	no data	9.8 (2.8)			
Psectrocladius	0.0	0.0			
Chironomus	0.0	0.0			
Endochironomus	0.0	0.0			
Parachironomus	0.0	0.0			
Paratendipes	0.0	0.0			
Phaenopsectra	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Polypedilum	0.0	0.0			
Micropsectra	2.4 (1.5)	0.0	2.398	4.0	< 0.10
Paratanytarsus	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Rheotanytarsus	0.0	0.0			
Tanytarsus	0.0	86.6 (15.9)	-15.318	4.0	< 0.001**
unidentified Chironomidae	no data	0.0			
Chironomidae pupae	no data	6.1 (1.7)			
corrected total	261.4 (90.9)	1315.8 (169.5)	-3.784	4.8	< 0.02*
actual total	261.4 (90.9)	1357.5 (168.1)			

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983.
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10d. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (August 31, 1983 and August 23, 1992).

	mean # individuals/square meter (std. error)		T-statistics		
taxon	1983	1991-92	T	deg. free.	p-value
Nematoda	1.2 (1.2)	6.1 (4.2)	-1.053	7.7	< 0.50
Platyhelminthes					
Turbellaria	12.0 (5.7)	29.3 (11.1)	-0.768	7.0	< 0.50
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	7.3 (4.0)	-2.853	4.0	< 0.05*
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0			
unidentified Lumbriculidae	1.2 (1.2)	28.0 (23.8)	-1.382	7.1	<0.50
Haplotaxida					
Enchytraeidae	0.0	0.0			
Naididae					
Chaetogaster limnaei	0.0	0.0			
Pristinella osborni	0.0	4.9 (4.4)	-1.272	4.0	< 0.50
Nais communis	0.0	0.0			
Nais pardalis	0.0	0.0			
Nais sp.	no data	0.0			
Stylaria lacustris	0.0	4.9 (4.4)	-1.272	4.0	< 0.50
Vejdovskyella intermedia	0.0	0.0			
Tubificidae					
Potamothrix moldaviensis	4.8 (2.2)	13.4 (10.7)	0.408	6.4	> 0.50
Potamothrix vejdovskyi	1.2 (1.2)	91.5 (51.7)	-2.171	6.5	< 0.10
Spirosperma ferox	0.0	68.3 (20.9)	-8.348	4.0	< 0.002**
unidentified Tubificidae	19.3 (4.8)	1130.5 (702.4)	-5.486	5.4	< 0.005**
Oligochaeta cocoons	no data	62.2 (20.7)			
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0			
Piscicolidae					
Piscicola punctata	0.0	0.0			
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	57.8 (9.8)	74.4 (22.2)	-0.378	5.8	> 0.50
Unionidae					
Ligumia nasuta	no data	0.0			
unidentified Unionidae	no data	0.0			
Pulmonata					
Ancylidae					
Ferrissia rivularis	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Planorbidae					
Gyraulus parvus	6.0 (3.8)	11.0 (3.2)	-1.590	7.4	< 0.20
Helisoma anceps	0.0	59.8 (9.7)	-13.726	4.0	< 0.001**
Physidae					
Physa heterostropha	8.4 (1.5)	645.1 (36.8)	-19.101	8.0	< 0.001**

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10d. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (August 31, 1983 and August 23, 1992).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Pulmonata (continued)					
Lymnaeidae					
Stagnicola catascopium	6.0 (3.3)	150.0 (15.4)	-7.801	6.1	< 0.001**
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	25.6 (9.7)	-7.728	4.0	< 0.002**
Bithyniidae					
Bithynia tentaculata	0.0	7.3 (5.3)	-2.040	4.0	< 0.20
Pleuroceridae					
Goniobasis livescens	25.3 (10.5)	276.8 (30.4)	-6.230	7.2	< 0.001**
Hydrobiidae					
Amnicola limosa	1.2 (1.2)	135.4 (27.0)	-8.424	7.4	< 0.001**
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea racovitzai	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Amphipoda					
Gammaridae					
Gammarus fasciatus	357.8 (66.6)	2095.1 (134.2)	-7.476	8.0	< 0.001**
Decapoda					
Cambaridae					
Orconectes propinquis	1.2 (1.2)	32.9 (6.8)	-5.695	7.5	< 0.001**
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	no data	25.6 (6.3)			
Lebertiidae					
Lebertia	no data	1.2 (1.1)			
Pionidae					
Forelia	no data	0.0			
Wettina	no data	0.0			
unidentified Acarina	no data	2.4 (1.3)			
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0			
Heptageniidae					
Stenacron	1.2 (1.2)	1.2 (1.1)	-0.102	8.0	> 0.50
Stenonema	6.0 (3.3)	0.0	4.067	4.0	< 0.02*
unidentified Heptageniidae	no data	0.0			
Trichoptera					
Hydroptilidae					
Agraylea	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Leptoceridae					
Ceraclea	0.0	0.0			
Polycentropidae					
Polycentropus	10.8 (4.8)	3.7 (2.2)	2.139	7.3	< 0.10
Trichoptera pupae	no data	0.0			

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 10d. Native Benthic Macroinvertebrate Abundance Estimates at the Cobble Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (August 31, 1983 and August 23, 1992).

	mean # individuals/square meter (std. error)		T-statistics		
taxon	1983	1991-92	T	deg. free.	p-value
Diptera					
Chironomidae					
Procladius	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Theinnemannimyia	0.0	2.4 (2.2)	-1.136	4.0	< 0.50
Cricotopus	0.0	0.0			
Eukiefferiella	0.0	0.0			
Heterotrissocladius	1.2 (1.2)	12.2 (3.9)	-2.821	7.9	< 0.05*
Orthocladius	0.0	0.0			
Orthocladius-Cricotopus	no data	0.0			
Psectrocladius	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Chironomus	0.0	43.9 (8.5)	-13.347	4.0	<0.001**
Endochironomus	0.0	0.0			
Parachironomus	0.0	0.0			
Paratendipes	1.2 (1.2)	2.4 (2.2)	-0.294	8.0	> 0.50
Phaenopsectra	0.0	0.0			
Polypedilum	0.0	0.0			
Micropsectra	0.0	0.0			
Paratanytarsus	0.0	0.0			
Rheotanytarsus	0.0	0.0			
Tanytarsus	3.6 (3.6)	3.7 (2.2)	-0.116	7.9	> 0.50
unidentified Chironomidae	no data	3.7 (2.2)			
Chironomidae pupae	no data	8.5 (2.8)			
corrected total	531.3 (64.2)	4970.7 (924.3)	-6.572	7.9	< 0.001**
actual total	531.3 (64.2)	5074.6 (941.1)			

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983.
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11a. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (July 12, 1983 and July 12, 1991).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Nematoda	0.0	0.0			
Platyhelminthes					
Turbellaria	1.2 (1.2)	97.6 (10.8)	-8.786	4.3	< 0.001**
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	0.0			
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0			
unidentified Lumbriculidae	0.0	0.0			
Haplotaxida					
Enchytraeidae	0.0	0.0			
Naididae					
Chaetogaster limnaei	0.0	29.0 (10.9)	-6.661	3.0	< 0.01**
Pristinella osborni	0.0	0.0			
Nais communis	0.0	4.6 (2.5)	-2.111	3.0	< 0.20
Nais pardalis	0.0	0.0			
Nais sp.	no data	7.6 (3.3)			
Stylaria lacustris	0.0	88.4 (46.7)	-4.689	3.0	< 0.02*
Vejdovskyella intermedia	0.0	0.0			
Tubificidae					
Potamothrix moldaviensis	0.0	0.0			
Potamothrix vejdovskyi	0.0	0.0			
Spirosperma ferox	0.0	0.0			
unidentified Tubificidae	0.0	0.0			
Oligochaeta cocoons	no data	0.0			
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0			
Piscicolidae					
Piscicola punctata	0.0	0.0			
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	1.2 (1.2)	0.0	0.780	3.0	< 0.50
Unionidae					
Ligumia nasuta	no data	0.0			
unidentified Unionidae	no data	0.0			
Pulmonata					
Ancylidae					
Ferrissia rivularis	0.0	0.0			
Planorbidae					
Gyraulus parvus	0.0	0.0			
Helisoma anceps	0.0	1.5 (1.3)	-1.064	3.0	< 0.50
Physidae					
Physa heterostropha	1.2 (1.2)	108.2 (33.2)	-6.977	5.9	< 0.001**

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11a. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (July 12, 1983 and July 12, 1991).

	mean # individuals/square meter (std. error)		T-statistics		
taxon	1983	1991-92	T	deg. free.	p-value
Pulmonata (continued)					
Lymnaeidae					
Stagnicola catascopium	9.6 (8.2)	175.3 (43.7)	-5.224	5.1	< 0.005**
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	0.0			
Bithyniidae					
Bithynia tentaculata	3.6 (3.6)	1.5 (1.3)	0.478	5.7	> 0.50
Pleuroceridae					
Goniobasis livescens	162.6 (27.8)	96.0 (19.3)	1.523	4.9	< 0.50
Hydrobiidae					
Amnicola limosa	0.0	144.8 (66.8)	-9.723	3.0	< 0.005**
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea racovitzai	0.0	0.0			
Amphipoda	–				
Gammaridae					
Gammarus fasciatus	669.9 (195.5)	1714.9 (341.4)	-2.554	6.0	< 0.05*
Decapoda					
Cambaridae					
Orconectes propinquis	2.4 (2.4)	6.1 (2.2)	-1.462	5.9	< 0.50
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	no data	0.0			
Lebertiidae					
Lebertia	no data	0.0			
Pionidae					
Forelia	no data	0.0			
Wettina	no data	0.0			
unidentified Acarina	no data	0.0			
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0			
Heptageniidae					
Stenacron	0.0	0.0			
Stenonema	0.0	0.0			
unidentified Heptageniidae	no data	0.0			
Trichoptera					
Hydroptilidae					
Agraylea	0.0	13.7 (5.4)	-3.787	3.0	< 0.05*
Leptoceridae					
Ceraclea	2.4 (1.5)	1.5 (1.3)	0.668	5.9	> 0.50
Polycentropidae					
Polycentropus	0.0	21.3 (5.1)	-7.577	3.0	< 0.005**
Trichoptera pupae	no data	1.5 (1.3)			

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11a. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (July 12, 1983 and July 12, 1991).

	mean # individuals/square meter (std. error)		T-statistics		
taxon	1983	1991-92	T	deg. free	p-value
Diptera					
Chironomidae					
Procladius	0.0	0.0			
Theinnemannimyia	0.0	0.0			
Cricotopus	9.6 (4.3)	1.5 (1.3)	2.725	5.8	< 0.05***
Eukiefferiella	0.0	0.0			
Heterotrissocladius	0.0	0.0			
Orthocladius	3.6 (2.4)	1.5 (1.3)	0.979	6.0	< 0.50
Orthocladius-Cricotopus	no data	0.0			
Psectrocladius	0.0	3.0 (2.6)	-1.220	3.0	< 0.50
Chironomus	6.0 (6.0)	0.0	2.116	3.0	< 0.20
Endochironomus	1.2 (1.2)	0.0	0.780	3.0	< 0.50
Parachironomus	1.2 (1.2)	0.0	0.780	3.0	< 0.50
Paratendipes	0.0	0.0			
Phaenopsectra	0.0	0.0			
Polypedilum	0.0	0.0			
Micropsectra	0.0	0.0			
Paratanytarsus	0.0	0.0			
Rheotanytarsus	0.0	0.0			
Tanytarsus	1.2 (1.2)	0.0	0.780	3.0	< 0.50
unidentified Chironomidae	no data	0.0			
Chironomidae pupae	no data	1.5 (1.3)			
corrected total	878.3 (194.4)	2510.7 (326.7)	-3.224	5.9	< 0.05*
actual total	878.3 (194.4)	2521.5 (325.3)			

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983.
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11b. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (September 10, 1983 and September 21, 1991).

taxon	mean # individuals/square meter 1983	1991-92	T-statistics T	deg. free.	p-value
Nematoda	0.0	0.0			
Platyhelminthes					
Turbellaria	7.2 (3.5)	24.4 (13.9)	-0.943	7.0	< 0.50
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	2.4 (1.3)	-1.789	4.0	< 0.20
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0			
unidentified Lumbriculidae	0.0	0.0			
Haplotaxida					
Enchytraeidae	0.0	0.0			
Naididae					
Chaetogaster limnaei	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Pristinella osborni	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Nais communis	0.0	2.4 (2.2)	-1.136	4.0	< 0.50
Nais pardalis	0.0	0.0			
Nais sp.	no data	1.2 (1.1)			
Stylaria lacustris	0.0	3.7 (3.3)	-1.216	4.0	< 0.50
Vejdovskyella intermedia	0.0	0.0			
Tubificidae					
Potamothrix moldaviensis	0.0	0.0			
Potamothrix vejdovskyi	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Spirosperma ferox	0.0	0.0			
unidentified Tubificidae	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Oligochaeta cocoons	no data	0.0			
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Piscicolidae					
Piscicola punctata	0.0	0.0			
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	0.0	0.0			
Unionidae					
Ligumia nasuta	no data	0.0			
unidentified Unionidae	no data	0.0			
Pulmonata					
Ancylidae					
Ferrissia rivularis	0.0	0.0			
Planorbidae					
Gyraulus parvus	1.2 (1.2)	4.9 (2.7)	-1.060	7.8	< 0.50
Helisoma anceps	0.0	6.1 (1.7)	-4.034	4.0	< 0.02*
Physidae					
Physa heterostropha	60.2 (27.5)	112.2 (12.5)	-2.121	6.6	< 0.10

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11b. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (September 10, 1983 and September 21, 1991).

taxon	mean # individuals/square meter 1983	1991-92	T-statistics T	deg. free	p-value
Pulmonata (continued)					
Lymnaeidae					
Stagnicola catascopium	71.1 (22.0)	20.7 (5.1)	2.756	8.0	< 0.05***
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	4.9 (1.1)	-3.960	4.0	< 0.02*
Bithyniidae					
Bithynia tentaculata	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Pleuroceridae					
Goniobasis livescens	179.5 (65.3)	461.0 (133.0)	-2.347	8.0	< 0.05*
Hydrobiidae					
Amnicola limosa	0.0	648.8 (80.9)	-25.402	4.0	< 0.001**
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea racovitzai	0.0	0.0			
Amphipoda					
Gammaridae					
Gammarus fasciatus	1543.4 (517.2)	3865.8 (374.9)	-3.089	7.1	< 0.02*
Decapoda					
Cambaridae					
Orconectes propinquis	0.0	0.0			
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	no data	9.8 (5.6)			
Lebertiidae					
Lebertia	no data	1.2 (1.1)			
Pionidae					
Forelia	no data	0.0			
Wettina	no data	0.0			
unidentified Acarina	no data	0.0			
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0			
Heptageniidae					
Stenacron	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Stenonema	0.0	9.8 (1.3)	-9.460	4.0	< 0.001**
unidentified Heptageniidae	no data	1.2 (1.1)			
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0			
Leptoceridae					
Ceraclea	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Polycentropidae					
Polycentropus	2.4 (2.4)	85.4 (18.2)	-6.400	6.6	< 0.001**
Trichoptera pupae	no data	0.0			

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11b. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (September 10, 1983 and September 21, 1991).

	mean # individuals/square meter		T-statistics		
taxon	1983	1991-92	T	deg. free.	p-value
Diptera					
Chironomidae					
Procladius	0.0	0.0			
Theinnemannimyia	0.0	0.0			
Cricotopus	0.0	0.0			
Eukiefferiella	0.0	0.0			
Heterotrissocladius	0.0	0.0			
Orthocladius	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Orthocladius-Cricotopus	no data	0.0			
Psectrocladius	0.0	0.0			
Chironomus	0.0	0.0			
Endochironomus	0.0	0.0			
Parachironomus	0.0	0.0			
Paratendipes	0.0	0.0			
Phaenopsectra	0.0	0.0			
Polypedilum	0.0	0.0			
Micropsectra	0.0	0.0			
Paratanytarsus	0.0	0.0			
Rheotanytarsus	0.0	0.0			
Tanytarsus	0.0	0.0			
unidentified Chironomidae	no data	0.0			
Chironomidae pupae	no data	0.0			
corrected total	1866.3 (577.4)	5267.1 (522.8)	-3.372	7.1	< 0.02*
actual total	1866.3 (577.4)	5280.6 (526.4)			

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983.
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11c. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (May 11, 1983 and May 15, 1992).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Nematoda	0.0	0.0			
Platyhelminthes					
Turbellaria	1.2 (1.2)	6.1 (5.5)	-0.528	7.7	> 0.50
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	0.0			
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0			
unidentified Lumbriculidae	0.0	0.0			
Haplotaxida					
Enchytraeidae	0.0	0.0			
Naididae					
Chaetogaster limnaei	0.0	0.0			
Pristinella osborni	0.0	0.0			
Nais communis	0.0	0.0			
Nais pardalis	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Nais sp.	no data	0.0			
Stylaria lacustris	0.0	0.0			
Vejdovskyella intermedia	0.0	0.0			
Tubificidae					
Potamothrix moldaviensis	0.0	0.0			
Potamothrix vejdovskyi	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Spirosperma ferox	0.0	0.0			
unidentified Tubificidae	0.0	2.4 (2.2)	-1.136	4.0	< 0.50
Oligochaeta cocoons	no data	0.0			
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	0.0			
Piscicolidae					
Piscicola punctata	0.0	0.0			
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	4.8 (4.8)	0.0	1.860	4.0	< 0.20
Unionidae					
Ligumia nasuta	no data	0.0			
unidentified Unionidae	no data	0.0			
Pulmonata					
Ancylidae					
Ferrissia rivularis	0.0	0.0			
Planorbidae					
Gyraulus parvus	6.0 (6.0)	2.4 (1.3)	0.553	7.6	> 0.50
Helisoma anceps	0.0	0.0			
Physidae					
Physa heterostropha	2.4 (2.4)	19.5 (7.2)	-2.628	8.0	< 0.05*

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11c. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (May 11, 1983 and May 15, 1992).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free	p-value
Pulmonata (continued)					
Lymnaeidae					
Stagnicola catascopium	9.6 (6.2)	6.1 (1.7)	0.278	8.0	> 0.50
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	25.6 (8.7)	-7.529	4.0	< 0.002**
Bithyniidae					
Bithynia tentaculata	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Pleuroceridae					
Goniobasis livescens	19.3 (12.3)	74.4 (23.0)	-2.707	7.7	< 0.05*
Hydrobiidae					
Amnicola limosa	0.0	79.3 (32.9)	-9.600	4.0	< 0.001**
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea racovitzai	0.0	0.0			
Amphipoda					
Gammaridae					
Gammarus fasciatus	44.6 (43.1)	1136.6 (250.4)	-5.798	6.4	< 0.002*
Decapoda					
Cambaridae					
Orconectes propinquis	0.0	0.0			
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	no data	15.9 (6.6)			
Lebertiidae					
Lebertia	no data	0.0			
Pionidae					
Forelia	no data	0.0			
Wettina	no data	0.0			
unidentified Acarina	no data	1.2 (1.1)			
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	2.4 (1.3)	-1.789	4.0	< 0.20
Heptageniidae					
Stenacron	4.8 (4.8)	0.0	1.860	4.0	< 0.20
Stenonema	1.2 (1.2)	3.7 (2.2)	-0.900	7.9	< 0.50
unidentified Heptageniidae	no data	1.2 (1.1)			
Trichoptera					
Hydroptilidae					
Agraylea	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Leptoceridae					
Ceraclea	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Polycentropidae					
Polycentropus	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Trichoptera pupae	no data	0.0			

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11c. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month, but a Different Year (May 11, 1983 and May 15, 1992).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T	T-statistics deg. free	p-value
Diptera					
Chironomidae					
Procladius	0.0	0.0			
Theinnemannimyia	0.0	0.0			
Cricotopus	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Eukiefferiella	0.0	3.7 (2.2)	-1.911	4.0	< 0.20
Heterotrissocladius	0.0	0.0			
Orthocladius	10.8 (8.0)	2.4 (1.3)	1.657	7.9	< 0.20
Orthocladius-Cricotopus	no data	2.4 (2.2)			
Psectrocladius	7.2 (7.2)	1.2 (1.1)	1.341	7.2	< 0.50
Chironomus	0.0	0.0			
Endochironomus	0.0	0.0			
Parachironomus	0.0	0.0			
Paratendipes	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Phaenopsectra	0.0	0.0			
Polypedilum	0.0	0.0			
Micropsectra	0.0	0.0			
Paratanytarsus	0.0	0.0			
Rheotanytarsus	0.0	0.0			
Tanytarsus	12.0 (12.0)	0.0	3.011	4.0	< 0.05***
unidentified Chironomidae	no data	1.2 (1.1)			
Chironomidae pupae	no data	4.9 (2.0)			
corrected total	126.5 (41.7)	1373.2 (306.9)	-4.691	6.4	< 0.005**
actual total	126.5 (41.7)	1401.3 (307.1)			

corrected total = actual total - abundance estimates estimates of taxa having "no data" obtained in 1983.
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11d. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month but a Different Year (August 31, 1983 and August 20, 1992).

	mean # individuals/square meter (std. error)		T-statistics		
taxon	1983	1991-92	T	deg. free	p-value
Nematoda	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Platyhelminthes					
Turbellaria	6.0 (2.7)	25.6 (10.8)	-1.387	6.6	< 0.50
Annelida					
Polychaeta					
Sabellidae					
Manayunkia speciosa	0.0	0.0			
Oligochaeta					
Lumbriculida					
Lumbriculidae					
Lumbriculus variegatus	0.0	0.0			
unidentified Lumbriculidae	0.0	0.0			
Haplotaxida					
Enchytraeidae	0.0	0.0			
Naididae					
Chaetogaster limnaei	0.0	0.0			
Pristinella osborni	0.0	0.0			
Nais communis	0.0	0.0			
Nais pardalis	0.0	4.9 (3.2)	-1.971	4.0	< 0.20
Nais sp.	no data	0.0			
Stylaria lacustris	0.0	0.0			
Vejdovskyella intermedia	0.0	0.0			
Tubificidae					
Potamothrix moldaviensis	0.0	0.0			
Potamothrix vejdovskyi	0.0	2.4 (2.2)	-1.136	4.0	< 0.50
Spirosperma ferox	0.0	2.4 (1.3)	-1.789	4.0	< 0.20
unidentified Tubificidae	0.0	168.3 (115.8)	-3.722	4.0	< 0.05*
Oligochaeta cocoons	no data	0.0			
Hirudinea					
Rhynchobdellida					
Glossiphoniidae					
Desserobdella phalera	0.0	4.9 (4.4)	-1.272	4.0	< 0.50
Piscicolidae					
Piscicola punctata	0.0	0.0			
Mollusca					
Bivalvia					
Sphaeriidae					
Musculium partumeium	1.2 (1.2)	0.0	0.780	4.0	< 0.50
Unionidae					
Ligumia nasuta	no data	0.0			
unidentified Unionidae	no data	0.0			
Gastropoda					
Pulmonata					
Ancylidae					
Ferrissia rivularis	0.0	0.0			
Planorbidae					
Gyraulus parvus	0.0	2.4 (1.3)	-1.789	4.0	< 0.20
Helisoma anceps	0.0	7.3 (5.3)	-2.040	4.0	< 0.20
Physidae					
Physa heterostropha	91.6 (12.8)	61.0 (20.0)	1.523	5.0	< 0.20

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11d. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month but a Different Year (August 31, 1983 and August 20, 1992).

	mean # individuals/square meter (std. error)			T-statistics	
taxon	1983	1991-92	T	deg. free.	p-value
Pulmonata (continued)					
Lymnaeidae					
Stagnicola catascopium	19.3 (12.4)	34.1 (7.2)	-1.656	7.3	< 0.20
Prosobranchia					
Valvatidae					
Valvata tricarinata	0.0	2.4 (1.3)	-1.789	4.0	< 0.20
Bithyniidae					
Bithynia tentaculata	1.2 (1.2)	1.2 (1.1)	-0.102	8.0	> 0.50
Pleuroceridae					
Goniobasis livescens	83.1 (22.2)	141.5 (16.8)	-1.918	8.0	< 0.10
Hydrobiidae					
Amnicola limosa	2.4 (2.4)	113.4 (24.2)	-6.314	7.4	< 0.001**
Arthropoda					
Crustacea					
Isopoda					
Asellidae					
Caecidotea racovitzai	0.0	0.0			
Amphipoda					
Gammaridae					
Gammarus fasciatus	669.9 (225.8)	1524.4 (201.1)	-2.559	7.8	< 0.05*
Decapoda					
Cambaridae					
Orconectes propinquis	1.2 (1.2)	1.2 (1.1)	-0.102	8.0	> 0.50
Arachnoidea					
Acarina					
Hygrobatidae					
Hygrobates	no data	50.0 (9.0)			
Lebertiidae					
Lebertia	no data	0.0			
Pionidae					
Forelia	no data	0.0			
Wettina	no data	0.0			
unidentified Acarina	no data	0.0			
Insecta					
Ephemeroptera					
Ephemerellidae					
Eurylophella	0.0	0.0			
Heptageniidae					
Stenacron	0.0	0.0			
Stenonema	3.6 (3.6)	0.0	1.559	4.0	< 0.20
unidentified Heptageniidae	no data	0.0			
Trichoptera					
Hydroptilidae					
Agraylea	0.0	0.0			
Leptoceridae					
Ceraclea	0.0	0.0			
Polycentropidae					
Polycentropus	0.0	4.9 (3.2)	-1.971	4.0	< 0.20
Trichoptera pupae	no data	0.0			

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 11d. Native Benthic Macroinvertebrate Abundance Estimates at the Artificial Reef Site, with T-statistics from Comparisons of Data Obtained During the Same Month but a Different Year (August 31, 1983 and August 20, 1992).

taxon	mean # individuals/square meter (std. error) 1983	1991-92	T-statistics T	deg. free.	p-value
Diptera					
Chironomidae					
Procladius	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Theinnemannimyia	0.0	1.2 (1.1)	-0.990	4.0	< 0.50
Cricotopus	0.0	0.0			
Eukieferriella	0.0	0.0			
Heterotrissocladius	2.4 (1.5)	3.7 (2.2)	-0.040	7.5	> 0.50
Orthocladius	0.0	0.0			
Orthocladius-Cricotopus	no data	0.0			
Psectrocladius	0.0	0.0			
Chironomus	0.0	2.4 (1.3)	-1.789	4.0	< 0.20
Endochironomus	0.0	0.0			
Parachironomus	0.0	0.0			
Paratendipes	0.0	0.0			
Phaenopsectra	0.0	1.2 (1.1)	-0.990	4.0	> 0.50
Polypedilum	0.0	1.2 (1.1)	-0.990	4.0	> 0.50
Micropsectra	0.0	0.0			
Paratanytarsus	0.0	0.0			
Rheotanytarsus	0.0	0.0			
Tanytarsus	0.0	1.2 (1.1)	-0.990	4.0	> 0.50
unidentified Chironomidae	no data	1.2 (1.1)			
Chironomidae pupae	no data	1.2 (1.1)			
corrected total	881.9 (250.5)	2115.8 (319.4)	-2.567	8.0	< 0.05*
actual total	881.9 (250.5)	2168.3 (317.6)			

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983.
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92.
**significantly more abundant (99% CI) in 1991-92.
***significantly more abundant (95% CI) in 1983.
****significantly more abundant (99% CI) in 1983.

Appendix 12. Abundance Estimates of Native Benthic Macroinvertebrate Taxa at the Cobble Site, by Sampling Date, 1983 and 1991-92

mean # individuals/square meter (standard error in parentheses)

taxon	7/12/83	7/12/91	9/10/83	9/21/91	5/11/83	5/15/92	8/31/83	8/20/92
Nematoda	0.0	3.7 (2.2)	0.0	2.4 (1.3)	0.0	3.7 (1.3)	1.2 (1.2)	6.1 (4.2)
Platyhelminthes								
Turbellaria	16.9 (2.2)	39.0 (11.5)	12.0 (3.3)***	3.7 (2.2)	12.0 (5.0)	7.3 (4.4)	12.0 (5.7)	29.3 (11.1)
Annelida								
Polychaeta								
Sabellidae								
Manayunkia speciosa	0.0	13.4 (8.2)*	0.0	31.7 (11.2)**	0.0	3.7 (1.3)	0.0	7.3 (4.0)*
Oligochaeta								
Lumbriculida								
Lumbriculidae								
Lumbriculus variegatus	0.0	0.0	0.0	4.9 (3.2)	0.0	0.0	0.0	0.0
unidentified Lumbriculidae	6.0 (4.7)	48.8 (22.4)	3.6 (2.4)	1.2 (1.1)	0.0	3.7 (3.3)	1.2 (1.2)	28.0 (23.8)
Haplotaxida								
Enchytraeidae	0.0	0.0	0.0	0.0	1.2 (1.2)	0.0	0.0	0.0
Naididae								
Chaetogaster limnaei	0.0	40.2 (12.9)**	0.0	0.0	0.0	3.7 (3.3)	0.0	0.0
Pristinella osborni	0.0	0.0	0.0	1.2 (1.1)	0.0	0.0	0.0	4.9 (4.4)
Nais communis	0.0	1.2 (1.1)	0.0	0.0	0.0	0.0	0.0	0.0
Nais pardalis	0.0	0.0	0.0	3.7 (3.3)	0.0	22.0 (3.7)**	0.0	0.0
Nais sp	no data	2.4 (2.2)	no data	0.0	no data	0.0	no data	0.0
Stylaria lacustris	0.0	496.3 (174.4)**	0.0	0.0	0.0	0.0	0.0	4.9 (4.4)
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	0.0	3.7 (2.2)	0.0	0.0
Tubificidae								
Potamothrix moldaviensis	2.4 (2.4)	3.7 (3.3)	1.2 (1.2)	0.0	14.5 (7.8)	11.0 (5.3)	4.5 (2.2)	13.4 (10.7)
Potamothrix vejdovskyi	2.4 (1.5)	4.9 (3.2)	0.0	90.2 (63.9)*	12.0 (12.0)	126.8 (59.4)	1.2 (1.2)	91.5 (51.7)
Spirosperma ferox	0.0	22.0 (14.3)*	1.2 (1.2)	12.2 (4.6)*	0.0	76.8 (30.7)**	0.0	68.3 (20.9)**
unidentified Tubificidae	22.9 (9.8)	102.4 (51.9)	13.2 (11.8)	151.2 (88.7)	20.5 (14.8)	174.4 (83.1)**	19.3 (4.8)	1130.5 (702.4)**
Oligochaeta cocoons	no data	0.0	no data	15.9 (8.0)	no data	2.4 (1.3)	no data	62.2 (20.7)
Hirudinea								
Rhynchobdellida								
Glossiphoniidae								
Desserobdella phalera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Piscicolidae								
Piscicola punctata	0.0	1.2 (1.1)	0.0	0.0	0.0	0.0	0.0	0.0
Mollusca								
Bivalvia								
Sphaeriidae								
Musculium partumeium	41.0 (6.7)	82.9 (42.3)	36.1 (9.5)	54.9 (26.6)	45.8 (21.6)	20.7 (6.4)	57.8 (9.8)	74.4 (22.2)
Unionidae								
Ligumia nasuta	no data	1.2 (1.1)	no data	1.2 (1.1)	no data	1.2 (1.1)	no data	0.0
unidentified Unionidae	no data	2.4 (1.3)	no data	0.0	no data	0.0	no data	0.0
Gastropoda								
Pulmonata								
Ancylidae								
Ferrissia rivularis	0.0	0.0	0.0	0.0	0.0	0.0	1.2 (1.2)	0.0
Planorbidae								
Gyraulus parvus	0.0	0.0	0.0	11.0 (3.2)*	4.8 (4.8)	2.4 (2.2)	6.0 (3.8)	11.0 (3.2)
Helisoma anceps	0.0	1.2 (1.1)	0.0	6.1 (3.0)*	0.0	8.5 (4.1)*	0.0	59.8 (9.7)**
Physidae								
Physa heterostropha	0.0	56.1 (25.1)**	7.2 (4.4)	152.4 (18.9)**	2.4 (1.5)	25.6 (9.2)*	8.4 (1.5)	645.1 (36.8)**
Lymnaeidae								
Stagnicola catascopium	219.3 (18.3)	495.1 (155.8)	20.5 (6.2)	159.8 (29.5)**	0.0	8.5 (5.1)*	6.0 (3.3)	150.0 (15.4)**
Prosobranchia								
Valvatidae								
Valvata tricarinata	0.0	4.9 (2.0)*	0.0	68.3 (21.0)**	0.0	14.6 (5.1)**	0.0	25.6 (9.7)**
Bithyniidae								
Bithynia tentaculata	0.0	0.0	1.2 (1.2)	1.2 (1.1)	2.4 (2.4)	4.9 (2.0)	0.0	7.3 (5.3)
Pleuroceridae								
Goniobasis livescens	102.4 (13.7)	148.8 (49.7)	104.8 (21.9)	1180.5 (200.8)**	39.8 (16.9)	357.3 (34.4)**	25.3 (10.5)	276.8 (30.4)**
Hydrobiidae								
Amnicola limosa	0.0	332.9 (57.8)**	3.6 (2.4)	943.9 (202.8)**	0.0	107.3 (21.2)**	1.2 (1.2)	135.4 (27.0)**

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983.
*significantly more abundant (95% CI) in 1991-92 than on a date from the same month in 1983.
**significantly more abundant (99% CI) in 1991-92 than on a date from the same month in 1983.
***significantly more abundant (95% CI) in 1983 than on a date from the same month in 1991-92.
****significantly more abundant (99% CI) in 1983 than on a date from the same month in 1991-92.

Appendix 12. Abundance Estimates of Native Benthic Macroinvertebrate Taxa at the Cobble Site, by Sampling Date, 1983 and 1991-92

mean # individuals/square meter (standard error in parentheses)

taxon	7/12/83	7/12/91	9/10/83	9/21/91	5/11/83	5/15/92	8/31/83	8/20/92
Arthropoda								
Crustacea								
Isopoda								
Asellidae								
Caecidotea racovitzai	0.0	0.0	0.0	0.0	0.0	0.0	1.2 (1.2)	0.0
Amphipoda								
Gammaridae								
Gammarus fasciatus	657.8 (66.8)	335.4 (73.9)	232.5 (72.0)	1669.5 (253.7)**	84.3 (29.6)	218.3 (32.5)*	357.8 (66.6)	2095.1 (134.2)**
Decapoda								
Cambaridae								
Orconectes propinquus	3.6 (1.5)	57.3 (15.7)*	0.0	17.1 (3.2)**	2.4 (1.5)	9.8 (3.3)	1.2 (1.2)	32.9 (6.8)**
Arachnoidea								
Acarina								
Hygrobatidae								
Hygrobates	no data	0.0	no data	13.4 (5.6)	no data	14.6 (3.3)	no data	25.6 (6.3)
Lebertiidae								
Lebertia	no data	0.0	no data	3.7 (2.2)	no data	0.0	no data	1.2 (1.1)
Pionidae								
Forelia	no data	0.0	no data	0.0	no data	1.2 (1.1)	no data	0.0
Wettina	no data	0.0	no data	0.0	no data	4.9 (3.2)	no data	0.0
unidentified Acarina	no data	0.0	no data	1.2 (1.1)	no data	1.2 (1.1)	no data	2.4 (1.3)
Insecta								
Ephemeroptera								
Ephemerellidae								
Eurylophella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heptageniidae								
Stenacron	0.0	17.1 (12.6)*	6.0 (3.3)	1.2 (1.1)	1.2 (1.2)	1.2 (1.1)	1.2 (1.2)	1.2 (1.1)
Stenonema	0.0	0.0	6.0 (1.9)	3.7 (2.2)	2.4 (1.5)	0.0	6.0 (3.3)***	0.0
unidentified Heptageniidae	no data	0.0	no data	0.0	no data	0.0	no data	0.0
Trichoptera								
Hydroptilidae								
Agraylea	0.0	12.2 (3.0)**	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)
Leptoceridae								
Ceraclea	4.8 (3.0)	11.0 (2.7)	4.8 (3.5)	2.4 (1.3)	0.0	1.2 (1.1)	0.0	0.0
Polycentropodidae								
Polycentropus	4.8 (2.2)	14.6 (3.3)*	21.7 (7.0)	15.9 (6.6)	4.8 (3.5)	2.4 (1.3)	10.8 (4.8)	3.7 (2.2)
Trichoptera pupae	no data	1.2 (1.1)	no data	0.0	no data	0.0	no data	0.0
Diptera								
Chironomidae								
Procladius	1.2 (1.2)	0.0	0.0	0.0	0.0	3.7 (2.2)	0.0	1.2 (1.1)
Thienemannimyia	0.0	3.7 (2.2)	0.0	0.0	0.0	0.0	0.0	2.4 (2.2)
Cricotopus	1.2 (1.2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eukiefferiella	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)	0.0	0.0
Heterotrissocladius	0.0	0.0	0.0	0.0	0.0	0.0	1.2 (1.2)	12.2 (3.9)*
Orthocladius	2.4 (2.4)	13.4 (3.2)*	0.0	0.0	7.2 (3.5)***	1.2 (1.1)	0.0	0.0
Orthocladius-Cricotopus	no data	3.7 (2.2)	no data	0.0	no data	9.8 (2.8)	no data	0.0
Psectrocladius	1.2 (1.2)	19.5 (9.7)*	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)
Chironomus	61.4 (24.9)****	0.0	0.0	4.9 (2.0)*	0.0	0.0	0.0	43.9 (8.5)**
Endochironomus	2.4 (1.5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parachironomus	2.4 (2.4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paratendipes	0.0	3.7 (2.2)	0.0	0.0	0.0	0.0	1.2 (1.2)	2.4 (2.2)
Phaenopsectra	0.0	0.0	0.0	0.0	0.0	3.7 (2.2)	0.0	0.0
Polypedilum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Micropsectra	1.2 (1.2)	0.0	0.0	0.0	2.4 (1.5)	0.0	0.0	0.0
Paratanytarsus	0.0	0.0	0.0	0.0	1.2 (1.2)	0.0	0.0	0.0
Rheotanytarsus	0.0	1.2 (1.1)	0.0	0.0	0.0	0.0	0.0	0.0
Tanytarsus	1.2 (1.2)	6.1 (2.4)	0.0	0.0	0.0	86.6 (15.9)**	3.6 (3.6)	3.7 (2.2)
unidentified Chironomidae	no data	2.4 (2.2)	no data	1.2 (1.1)	no data	0.0	no data	3.7 (2.2)
Chironomidae pupae	no data	4.9 (2.0)	no data	0.0	no data	6.1 (1.7)	no data	8.5 (2.5)
corrected total	1159.0 (106.8)	2390.2 (507.6)	475.9 (84.5)	4595.1 (745.2)**	261.4 (90.9)	1315.8 (169.5)*	531.3 (64.2)	4970.7 (924.3)**
actual total	1159.0 (106.8)	2412.4 (509.1)	475.9 (84.5)	4631.8 (753.1)	261.4 (90.9)	1357.5 (168.1)	531.3 (64.2)	5074.6 (941.1)

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983
*significantly more abundant (95% CI) in 1991-92 than on a date from the same month in 1983
**significantly more abundant (99% CI) in 1991-92 than on a date from the same month in 1983
***significantly more abundant (95% CI) in 1983 than on a date from the same month in 1991-92
****significantly more abundant (99% CI) in 1983 than on a date from the same month in 1991-92

Appendix 13. Abundance Estimates of Native Benthic Macroinvertebrate Taxa at the Artificial Reef Site, by Sampling Date, 1983 and 1991-92

mean # individuals/square meter (standard error in parentheses)

taxon	7/12/83	7/12/91	9/10/83	9/21/91	5/11/83	5/15/92	8/31/83	8/20/92
Nematoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)
Platyhelminthes								
Turbellaria	1.2 (1.2)	97.6 (10.8)**	7.2 (3.5)	24.4 (13.9)	1.2 (1.2)	6.1 (5.5)	6.0 (2.7)	25.6 (10.8)
Annelida								
Polychaeta								
Sabellidae								
Manayunkia speciosa	0.0	0.0	0.0	2.4 (1.3)	0.0	0.0	0.0	0.0
Oligochaeta								
Lumbriculida								
Lumbriculidae								
Lumbriculus variegatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
unidentified Lumbriculidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Haplotaxida								
Enchytraeidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naididae								
Chaetogaster limnaei	0.0	29.0 (10.9)**	0.0	1.2 (1.1)	0.0	0.0	0.0	0.0
Pristinella osborni	0.0	0.0	0.0	1.2 (1.1)	0.0	0.0	0.0	0.0
Nais communis	0.0	4.6 (2.5)	0.0	2.4 (2.2)	0.0	0.0	0.0	0.0
Nais pardalis	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)	0.0	4.9 (3.2)
Nais sp	no data	7.6 (3.3)	no data	1.2 (1.1)	no data	0.0	no data	0.0
Stylaria lacustris	0.0	88.4 (46.7)*	0.0	3.7 (3.3)	0.0	0.0	0.0	0.0
Vejdovskyella intermedia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tubificidae								
Potamothrix moldaviensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Potamothrix vejdovskyi	0.0	0.0	0.0	1.2 (1.1)	0.0	1.2 (1.1)	0.0	2.4 (2.2)
Spirosperma ferox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4 (1.3)
unidentified Tubificidae	0.0	0.0	0.0	3.7 (2.2)	0.0	2.4 (2.2)	0.0	168.3 (115.8)*
Oligochaeta cocoons	no data	0.0	no data	0.0	no data	0.0	no data	0.0
Hirudinea								
Rhynchobdellida								
Glossiphoniidae								
Desserobdella phalera	0.0	0.0	0.0	1.2 (1.1)	0.0	0.0	0.0	4.9 (4.4)
Piscicolidae								
Piscicola punctata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mollusca								
Bivalvia								
Sphaeriidae								
Musculium partumeium	1.2 (1.2)	0.0	0.0	0.0	4.8 (4.8)	0.0	1.2 (1.2)	0.0
Unionidae								
Ligumia nasuta	no data	0.0	no data	0.0	no data	0.0	no data	0.0
unidentified Unionidae	no data	0.0	no data	0.0	no data	0.0	no data	0.0
Gastropoda								
Pulmonata								
Ancylidae								
Ferrissia rivularis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planorbidae								
Gyraulus parvus	0.0	0.0	1.2 (1.2)	4.9 (2.7)	6.0 (6.0)	2.4 (1.3)	0.0	2.4 (1.3)
Helisoma anceps	0.0	1.5 (1.3)	0.0	6.1 (1.7)*	0.0	0.0	0.0	7.3 (5.3)
Physidae								
Physa heterostropha	1.2 (1.2)	108.2 (33.2)**	60.2 (27.5)	112.2 (12.5)	2.4 (2.4)	19.5 (7.2)*	91.6 (12.8)	61.0 (20.0)
Lymnaeidae								
Stagnicola catascopium	9.6 (8.2)	175.3 (43.7)**	71.1 (22.0)***	20.7 (5.1)	9.6 (6.2)	6.1 (1.7)	19.3 (12.4)	34.1 (7.2)
Prosobranchia								
Valvatidae								
Valvata tricarinata	0.0	0.0	0.0	4.9 (1.1)*	0.0	25.6 (8.7)**	0.0	2.4 (1.3)
Bithyniidae								
Bithynia tentaculata	3.6 (3.6)	1.5 (1.3)	0.0	1.2 (1.1)	1.2 (1.2)	0.0	1.2 (1.2)	1.2 (1.1)
Pleuroceridae								
Goniobasis livescens	162.6 (27.8)	96.0 (19.3)	179.5 (65.3)	461.0 (133.0)*	19.3 (12.3)	74.4 (23.0)*	83.1 (22.2)	141.5 (16.8)
Hydrobiidae								
Amnicola limosa	0.0	144.8 (66.8)**	0.0	648.8 (80.9)**	0.0	79.3 (32.9)**	2.4 (2.4)	113.4 (24.2)**

Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983
*significantly more abundant (95% CI) in 1991-92 than on a date from the same month in 1983
**significantly more abundant (99% CI) in 1991-92 than on a date from the same month in 1983
***significantly more abundant (95% CI) in 1983 than on a date from the same month in 1991-92
****significantly more abundant (99% CI) in 1983 than on a date from the same month in 1991-92

Appendix 13. Abundance Estimates of Native Benthic Macroinvertebrate Taxa at the Artificial Reef Site, by Sampling Date, 1983 and 1991-92

mean # individuals/square meter (standard error in parentheses)

taxon	7/12/83	7/12/91	9/10/83	9/21/91	5/11/83	5/15/92	8/31/83	8/20/92
Arthropoda								
Crustacea								
Isopoda								
Asellidae								
Caecidotea racovitzai	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda								
Gammaridae								
Gammarus fasciatus	669.9 (195.5)	1714.9 (341.4)*	1543.4 (517.2)	3865.8 (374.9)*	44.6 (43.1)	1136.6 (250.4)*	669.9 (225.8)	1524.4 (201.1)*
Decapoda								
Cambaridae								
Orconectes propinquus	2.4 (2.4)	6.1 (2.2)	0.0	0.0	0.0	0.0	1.2 (1.2)	1.2 (1.1)
Arachnoidea								
Acarina								
Hygrobatidae								
Hygrobates	no data	0.0	no data	9.8 (5.6)	no data	15.9 (6.6)	no data	50.0 (9.0)
Lebertiidae								
Lebertia	no data	0.0	no data	1.2 (1.1)	no data	0.0	no data	0.0
Pionidae								
Forelia	no data	0.0	no data	0.0	no data	0.0	no data	0.0
Wettina	no data	0.0	no data	0.0	no data	0.0	no data	0.0
unidentified Acarina	no data	0.0	no data	0.0	no data	1.2 (1.1)	no data	0.0
Insecta								
Ephemeroptera								
Ephemerellidae								
Eurylophella	0.0	0.0	0.0	0.0	0.0	2.4 (1.3)	0.0	0.0
Heptageniidae								
Stenacron	0.0	0.0	0.0	3.7 (2.2)	4.8 (4.8)	0.0	0.0	0.0
Stenonema	0.0	0.0	0.0	9.8 (1.3)**	1.2 (1.2)	3.7 (2.2)	3.6 (3.6)	0.0
unidentified Heptageniidae	no data	0.0	no data	1.2 (1.1)	no data	1.2 (1.1)	no data	0.0
Trichoptera								
Hydroptilidae								
Agraylea	0.0	13.7 (5.4)*	0.0	0.0	0.0	1.2 (1.1)	0.0	0.0
Leptoceridae								
Ceraclea	2.4 (1.5)	1.5 (1.3)	1.2 (1.2)	0.0	0.0	1.2 (1.1)	0.0	0.0
Polycentropodidae								
Polycentropus	0.0	21.3 (5.1)**	2.4 (2.4)	85.4 (18.2)**	0.0	1.2 (1.1)	0.0	4.9 (3.2)
Trichoptera pupae	no data	1.5 (1.3)	no data	0.0	no data	0.0	no data	0.0
Diptera								
Chironomidae								
Procladius	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)
Thienemannimyia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)
Cricotopus	9.6 (4.3)***	1.5 (1.3)	0.0	0.0	0.0	1.2 (1.1)	0.0	0.0
Eukiefferiella	0.0	0.0	0.0	0.0	0.0	3.7 (2.2)	0.0	0.0
Heterotrissocladius	0.0	0.0	0.0	0.0	0.0	0.0	2.4 (1.5)	3.7 (2.2)
Orthocladius	3.6 (2.4)	1.5 (1.3)	0.0	1.2 (1.1)	10.8 (8.0)	2.4 (1.3)	0.0	0.0
Orthocladius-Cricotopus	no data	0.0	no data	0.0	no data	2.4 (2.2)	no data	0.0
Psectrocladius	0.0	3.0 (2.6)	0.0	0.0	7.2 (7.2)	1.2 (1.1)	0.0	0.0
Chironomus	6.0 (6.0)	0.0	0.0	0.0	0.0	0.0	0.0	2.4 (1.3)
Endochironomus	1.2 (1.2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parachironomus	1.2 (1.2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paratendipes	0.0	0.0	0.0	0.0	1.2 (1.2)	0.0	0.0	0.0
Phaenopsectra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)
Polypedilum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2 (1.1)
Micropsectra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paratanytarsus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rheotanytarsus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tanytarsus	1.2 (1.2)	0.0	0.0	0.0	12.0 (12.0)***	0.0	0.0	1.2 (1.1)
unidentified Chironomidae	no data	0.0	no data	0.0	no data	1.2 (1.1)	no data	1.2 (1.1)
Chironomidae pupae	no data	1.5 (1.3)	no data	0.0	no data	4.9 (2.0)	no data	1.2 (1.1)
corrected total	878.3 (194.4)	2510.7 (326.7)*	1866.3 (577.4)	5267.1 (522.8)*	126.5 (41.2)	1373.2 (306.9)**	881.9 (250.5)	2115.8 (319.4)*
actual total	878.3 (194.4)	2521.5 (325.3)	1866.3 (577.4)	5280.6 (526.4)	126.5 (41.2)	1401.3 (307.1)	881.9 (250.5)	2168.3 (317.6)

corrected total = actual total - abundance estimates of taxa having "no data" obtained in 1983
Abundance estimates were not compared statistically if "no data" were obtained for that particular taxon in 1983
*significantly more abundant (95% CI) in 1991-92 than on a date from the same month in 1983
**significantly more abundant (99% CI) in 1991-92 than on a date from the same month in 1983
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Appendix 14. Morisita's Native Benthic Macroinvertebrate Community Similarity (Cobble and Artificial Reef Sites), 1983 and 1991-92.

	Morisita's Index value by month			
community comparison	July	September	May	August
cobble (1983) and cobble (1991-92)	0.503	0.877	0.725	0.828
cobble (1983) and reef (1983)	0.916	0.861	0.863	0.972
cobble (1991-92) and reef (1991-92)	0.422	0.782	0.377	0.843
reef (1983) and reef (1991-92)	0.964	0.980	0.698	0.986

1983 sampling dates (5/11, 7/12, 9/10, 8/31).
1991-92 sampling dates (7/12/91, 9/21/91, 5/15/92, 8/20/92-8/23/92).

Appendix 15. Native Benthic Macroinvertebrate Species Richness at Cobble and Artificial Reef Sites, 1983 and 1991-92.

cobble site

month	1983	# taxa/0.82 square meter 1991-92
July	21	31
September	16	26
May	18	30
August	22	31

artificial reef site

month	1983	# taxa/0.82 square meter 1991-92
July	15	18*
September	8	22
May	14	20
August	11	25

*# taxa/0.66 square meter.
1983 sampling dates (5/11, 7/12, 9/10, 8/31).
1991-92 sampling dates (7/12/91, 9/21/91, 5/15/92, 8/20/92-8/23/92).

Appendix 16. Simpson's Diversity of Native Benthic Macroinvertebrate Communities (Cobble and Artificial Reef Sites), 1983 and 1991-92.

cobble site

Simpson's Diversity Index value

month	1983	1991-92
July	0.629	0.866
September	0.702	0.755
May	0.829	0.856
August	0.527	0.748

artificial reef site

Simpson's Diversity Index value

month	1983	1991-92
July	0.382	0.519
September	0.304	0.437
May	0.827	0.308
August	0.403	0.466

1983 sampling dates (5/11, 7/12, 9/10, 8/31).
1991-92 sampling dates (7/12/91, 9/21/91, 5/15/92, 8/20/92-8/23/92).