Macrobenthic Invertebrate Fauna From the Nearshore Waters of Central Lake Erie 1987/1995

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Introduction:

Over the past century the Great Lakes have undergone dramatic changes in water quality, chemistry, flora, and fauna. The eutrophication rate of Lake Erie was greatly accelerated between the years of 1900 and 1961 through human activities. These impacts resulted in a change of the benthic community (Schloesser et al.1995). More specifically, there were increased numbers of oligochaetes, chironomids, Sphaeriidae (fingernail clams), and Gastropoda while subsequently there was a substantial decrease of pollution-sensitive species. Most notably, declines of the burrowing mayfly *Hexagenia* were correlated with annual oxygen depletion (anoxia), increased turbidity, and increased sedimentation. By the early 1980's increased legislation, regulation, and management dramatically improved the water chemistry and biota of the Great Lakes (Stoermer et al. 1996). Reductions in phosphorous loadings, industrial point-source pollution, and improved domestic sewage treatment all contributed to the reversal of these trends (Krieger and Ross 1993). Through aggressive pollution abatement programs the Great Lakes were beginning to show signs of recovery.

Historically, the distribution, composition, and abundance of benthic communities have been considered to be excellent tools for assessing trophic trends in aquatic systems. Benthic fauna form stable aggregations that integrate and reflect environmental/biological conditions over long periods of time (Johnson and Brinkhurst 1971, Nalepa 1987). Changes in the benthic community may be reflected in the presence or absence of indicator species, species associations, and relative abundance. In the Great Lakes, long-term changes in the benthic fauna have been examined in the past for Lake Michigan (Robertson and Alley 1966, Nalepa 1987, Nalepa et al. 1998) and Lake Ontario (Stewart and Haynes 1994). In Lake Erie, studies of benthic fauna have been concentrated in the western basin (Carr and Hiltunen 1965, MaCall and Soster 1990). Limited research has been done in the central (Krieger 1984) and eastern basin (Dermott and Kerec 1995). Overall, the post-zebra mussel central basin of Lake Erie has been neglected except for investigations into the benthic changes within the Cleveland Harbor area (Krieger and Ross 1993)

In the past ten years, only two extensive sets of benthic invertebrate samples have been obtained in the nearshore waters of the central basin of Lake Erie in Ohio. One set was collected by the staff of the United States Geological Service (USGS)/Biological Resources Division (BRD), Sandusky, Ohio, in 1987, prior to the invasion of zebra and quagga mussels (*Dreissena* spp.). These collections were analyzed by Dr. Kenneth Krieger. The second set of samples was also collected in 1995 by BRD from the same sites as the 1987 samples, but analysis has awaited funding and available expertise.

Several major changes since 1987 in the ecology of Lake Erie's central basin are known or suspected, including phosphorous reductions, improvement in water/sediment quality, and large-scale invasion by *Dreissena* spp.. All of these may have lead to consequent changes in total benthic community composition. Unless such changes are documented, it will be impossible to interpret accurately later changes that will inevitably occur and to understand their consequences throughout the Lake Erie food web. Thus, insight into possible benthic community changes will permit further research into Lake Erie food web dynamics and future benthic trends.

Methods:

Collection of 1995 Central Basin (Lake Erie) Benthic Invertebrates

Samples were collected for the months of May through October 1995 by the staff of the Lake Erie Biological Station (Biological Resources Division, United States Geological Service) Sandusky, Ohio aboard the R/V Musky. Sites selected for analysis were Lorain 9.1 m (30ft), 12.2 m (40ft), Huron 9.1 m (30ft), and 12.2 m (40ft), Cleveland 12.2 m (40ft), and Fairport Harbor 9.1 m (30 ft), 12.2 m (40ft). Three separate samples (three repetitions) were collected from each site with a 23cm-by-23cm (0.53 m^2) Ponar sampler (Eaton et al. 1995). Samples were slightly rinsed and transferred into 1 quart wide mouth jars. The samples were preserved with a 10 % Formalin/Rose Bengal solution.

Laboratory Analysis of 1995 Central Basin (Lake Erie) Benthic Invertebrates

Two (repetition one and two) of the three collected samples were selected (a total of 171 samples) for laboratory analysis. The contents of the 1 quart jars were transferred into Tucker brand 2.0 L plastic lidded containers (24cm x 16 cm x 6 cm) which acted as both rinse trays and sorting pans. The containers were customized by cutting out the lid and fitting with U.S. Standard # 40 mesh stainless steel bolting cloth (secured to the lid with Permatex silicon sealant). The bottom of the sorting pan was marked/sectioned into 24 (4 cm x 4 cm) counting squares. With the lid securely in place, the samples were gently washed (with cold tap water) until the water ran clear and the organisms were easily distinguished from the sediment. Organisms were then picked from the sediment (using magnified lights/dissecting scopes 10X), sorted into major taxons: (Oligochaeta, Chironomidae, Sphaerridae, etc.), and stored in 16 ml screw top vials containing A.G.W. preservative (an aqueous 85% alcohol. 5% glycerin solution).

Samples were then transferred to 60 mm x 15 mm petri dishes for initial taxonomy and enumeration under dissecting scopes. When appropriate, sub-sampling of specimens was done. All specimens were enumerated for estimation of abundance. For this report we identified organisms to Order or to lowest practical taxa (as a result of time constraints).

Six major (most numerous) taxa were selected for 1995 monthly comparisons and for comparison with the 1987 data. ANOVA comparisons (using mean (n = 2) abundances) of Oligochaeta, Chironomidae, Sphaeriidae, Gastropoda, and Dreissena spp. were done for 1987 and 1995 using SPSS statistical software.

Results:

1995 Macroinvertebrate Fauna:

Of the eight sampling sites in 1995 the two most similar appear to be Huron and Cleveland 12 meter samples (tables 1 through 4 present the data collected on the samples from 1995). Our notes taken during the initial washing of the samples (to separate organisms from media) indicate that both sites have a mainly silty clay base with little sand or gravel. The dominant fauna at these sites were oligochaetes and chironomids which prefer this sediment type. At both sites the oligochaete numbers peaked in July (Figures 1&2), while the chironomids remained relatively constant over the sampling period (Figures 1&2). There were no samples taken at Cleveland at the 9 meter depth so no comparisons could be made. However, the chironomids and the oligochaetes (9&12m samples) at Huron showed very similar population patterns in 1995 (Figure 1).

The Lorain and Fairport Harbor samples showed much more variation in populations of oligochaetes and chironomids over the sampling period. Both when compared to each other and when comparing the 9 meter and 12 meter samples at each location (Figures 3&4). In the Lorain samples, the chironomid population steadily increased from May through September at the 12 meter level; while the 9 meter population peaked in July. The oligochaetes at the 9 meter depth had maximum populations in May and July dropping off to the lowest population in October (Figure 3). At the 12 meter depth the oligochaetes showed more variation (Figure 3).

In figure 4, Fairport Harbor, 9 and 12 meter chironomids peaked in June and were the dominant fauna. However, the 9 meter oligochaete populations appeared to peak in September while the 12 meter oligochaetes peaked in July (Figure 4). Again, our notes (taken during initial separation) show that both Lorain and Fairport Harbor areas seem to have a substrate of sand, gravel, and silt. Although, the Fairport Harbor site seemed to be more sandy than Lorain. When we look at the data on total organisms per sq. meter in figure 5 (ignoring *Dreissena* spp.) at the 12 meter level, the populations at Huron and Cleveland peak in July. The 9 meter samples peak in June at both Fairport and Lorain and after a minimum in August, the population at Lorain reached a maximum in October (Figure 6). If we look at the total number of taxa identified

(Figure 7) there is a wide variation between sample dates and sites. The Fairport and Lorain locations exhibit similar population patterns through September. The Cleveland and Huron sites exhibit little similarity over the sampling period (Figure 7).

A comparison of Sphaeriidae and *Dreissena* spp. (both prescence and numbers) showed inconclusive evidence for relationships or competition for benthic substrate (Figures 8-15). For example, at Lorain (12 m) in June there were 30,136 *Dreissena* spp. and by September there were none. While Fairport Harbor produced a low of 29 individuals in August with a population size of 29,246 in September.

1987/1995 Macroinvertebrate Comparisons:

Huron 9.1 meter: Overall, there were higher mean abundances of oligochaetes in 1987 than there were in 1995 except in July and August. During 1987 and 1995 their numbers were highest in early summer and late fall while they were lowest for 1987 in August and 1995 in September (Table 5). Chironomid larvae were also more abundant in 1987 than they were in 1995 except in July and August. Both years display highest numbers of chironomids in spring and fall while the lowest numbers were seen in the month of August (Table 5). Sphaeriidae were much more abundant in 1995 than in 1987. Both years had high abundances in July and low numbers in August respectively. Gastropods were not present in any samples taken in 1987 and were very sparse in 1995. The exotic *Dreissena* spp. were seen in only low numbers during spring and early summer. The 1987 total mean abundances of selected macroinvertebrates were higher in numbers than 1995 samples for every month except July and August (Figure 16).

Huron 12.2 meter: 1987 oligochaetes consistently had higher densities except in the month of July when 1995 densities peaked. 1987 densities were highest in October (Table 5). Chironomid numbers were also generally higher in 1987 than 1995 until there was a drastic decline in numbers in August. Sphaeriidae numbers were higher in 1995 than in 1987 also displaying peaks in July. *Dreissena* spp. were seen in low numbers in May and June of 1995. The 1987 total mean abundances of selected macroinvertebrates were higher in numbers than 1995 samples for every month except July and August when oligochaetes and Sphaeriidae numbers peaked (Figure 16).

Lorain 9.1 meter: Oligochaete densities remained almost the same for both years. The highest values for both years were in July and August while the lowest numbers were in October (Table 6). Monthly chironomid densities in 1987 were lower than in 1995 except for the month of July when both had high numbers. 1987 sphaeriids were generally higher in abundance than in 1995 (Table 6). Gastropoda had high numbers in the spring and lowest numbers in the fall. *Dreissena* spp. displayed highest densities in the spring and late summer (Table 6). 1995 estimates of total numbers of selected organisms were more productive for two (July and October) out of the four comparable sites (Figure 17).

Lorain 12.2 meter: Oligochaete densities were larger in 1987 than 1995 for all comparable months. Both years revealed the largest populations occurred in the month of August. 1987 chironomid populations were higher for all months except August. 1987 sphaeriid densities were higher than 1995 during every month except October. Gastropods were more common 1995 samples. Zebra and Quagga mussels had peak abundances in June (Table 6). 1987 total numbers were consistently higher than 1995 densities (Figure 17).

Cleveland 12.2 meter: During June and July 1995, oligochaetes were more abundant than in 1987. Conversely, the month of August had higher 1987 estimates. In 1987 peak densities were reached in August while 1995 peaks were obtained in July (Table 7). Sphaeriidae population estimates were always larger for 1987 than 1995. The largest numbers of these organisms were seen in July during both years. Gastropod showed their highest numbers in August while Zebra and Quagga mussel populations displayed wide fluctuations. During June and July of 1995 there were very high numbers of oligochaetes and chironomids which resulted in higher (than 1987) total densities (Figure 18).

Fairport Harbor 9.1 meter: Investigation revealed a drastic difference in oligochaete numbers between the years of 1987 and 1995. The former reaching densities upwards of 23,000 individuals/m^2, while the later had slightly above 1,000 individuals/m^2. 1987 densities were highest in August while 1995 densities were highest in September (Table 8). Similarly, chironomids diplayed these same extreme differences but, both years had peak abundances in June. Sphaeriidae were very common during every month in 1987 (reaching densities of 2,679 individuals/m^2) while they were completely absent in 1995 (Table 8). During 1987 gastropod numbers were lowest in the spring and highest during late summer. Exotic mussel populations were present in the spring and revealed a large population by fall. There were dramatic differences seen in total numbers of macroinvertebrates between the years (Figure 19).

Fairport Harbor 12.2 meter: The oligochaetes at 12.2 m did not have the high density estimates of the 9.1 m worms. The 1987 12.2 meter data revealed larger estimates than in 1995 for every month except July. Highest values were seen in July and October (Table 8). Chironomid numbers for both years were high in June. During the 1987 season there was a very large number of chironomids seen again in October. 12.2 meter Sphaeriidae follow trends that are very similar to the 9.1 meter clams. They have very high (3,560 individuals/m^2) and stable populations throughout 1987 while in 1995 they are absent except for very low numbers in June. Gastropods are seen throughout 1987 but have largest numbers in the fall. While during 1995 gastropods are not present until August. Zebra and Quagga mussels are present in every 1995 sample and show their largest numbers in the fall months (Table 8). In 1987 there was a considerable difference between depth and numbers of macroinvertebrates. 1987 yielded higher numbers of organisms for every month except July (Figure 19).

Statistical Differences: There was a significant difference (p = .029) between 1987 Sphaeriidae abundances and 1995 Sphaeriidae abundances. While there is some indication of significant differences between Gastropoda and site and Oligochaete and year (Table 9).

Discussion:

1995 Macoinvertebrate Fauna:

Although the data and figures indicate differences between the 9 and 12 meter samples at all locations and differences between the locations (e.g. Huron and Lorain), one must be careful not to draw too much significance when comparing the sample sites with each other.

The data gathered in 1995 indicates no relationship between the presence of *Dreissena* spp. (in a sample) and the presence or absence of other taxa. These data do indicate that the four locations (Huron, Lorain, Cleveland, and Fairport Harbor) represent different benthic communities and microhabitats. In general, these data do show monthly changes in populations and community structure at both the 9 and 12 meter contours with similarities between the four locations. They also indicate that the 9 and 12 meter depths are different habitats.

The Lorain sites have a slightly greater variety of organisms throughout the sampling period (Table 2). The lack of samples from Cleveland at the 9 meter depth and the month of October seriously limits this location for comparative purposes (Table 3).

From our observations of the samples (before sorting) it was evident that there were severe differences between the replicates of many samples. For example, replicate one may have been full of *Dreissena* spp. shells while replicate two had very few. Furthermore, observations of the replicate jars showed differences in the amounts and composition of the benthic substrate (sand, silt, clay, and gravel), probably due to on site sample washing.

The relationship between the prescence and absence of benthic organisms and their distribution in a habitat is based upon their preferences and limits of tolerances. The data we have been given on sample site location is not accurate enough to locate the exact position of sample collection. Some samples, over the sampling period, seem to not be from the same location (month to month sampling). It is known that sediment distribution along the nearshore waters of Lake Erie is not regular, and often bears no relationship to depth contour. This sediment distribution is rather the effect of nearshore currents and/or inputs from the rivers of the southern shore. These physical and/or chemical parameters may well be the cause of the distribution differences in the fauna collected in 1995.

1987/1995 Macroinvertebrate Comparisons:

In general, 1987 sites yielded higher populations of all selected taxa. The only exceptions were Cleveland (June and July) and Huron (July and August) (Figures 16-19). These trends may be the result of changes in Lake Erie's trophic (pollution abatement, etc.) status which occurred between sampling years. Lake Erie in the past was known as a highly eutrophic system but now is considered mesotrophic. Huron's July and August 1987 macroinvertebrate densities may have been suppressed as a result of lowered oxygen levels (also possible anoxic conditions) known to effect Lake Erie during this period. Similarly, Cleveland macroinvertebrate fauna may have been reduced as a result of the same trends. The lack of a 9 meter sample (in 1995) precludes further comparisons between the two years.

Both oligochaetes and chironomid larvae at all sample sites were usually more abundant during 1987 than 1995. The only exceptions for oligochaetes was Lorain (July 9.1 m), Cleveland (July), Huron (July 9.1m / 12.2 m and August 9.1 m), and Fairport Harbor (July 12.2 m). The only exceptions for chironomids were Huron (July 9.1 m, and August 9.1 m / 12.2 m), Lorain (June 9.1 m, July 12.2 m, and August 9.1 m / 12.2 m), Cleveland (June and July), Fairport Harbor (July 12.2 m, August 12.2 m, and October 9.1 m / 12.2 m). Higher abundances of oligochaetes and chironomids in the spring and fall of 1987 may be further evidence of a more eutrophic environment or, it may be attributed to differing species compositions and/or seasonal influences. Fairport Harbor is the only site which consistently (across all taxa) shows a decline (from 1987 to 1995) in abundances of macroinvertebrates. These data may be a reflection of site location sediment changes. Thus, the Fairport Harbor site sediments may have changed from a silty to a more sandy composition (via. shore erosion, current deposition, etc.) during 1987-1995. These factors may become better understood upon our future investigation into detailed species composition and water chemistry data.

Sphaeriidae numbers seem to be on an average (across sampling sites) higher in 1987 than in 1995 (potentially due to changes in the sediments). The most dramatic declines were seen at Fairport Harbor where very high numbers of *Dreissena polymorpha* were seen in September and October of 1995. Only Huron seems to have a larger population of sphaeriids in 1995 than in 1987. Interestingly, *Dreissena* spp. were very rare at this site. Observed differences between sphaeriid and *Dreissena* spp. distributions may be due to substrate changes from a more silt based sediment to a more gravel based substrate.

Zebra mussels are also known to cause major energy and ecological shifts from pelagic to benthic zones through increases in sedimentation rates, organic matter (feces/pseudofeces), and interstitial habitat (Klerks 1996, Nalepa et al. 1996, Stewart et al. 1998). All of these factors have been shown to cause an increase in the total densities of sediment suspension feeding benthic invertebrates (Stewart and Haynes 1994, Burlakova 1995, Dermott and Kerec 1995). These data (1995) do not indicate any dramatic increases in selected taxa associated with *Dreissena* spp.. Past investigation has attributed dramatic declines of native unionid bivalves, *Diporeia* (burrowing Amphipoda), and certain oligochaetes to zebra mussel infestations (Schloesser and Nalepa 1994, Dermott and Kerec 1995, Nalepa et al. 1996, Ricciardi et al. 1996). Our data seems to suggest that native sphaeriid populations have changed from 1987 to 1995 but, direct evidence for interspecific competition and/or Lake Erie trophic changes is uncertain. Thus, more detailed and long term research into central basin benthic macroinvertebrate trends is needed.

Identification of all major fauna from 1995 to species may give further insight into community structure and dynamics at the sample locations. We are continuing to identify the major groups to species level if possible. Furthermore, size frequency distributions of zebra mussels (which may have be insightful in discerning year classes, recruitment, and population ecology) will be done. This information will be forthcoming in June of 2000 as a Master's Thesis.

Summary Conclusions:

1. Differences in communities appears to be more habitat than location orientated (Huron, Lorain, Cleveland, and Fairport Harbor), as indicated by 9 and 12 meter sampling.
2. Both Sphaeriidae and *Dreissena* spp. populations appear to have changed between 1987 and 1995.

3. Distribution and changes of 1987 and 1995 Sphaeriidae and *Dreissena* spp. populations appear to be substrate orientated.

4. Collection location data does not give exact locations or substrate type.

5. All substrate data is qualitatively based upon washed samples and laboratory observation.

6. The continued analysis of 1995 samples to species level (when possible) may further clarify the distributions and trends of central basin macroinvertebrate fauna.

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Table 1: 1995 mean monthly densities (no. m^{2}) of gross taxa at 9.1m and 12.2m depths at Huron sites.

	May		June		July		August		September		October		
	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	
Planaria													
Hydridae													
Nematoda	230	153	172	67	354	268	421	268		57	574	239	
Branchiura	67	38	153	67	153	38	57	96	38	29	48	38	
Oligochaeta	3043	4173	1646	3962	4986	8824	1235	2603	1014	1656	1455	1053	
Hirudinea					38		77			10		10	
Isopoda													
Amphipoda			10	19	10						191	19	
Chironomidae	957	1177	651	1053	727	909	249	766	507	967	900	1330	
Trichoptera		10	10		10	10			29	57		67	
Ostracoda	144	29	1474	345	718	48	48		10	67	230	431	
Dreissena	29	29	19		10								
Quagga													
Sphaeriidae	555	871	737	890	804	1531	622	1120	440	794	861	1139	
Gastropoda	10				10							19	
													Total
Total	5034	6479	4871	6402	7819	11628	2708	4852	2038	3637	4259	4345	64071
Total w/o Zeb	5005	6450	4852	6402	7809	11628	2708	4852	2038	3637	4259	4345	63985
Total taxa	8	8	9	7	11	7	7	5	6	8	7	10	11

Table 2: 1995 mean monthly densities (no. m^2) of gross taxa at 9.1m and 12.2m depths at Lorain sites.

	May		June		July		August		September		October		
	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	
Planaria					10								
Hydridae		10	373	19			498						
Nematoda	29	517		115	297	191	19	124		38	10	172	
Branchiura	10					144		77		67		10	
Oligochaeta	3723	1493	1369	2134	3885	1397	3024	2268	1043	335	479	842	
Hirudinea	10		77	67	153	134	115	124	86	38	10	77	
Isopoda				105									
Amphipoda	153	19	268	258	48	19	29	19	38			48	
Chironomidae	172	38	335	345	488	785	124	1292	67	182	29	651	
Trichoptera	96				10		38	10	19		10	29	
Ostracoda	115			459	86	86	86	459				124	
Dreissena	2546	325	115	23112	239	19	1081	191			19	10	
Quagga	1866	325	823	7024	10		718	10			48		
Sphaeriidae		10	10	48	124	144	10	268		105		306	
Gastropoda	766	144	38	48	29	10	124	19	10		19	19	
													Total
Total	9484	2881	3407	33734	5378	2928	5866	4862	1263	766	622	2287	73478
Total w/o Zeb	5072	2230	2469	3598	5130	2909	4067	4661	1263	766	555	2278	34997
Total taxa	11	9	9	12	12	10	12	12	6	6	8	11	15

Table 3: 1995 mean monthly densities (no. m^2) of gross taxa at 9.1m and 12.2m depths at Cleveland sites.

	May		June		July		August		September		October		
	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	Total
Planaria	N/S*		N/S		N/S		N/S		N/S		N/S	N/S	
Hydridae	N/S		N/S	10	N/S		N/S		N/S		N/S	N/S	
Nematoda	N/S	459	N/S	392	N/S	86	N/S	77	N/S	172	N/S	N/S	
Branchiura	N/S		N/S		N/S		N/S		N/S		N/S	N/S	
Oligochaeta	N/S	5627	N/S	6709	N/S	9493	N/S	5283	N/S	1646	N/S	N/S	
Hirudinea	N/S		N/S		N/S	565	N/S	86	N/S	144	N/S	N/S	
Isopoda	N/S		N/S		N/S		N/S		N/S		N/S	N/S	
Amphipoda	N/S	144	N/S	29	N/S	995	N/S		N/S		N/S	N/S	
Chironomidae	N/S	574	N/S	392	N/S	565	N/S	10	N/S	220	N/S	N/S	
Trichoptera	N/S	10	N/S	19	N/S	19	N/S		N/S	10	N/S	N/S	
Ostracoda	N/S	105	N/S	373	N/S		N/S		N/S		N/S	N/S	
Dreissena	N/S	172	N/S	96	N/S	9350	N/S		N/S	29	N/S	N/S	
Quagga	N/S		N/S		N/S	450	N/S		N/S		N/S	N/S	
Sphaeriidae	N/S	345	N/S	230	N/S	1617	N/S	412	N/S	517	N/S	N/S	
Gastropoda	N/S	86	N/S	10	N/S	105	N/S	191	N/S	57	N/S	N/S	
Total	N/S	7522	N/S	8259	N/S	23246	N/S	6058	N/S	2794	N/S	N/S	47879
Total w/o Zeb	N/S	7350	N/S	8163	N/S	13446	N/S	6058	N/S	2766	N/S	N/S	37782
Total taxa	N/S	9	N/S	10	N/S	10	N/S	6	N/S	8	N/S	N/S	12

* N/S = No sample taken.

Table 4: 1995 mean monthly densities (no. m^{2}) of gross taxa at 9.1m and 12.2m depths at Fairport Harbor sites.

	May		June		July		August		September		October		
	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	9.1	12.2	
Planaria													
Hydridae			230	766	29	105		96	29				
Nematoda	38	345	230	345	57	48		38	115	335		29	
Branchiura													
Oligochaeta	345	967	144	1043	306	1646	67	1589	1120	1177	38	507	
Hirudinea													
Isopoda													
Amphipoda	29		86	38		373		220	105		19		
Chironomidae		57	1550	2909	96	536	77	278	392	96	211	67	
Trichoptera				38	10	29		19		38			
Ostracoda		29			10		10		10				
Dreissena	708	258	115	507		191	29	29	9656	29246	1110	5053	
Quagga	38			191									
Sphaeriidae				19									
Gastropoda					10			77	48	105	124		
													Total
Total	1158	1656	2354	5857	517	2928	182	2345	11474	30997	1502	5656	66626
Total w/o Zeb	412	1397	2239	5158	517	2737	153	2316	1818	1751	392	603	19494
Total taxa	5	5	6	9	7	7	4	8	8	6	5	4	11

Table 5: Mean numbers (m^2) of selected 1987 versus 1995 Huron macroinvertebrates. N/S* = no sample taken.

	May		June		July		August		September		October	
	1987	1995	1987	1995	1987	1995	1987	1995	1987	1995	1987	1995
Huron 9.1 m												
Oligochaete	3684	3043	3914	1646	2785	4986	823	1235	3885	1014	4871	1455
Chironomidae	2086	957	1263	651	651	727	38	249	1263	507	1053	900
Sphaeriidae	124	555	124	737	737	804	48	622	459	440	115	861
Gastropoda	0	10	0	0	0	10	0	0	0	0	0	0
Dreissena polymorpha	0	29	0	19	0	10	0	0	0	0	0	0
Dreissena bugensis	0	0	0	0	0	0	0	0	0	0	0	0
Total w/o Dreissena spp.	5895	4565	5302	3034	4173	6527	909	2105	5608	1962	6039	3216
Huron 12.2 m												
Oligochaete	N/S*	4173	3445	1646	3560	8824	2871	2603	4326	1656	7838	1053
Chironomidae	N/S*	1177	1148	651	1034	909	0	766	1091	967	1043	1330
Sphaeriidae	N/S*	871	48	737	813	1531	278	1120	48	794	10	1139
Gastropoda	N/S*	0	0	0	0	0	0	0	0	0	0	19
Dreissena polymorpha	N/S*	29	0	19	0	0	0	0	0	0	0	0
Dreissena bugensis	N/S*	0	0	0	0	0	0	0	0	0	0	0
Total w/o Dreissena spp.		6221	4641	3034	5407	11264	3149	4488	5464	3416	8891	3541

Table 6: Mean numbers (m^2) of selected 1987 versus 1995 Lorain macroinvertebrates. N/S* = no sample taken.

	May		June		July		August		September		October	
	1987	1995	1987	1995	1987	1995	1987	1995	1987	1995	1987	1995
Lorain 9.1 m												
Oligochaete	N/S*	3723	1569	1369	3378	3885	3474	3024	N/S*	1043	507	842
Chironomidae	N/S*	172	153	335	584	488	57	124	N/S*	67	86	651
Sphaeriidae	N/S*	0	19	10	211	124	325	10	N/S*	0	38	306
Gastropoda	N/S*	766	38	38	67	29	38	124	N/S*	10	0	19
Dreissena polymorpha	N/S*	2546	0	115	0	239	0	1081	N/S*	0	0	10
Dreissena bugensis	N/S*	1866	0	823	0	10	0	718	N/S*	0	0	0
Total w/o Dreissena spp.		4661	1780	1751	4240	4527	3895	3283		1120	632	1818
Lorain 12.2 m												
Oligochaete	1684	1493	2660	2134	1416	1397	5943	2268	N/S*	335	3694	842
Chironomidae	172	38	498	345	1464	785	833	1292	N/S*	182	1550	651
Sphaeriidae	498	10	383	48	392	144	1206	268	N/S*	105	306	306
Gastropoda	19	144	10	48	0	10	0	19	N/S*	0	0	19
Dreissena polymorpha	0	325	0	23112	0	19	0	191	N/S*	0	0	10
Dreissena bugensis	0	325	0	7024	0	0	0	10	N/S*	0	0	0
Total w/o Dreissena spp.	2373	1685	3550	2575	3273	2336	7981	3847		622	5551	1818

Table 7: Mean numbers (m^2) of selected 1987 versus 1995 Cleveland macroinvertebrates. N/S* = no sample taken.

	May		June		July		August		September		October	
	1987	1995	1987	1995	1987	1995	1987	1995	1987	1995	1987	1995
Cleveland 12.2 m												
Oligochaete	N/S*	5627	2919	6709	4728	9493	6910	5283	N/S*	1646	565	N/S*
Chironomidae	N/S*	574	345	373	38	565	641	10	N/S*	220	756	N/S*
Sphaeriidae	N/S*	345	813	230	1904	1617	1560	412	N/S*	517	134	N/S*
Gastropoda	N/S*	86	19	10	57	105	96	191	N/S*	57	19	N/S*
Dreissena polymorpha	N/S*	172	0	96	0	9350	0	0	N/S*	29	0	N/S*
Dreissena bugensis	N/S*	0	0	0	0	450	0	0	N/S*	0	0	N/S*
Total w/o Dreissena spp.		6632	4096	7322	6728	11780	9206	5896		2440	1474	

Table 8: Mean numbers (m^2) of selected 1987 versus 1995 Fairport Harbor macroinvertebrates. N/S* = no sample taken.

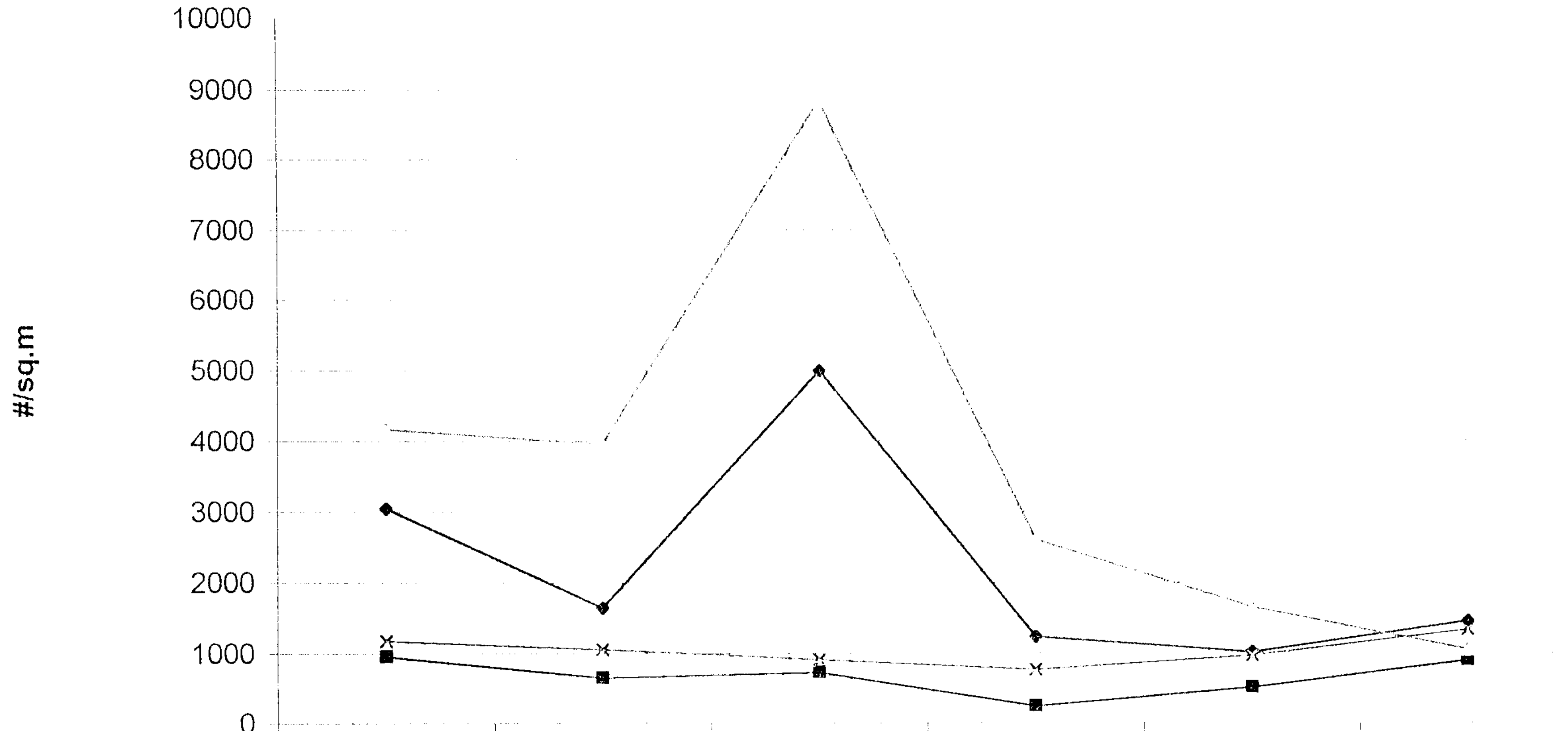
	May		June		July		August		September		October	
	1987	1995	1987	1995	1987	1995	1987	1995	1987	1995	1987	1995
Fairport 9.1 m												
Oligochaete	N/S*	967	16307	144	23580	306	19446	67	5474	1120	842	38
Chironomidae	N/S*	57	6747	1550	1608	96	2249	77	622	392	96	211
Sphaeriidae	N/S*	0	1560	0	1780	0	2680	0	1761	0	450	0
Gastropoda	N/S*	0	19	0	77	10	191	0	115	48	96	124
Dreissena polymorpha	N/S*	708	0	115	0	0	0	29	0	9656	0	1110
Dreissena bugensis	N/S*	38	0	0	0	0	0	0	0	0	0	0
Total w/o Dreissena spp.		1024	24633	1694	27045	412	24566	144	7972	1560	1483	373
Fairport 12.2 m												
Oligochaete	N/S*	967	3330	1043	976	1546	2766	1589	2373	1177	3560	507
Chironomidae	N/S*	57	727	2909	555	536	230	278	220	96	3560	67
Sphaeriidae	N/S*	0	947	19	306	0	842	0	440	0	1761	0
Gastropoda	N/S*	0	19	0	115	0	48	77	392	105	392	0
Dreissena polymorpha	N/S*	258	0	507	0	191	0	29	0	29246	0	5053
Dreissena bugensis	N/S*	0	0	191	0	0	0	0	0	0	0	0
Total w/o Dreissena spp.		1024	5024	3971	1952	2182	3885	1944	3426	1378	9273	574

Table 9: p-value (ANOVA) results for selected macroinvertebrates.

Note: * = significant at the $p < .05$ level, ** = significant at the $p<.06$ level.

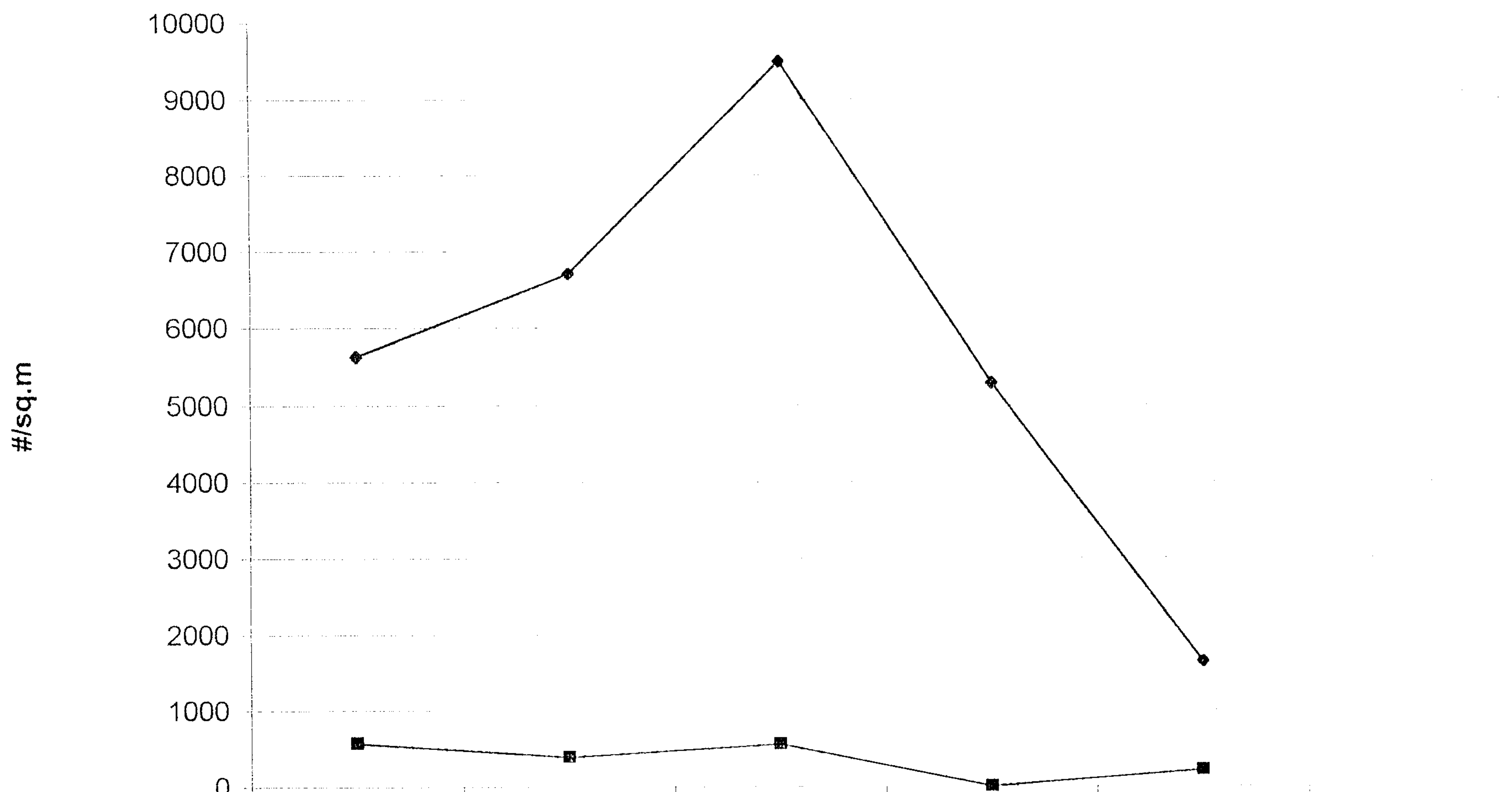
	Oligochaeta	Chironomidae	Sphaeriidae	Gastropoda
Year	0.053**	0.067	.029*	0.54
Site	0.137	0.133	0.112	0.054**
Month	0.168	0.266	0.178	0.315

Fig. 1 Oligochaetes vs. Chironomids Huron 1995



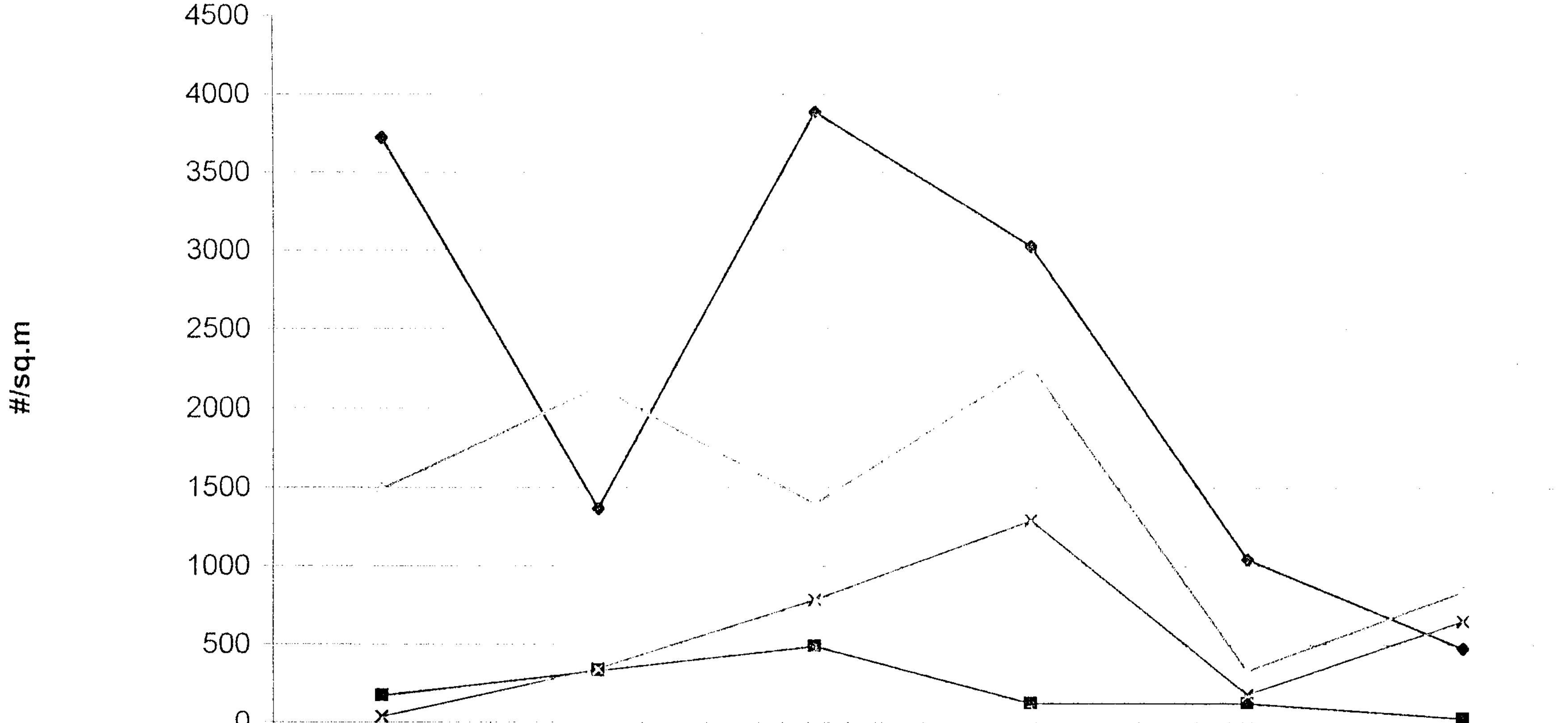
	May	Jun	Jul	Aug	Sep	Oct
Oligo - 9m	3043	1648	4986	1235	1014	1455
Chiro - 9m	957	651	727	249	507	900
Oligo - 12m	4173	3962	8824	2603	1656	1053
Chiro - 12m	1177	1053	909	766	967	1330

Fig. 2 Oligochaetes vs. Chironomids Cleveland 1995



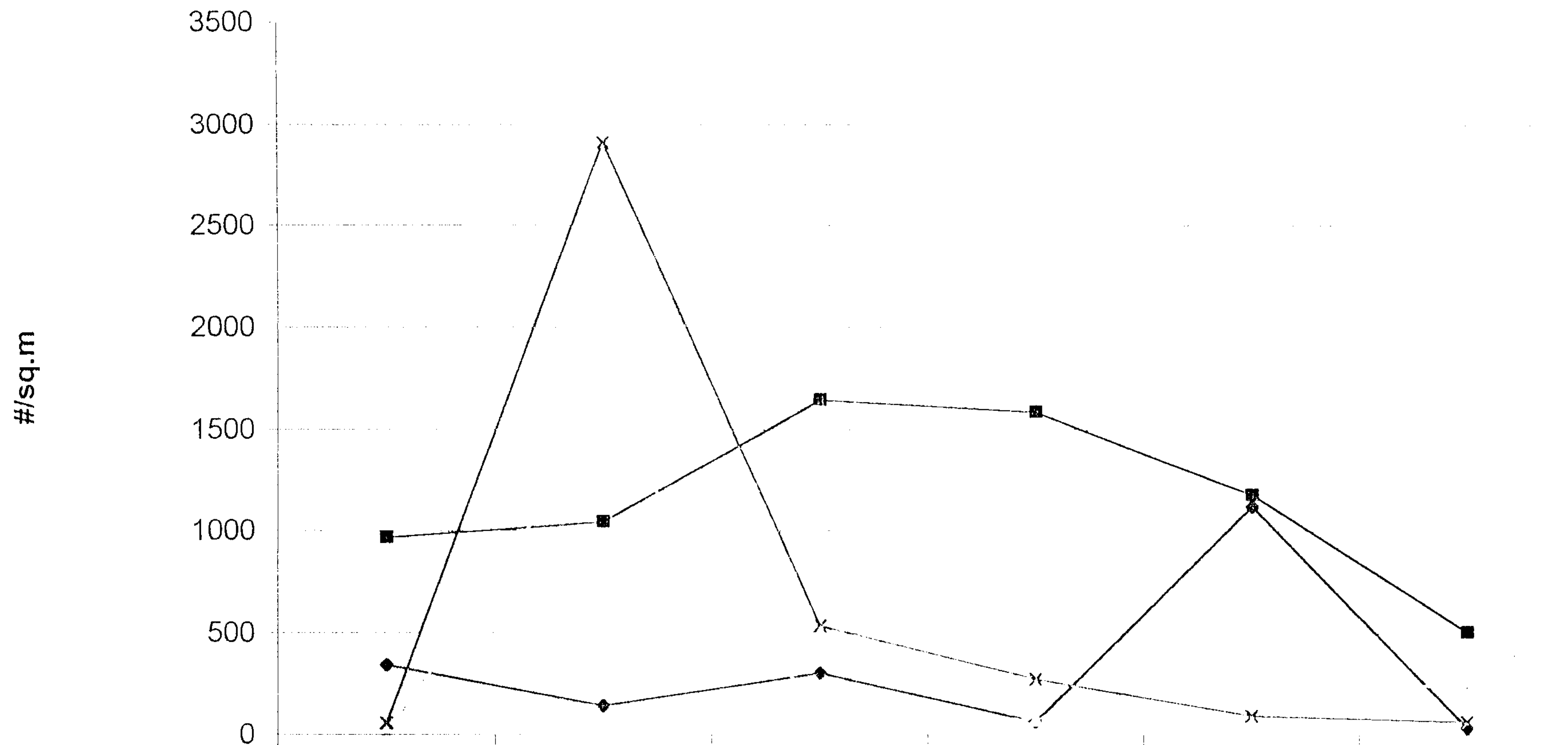
	May	Jun	Jul	Aug	Sep	Oct
Olig - 12m	5627	6709	9493	5283	1646	
Series2	574	392	565	10	220	

Fig. 3 Oligochaetes vs. Chironomids Lorain 1995



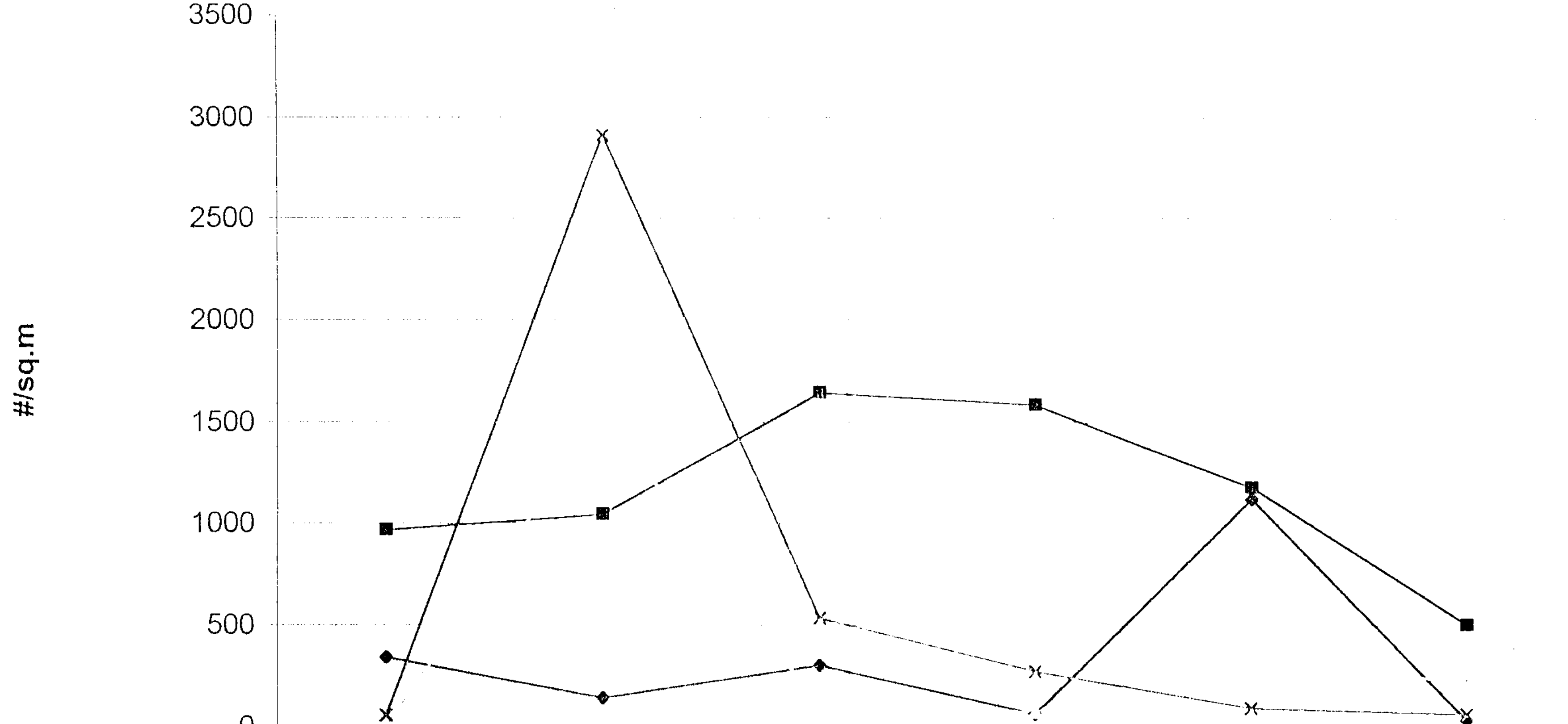
	May	Jun	Jul	Aug	Sep	Oct
Oligo - 9m	3723	1369	3885	3024	1043	479
Chiro - 9m	172	335	488	124	124	29
Oligo - 12m	1493	2134	1397	2268	335	842
Chiro - 12m	38	345	785	1292	182	651

Fig. 4 Oligochaetes vs. Chironomids Fairport Harbor 1995



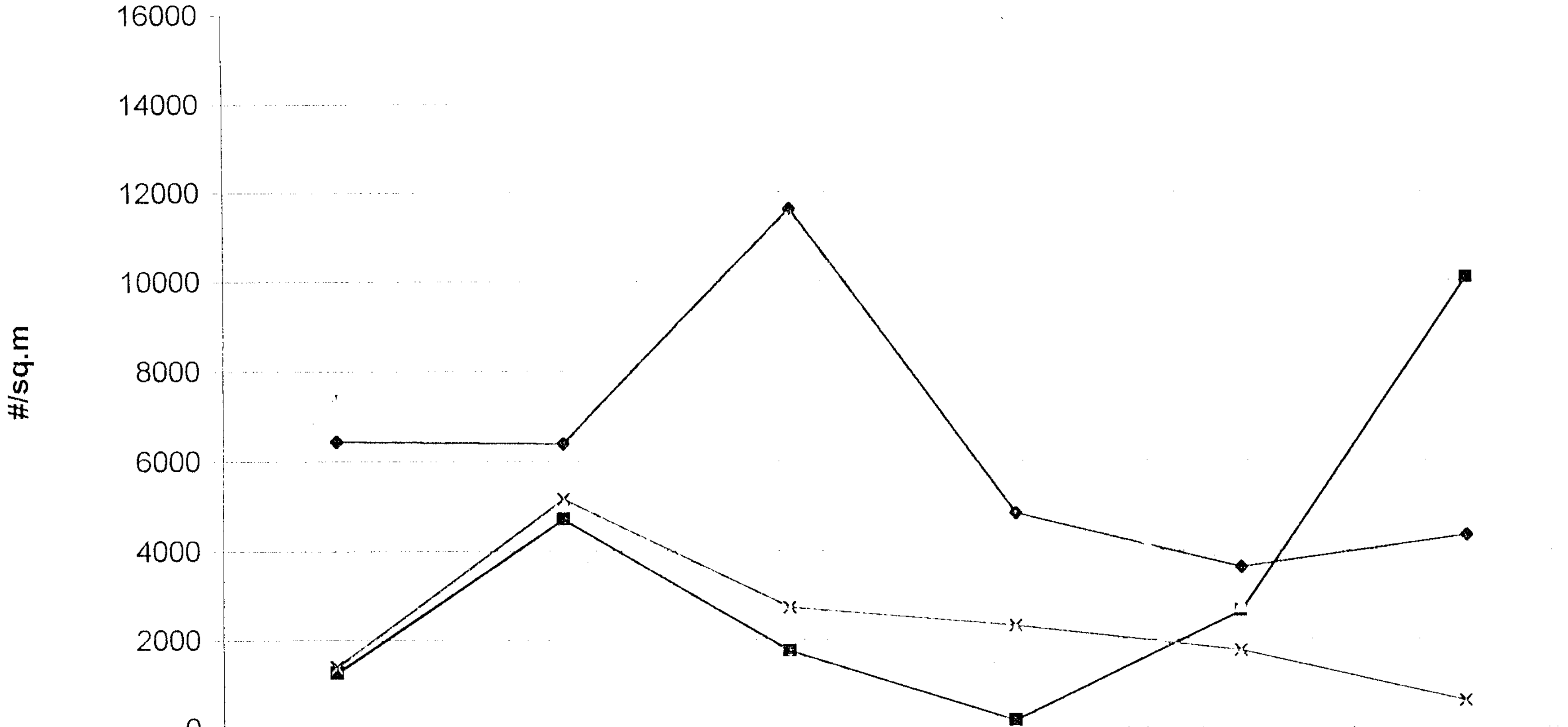
	May	Jun	Jul	Aug	Sep	Oct
Oligo - 9m	345	144	306	67	1120	38
Chiro - 9m	967	1043	1646	1589	1177	507
Oligo - 12m	0	1550	96	77	392	211
Chiro - 12m	57	2909	536	278	96	67

Fig. 4 Oligochaetes vs. Chironomids Fairport Harbor 1995



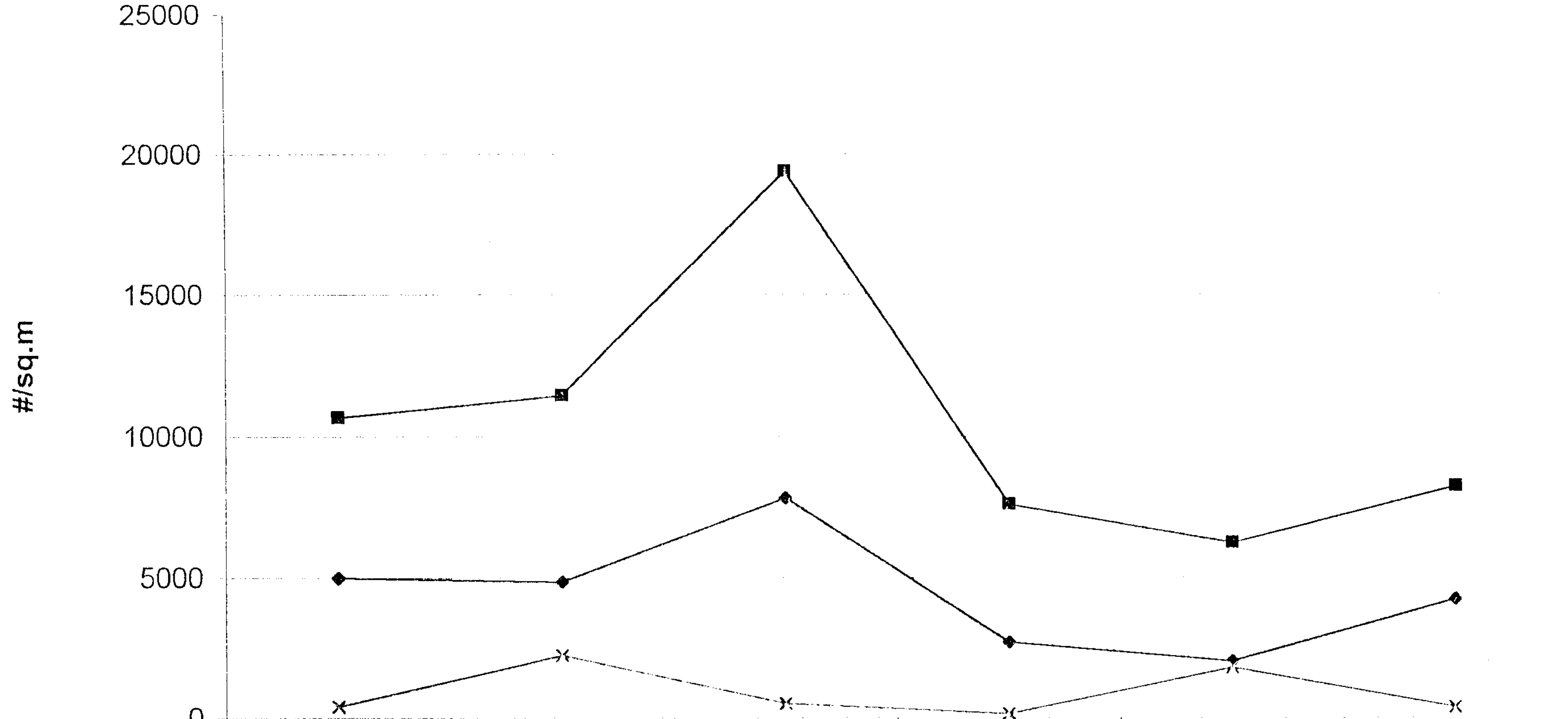
	May	Jun	Jul	Aug	Sep	Oct
Oligo - 9m	345	144	306	67	1120	38
Chiro - 9m	967	1043	1646	1589	1177	507
Oligo - 12m	0	1550	96	77	392	211
Chiro - 12m	57	2909	536	278	96	67

Fig. 5 Total No.s w/o Dreissena 12 1995



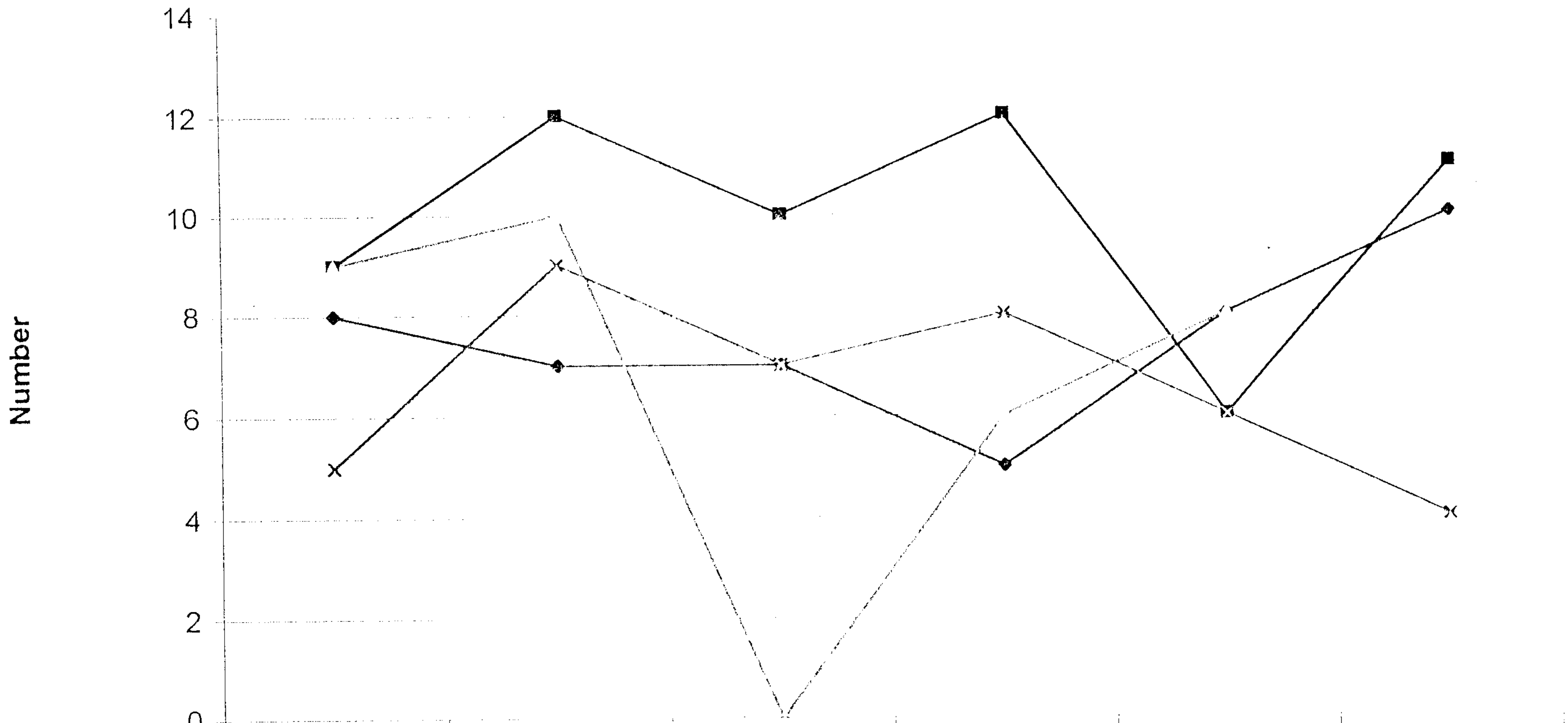
	May	Jun	Jul	Aug	Sep	Oct
Huron	6450	6402	11628	4852	3637	4345
Lorain	1263	4708	1751	172	2641	10067
Cleve	7357	8163	13446	6058	2766	
Fairport	1397	5158	2737	2316	1751	603

Fig. 6 Total No's w/o Dreissena 9m 1995



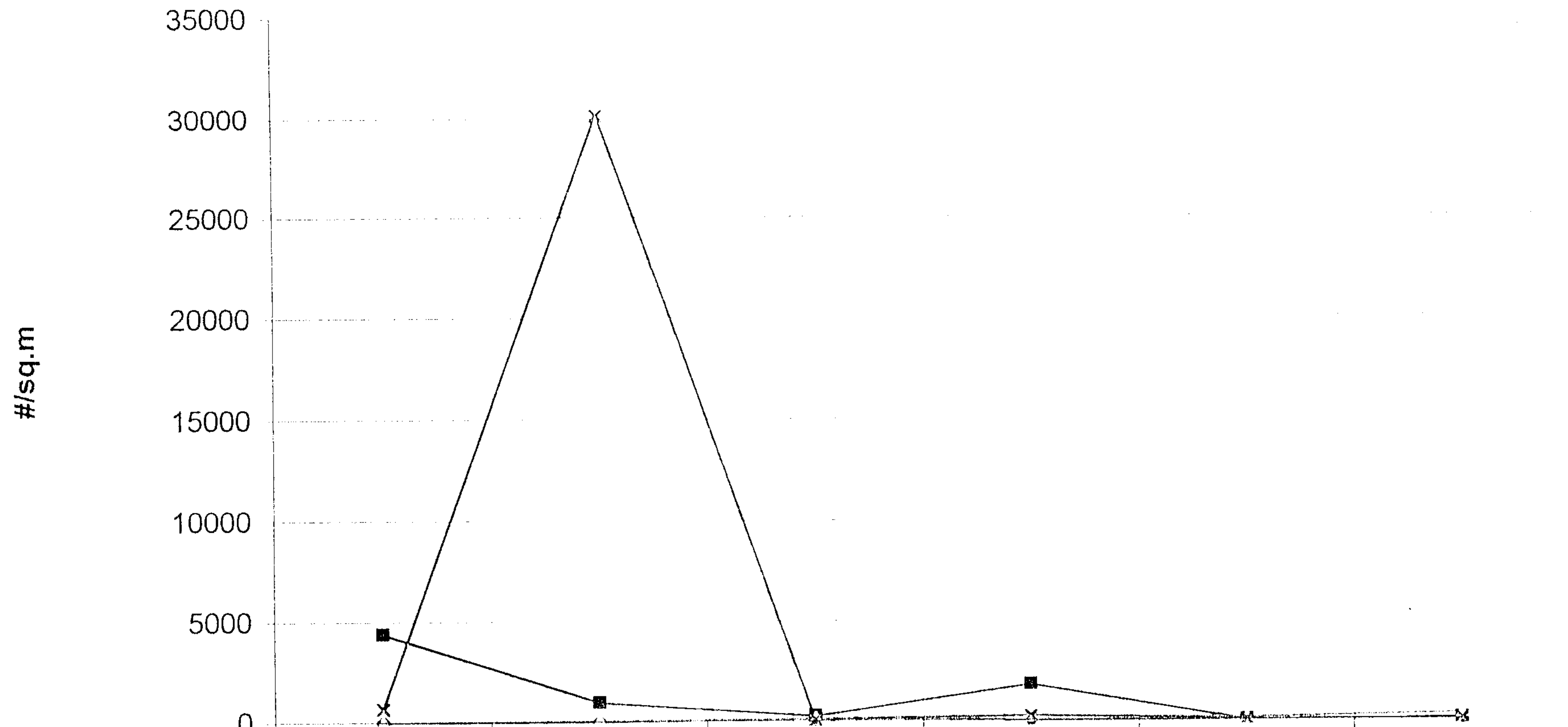
	May	Jun	Jul	Aug	Sep	Oct
Huron	5005	4853	7809	2708	2038	4259
Lorain	10669	11443	19377	7584	6238	8221
Cleve						
Fairport	412	2239	517	153	1818	392

Fig. 7 Number of Taxa 1995



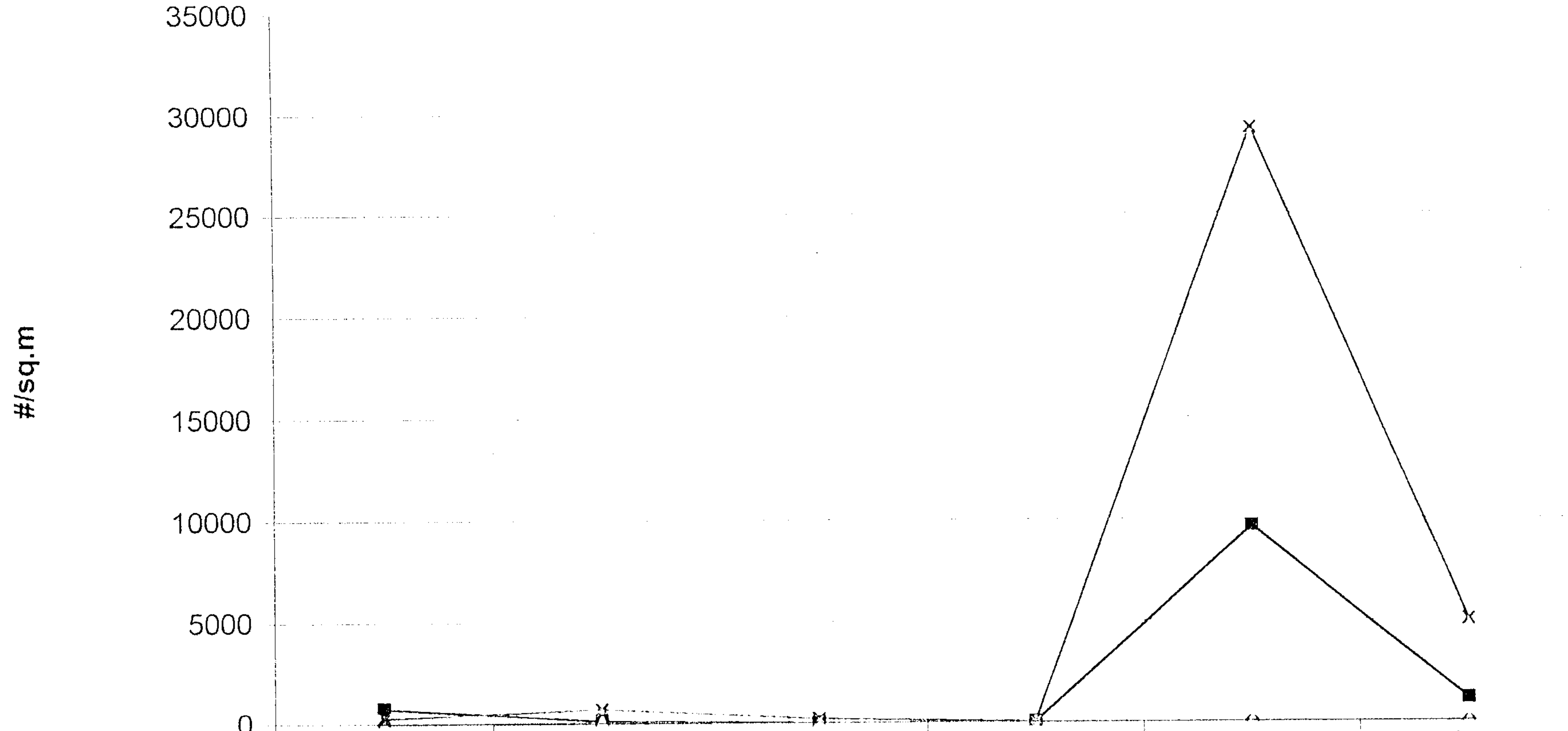
	May	Jun	Jul	Aug	Sep	Oct
Huron	8	7	7	5	8	10
Lorain	9	12	10	12	6	11
Cleve	9	10	0	6	8	
Fairport	5	9	7	8	6	4

Fig. 8 Sphaeriidae vs. Dreissena Lorain 1995



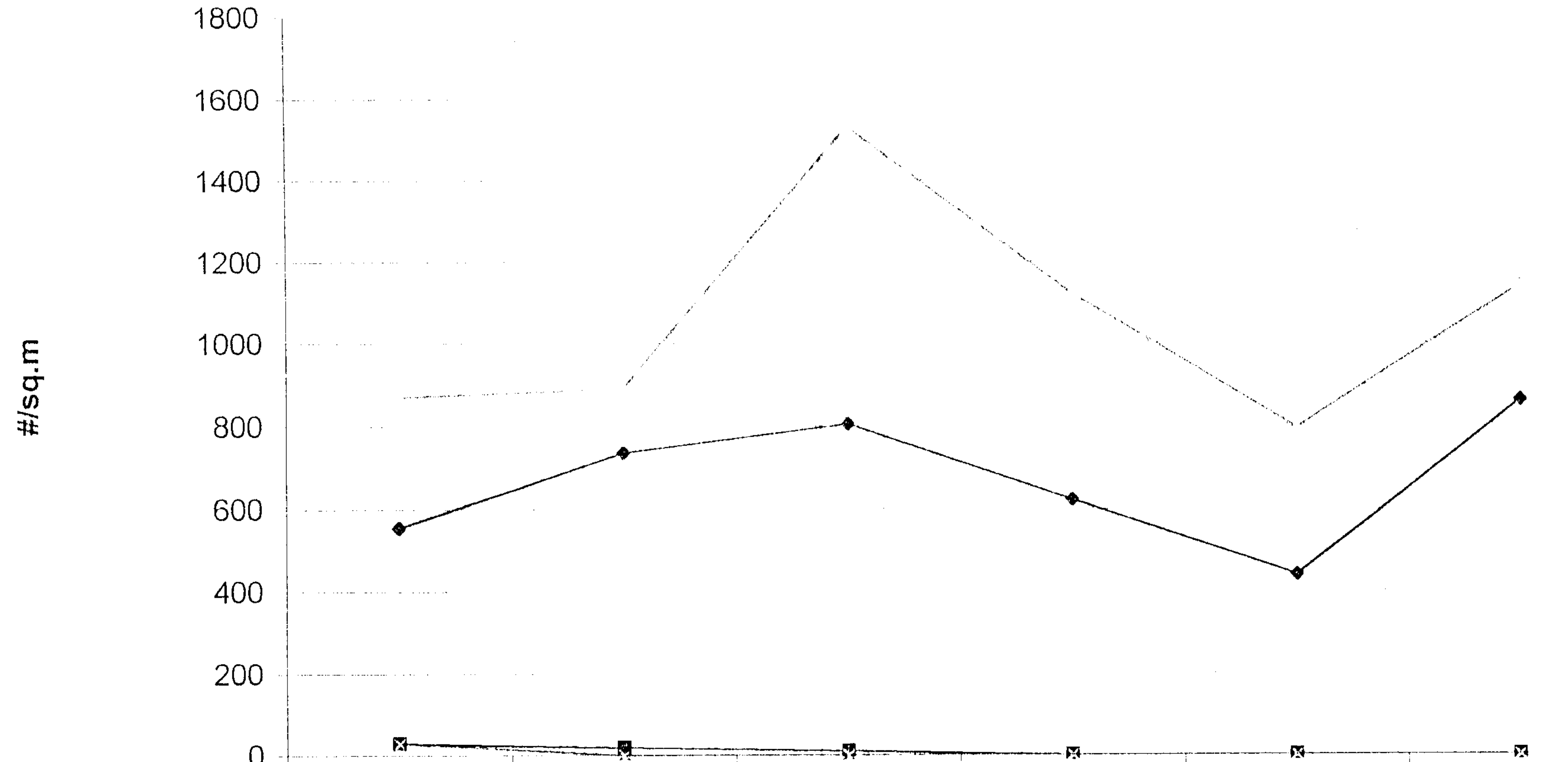
	May	Jun	Jul	Aug	Sep	Oct
sphae 9m	0	10	124	10	0	0
Dress 9m	4412	938	249	1799	0	67
Sphae 12m	10	48	144	268	105	306
Dress 12m	650	30136	19	201	0	10

Fig. 9 Sphaeriidae vs. Dreissena Fairport harbor 1995



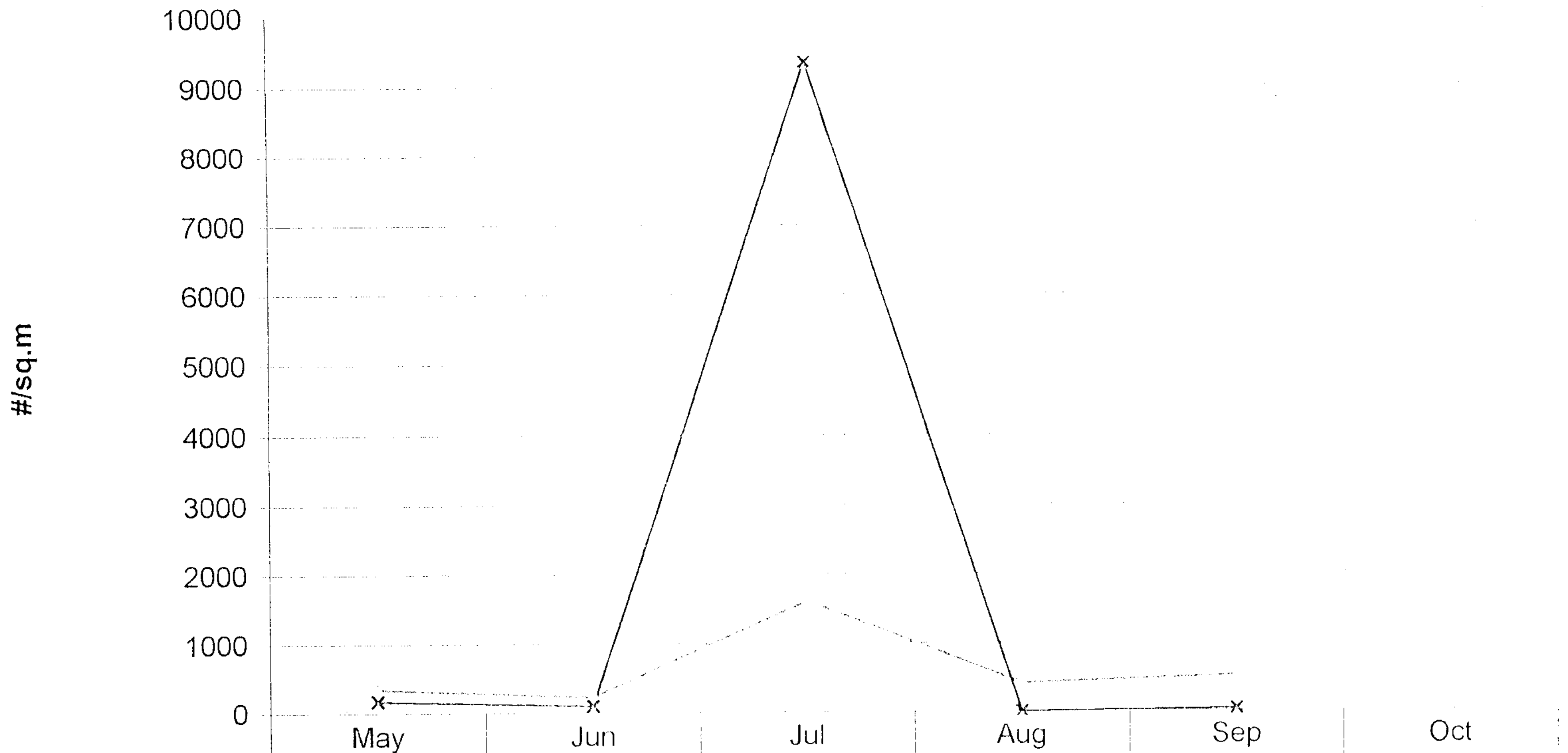
	May	Jun	Jul	Aug	Sep	Oct
Sphae 9m	0	0	0	0	0	0
Dress 9m	746	115	0	29	9656	1110
Sphae 12m	0	19	0	0	0	0
Dress 12m	258	698	191	29	29246	5053

Fig. 10 Sphaeriidae vs. Dreissena Huron 1995



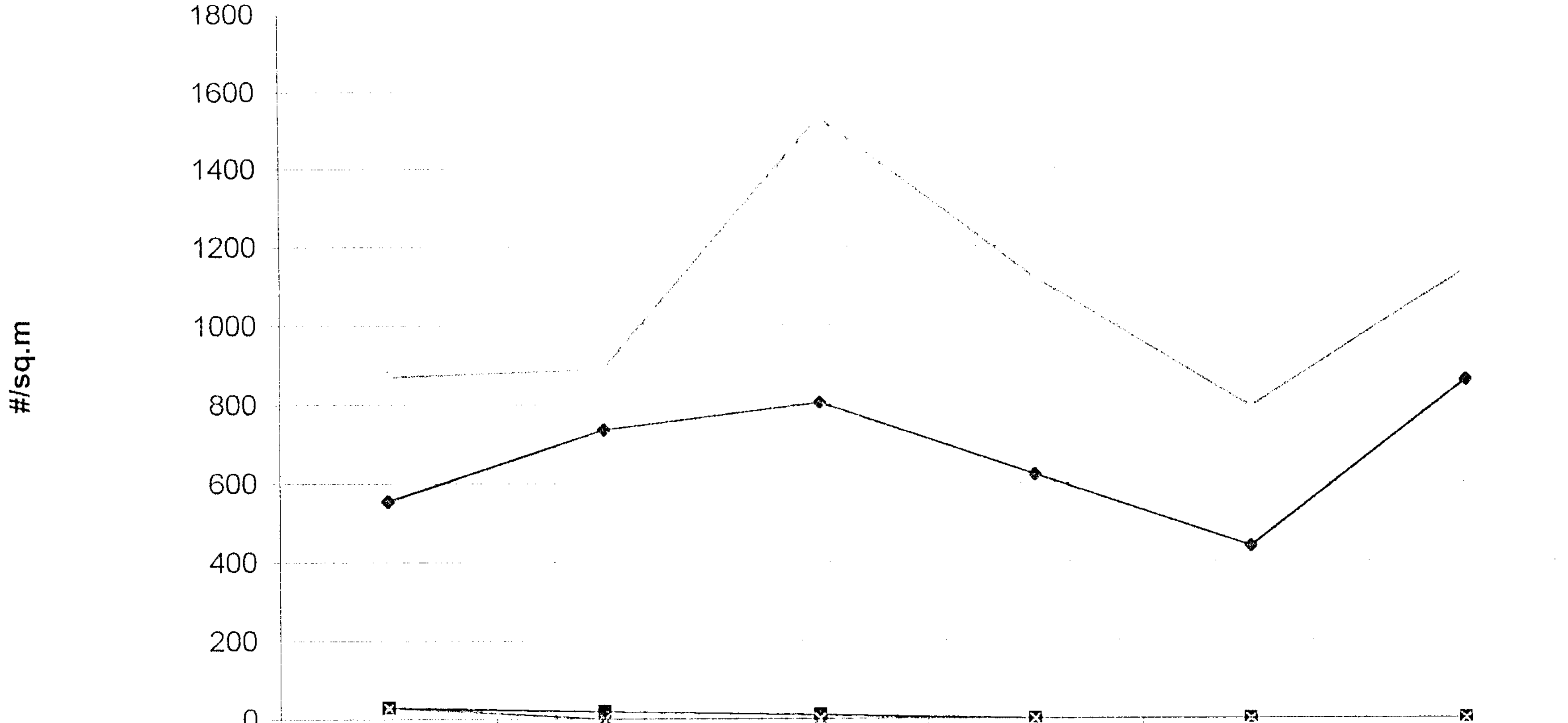
	May	Jun	Jul	Aug	Sep	Oct
Sphae 9m	555	737	804	622	440	861
Dress 9m	29	19	10	0	0	0
Sphae 12m	871	890	1531	1120	794	1139
Dress 12m	29	0	0	0	0	0

Fig. 11 Sphaeriidae vs. Dreissena Cleveland 1995



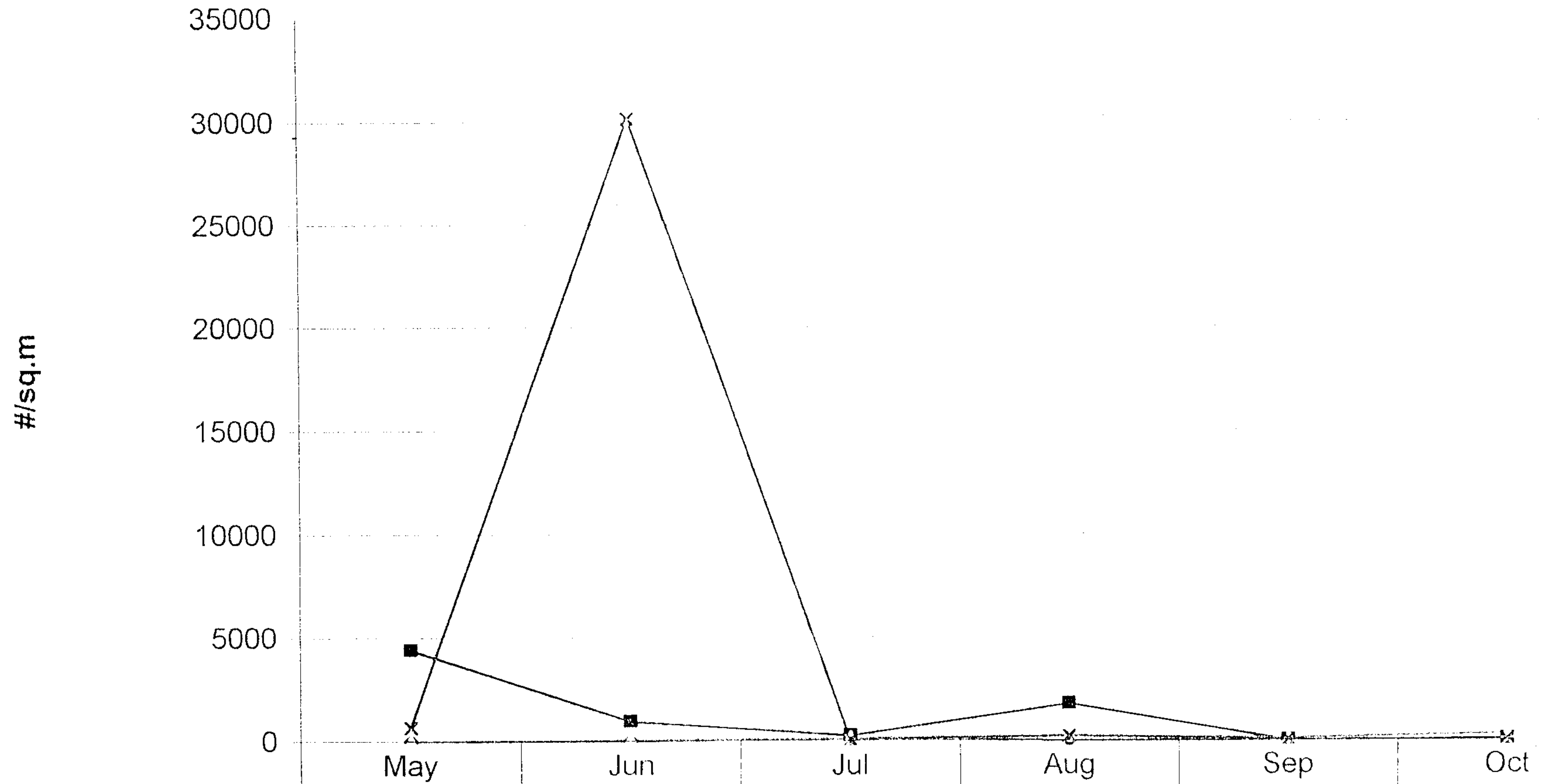
	May	Jun	Jul	Aug	Sep	Oct
Sphae 9m						
Dress 9m						
Sphae 12m	345	230	1617	412	517	
Dress 12m	172	96	9350	0	29	

Fig. 12 Sphaeriidae vs. Dreissena Huron 1995



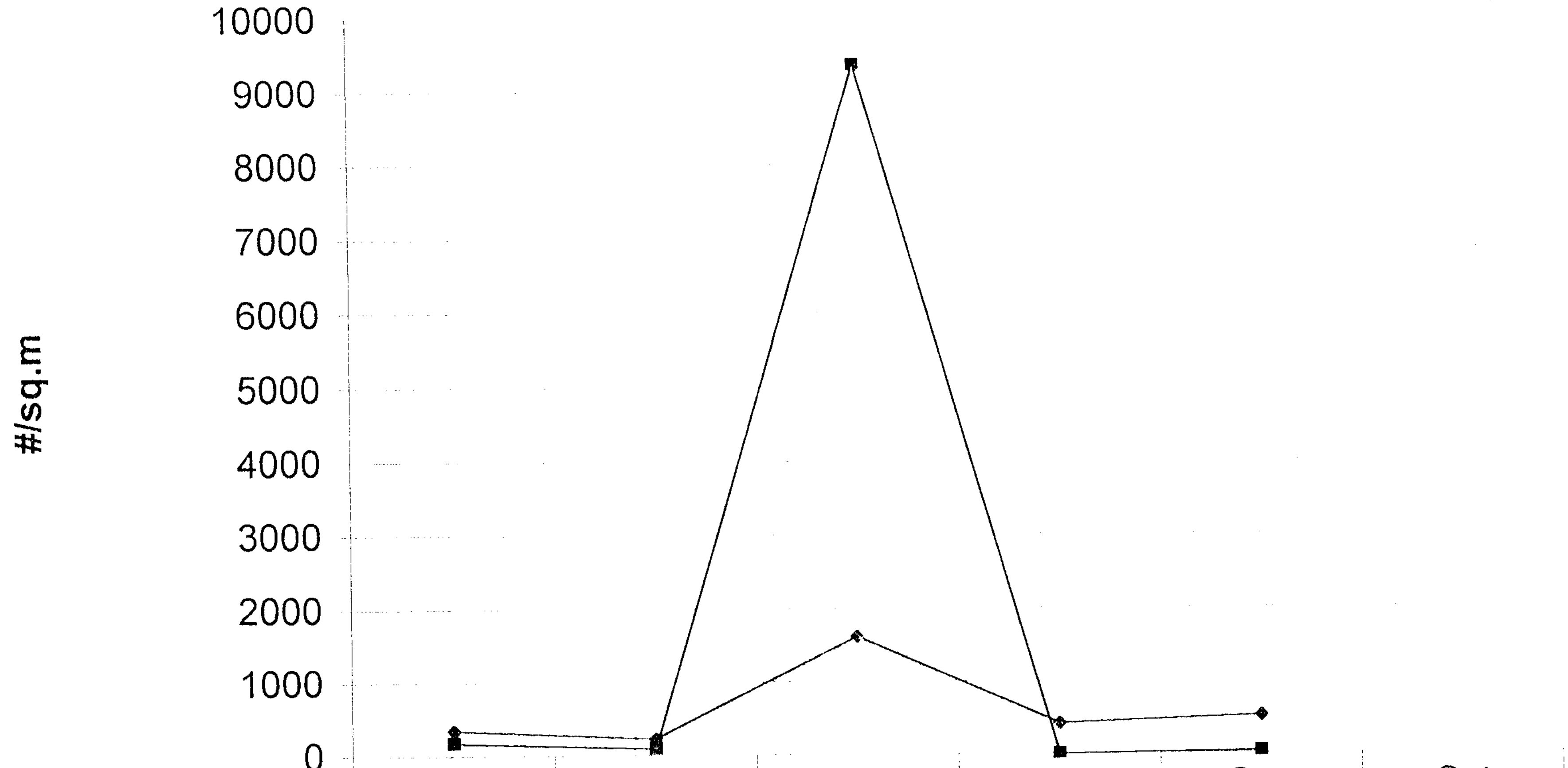
	May	Jun	Jul	Aug	Sep	Oct
Sphae - 9m	555	737	804	622	440	861
Dress - 9m	29	19	10	0	0	0
Sphae - 12	871	890	1531	1120	794	1139
Dress - 12m	29	0	0	0	0	0

Fig. 13 Sphaeriidae vs. Dreissena Lorain 1995



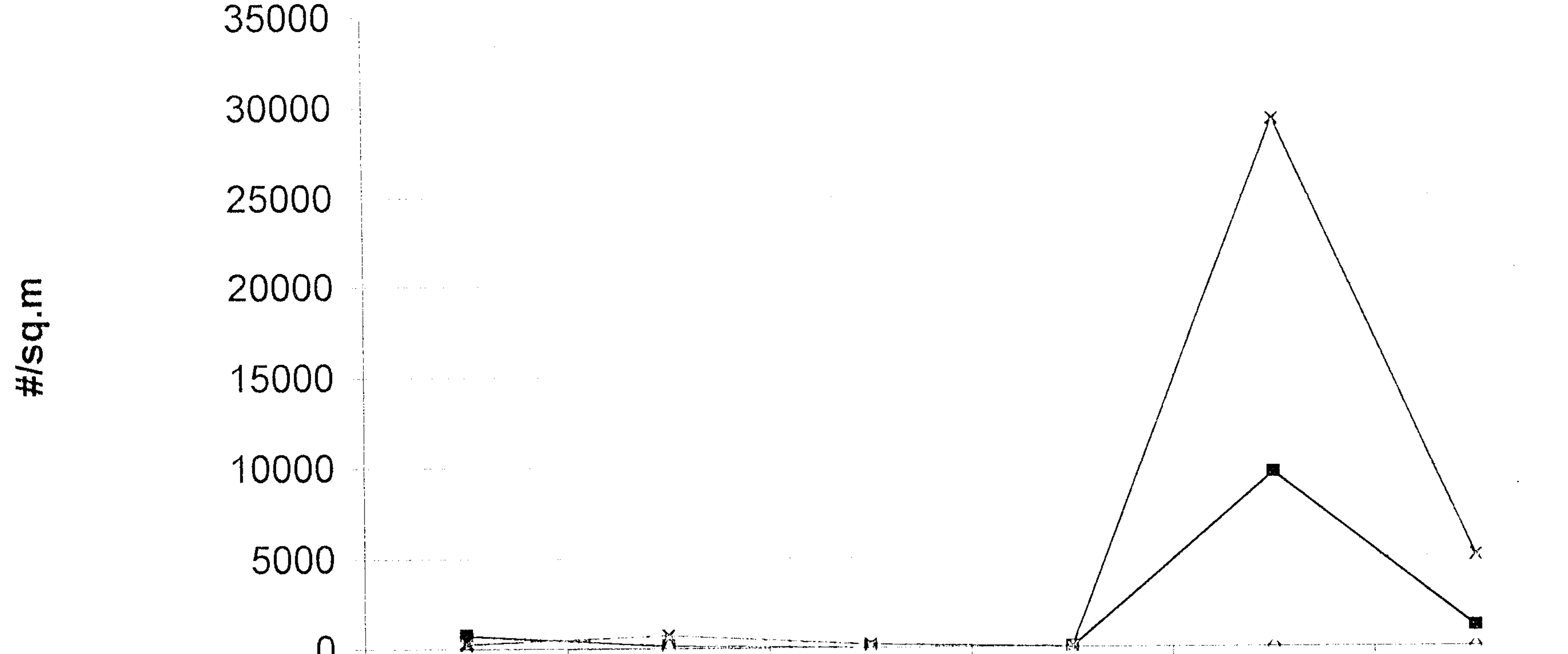
	May	Jun	Jul	Aug	Sep	Oct
Sphae - 9m	0	10	124	10	0	0
Dress - 9m	4412	938	249	1799	0	67
Sphae - 12m	10	48	144	268	105	306
Dress - 12m	650	30136	19	201	0	10

Fig. 14 Sphaeriidae vs. Dreissena Cleveland 1995



	May	Jun	Jul	Aug	Sep	Oct
Sphae -12m	345	230	1617	412	517	
Dress - 12m	172	96	9350	0	29	

Fig. 15 Sphaeriidae vs. Dreissena Fairport Harbor 1995



	May	Jun	Jul	Aug	Sep	Oct
Sphae - 9m	0	0	0	0	0	0
Dress - 9m	746	115	0	29	9656	1110
Sphae - 12m	0	19	0	0	0	0
Dress - 12m	258	698	191	29	29246	5053

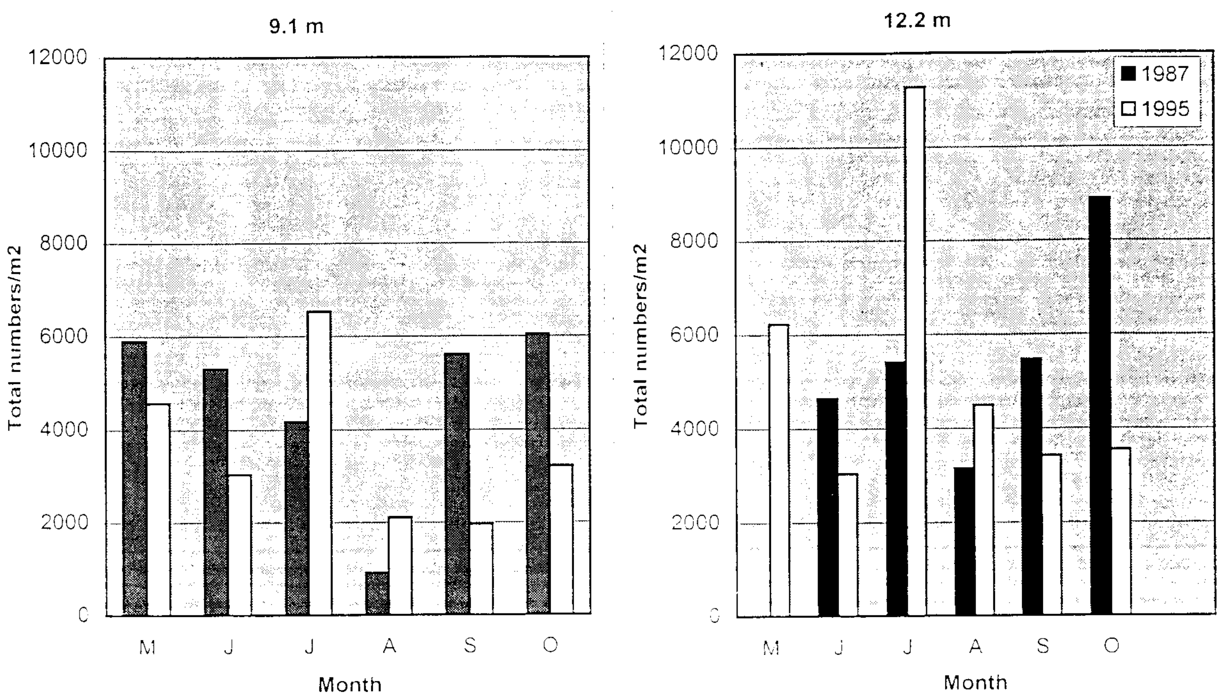


Figure 16: Mean (N=2) total numbers (w/o *Driessena* spp.) of selected macroinvertebrates from Huron site.

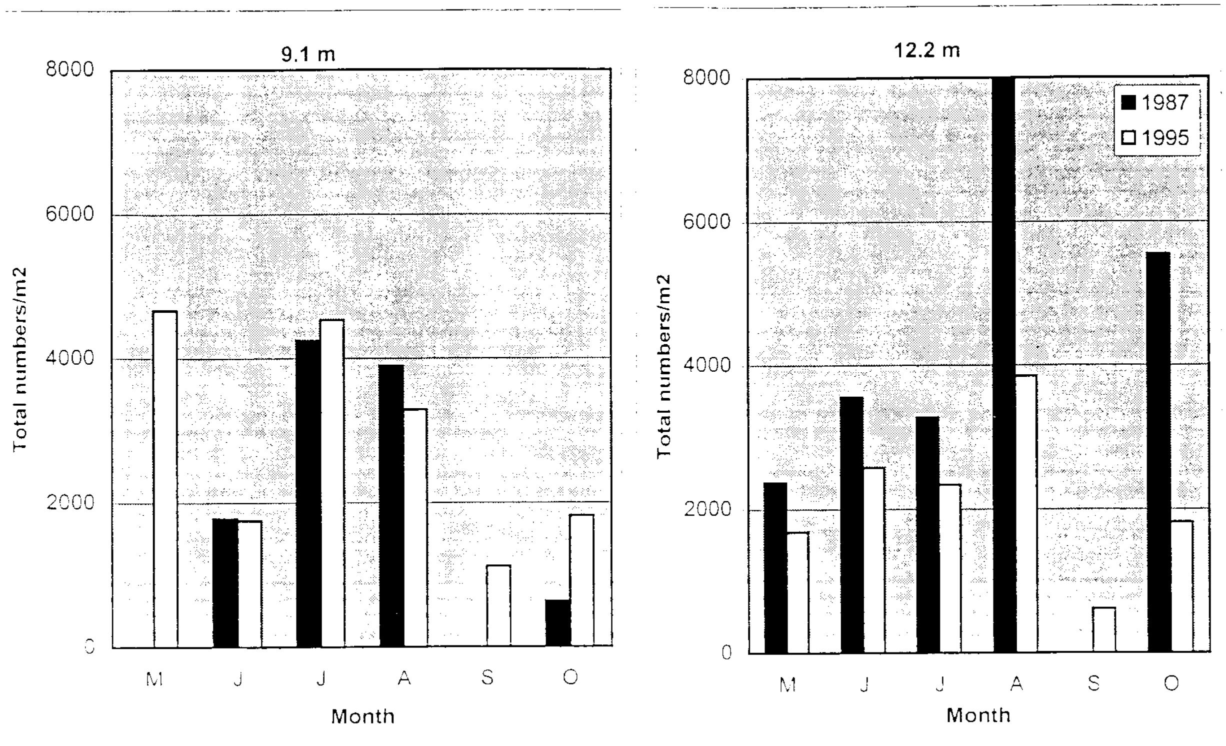


Figure 17: Mean (N=2) total numbers (w/o *Driessena* spp.) of selected macroinvertebrates from Lorain site.

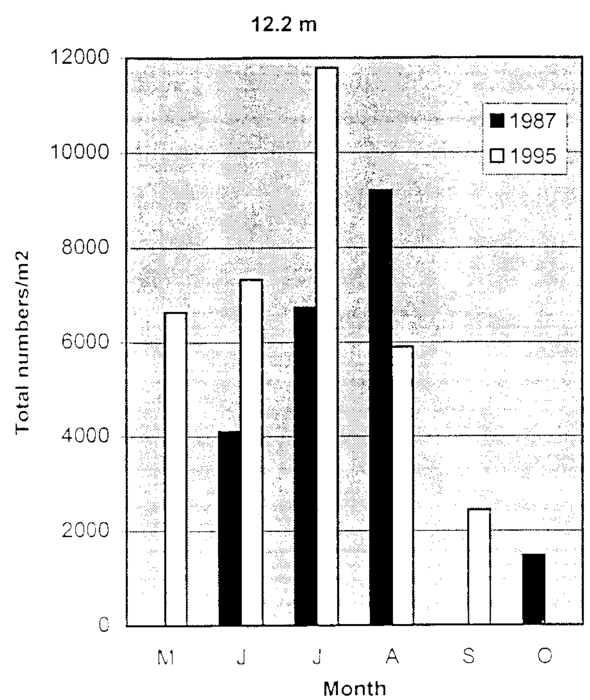


Figure 18: Mean (N=2) total numbers (w/o *Driessena* spp.) of selected macroinvertebrates from Cleveland site.

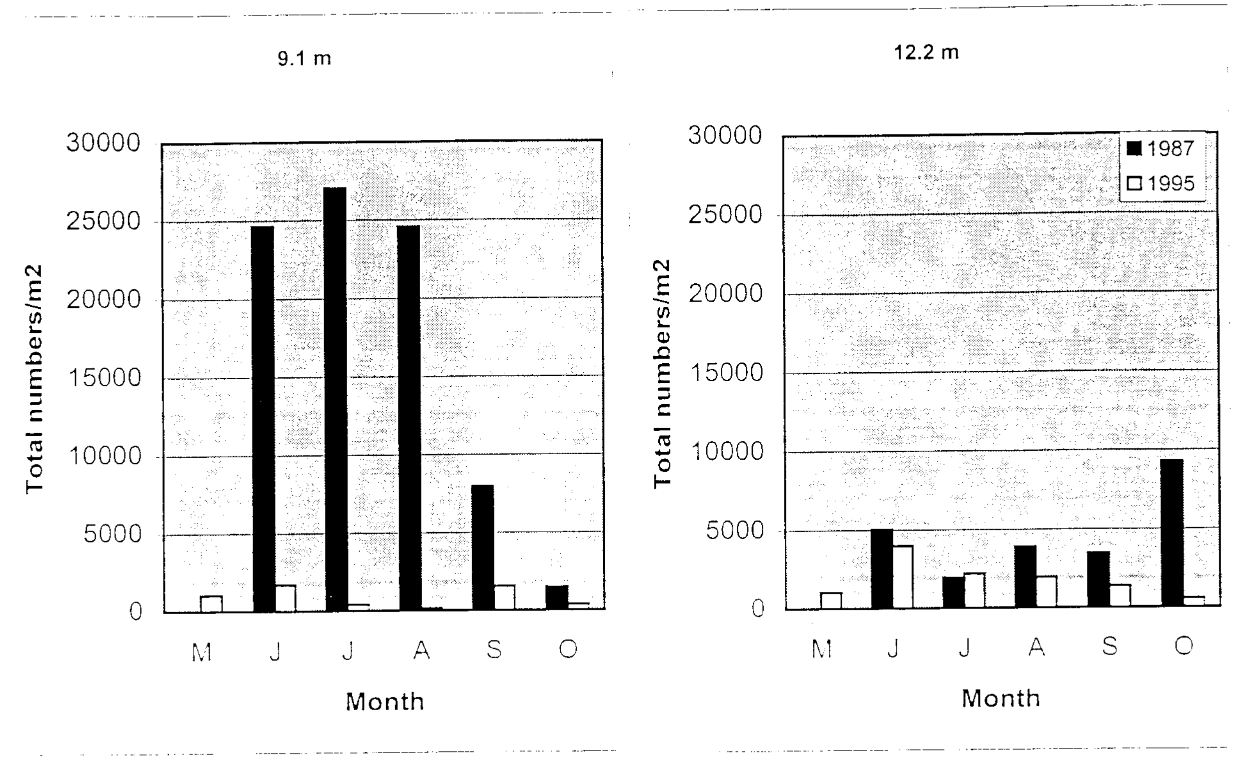


Figure 19: Mean (N=2) total numbers (w/o *Driessena* spp.) of selected macroinvertebrates from Fairport Harbor site.