A COMPARISON OF MACROINVERTEBRATE COMMUNITIES, HABITAT, AND WATER CHEMISTRY ALONG THE LENGTH OF MILLER CREEK

A Report Submitted to: South St. Louis County Soil and Water Conservation District

by

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17 September 1992

NRRI Technical Report Number: NRRI/TR-92/13

Introduction

Biological communities in streams can serve as useful monitors of habitat and chemical conditions. Recently, the use of biomonitoring to examine water resource quality has become a popular alternative or addition to standard water assessment protocols for the purposes of management and planning, problem prioritization, and documentation of recovery following remediation efforts. A general theoretical framework for the development of biosurveys has been discussed by Karr (1991). The advantages of using biosurveys for monitoring and assessment purposes include: 1) biological communities reflect overall ecological integrity and therefore may be the most accurate status of a waterbody, 2) biological communities integrate the effects of different pollutant stressors and thus provide a measure of aggregate impact, 3) biological communities integrate stresses over time and provide an ecological measure of fluctuating environmental conditions 4) routine biological monitoring can be relatively inexpensive compared to the costs of detailed chemical and toxicity testing, 5) biological communities are often of direct interest to the public as an indicator of a pollution free environment.

Macroinvertebrate communities in streams are effective biomonitors in streams that are relatively stable in time and reflect subtle differences in environmental conditions (Richards and Minshall 1992). Furthermore, general guidelines towards development and use of these communities for biomonitoring have been published widely (Plafkin et al. 1989, OHIO EPA 1987). These approaches follow the suggestions of Karr (1991) in that they utilize multiple community metrics to evaluate instream biological impairment. This approach consists of analyzing different components of the structure and function of macroinvertebrate communities. Each metric contributes ecological information on the integrity of the community in question. Several studies have reported the use of the metric approach with macroinvertebrates in streams (Barbour et al. 1992). Since many aspects of biological communities are dependant on regional and local characteristics, it is necessary to interpret biomonitoring data in light of unique regional characteristics.

The purpose of the present study was to examine macroinvertebrate communities at several locations along Miller Creek to determine if biomonitoring techniques indicate significant problems along the watercourse, to compare various techniques for assessment, and to provide a preliminary database for future comparison.

Study Area

The study was conducted in Miller Creek, a X order stream located in St. Louis County, MN. Much of the Miller Creek watershed lies within the Duluth city limits. The stream is typical in many ways of other north shore Lake Superior stream in that it is a blackwater river with its headwaters in largely wetland watersheds. In this region the stream has low gradient. Further along the stream course, gradient increases substantially as the streams drops to its confluence with the St. Louis River at the Duluth Harbor. The watershed supports a variety of urban landuses.

Sampling stations were established at a series of locations along the stream based upon longitudinal position within the watershed, past sampling locations, and access (Table 1).

Methods

Benthic organisms were primarily sampled with modified Hester-Dendy multi-plate samplers (1 foot^2 of surface area; Ohio EPA 1987) at sites 1-9 and 11 (Table 1). These samplers were anchored in pairs by attaching them to concrete patio blocks. These blocks also separated the samplers from the natural substrate for standardization. We set two or three pairs of samplers in available run habitats at each location on 22 July, 1991. After six weeks the samplers were carefully bagged and cut from the anchors while still underwater to avoid loss of organisms. Samplers at sites 6, 8, 9, and 11 were damaged or lost due to high flows, deposition of fines, or vandalism. We replaced these samplers on 24 September, 1991 and pulled them after 4 weeks when ice began to form. Samples were refrigerated overnight, then washed through 0.150 mm sieves, and stored in 70% ethyl alcohol for later identification. In the lab, samples were sorted and most taxa identified to genus.

We collected additional benthic samples in run habitats with kick nets in mid July 1991 and Surber samplers during September and October, 1991. Kick net samples were composited and the first 100 organisms encountered were removed (Kick 100) as recommended for the Rapid Bioassessment Protocol II (Plafkin et al. 1989). This allowed us to assess the utility of rapid and more thorough collection techniques. The benthic organisms were immediately preserved and later identified as above.

We evaluated habitat quality in spring, 1992. Several of the basic component scores for the Qualitative Habitat Evaluation Index (QHEI) were estimated using standard technique: Substrate Quality, Instream Cover, Channel Morphology, Riparian Zone Quality, Pool-Riffle Quality, and Average Gradient (Ohio EPA, 1987). We also visually estimated canopy coverage to the nearest 10% and measured several stream cross-sections for a determination of average stream width.

Dissolved oxygen and temperatures were taken at the sites on Miller Creek on one occasion in late August to determine in these parameters varied greatly among the sites. Dissolved oxygen was measured within two hours of sunrise so that the lowest values of this parameter would be assessed. In addition, maximum/minimum thermometers were placed at several of the sites for one week on the same day.

Choice of Metrics

Twelve metrics were developed for invertebrate data (Table 2). These metrics were chosen because they have been used to examine invertebrate communities in many other studies (see Plafkin et al 1989, Barbour et al. 1992), they assess different functional aspects of the communities, or they assess structural components of the communities. Unless otherwise noted categorization of functional and habitat groups followed those presented in Merrit and Cummins (1987). For Hester-Dendy data, means were compared among sites with ANOVA. Tukeys test was used to examine differences among means. Since Kick 100 samples were not replicated, statistics were not appropriate but values were plotted against Hester-Dendy data for comparison. Means of several metrics derived from surber data were also plotted against Hester-Dendy data for comparative purposes.

Comparison with other Regional Streams

Several other streams within the general Duluth metropolitan area were sampled with Hester-Dendy samplers at the same time as Miller Creek sites. These additional streams were surveyed to provide background information on the extent of variation that exists in macroinvertebrate communities of other similar sized streams in the same geographic area. Six sites were chosen (Table 3) based upon general watershed characteristics. Two of the sites (Amity, Lester) have watersheds dominated by rural and forested landcover. Two sites (Tischer, Chester) have watersheds that are almost entirely urban. The remaining two sites were both located on Keenes Creek, one in an upstream location with mixed urban and forested landcover and one in a downstream location with much urban landuse.

Results and Discussion

Water Quality

No strong differences were observed in temperatures during the one day of sampling on Miller Creek (Table 4). Both the temperatures recorded at the time dissolved oxygen levels were recorded and temperatures recorded with 1 wk max/min thermometers exhibited little variation among sites. A large fluctuation in temperature was observed during the 1 wk interval from approximately 10 to over 23 C^0.

Dissolved oxygen levels increased dramatically along the course of the stream (Table 4). Levels were less than 5 mg/l upstream of site 5. As the stream increased gradient, dissolved oxygen levels increased to approximately 10 mg/l.

Lowest turbidity readings during both sample periods were at the upper three sampling stations (Table 5), although, turbidities were relatively low at all stations No great differences were observed for either TIC or TOC during either sampling period among the sites. A distinct increasing trend in conductivity was observed going downstream. The highest value was observed at the most downstream site during both seasons. In both fall and spring a relatively large increase occurred between sites 5 and 6. Cl and SO4 also increased downstream although the trend was strongest for SO4 in fall. The largest differences between upstream and downstream values of Cl concentrations occurred in fall. Concentrations doubled between sites 5 and 6. In spring, the greatest increases in concentration occurred between sites 2 and 3 and sites 5 and 6.

No distinct trend in NH4 concentrations were observed during fall other than a relatively high reading at the uppermost site. All other sites had low concentrations. In spring, site 6 had a much higher concentration than the other sites which were all low. The other nutrient measurements, total P and total N, exhibited no strong downstream trends in concentration. Total P concentrations were similar in both fall and spring. Total N concentrations were somewhat higher in fall than spring.

Habitat

The QHEI scores for the sites showed relatively large differences among the sites for several habitat categories (Table 6). Lowest overall scores were observed for sites 10 and 12. These sites had low values for all habitat categories. Highest overall scores were observed at sites 8 and 11. Upstream sites (sites 1 thru 6) had lower values for substrate which reflected the high amounts of sand and other fine sediments that were predominant in these sites. Downstream sites (sites 7 thru 12) had greater amounts of larger silt-free substrates that typically support more diverse communities. Morphology scores also tended to be higher at the downstream sites where which reflects the increased heterogeneity of the stream channel at these sites largely due to higher gradient. Other habitat categories varied more as a function of local conditions. Gradient (Table 6) was considerable higher at the downstream sites.

Macroinvertebrates

A total of 76 taxa were identified from invertebrate samples at the Miller Creek sites (Appendix 1). Considerable variation was seen in scores for various metrics. All metrics were significantly different ($p < 0.05$) when observed across the sites. The abundance of organisms as indicated by hester-dendy samples was greatest at sites 1 thru 7 and declined dramatically at sites further downstream (Figure 1).

Metrics that characterize taxonomic differences among the sites (richness, EPT taxa) indicated several regions in Miller Creek. The first region includes the 5 uppermost sites on the river (sites 1 thru 5). These sites were characterized by moderate to high species richness (Figure 2) and relatively low EPT richness (Figure 3) indicating that EPT taxa were not well represented at these sites. Kick 100 samples at these sites showed similar trends (Figures 2 and 3); species richness was relatively high except at site 1 and 4 and EPT richness was relatively low at sites 1 and 3. In general, both EPT and species richness were higher immediately upstream and downstream of sites 3 and 4.

The second identifiable region was site 6. This site had noticeably fewer species, both total richness and EPT, than the next upstream site (site 5) and the next downstream location (site 7). The third region (sites 7 and 8) had among the highest total species richness for hester-dendy samples and the highest EPT richness values. The fourth region consisted of the most downstream sites (sites 9, 10, 11, and 12) which had relatively low total species richness values for hester-dendy samples and EPT values similar to those of the upstream region 1. However, kick 100 samples at these sites indicated considerably higher richness and EPT values for sites 9 and 10 than were indicated by the hester-dendy samples. High flows during the hester-dendy sampling interval may have disturbed the samplers and caused artificially low values for these parameters at these sites. Nevertheless, the third mode of benthic sampling (surber samples) also indicated that a decline in richness and EPT values occurred downstream of site 8 (Figure 2 and 3).

Some of the fundamental habitat differences that exist among sites within Miller Creek can be seen by examining differences in community characteristics of the upstream (sites 1 thru 6) and downstream (sites 7 thru 12) sites with respect to the proportion of taxa that are exclusive erosional (Figure 5) and depositional (Figure 6) habitat dwellers. More taxa in the upstream sites were composed of depositional taxa and more taxa in the downstream sites were composed of erosional taxa. Downstream of site 6, stream gradient increases significantly which results in increase availability of erosional habitats. Consequently, greater proportions of taxa at these sites are composed of erosional fauna. These habitat differences also explain much of the difference in number of EPT taxa found between the upstream and downstream sites since many taxa in these aquatic orders are restricted to erosional habitats with relatively large particle sizes such as gravel and cobble.

Analysis of functional feeding groups among the sites indicated that gatherers dominated the invertebrate community at all sites (Figure 7). The most variation among sites was in the relative proportion of filterers within the communities. Downstream locations (sites 7 thru 11) had greater proportions of this feeding group than upstream locations. This may also have reflected habitat based differences between the two areas of the stream since most filterers require hard relatively stable substrates for attachment and these substrates were more abundant at the downstream sites.

Average HBI scores for the sites generally indicated that taxa were less pollution tolerant (lower HBI scores) at sites 7 thru 11 and more pollution tolerant (high HBI scores) at sites 1 thru 6 (Figure 8). This trend was seen in both hester-dendy and kick 100 samples. Lower scores at the downstream sites were due to the presence of a greater number of EPT taxa many of which have lower tolerance to organic pollution. The upstream sites have fewer turbulent erosional areas and increased organic loads due to the presence of wetland vegetation. These may experience a higher frequency of low dissolved oxygen periods than the downstream sites. Consequently, HBI values, which are sensitive to low dissolved oxygen, were higher in upstream areas.

The three invertebrate sampling methods used in this study gave similar results. Increasing and decreasing trends in species richness and EPT taxa along the length of Miller Creek were similar for all three methods with the exception of the lower sites downstream of site 8. At the lower sites, particularly site 9, kick 100 samples indicated much higher EPT and species richness values than the Hester-Dendy or surber samplers. This result may be an artifact of the kick 100 sampling technique since the total number of individuals in a sampling area is not accounted for in the analysis of kick

100 samples and total numbers of individuals declined significantly in the lower sections of the stream. Hester-Dendy and Surber sampling employed averaging of several density based samples that accounted for total numbers of individuals. Kick 100 samples required some less processing time in the laboratory, however, results are more difficult to interpret since no replication is inherent to the technique. Since several samples were taken at each site with the other two techniques, they were easier to interpret with the assistance on common statistical methods.

Comparisons with other regional streams

Three metrics which accounted for much of the variability of the Miller Creek samples were compared to the same values at the reference streams (Figure 9). HBI scores in the reference streams were lower than those at several of the sites in Miller Creek. The upper 95% confidence level for HBI in reference streams (Figure 9) was lower than the average for Miller Creek at all sites upstream of site 6 (Figure 8). Species richness was also higher at reference streams than at several of the Miller Creek sites (Figure 9) particularly at sites 4, 6, and 11 (Figure 2). EPT taxa exhibited similar trends, Miller Creek sites were generally lower than reference streams, however, differences between Miller Creek and reference streams were even greater than observed with species richness. The average number of EPT taxa at reference streams was greater than six (Figure 9). Only site 7 exhibited an EPT value this high in Hester-Dendy samples. Sites 8 thru 10 had values that high in kick 100 samples.

Conclusions

-- Two distinct regions exist on Miller Creek which are characterized by the relative numbers of taxa that are predominantly found in erosional habitats. These taxa are predominantly in the insect orders Ephemeroptera, Plecoptera, and Tricoptera. Areas downstream from the mall have higher numbers of these taxa due to higher abundance of substrates with relatively large particle sizes (e.g. gravel, cobble) and higher dissolved oxygen levels.

-- Three areas on Miller Creek appear to have impaired macroinvertebrate communities. The stream in the vicinity of Hwy 53 (sites 3 and 4) has generally lower values for important invertebrate metrics than areas upstream and downstream from this location. Similarly, the stream in vicinity of the Miller Creek mall parking lot outflow has substantially lower values for most metrics compared with locations immediately upstream or downstream. The stream downstream from Lincoln Park also has significantly lower metric values than other locations. Low invertebrate metric values at the Hwy 53 sites and mall site cannot be entirely explained by habitat variables. Although substrates are generally poor at all three of the sites, overall habitat scores were similar to other Miller Creek sites. These data suggest that surface runoff from the airport region and the parking lots in the vicinity of the mall may have a toxic effect on stream communities. Downstream from Lincoln Park, habitat in the stream is of low quality and several storm sewers empty to the river. Both of these factors contribute to impairment of stream communities in that portion of the stream.

--The average values for several macroinvertebrate community metrics in Miller Creek are less than those reported in other Duluth area streams of similar size. This indicates that water quality trends in some portions of Miller Creek are below those achievable in the region.

--High water temperatures and low dissolved oxygen make Miller Creek unsuitable or of low habitat quality for Brook trout. Temperatures observed in late summer (23.5 C^0) were close to those considered lethal for this species (25.0 C^0). Temperatures well below this level can be stressful (Clark 1969). Dissolved oxygen levels below 5 mg/l, which is detrimental to brook trout, appear to be common in the upper portions of the stream. Although brook trout inhabit the stream and appear to reproduce periodically (Minn. DNR, unpublished data), the extent of areas suitable for these fish is restricted and of marginal habitat.

--Distinct loading of chlorides in Miller Creek occurs in vicinity of the Miller Creek mall and downstream. Loading occurs during both early fall and spring.

----Biotic communities in Miller Creek would benefit from increased protection and enhancement of riparian zones in stream margins and through control of runoff from parking lots and roadways. The stream rapidly warms to unsuitable temperatures during summer due to solar radiation. Since a relatively high proportion of Miller creek has little or no riparian canopy, increased development of such a canopy in the middle and upper sections of the stream would decrease maximum stream temperatures. Increased development of woody riparian buffers would also result in increased woody debris in the stream channel. In stream channels with little or no hard stony substrates such as most of Miller Creek upstream of the Hwy 53, woody debris is essential for invertebrate and fish habitat and secondary production.

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Table 1. Sampling sites on Miller Creek. Invertebrate samples were collected in 1991.

Site Number	Description	Sample Methods
M1	Haines Rd. Above Airport Rd.	1, 4
M2	Swan Lake Rd.	1, 4
M3	Above Hwy 53	1, 4
M4	Sundby Rd.	1, 3, 4
M5	Below Maple Grove Rd.	1, 3, 4
M6	Below Mall Parking Lot	1, 4
M7	Below Anderson Rd.	1, 3, 4
M8	Above Trinity Rd.	1, 3, 4
M9	Lincoln Park	1, 3, 4
M10	Below 3rd St.	1
M11	Below DTA	1, 3
M12	Mouth at St. Louis Bay	4
	1=Hester Dendy	
	3=Surber	
	4=Kick-100	

Table 2. Metrics used to examine macroinvertebrate communities on Miller Creek.

Metric	Attribute
Richness	total number of macroinvertebrate taxa
EPT Richness	total number of Ephemeroptera, Plecoptera, and Tricoptera taxa
log Total Abundance	total number of macroinvertebrates
% Dominant 2 Taxa	proportion of the total numbers of individuals accounted for by the two most abundant taxa at a site
% Erosional Taxa	proportion of the total numbers of individuals that are exclusively found in erosional habitats
% Depositional Taxa	proportion of the total number of individuals that are exclusively found in depositional habitats
HBI	Hilsenhoff's Improved Biotic Index (Hilsenhoff 1987), assess organic pollution
% Predators	proportion of total individuals that are predators
% Shredders	proportion of total individuals that are shredders, large organic particle feeders
% Gatherers	proportion of total individuals that are gatherers, small organic particle feeders
% Filterers	proportion of total individuals that are filterers, filter small organic particles
% Grazers	proportion of total individuals that are grazers, scrape algae and other material from rock surfaces

Table 4. Dissolved oxygen and temperature values of several sites on Miller Creek August X, 1991.

Site	Diss. Oxygen mg/l	Temperature C^0	Max/min Temp.
1	2.71	12.4	25.5/10
2	7.52	11.2	
3	3.01	12.5	23.8/11.1
4	3.92	13.1	
5	6.88	13.1	
6	6.92	13.8	23.8/12.2
7	9.23	11.4	
8	10.50	11.9	23.8/10.5
9	10.54	12.8	
10	10.79	14.0	
11	10.47	13.9	

Table 5. Water quality characteristics of Miller Creek.

		Turbidity	TIC	Spec. Cond.	TOC	NH4-N (dis)	Cl	NO3-N	SO4	Total P	Total N
Date	Site	NTU	mg/L C	umho/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
9–1-92	Haines Rd.	1.85	36.3	253	15.5	0.126	16.41	0.026	2.49	0.012	0.908
	Swan Lake Rd.	1.81	35.7	260	16.2	0.055	15.27	0.273	3.67	0.010	0.997
	Highway 53	1.93	32.8	236	16.9	0.046	16.68	0.019	4.83	0.027	0.785
	Sundby Rd.	4.33	30.3	210	17.1	0.037	15.00	0.014	3.79	0.027	0.872
	Maple Grove Rd.	3.37	29.4	225	16.5	0.035	17.94	0.030	4.31	0.018	0.812
	Mall	4.59	29.7	288	15.9	0.049	35.53	0.046	4.83	0.017	0.817
	Anderson Rd.	3.88	29.9	302	14.5	0.036	37.52	0.120	6.06	0.020	0.817
	Trinity Rd.	2.16	29.1	315	13.0	0.028	40.41	0.165	6.91	0.013	0.770
	Lincoln Park	2.32	29.9	330	12.7	0.024	43.56	0.168	7.56	0.011	0.720
	DTA	1.93	31.8	342	12.3	0.025	44.69	0.148	8.16	0.016	0.678
4-1-92	Haines Rd.	1.97	17.5	147	17.5	0.005	11.00	0.067	7.25	0.022	0.446
	Swan Lake Rd.	3.71	20.9	152	17.3	0.023	13.16	0.303	6.07	0.022	0.801
	Highway 53	3.25	17.2	197	13.8	0.008	26.55	0.228	6.98	0.019	0.669
	Sundby Rd.	5.39	16.4	185	17.9	0.011	25.03	0.166	6.56	0.023	0.589
	Maple Grove Rd.	5.7	16.8	192	18.4	0.003	26.03	0.163	6.75	0.024	0.602
	Mall	6.9	16.2	214	14.9	0.111	22.92	0.287	7.26	0.024	0.585
	Anderson Rd.	6.56	15.8	217	12.8	0.006	34.09	0.187	7.08	0.027	0.597
	Trinity Rd.	6.3	15.8	217	16.8	0.004	35.56	0.238	7.32	0.025	0.614
	Lincoln Park	7.42	15.3	223	17.2	0.003	35.59	0.223	7.53	0.024	0.619
	DTA	6.76	15.5	228	16.2	0.011	36.22	0.224	7.65	0.027	0.607

Table 6. Physical habitat characteristics of 12 sites on Miller Creek. [1]= QHEI score for habitat category, increasing scores indicate increasing value fish and invertebrate communities; [2]= excludes scores for gradient and watershed size.

site	gradient ft/mile	overhead shading	substrate[1]	cover[1]	morphology[1]	riparian[1]	pool/riffle[1]	total[2]
1	32.5	0	9	4	9	9.5	9	40.5
2	17.3	100	6	8	10	12.5	9	45.5
3	12.0	20	9	12	9	9.5	11	50.5
4	19.2	50	6	6	7	8.5	10	37.5
5	32.5	0	11	8	8	6	11	44
6	32.5	70	8	8	12	10	9	47
7	52.1	70	10	11	11	7	11	50
8	86.9	50	15	8	13	12	10	58
9	740.7	85	12	4	14	8.5	11	49.5
10	130.0	55	15	11	10	5.5	13	54.5
11	64.9	70	10	4	6	6	8	34
12	0	10	6	1	5	7	2	21

Table 7. Results of ANOVA on metrics examined with Hester-Dendy artificial substrate sampler data in Miller Creek.

Metric	F	p
Richness	7.9	< 0.01
EPT Richness	21.02	< 0.01
Log Total Abundance	22.7	< 0.01
% Dominant 2 Taxa	16.7	<0.01
% Erosional Taxa	12.06	<0.01
% Depositional Taxa	3.12	<0.01
HBI	25.69	<0.01
% Predators	3.26	<0.01
% Shredders	2.15	0.05
% Gatherers	9.12	< 0.01
% Filterers	8.78	< 0.01
% Grazers	2.76	0.02

List of Figures

Appendix 1.

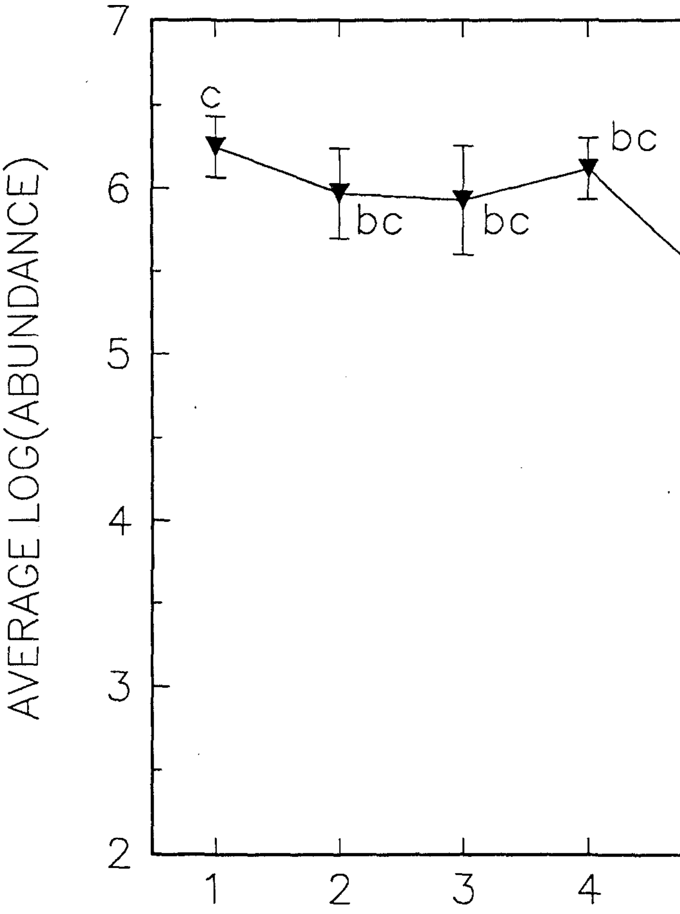
	1	2	3	4	5	6	7	8	9	10	11	12
COLEOPTERA												
Deronectes							*					
Dubiraphia	*	*	*	*			*					
Hydroporus								*				
Onychylis				*								
Optioservus	*	*		*	*	*	*	*	*	*	*	*
Stenelmis					*							
DIPTERA												
Antocha					*							
Atherix variegata					*		*					
Ceratopogonidae	*	*	*	*								
Chironomidae	*	*	*	*	*	*	*	*	*	*	*	*
Chrysops		*										
Dicranota							*	*		*	*	
Empididae	*	*	*	*	*	*	*	*	*			
Simuliidae	*	*	*	*	*	*	*	*	*			
Tipula					*			*	*			
Tipulidae				*								
EPHEMEROPTERA												
Baetis		*			*		*	*	*	*	*	*
Caenis		*		*	*		*					
Leptophlebia			*									
Pseudocloeon									*			
Tricorythodes		*				*	*	*	*		*	*
HEMIPTERA												
Belostoma				*								
Hesperocorixa					*							
Mesovelia										*		

Saldidae				*								
LEPIDOPTERA												
Parargyractis							*					
ODONATA												
Anax					*							
Perithemis		*										
Somatochlora	*		*									
PLECOPTERA												
Allocapnia								*				
Amphinemura									*			
Isoperla							*	*				
Nemoura						*						
Neoperla		*										
Paracapnia										*		
Paragnetina								*	*			
Taeniopteryx					*		*	*				
TRICHOPTERA												
Anagapetus							*					
Ceraclea		*			*							
Ceratopsyche		*		*	*	*	*	*	*	*	*	
Cheumatopsyche	*	*		*	*		*	*	*		*	
Chimarra							*	*	*			
Glossosoma		*					*	*	*		*	
Goera								*				
Hydropsyche	*	*		*								
Hydroptila					*			*	*		*	
Lepidostoma				*			*	*	*	*	*	
Limnephilidae							*					
Limnephilus		*		*								

Micrasema							*		*			
Ochrotrichia		*										
Oecetis		*				*	*			*		
Oligostomis	*											
Polycentropus							*					
Psychomyia					*						*	
Psychomyiidae										*		
Ptilostomis	*	*										
ACARI												
Hydracarina	*	*	*	*	*		*				*	
AMPHIPODA												
Gammarus								*	*	*		
Hyalella azteca		*	*	*	*	*						
COPEPODA			*			*						
DECAPODA												
Cambaridae					*							
HIRUDINEA	*	*	*	*	*		*	*	*			
Helobdella stagnalis				*								
ISOPODA												
Asellus		*		*	*	*	*	*	*	*	*	
LIMNOPHILA												
Ferrissia				*	*		*					
Fossaria									*			
Helisoma				*								
Helisoma anceps	*											
Physa	*	*	*	*	*		*	*	*	*		
MESOGASTROPODA												
Valvata sincera	*							*				
NEMATODA	*	*	*	*	*	*		*				

OLIGOCHAETA	*	*	*	*	*	*	*	*	*	*	*	*
OSTRACODA	*	*	*									
TRICLADIDA												
Planariidae									*			
VENEROIDA												
Sphaerium	*	*	*	*	*		*					

Figure 1.



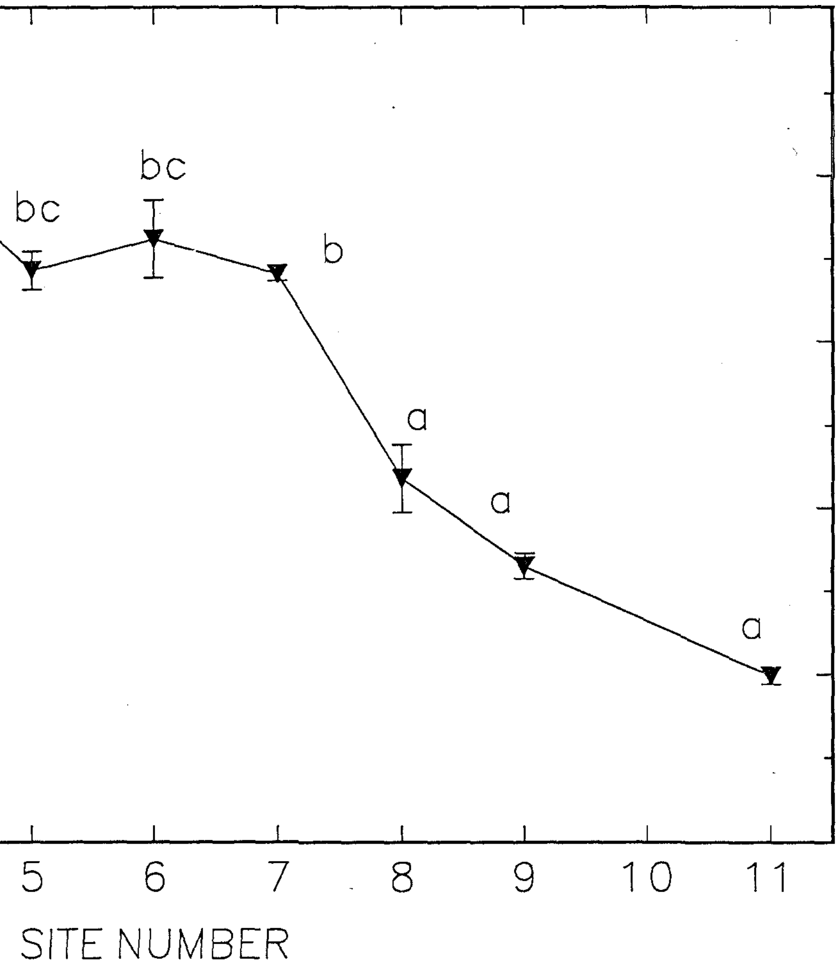
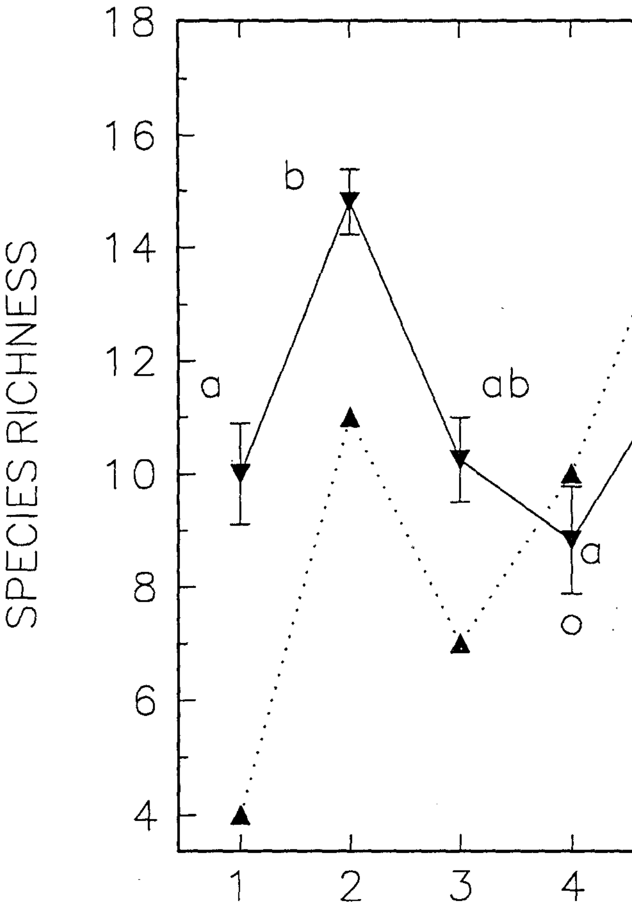
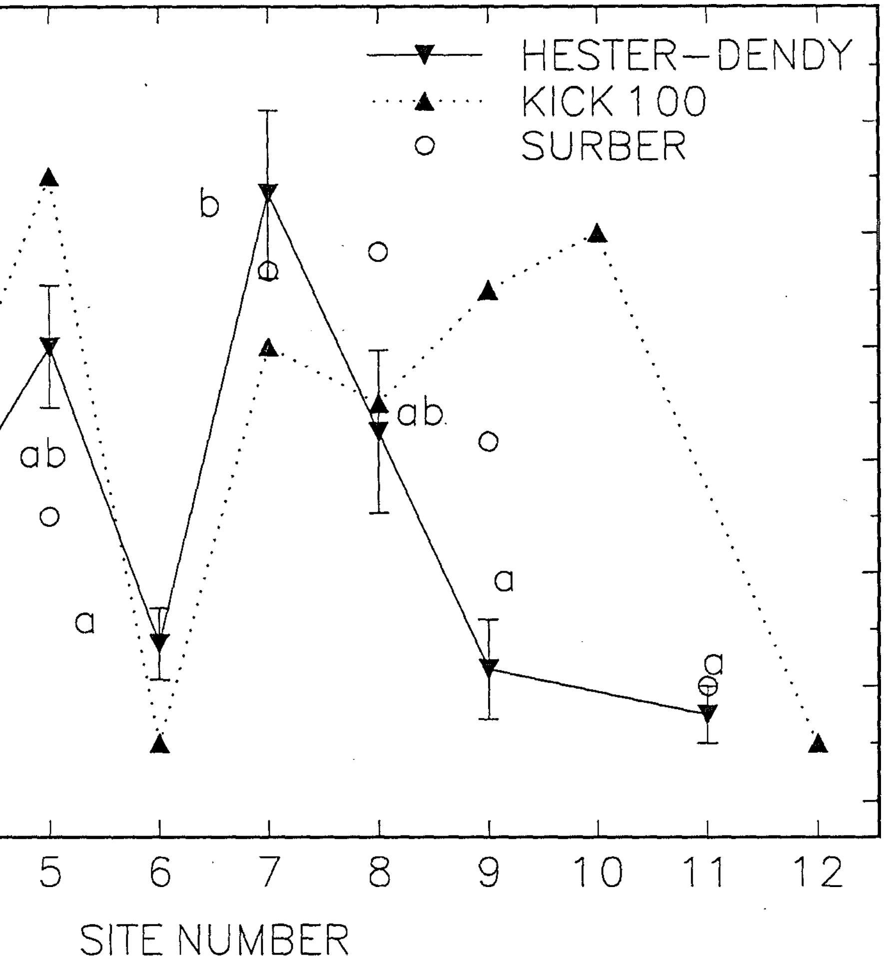

bc
bc
b
a
a
a
5
6
7
8
9
10
11
SITE NUMBER

Figure 2.





HESTER—DENDY
KICK 100
SURBER
b
ab
ab
a
a
a
5
6
7
8
9
10
11
12
SITE NUMBER

Figure 3.

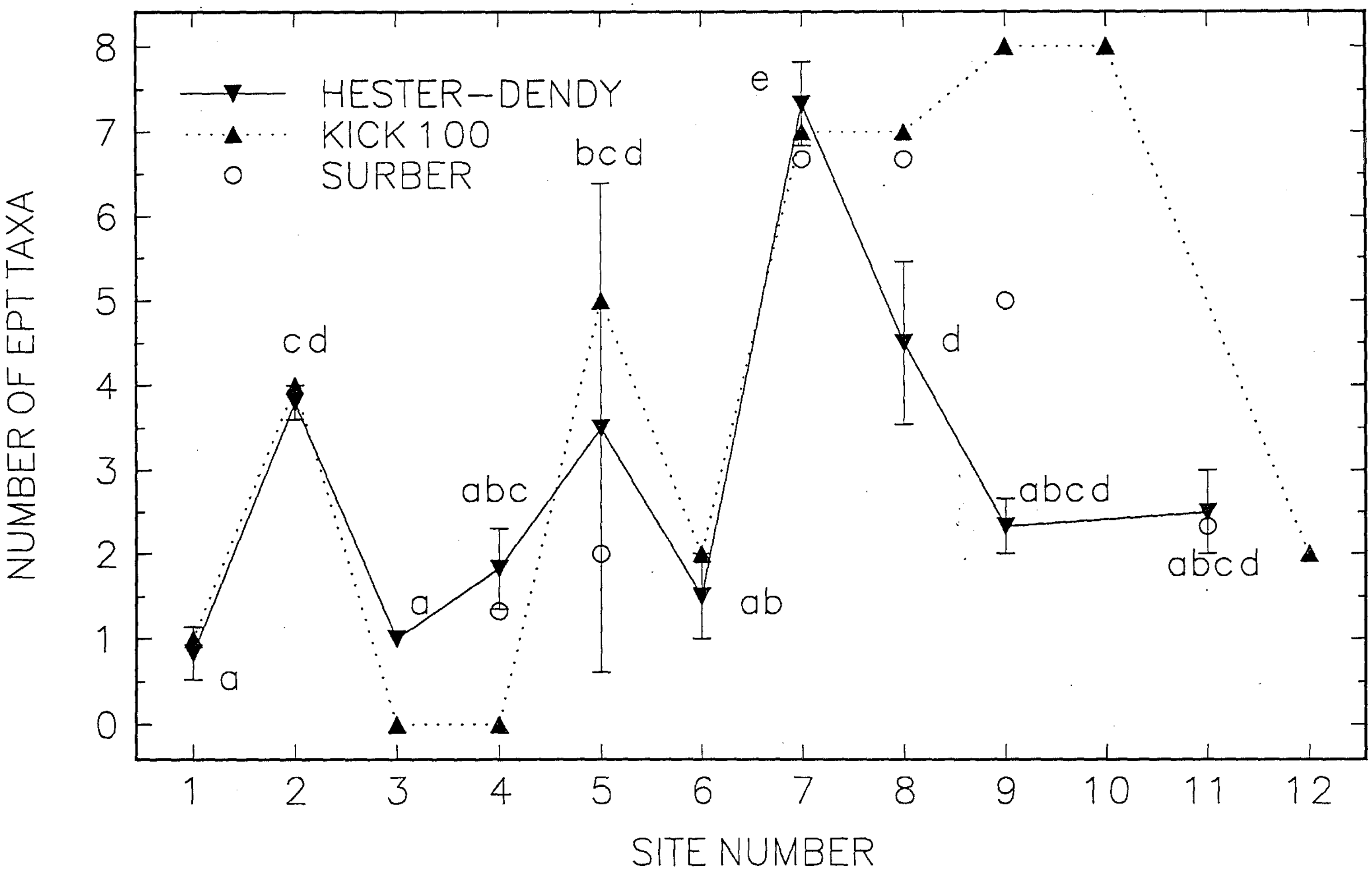
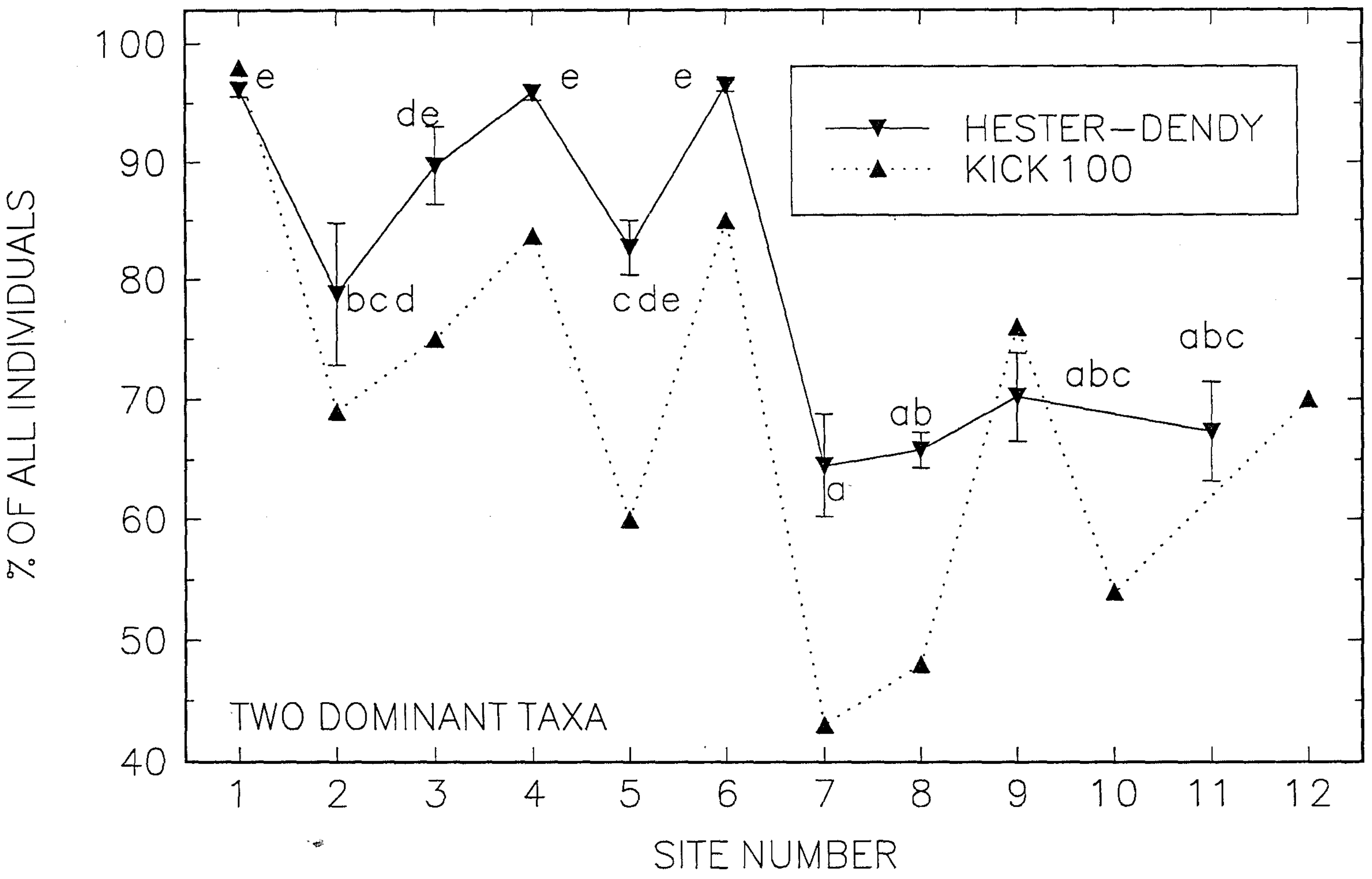

HESTER–DENDY
KICK 100
SURBER
NUMBER OF EPT TAXA
SITE NUMBER
0
1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8
9
10
11
12
a
cd
a
abc
bcd
ab
e
d
abcd
abcd

Figure 4.



100
90
80
70
60
50
40
% OF ALL INDIVIDUALS
1
2
3
4
5
6
7
8
9
10
11
12
SITE NUMBER
HESTER–DENDY
KICK 100
TWO DOMINANT TAXA
e
bcd
de
e
cde
e
a
ab
abc
abc

Figure 5.

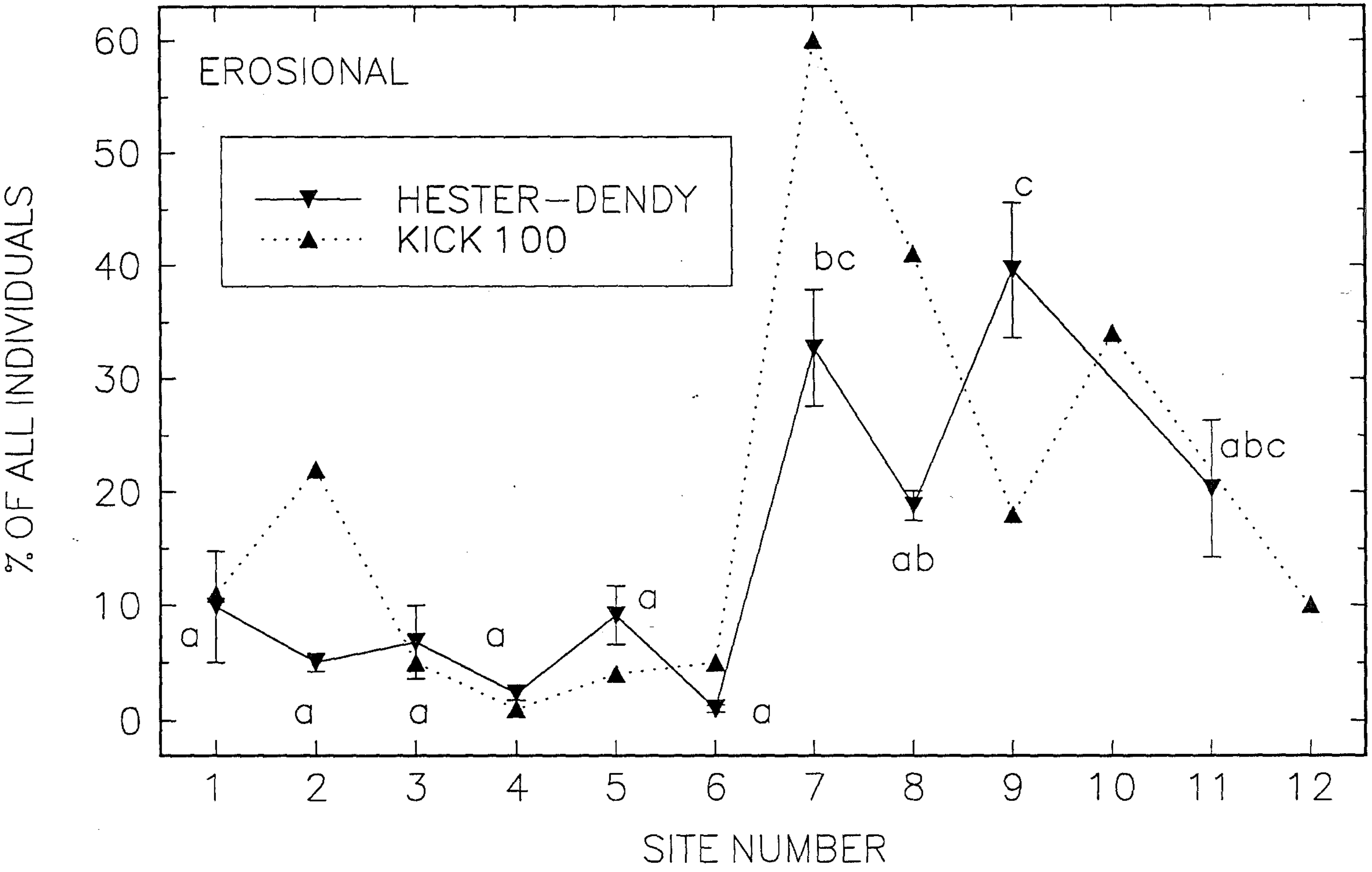

EROSIONAL
HESTER–DENDY
KICK 100
% OF ALL INDIVIDUALS
SITE NUMBER
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8
9
10
11
12
a
a
a
a
a
a
bc
ab
c
abc

Figure 6.

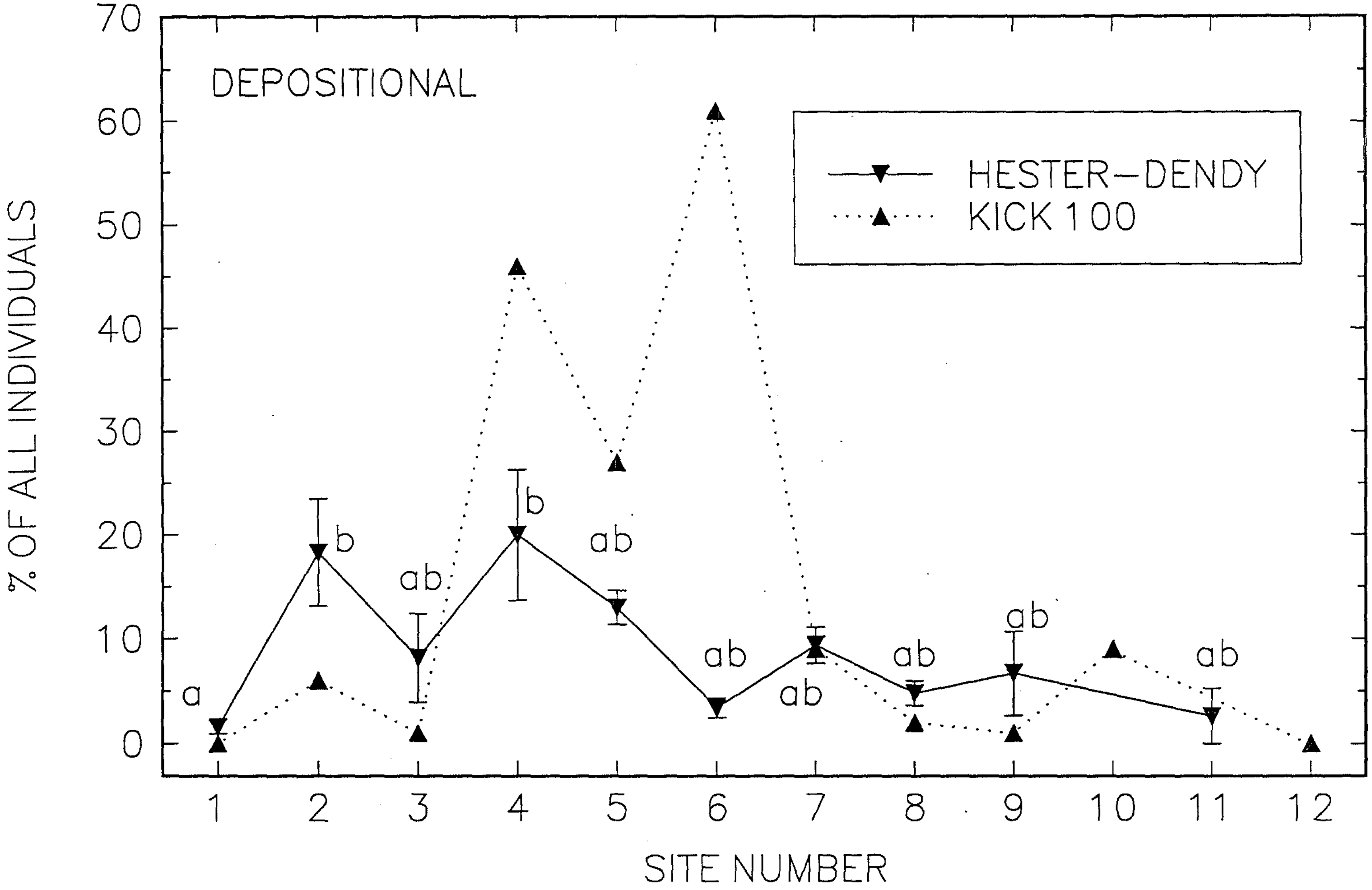
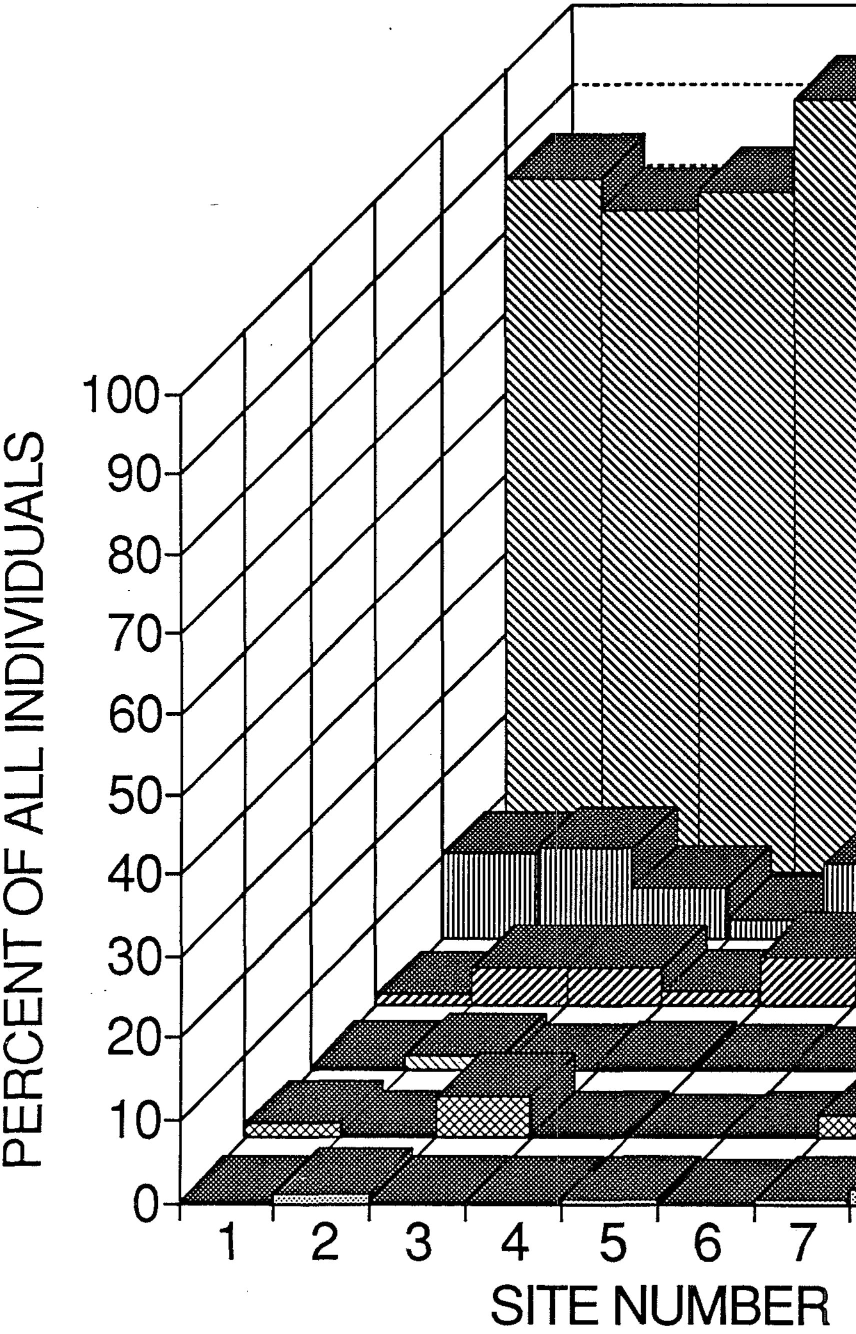

DEPOSITIONAL
HESTER−DENDY
KICK 100
% OF ALL INDIVIDUALS
0
10
20
30
40
50
60
70
SITE NUMBER
1
2
3
4
5
6
7
8
9
10
11
12
a
b
ab
b
ab
ab
ab
ab
ab
ab

Figure 7.


PERCENT OF ALL INDIVIDUALS
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
SITE NUMBER

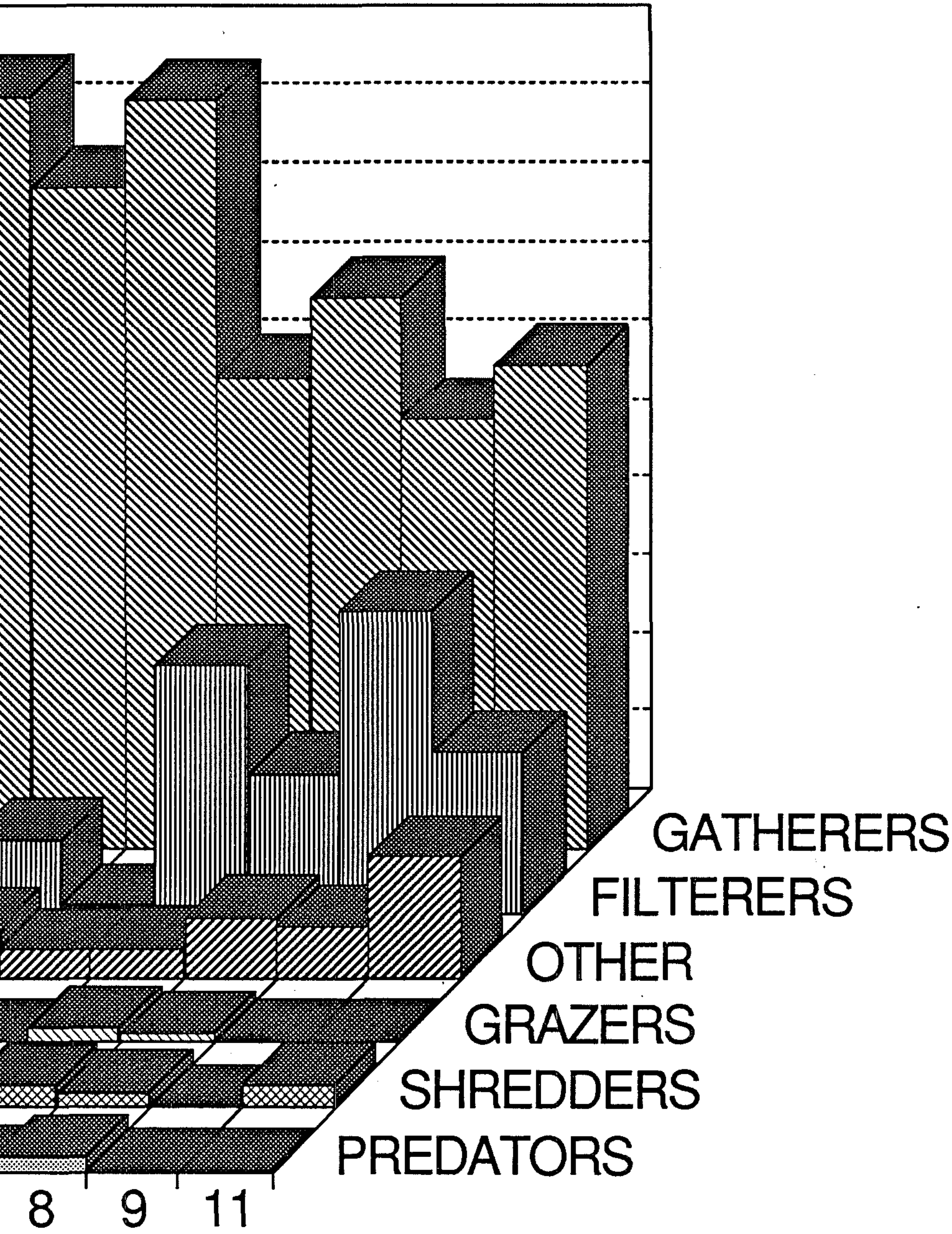
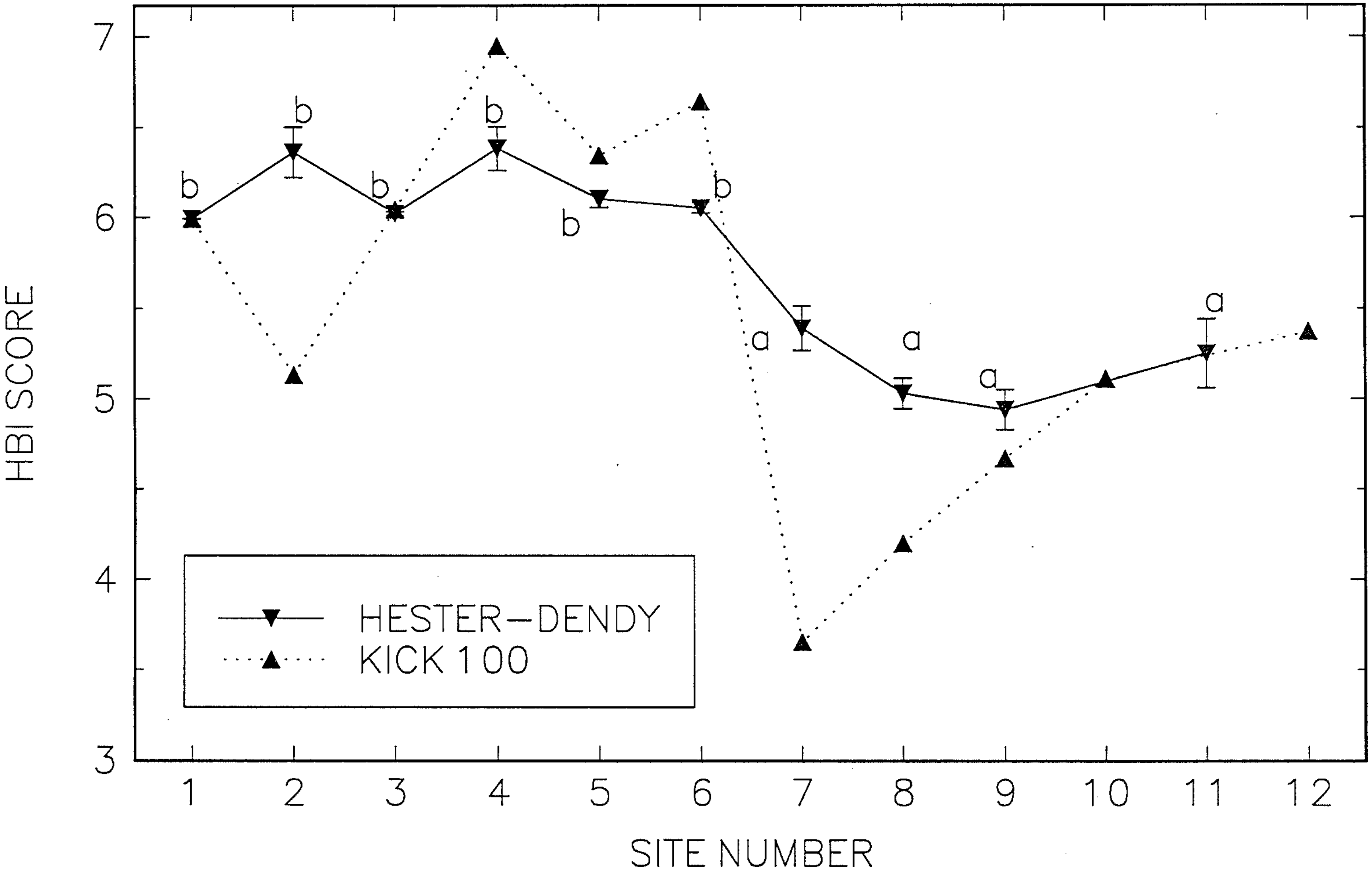
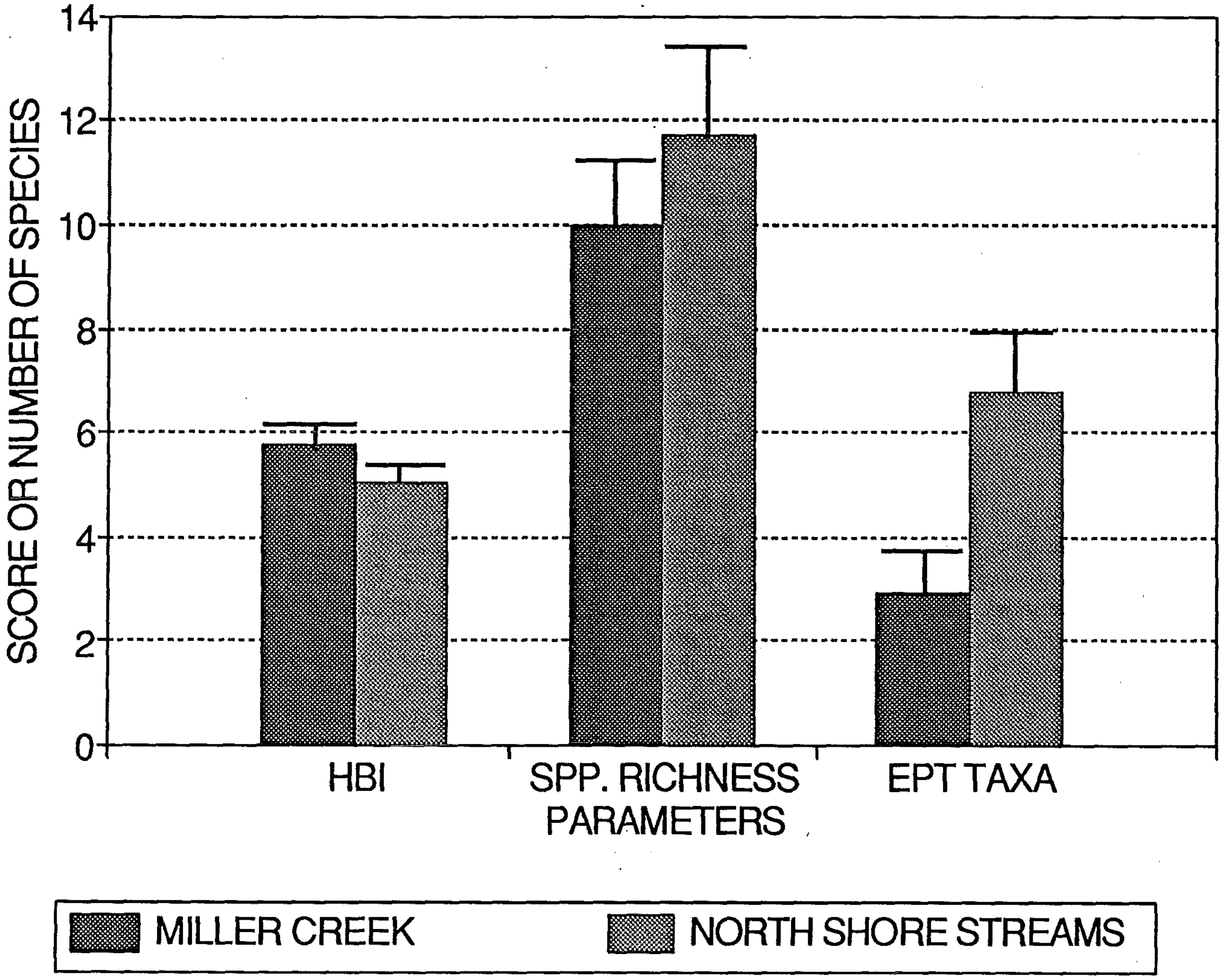

GATHERERS
FILTERERS
OTHER
GRAZERS
SHREDDERS
PREDATORS
8
9
11

Figure 8.



HBI SCORE
SITE NUMBER
3
4
5
6
7
1
2
3
4
5
6
7
8
9
10
11
12
HESTER—DENDY
KICK 100
b
b
b
b
b
b
a
a
a
a

Figure 9.



SCORE OR NUMBER OF SPECIES
0
2
4
6
8
10
12
14
HBI
SPP. RICHNESS
EPT TAXA
PARAMETERS
MILLER CREEK
NORTH SHORE STREAMS