EFFECTS OF DREDGE MATERIAL PLACEMENT ON MACROINVERTEBRATE COMMUNITIES

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Kip E. Stevenson And Todd M. Koel

Illinois Natural History Survey
LTRMP Havana Field Station
704 N. Schrader Avenue
Havana, IL 62644
(309)543-6000

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Introduction

The U.S. Army Corps of Engineers Rock Island District is responsible for the operation and maintenance of a 9-foot-deep navigation channel on the Illinois River (Rm 80.0-327.0). Maintenance often requires removal of accumulated sediments; hydraulic dredging is often used with bankline placement of dredged material. Impacts of this dredged material on benthic macroinvertebrate communities is not well documented or understood. The major purpose of this study was to determine if there were differences in benthic macroinvertebrate abundances between sites which had received dredged material placement and those which had not.

Methods

Macroinvertebrate collections were made from offshore areas of main channel border habitat in La Grange Reach of the Illinois River during two separate sampling episodes (November 1997 and November/December 1998) (Figure 1). To select sampling sites we first identified 7800 sites at 0.01-mile intervals along each main channel border (right and left) of the 78-mile La Grange Reach (Figure 2). Using records from the Rock Island District, U.S. Army Corps of Engineers and discussions with district personnel, we identified the last date (year) dredged material was placed on each site. In this report, sites never receiving dredged material are referred to as "NP" (No Placement) sites. Sites on which dredged materials were placed are denoted as "P" (Placement) sites. For P sites, an accompanying number refers to the last date the P site received dredged material; therefore a P97 site last received dredged material in 1997. Because of the precision of the boundaries for areas receiving dredged material was poor (sometimes ±0.1 river miles), we designated buffer zones at the transitions between placement (P) and no placement (NP) areas (0.05 mile beyond or 0.10 mile inside the reported outer edge [upriver or downriver] of the dredged material placement site) and between areas receiving placement in different years (Figure 2); sites within these buffer zones were eliminated from the pool of potential sampling sites. Sample sites were located in the field using a hand-held global positioning system (GARMIN-GPS 75) and an Illinois Waterway Chart (U.S. Army Corps of Engineers 1987).

All macroinvertebrate collections were made using a 508-cm^2 Ponar grab sampler. Methods were adapted from those used by the invertebrate component of the Long Term Resource Monitoring Program (Thiel and Sauer 1995). Between 7 November and 1 December 1997, we collected 15 Ponar grab samples at each of 35 sites for a total of 525 Ponar grab samples. We distributed our sampling effort among the following three treatment groups based on when they last received dredged material: never (NP), 1997 (P97), and 1996 (P96). Between 16 November 1998 and 9 December 1998, we collected 15 Ponar grab samples at each of 36 sites for a total of 540 Ponar grab samples. We distributed our sampling effort among the following three treatment groups based on when they last received dredged material: never (NP), 1998 (P98), and 1997 (P97). If the Ponar did not collect a complete sample (i.e., a rock or shell kept the jaws from closing completely), that partial sample was discarded and another was taken. If a site contained large rocks or numerous shells from which a complete set of replicates could not be taken, another site was selected from the sites list. Each sample was characterized by depth, substrate (hard clay, silt/clay, mostly silt/clay with sand, mostly sand with silt/clay, sand, or gravel/rock), and estimated percent shells and detritus (0, 1-20, 21-50, 51-90, or 91-100%). In the field, each sample was washed through a 1-mm-mesh screen. As the sample was washed, macroinvertebrates were picked from the screen and preserved in 10% formalin. The material retained on the screen was stained with Rose Bengal, preserved with 10% formalin, and returned to the laboratory for further processing. In the laboratory, samples were washed through a 600-μm sieve. Material retained on the sieve was examined under a 2x magnifier and macroinvertebrates were picked, sorted into one of nine groups (i.e., mayflies, midges, fingernail clams, Asiatic clams, zebra mussels, dragonflies, Unionid mussels, snails, or other), and enumerated. Mean numbers and densities of these target organisms were calculated.

Substrate analysis

Substrates were classified in the field using methods adapted from the invertebrate component of the Long Term Resource Monitoring Program (Thiel and Sauer 1995). Substrates were placed into one of 6 groups (hard clay, silt/clay, mostly silt/clay with sand, mostly sand with silt/clay, sand, or gravel/rock) based on visual inspection and touch. Fifty four samples were collected in the field and returned to the lab for particle size analysis. Three replicates of each sample were air dried and homogenized. Each replicate was dry sieved through a series of 4 sieves:

gravel (1mm), coarse sand (0.5mm), medium sand (0.25mm), fine sand (0.063mm), and silt/clay (<0.063mm). Percentages were calculated by the weight retained by each sieve.

Statistical Analysis

All statistical analyses were conducted utilizing PC SAS (1989). Frequency distributions of all invertebrate count data were analyzed for univariate normality using PROC UNIVARIATE. Since the tests for normality were rejected, and the data also fail the assumption of homogeneity of variance (Zar 1984), we utilized only multivariate analysis of variance (MANOVA) and non-parametric ANOVA (Kruskal-Wallis tests) for analyses presented in this report.

Comparisons of macroinvertebrate collections between years

For all eight invertebrate groups collected and enumerated during the November sampling, data from the 15 ponar grabs were combined to constitute a single sample for each of n=35 and n=36 sites in 1997 and 1998, respectively. Each site was characterized by when it last received dredged material and placed into one of three classes, including 1) never received dredged material, 2) received dredged material one year previous, or 3) received dredged material during current year. For each dredge placement class, we utilized MANOVA, with the eight macroinvertebrate groups as dependant variables, to compare collections made in 1997 with that obtained in 1998.

Recovery (recolonization) of dredge placement areas

To assess possible recovery or recolonization of macroinvertebrates following dredged material placement, we compared collections made in 1997 (which were from sites that received dredged material in the current year) with collections made in 1998 (which were from sites that received dredged material one year previous). We utilized MANOVA, with the eight macroinvertebrate groups as dependant variables, to make this comparison.

Overall dredged material effect, 1997 and 1998 data combined

Effects of dredged material placement on densities of macroinvertebrates at sites were determined utilizing a series of non-parametric tests. For each of the macroinvertebrate groups separately, we utilized a Kruskal-Wallis ANOVA (PROC NPAR1WAY, with option WILCOXON) with the dredge material placement classification (three categories as described above, including never, one year previous, and current year) entered as the class variable for each analysis.

Overall substrate effect, 1997 and 1998 data combined

Substrate composition effects on densities of macroinvertebrates at sites were determined utilizing a series of non-parametric tests. For each of the macroinvertebrate groups separately, we utilized a Kruskal-Wallis ANOVA (PROC NPAR1WAY, with option WILCOXON) with the LTRMP substrate classification (four categories, including silt/clay, mostly silt/clay with sand, mostly sand with silt/clay, or sand) entered as the class variable for each analysis.

Results

In November 1997, we identified a total of 1222 macroinvertebrates from 525 ponar grabs taken at 35 sites. Of these, 804 (65.8%) were midges, 73 (6.0%) were mayflies, 43 (3.5%) were fingernail clams, and the remainder were Asiatic clams, zebra mussels, dragonflies, Unionid mussels, snails, or other taxa (Table 1, Figure 3). The average densities of these macroinvertebrates varied among taxa and among dredge material placement class. Overall (all dredge material placement classes combined), average densities ranged from 30.97/m^2 for midges to only 0.15/m^2 for dragonflies. Most (733, average density of 71.86/m^2) macroinvertebrates were collected from sites which had never received dredge placement material, whereas 313 individuals (30.08/m^2) were collected at sites receiving material in 1996, and 176 (32.87/m^2) individuals from sites receiving material in 1997.

In November 1998, we identified a total of 731 macroinvertebrates from 540 ponar grabs taken at 36 sites. Of these, 541 (74.0%) were midges, 64 (8.8%) were Asiatic clams, 23 (3.2%) were fingernail clams, 15 (2.1%) were mayflies, and the remainder were zebra mussels, dragonflies, Unionid mussels, snails, or other taxa (Table 2, Figure 3). The average densities of these macroinvertebrates varied among taxa and among dredge material placement class. Overall (all dredge material placement classes combined), average densities ranged from 19.64/m^2 for midges to only 0.15/m^2 for zebra mussels and Unionid mussels. Most (350, average density of 38.13/m^2) macroinvertebrates were collected from sites which had never received dredge placement material, whereas 166 individuals (18.08/m^2)

were collected at sites receiving material in 1997, and 215 (23.42/m^2) individuals from sites receiving material in 1998.

Comparisons of macroinvertebrate collections between years

Although total numbers of macroinvertebrates collected was lower in 1998 than in 1997, relative abundances of eight identified taxa were highly similar both years. Midges were most abundant, and comprised 66% and 74% of all macroinvertebrates collected in 1997 and 1998, respectively (Figure 3). We noted very little differences in other taxa, except that relative abundance of Asian clams increased from 2% to 9%, and of mayflies decreased from 6% to 2%. There also were no major differences in relative abundances of taxa between years when considering the three dredge material placement classes (never, one-year previous, current year) separately (Tables 1-3).

Results of MANOVA utilizing total numbers of organisms collected at n=35 sites in 1997 and n=36 sites in 1998 indicated no statistically significant differences in collections of macroinvertebrates between years (P=0.07, 0.33, and 0.08 for never, one-year previous, and current year sites, respectively). Because of this, we fail to reject our null hypotheses 1-3, which state that there is no difference in overall macroinvertebrate collections between November 1997 and November 1998. Analyses which follow include data from both years combined.

Recovery (recolonization) of dredge placement areas

Macroinvertebrate collections which were made at sites in 1997 and had received dredge material placement in 1997 (current year) were compared to collections which were made in 1998 and had received dredge material placement in 1997 (one-year previous) (Tables 1 and 2). Results of MANOVA utilizing total numbers of organisms collected at n=7 sites (105 ponar grabs) in 1997 and n=12 sites (180 ponar grabs) in 1998 indicated no statistically significant difference in collections of macroinvertebrates at these sites (P=0.14) and we failed to reject null hypothesis 4. Since fewer organisms existed at dredge placement areas and overall diversity was lower in these areas, this analysis indicates no significant "recovery" of dredge placement areas in La Grange Reach over one year.

Overall dredged material effect, 1997 and 1998 data combined

Overall abundance as well as diversity of macroinvertebrates was much higher at sites which had never received dredge placement material (Table 3, Figure 6). From all 1065 ponar grabs taken during 1997 and 1998, 1083 macroinvertebrates (55.4%, average density of 55.88/m^2) were collected from sites which had never received dredge placement material, whereas 479 individuals (24.5%, 24.46/m^2) were collected from sites which received dredge placement material one year previous, and 391 individuals (20.0%, 26.9/m^2) were collected from sites which received dredge placement material during the current year. Also, in both years we noted a trend of declining diversity among the three dredge material placement classes. Overall, relative abundance of taxa other than midges was 43% at areas which have never received dredge material, 25% in areas which received dredge material one-year previous, and only 6% in areas receiving dredge material the current year (Figure 6).

Although overall densities of several taxa were very low, results of Kruskal-Wallis ANOVAs indicated that all observed reductions in density due to dredge material placement were significant. Differences in densities of mayflies, midges, fingernail clams, Asiatic clams, zebra mussels, dragonflies, Unionid mussels, and snails among the three dredge material placement classes were all significant ($P \leq 0.08$)(Figures 4 and 5). For all taxa, densities were highest at sites which had never received dredge placement material, and, for all taxa except midges, densities were lowest at sites which received dredge placement material during the current year. We noted at least two different midge species, with one of them preferring the substrates available at sites recently receiving dredge material.

Overall substrate composition effect, 1997 and 1998 data combined

Substrate composition of LTRMP substrate classes as determined by U.S. standard sieves ranged from 47%, 43%, and 8% silt/clay, fine sand, and medium sand, respectively for substrate class 2 (silt/clay); 29%, 41%, and 27% silt/clay, fine sand, and medium sand, respectively for substrate class 3 (silt/clay with sand); 3%, 27%, and 64% silt/clay, fine sand, and medium sand, respectively for substrate class 4 (sand with silt clay); and 2%, 35%, and 59% silt/clay, fine sand, and medium sand, respectively for substrate class 5 (sand) (Figure 7). Coarse sand and gravel made up <5% of all substrate classifications.

Overall densities of macroinvertebrates was higher in silt/clay substrates than other substrate classes for nearly all taxa (Tables 4, 5, and 6). From all 1065 ponar grabs taken during 1997 and 1998, 925 macroinvertebrates (47.4%, average density of 66.93/m^2) were collected from ponar grabs in silt/clay substrate, whereas 498 individuals (25.5%, 22.71/m^2) were collected from ponar grabs in sand substrates, 262 individuals (13.4%, 23.57/m^2) were collected from ponar grabs in sand with silt/clay substrates, and 259 individuals (13.3%, 41.97/m^2) were collected from ponar grabs in silt/clay with sand substrates (Table 6).

Analysis of individual macroinvertebrate taxa by Kruskal-Wallis ANOVAs indicated that all observed reductions in density due to substrate composition were highly significant. Differences in mean densities of mayflies, midges, fingernail clams, Asiatic clams, zebra mussels, dragonflies, Unionid mussels, and snails among the four LTRMP substrate classes were all significant ($P \leq 0.01$)(Figures 8 and 9). For all taxa except Unionid mussels, densities were highest in ponar grabs containing silt/clay, and, for all taxa except midges, densities were lowest in ponar grabs containing sand.

Discussion

Previous collections in the main channel border of the La Grange reach (Sauer 1998) have shown densities and yearly fluctuations of those densities similar to those we found. For example Sauer (1998) noted an increase in Chironomidae densities from 27.3/m^2 to 57.7/m^2 between 1993 and 1994 followed by a decrease (14.8/m^2) in 1995. Mayflies, fingernail clams, and Asiatic clams followed a similar yearly trend. Factors such as life cycles, dispersal, growth and development may account for the differences in relative abundance from one year to the next.

The NP sites contained higher numbers of the target organisms than either of the dredged material sites. Several factors may account for the lower densities in the P sites. The most obvious is direct burial of organisms by the dredged material. Many organisms are killed outright while others are unable to reach the surface before they suffocate. Another effect of dredged material placement is severe habitat alteration resulting from the change in the physical and chemical characters of the bottom sediments, loss of cover, or change in circulation patterns at the disposal site (Morton 1977). The invertebrate response may be characterized as a destablization of the community and an increase density of opportunistic species (Flint 1979). The only group that did not show a dramatic decline in numbers between placement years was the chironomidae which is considered to be less affected by and sometimes favors alteration of habitat. Fingernail clams, on the other hand, are fairly intolerant organisms, capable of high reproductive success and survival when in a favorable controlled or stable environment (Kirby and Gritters 1997).

Substrate type seemed to be related to the year the site had received dredged material. Many organisms found in the main channel border habitat such as mayflies, fingernail clams, and dragonflies require harder more stable substrates which they can burrow into or cling to in the faster current (Nuttall 1972; Ali and Mulla 1976). Our results showed that the silt/clay substrate generally supported a higher density of all target organisms, whereas sand substrates supported very low numbers of organisms except in the case of small-bodied midges. Midges have short life cycles, rapid colonization, and high turnover rates and can adapt to different substrate types (Benke 1984). Reduced species richness and abundance are commonly associated with areas of shifting sand, although certain species of mayflies and midge larva apparently prefer this substrate (Nuttall 1972; Ali and Mulla 1976). Sauer (1998) found the highest densities of mayflies (30.9/m^2), fingernail clams (35.0/m^2), an midges (56.8/m^2) in the silt/clay substrate within the La Grange reach. Mayflies are tolerant generalists, capable of good success if silt/clay substrate is present (Kirby and Gritters 1997). Low densities were found by Sauer (1998) from the sand substrate: mayflies (1.7/m^2) and fingernail clams (6.9/m^2). She also found midge density in the sand substrate (31.2/m^2) similar to our findings (20.57/m^2).

Our results showed no recovery or recolonization of dredge placement areas by our target organisms between 1997 and 1998 sampling. Flint (1979) reported at a Lake Erie disposal site that more than a year was required for the affected areas to reestablish a community structure similar to those of unaffected areas.

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		Mayfly	Midge	Fingernail clam	Asiatic clam	Zebra mussel	Dragonfly	Unionid mussel	Snail	Other	Overall
1997											
	Total organisms	5	165	0	0	0	0	1	0	5	**176**
	Ponar grabs	105	105	105	105	105	105	105	105	105	**105**
	Mean density (#/m^2)	0.93	30.81	0	0	0	0	0.19	0	0.93	**32.87**
	Standard error	0.41	4.57	0	0	0	0	0.19	0	0.41	**4.62**
1996											
	Total organisms	7	227	14	2	2	1	8	2	50	**313**
	Ponar grabs	210	210	210	210	210	210	210	210	210	**210**
	Mean density (#/m^2)	0.67	21.82	1.35	0.19	0.19	0.1	0.77	0.19	4.8	**30.08**
	Standard error	0.25	2.57	0.52	0.19	0.14	0.1	0.3	0.14	1.5	**3.64**
Never											
	Total organisms	61	412	29	23	31	3	21	31	122	**733**
	Ponar grabs	210	210	210	210	210	210	210	210	210	**210**
	Mean density (#/m^2)	5.98	40.39	2.84	2.25	3.04	0.29	2.06	3.04	11.84	**71.86**
	Standard error	1.38	4.86	0.75	0.54	1.01	0.17	0.51	0.64	2.9	**7.79**
Overall											
	Total organisms	**73**	**804**	**43**	**25**	**33**	**4**	**30**	**33**	**177**	**1222**
	Ponar grabs	**525**	**525**	**525**	**525**	**525**	**525**	**525**	**525**	**525**	**525**
	Mean density (#/m^2)	**2.81**	**30.97**	**1.66**	**0.96**	**1.27**	**0.15**	**1.15**	**1.27**	**6.81**	**47.07**
	Standard error	**0.57**	**2.39**	**0.36**	**0.23**	**0.41**	**0.08**	**0.24**	**0.26**	**1.31**	**3.63**

Table 1. Total organisms, mean density, and standard error from each placement year during November 1997 sampling.

		Mayfly	Midge	Fingernail clam	Asiatic clam	Zebra mussel	Dragonfly	Unionid mussel	Snail	Other	Overall
1998											
	Total organisms	0	204	0	4	0	0	1	0	6	**215**
	Ponar grabs	180	180	180	180	180	180	180	180	180	**180**
	Mean density (#/m^2)	0	22.22	0	0.44	0	0	0.11	0	0.65	**23.42**
	Standard error	0	3.7	0	0.27	0	0	0.11	0	0.31	**3.71**
1997											
	Total organisms	2	137	3	15	1	0	0	5	3	**166**
	Ponar grabs	180	180	180	180	180	180	180	180	180	**180**
	Mean density (#/m^2)	0.22	14.92	0.33	1.63	0.11	0	0	0.54	0.33	**18.08**
	Standard error	0.15	3.55	0.19	0.51	0.11	0	0	0.24	0.19	**3.79**
Never											
	Total organisms	13	200	20	45	3	8	3	3	55	**350**
	Ponar grabs	180	180	180	180	180	180	180	180	180	**180**
	Mean density (#/m^2)	1.42	21.79	2.18	4.9	0.33	0.87	0.33	0.33	5.99	**38.13**
	Standard error	0.38	3.23	0.55	0.9	0.19	0.3	0.19	0.19	1.69	**4.42**
Overall											
	Total organisms	**15**	**541**	**23**	**64**	**4**	**8**	**4**	**8**	**64**	**731**
	Ponar grabs	**540**	**540**	**540**	**540**	**540**	**540**	**540**	**540**	**540**	**540**
	Mean density (#/m^2)	**0.54**	**19.64**	**0.84**	**2.32**	**0.15**	**0.29**	**0.15**	**0.29**	**2.32**	**26.54**
	Standard error	**0.14**	**2.02**	**0.2**	**0.36**	**0.07**	**0.1**	**0.07**	**0.1**	**0.58**	**2.33**

Table 2. Total organisms, mean density, and standard error from each placement year during November 1998 sampling.

		Mayfly	Midge	Fingernail clam	Asiatic clam	Zebra mussel	Dragonfly	Unionid mussel	Snail	Other	Overall
Current Year											
	Total organisms	5	369	0	4	0	0	2	0	11	**391**
	Ponar grabs	285	285	285	285	285	285	285	285	285	**285**
	Mean density (#/m^2)	0.34	25.39	0	0.28	0	0	0.14	0	0.76	**26.9**
	Standard error	0.15	2.89	0	0.17	0	0	0.097	0	0.24	**2.9**
One Year Previous											
	Total organisms	9	364	17	17	3	1	8	7	53	**479**
	Ponar grabs	390	390	390	390	390	390	390	390	390	**390**
	Mean density (#/m^2)	0.46	18.59	0.87	0.87	0.15	0.05	0.41	0.36	2.71	**24.46**
	Standard error	0.15	2.16	0.29	0.26	0.09	0.05	0.16	0.13	0.8	**2.64**
Never											
	Total organisms	74	612	49	68	34	11	24	34	177	**1083**
	Ponar grabs	390	390	390	390	390	390	390	390	390	**390**
	Mean density (#/m^2)	3.82	31.58	2.53	3.51	1.75	0.57	1.24	1.75	9.09	**55.88**
	Standard error	0.76	3.01	0.48	0.52	0.54	0.17	0.29	0.35	1.74	**4.68**
Overall											
	Total organisms	**88**	**1345**	**66**	**89**	**37**	**12**	**34**	**41**	**241**	**1953**
	Ponar grabs	**1065**	**1065**	**1065**	**1065**	**1065**	**1065**	**1065**	**1065**	**1065**	**1065**
	Mean density (#/m^2)	**1.64**	**25.14**	**1.23**	**1.66**	**0.69**	**0.22**	**0.64**	**0.77**	**4.5**	**36.51**
	Standard error	**0.29**	**1.57**	**0.2**	**0.22**	**0.2**	**0.06**	**0.12**	**0.14**	**0.71**	**2.15**

Table 3. Total organisms, mean density, and standard error from each placement class during November 1997 and 1998 sampling combined.

Substrate		Mayfly	Midge	Fingernail clam	Asiatic clam	Zebra mussel	Dragonfly	Unionid mussel	Snail	Other	Overall
1	**Total organisms**	0	7	0	0	2	0	0	0	0	**9**
	Ponar grabs	9	9	9	9	9	9	9	9	9	**9**
	Mean density (#/m^2)	0	15.25	0	0	4.36	0	0	0	0	**19.61**
	Standard error	0	5.45	0	0	2.88	0	0	0	0	**6.54**
2	**Total organisms**	62	348	29	12	26	3	12	20	92	**604**
	Ponar grabs	136	136	136	136	136	136	136	136	136	**136**
	Mean density (#/m^2)	9.65	54.15	4.51	1.87	4.05	0.47	1.87	3.11	14.32	**93.99**
	Standard error	2.05	6.57	1.24	0.5	1.51	0.26	0.62	0.81	3.11	**10.76**
3	**Total organisms**	4	144	8	7	3	0	8	7	56	**237**
	Ponar grabs	104	104	104	104	104	104	104	104	104	**104**
	Mean density (#/m^2)	0.78	27.96	1.55	1.36	0.58	0	1.55	1.36	10.87	**46.01**
	Standard error	0.38	4.95	0.59	0.73	0.33	0	0.59	0.49	4.43	**8.03**
4	**Total organisms**	3	110	6	6	2	1	6	5	17	**156**
	Ponar grabs	126	126	126	126	126	126	126	126	126	**126**
	Mean density (#/m^2)	0.48	17.54	0.96	0.96	0.32	0.16	0.96	0.8	2.71	**24.87**
	Standard error	0.27	2.27	0.44	0.49	0.22	0.16	0.44	0.47	1.93	**3.63**
5	**Total organisms**	4	195	0	0	0	0	4	1	12	**216**
	Ponar grabs	150	150	150	150	150	150	150	150	150	**150**
	Mean density (#/m^2)	0.52	25.49	0	0	0	0	0.52	0.13	1.57	**28.24**
	Standard error	0.26	3.72	0	0	0	0	0.26	0.13	0.57	**3.81**
Overall	**Total organisms**	**73**	**804**	**43**	**25**	**33**	**4**	**30**	**33**	**177**	**1222**
	Ponar grabs	**525**	**525**	**525**	**525**	**525**	**525**	**525**	**525**	**525**	**525**
	Mean density (#/m^2)	**2.81**	**30.97**	**1.66**	**0.96**	**1.27**	**0.15**	**1.15**	**1.27**	**6.81**	**47.07**
	Standard error	**0.57**	**2.39**	**0.36**	**0.23**	**0.41**	**0.08**	**0.24**	**0.26**	**1.31**	**3.63**

Substrate
1 Hard Clay
2 Silt/Clay
3 Mostly Silt/Clay with Sand
4 Mostly Sand with Silt/Clay
5 Sand

Table 4. Total organisms, mean density; and standard error from each substrate during November 1997 sampling.

Substrate		Mayfly	Midge	Fingernail clam	Asiatic clam	Zebra mussel	Dragonfly	Unionid mussel	Snail	Other	Overall
1											
	Total organisms	0	0	0	0	0	0	0	0	0	**0**
	Ponar grabs	0	0	0	0	0	0	0	0	0	**0**
	Mean density (#/m^2)	0	0	0	0	0	0	0	0	0	**0**
	Standard error	0	0	0	0	0	0	0	0	0	**0**
2											
	Total organisms	11	193	17	30	3	7	3	2	55	**321**
	Ponar grabs	145	145	145	145	145	145	145	145	145	**145**
	Mean density (#/m^2)	1.49	26.1	2.3	4.06	0.41	0.95	0.41	0.27	7.44	**43.41**
	Standard error	0.43	3.9	0.62	0.86	0.23	0.35	0.23	0.19	2.08	**5.31**
3											
	Total organisms	2	6	3	9	0	1	0	1	0	**22**
	Ponar grabs	20	20	20	20	20	20	20	20	20	**20**
	Mean density (#/m^2)	1.96	5.88	2.94	8.82	0	0.98	0	0.98	0	**21.57**
	Standard error	1.35	2.5	2.15	4.6	0	0.98	0	0.98	0	**0.18**
4											
	Total organisms	2	86	1	15	0	0	0	0	2	**106**
	Ponar grabs	95	95	95	95	95	95	95	95	95	**95**
	Mean density (#/m^2)	0.41	17.75	0.21	3.1	0	0	0	0	0.41	**21.82**
	Standard error	0.29	4.96	0.21	0.94	0	0	0	0	0.29	**0.19**
5											
	Total organisms	0	256	2	10	1	0	1	5	7	**282**
	Ponar grabs	280	280	280	280	280	280	280	280	280	**280**
	Mean density (#/m^2)	0	17.93	0.14	0.7	0.07	0	0.07	0.35	0.49	**19.75**
	Standard error	0	2.86	0.1	0.26	0.07	0	0.07	0.16	0.21	**2.91**
Overall											
	Total organisms	**15**	**541**	**23**	**64**	**4**	**8**	**4**	**8**	**64**	731
	Ponar grabs	**540**	**540**	**540**	**540**	**540**	**540**	**540**	**540**	**540**	540
	Mean density (#/m^2)	**0.54**	**19.64**	**0.84**	**2.32**	**0.15**	**0.29**	**0.15**	**0.29**	**2.32**	26.54
	Standard error	**0.14**	**2.02**	**0.2**	**0.36**	**0.07**	**0.1**	**0.07**	**0.1**	**0.58**	2.33

Substrate
1 Hard Clay
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4 Mostly Sand with Silt/Clay
5 Sand

Table 5. Total organisms, mean density, and standard error from each substrate during November 1998 sampling.

		Mayfly	Midge	Fingernail clam	Asiatic clam	Zebra mussel	Dragonfly	Unionid mussel	Snail	Other	Overall
1											
	Total organisms	0	7	0	0	2	0	0	0	0	9
	Ponar grabs	9	9	9	9	9	9	9	9	9	9
	Mean density (#/m^2)	0	15.25	0	0	4.36	0	0	0	0	19.61
	Standard error	0	5.45	0	0	2.88	0	0	0	0	6.54
2											
	Total organisms	73	541	46	42	29	10	15	22	147	925
	Ponar grabs	281	281	281	281	281	281	281	281	281	281
	Mean density (#/m^2)	5.28	39.14	3.33	3.04	2.1	0.72	1.09	1.59	10.64	66.93
	Standard error	1.04	3.69	0.69	0.52	0.75	0.22	0.33	0.41	1.88	5.94
3											
	Total organisms	6	150	11	16	3	1	8	8	56	259
	Ponar grabs	124	124	124	124	124	124	124	124	124	124
	Mean density (#/m^2)	0.97	24.31	1.78	2.59	0.49	0.16	1.3	1.3	9.07	41.97
	Standard error	0.39	4.27	0.61	1.0	0.28	0.16	0.5	0.44	3.77	6.84
4											
	Total organisms	5	196	7	21	2	1	6	5	19	262
	Ponar grabs	221	221	221	221	221	221	221	221	221	221
	Mean density (#/m^2)	0.45	17.63	0.63	1.89	0.18	0.09	0.54	0.45	1.71	23.57
	Standard error	0.2	2.51	0.27	0.5	0.13	0.09	0.25	0.27	1.11	3.07
5											
	Total organisms	4	451	2	10	1	0	5	6	19	498
	Ponar grabs	430	430	430	430	430	430	430	430	430	430
	Mean density (#/m^2)	0.18	20.57	0.09	0.46	0.05	0	0.23	0.27	0.87	22.71
	Standard error	0.09	2.27	0.06	0.17	0.05	0	0.1	0.11	0.24	2.32
Overall											
	Total organisms	88	1345	66	89	37	12	34	41	241	1953
	Ponar grabs	1065	1065	1065	1065	1065	1065	1065	1065	1065	1065
	Mean density (#/m^2)	1.64	25.14	1.23	1.66	0.69	0.22	0.64	0.77	4.5	36.51
	Standard error	0.29	1.57	0.2	0.22	0.2	0.06	0.12	0.14	0.71	2.15

Substrate
1 Hard Clay
2 Silt/Clay
3 Mostly Silt/Clay with Sand
4 Mostly Sand with Silt/Clay
5 Sand

Table 6. Total organisms, mean density, and standard error from each substrate during November 1997 and 1998 sampling combined.

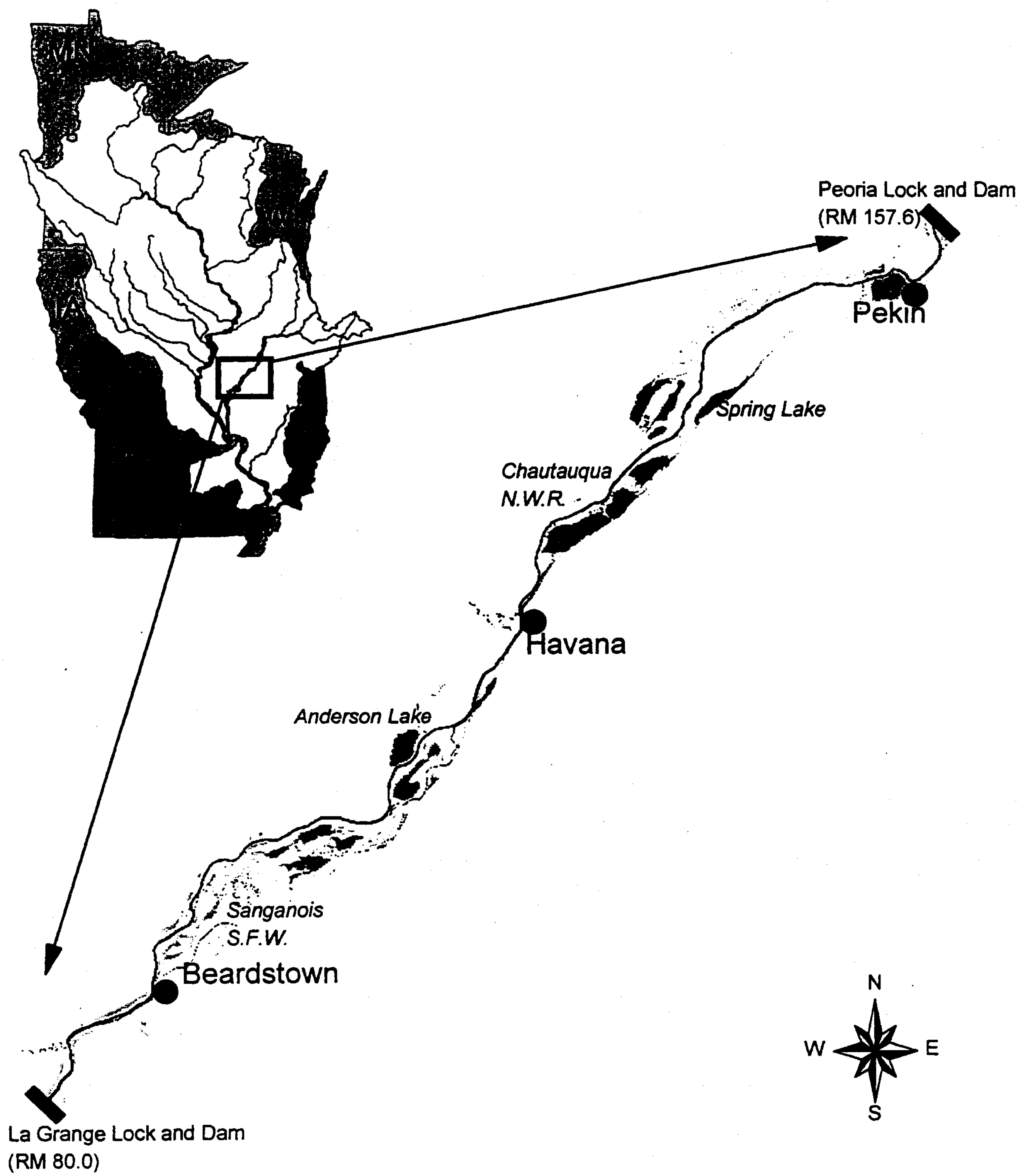

Figure 1. La Grange Reach (RM 80.0-157.6) of the Illinois River sampled for invertebrates during November 1997 and 1998.

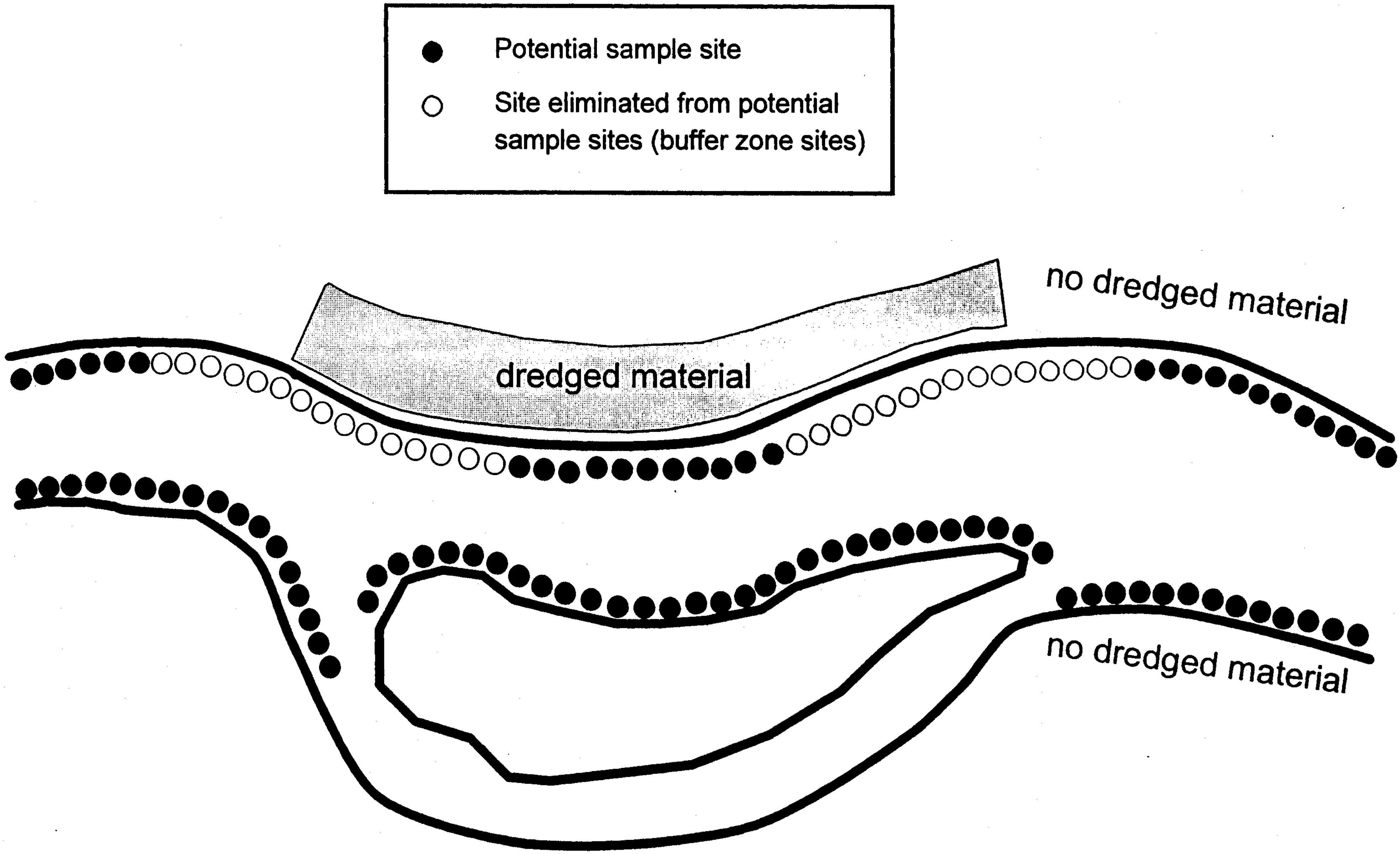

Figure 2. Example of potential sampling sites and sites eliminated from potential sampling sites (buffer zones).

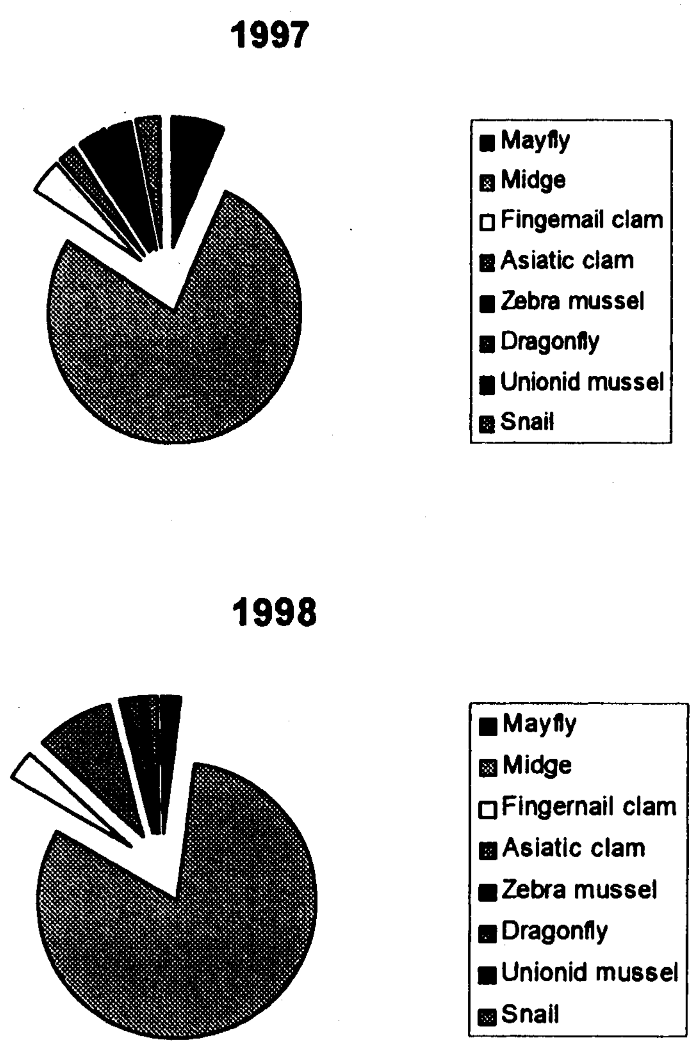

Figure 3. Relative abundances of eight macroinvertebrate taxa collected from La Grange Reach, Illinois River in all dredge material placement classes.

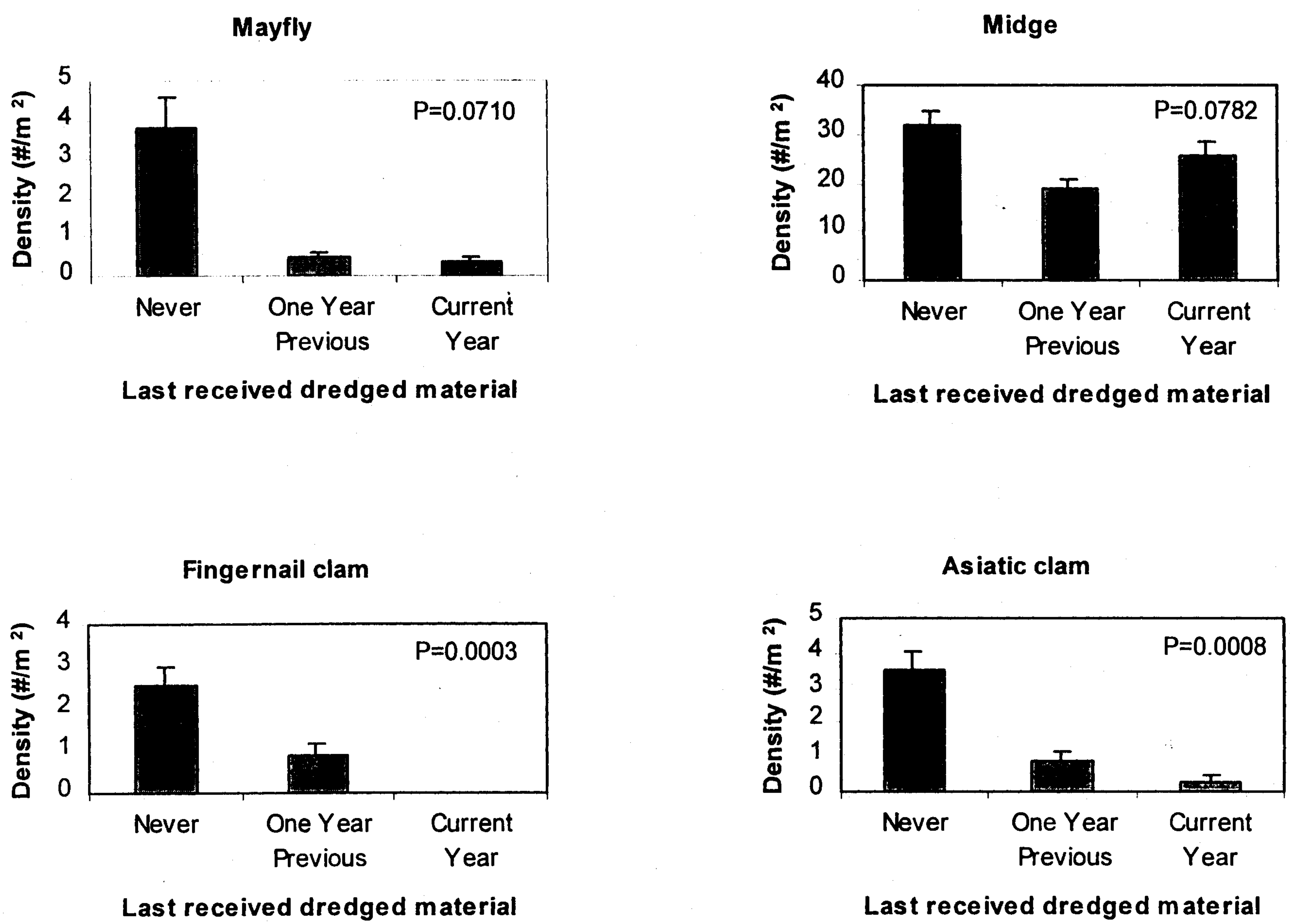

Figure 4. Mean densities of mayflies, midges, fingernail clams, and Asiatic clams in three dredge material placement classes as determined by November 1997 and 1998 sampling in La Grange Reach, Illinois River. P-values result from Kruskal-Wallis ANOVAs.

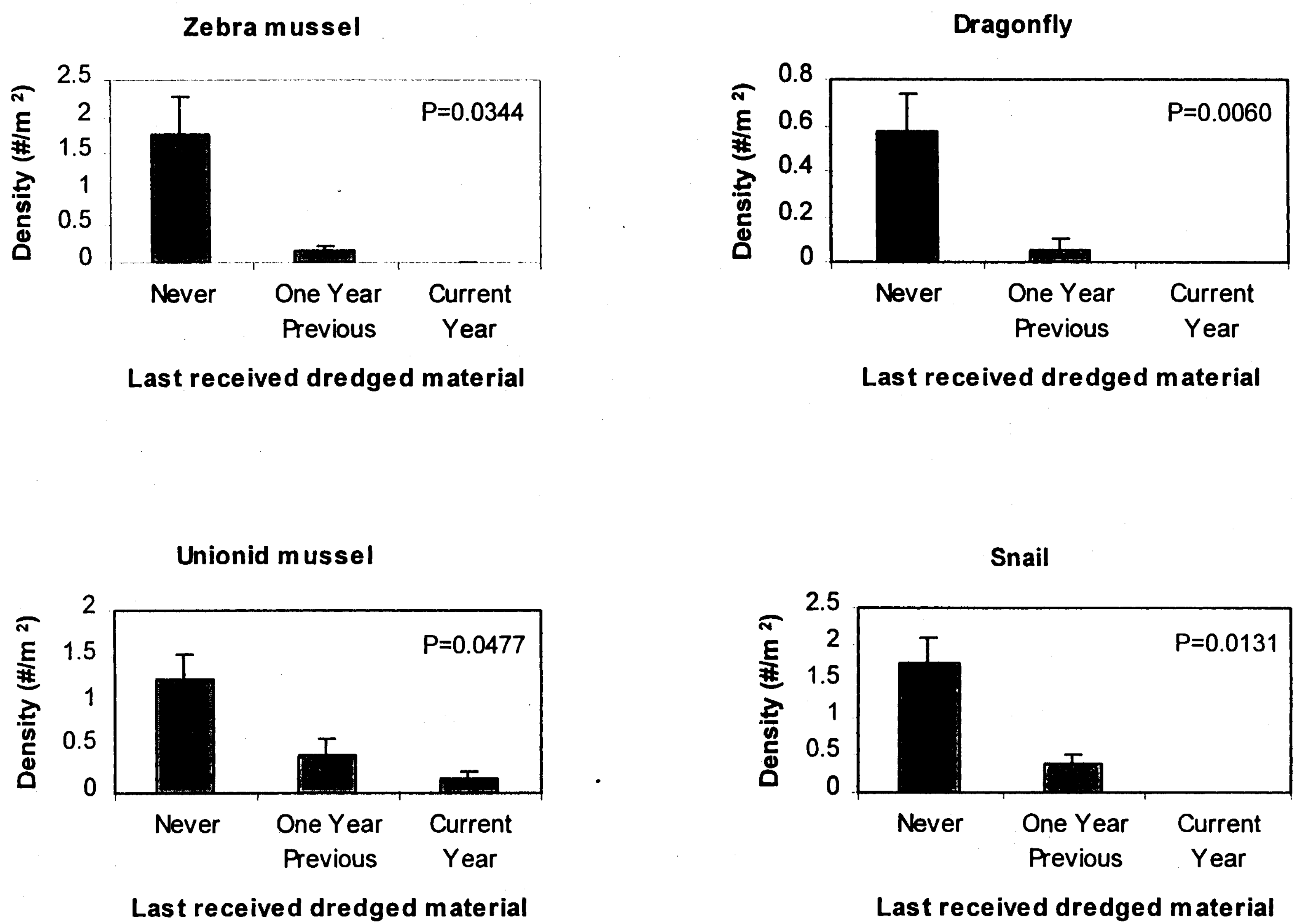

Figure 5. Mean densities of zebra mussels, dragonflies, Unionid mussels, and snails in three dredge material placement classes as determined by November 1997 and 1998 sampling in La Grange Reach, Illinois River. P-values result from Kruskal-Wallis ANOVAs.

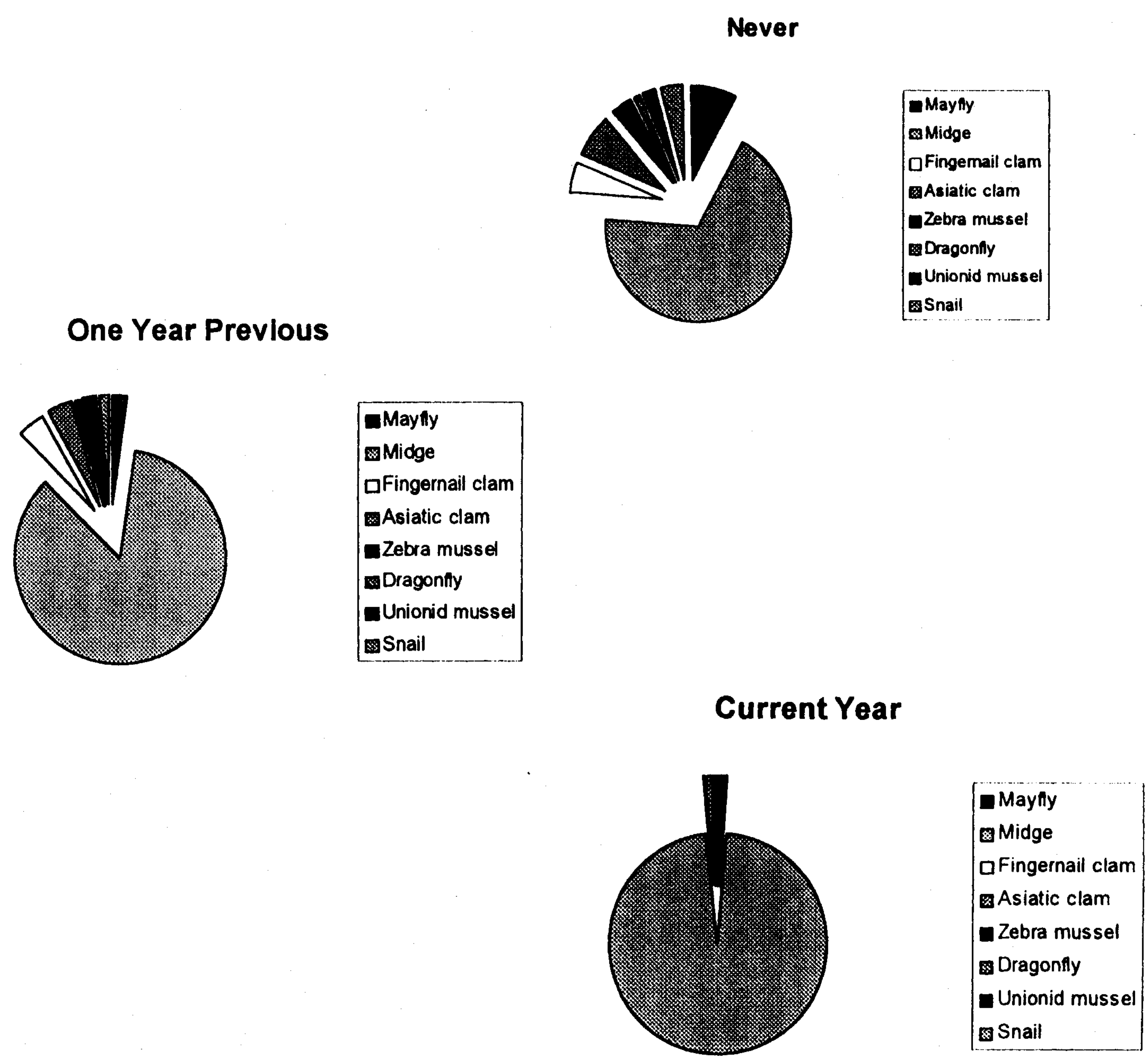

Figure 6. Relative abundances of eight macroinvertebrate taxa collected from La Grange Reach, Illinois River, 1997 and 1998 combined.

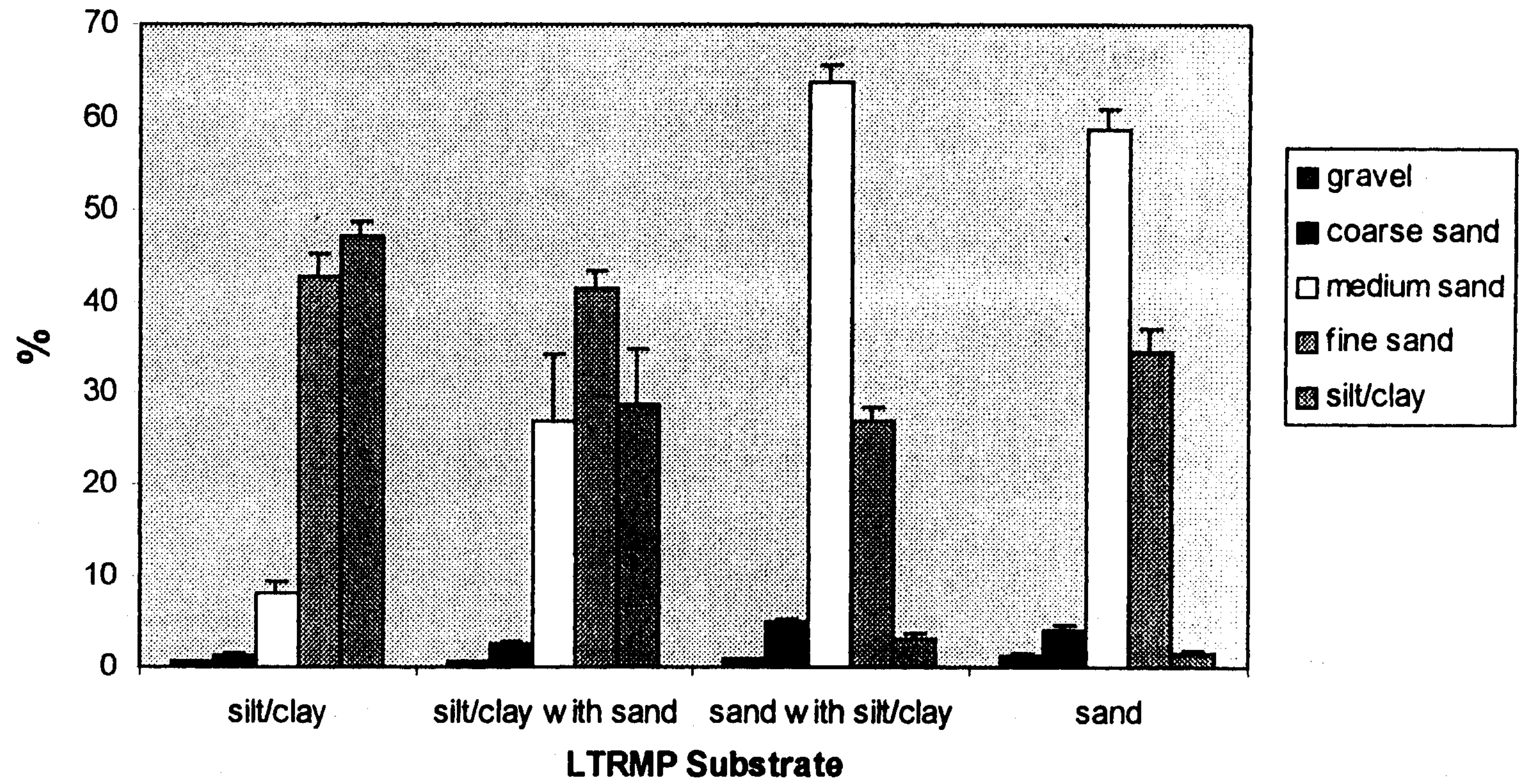

Figure 7. Relative abundances of gravel, coarse sand, medium sand, fines sand, and silt/clay in four LTRMP substrate classes collected from La Grange Reach, Illinois River in November 1998.

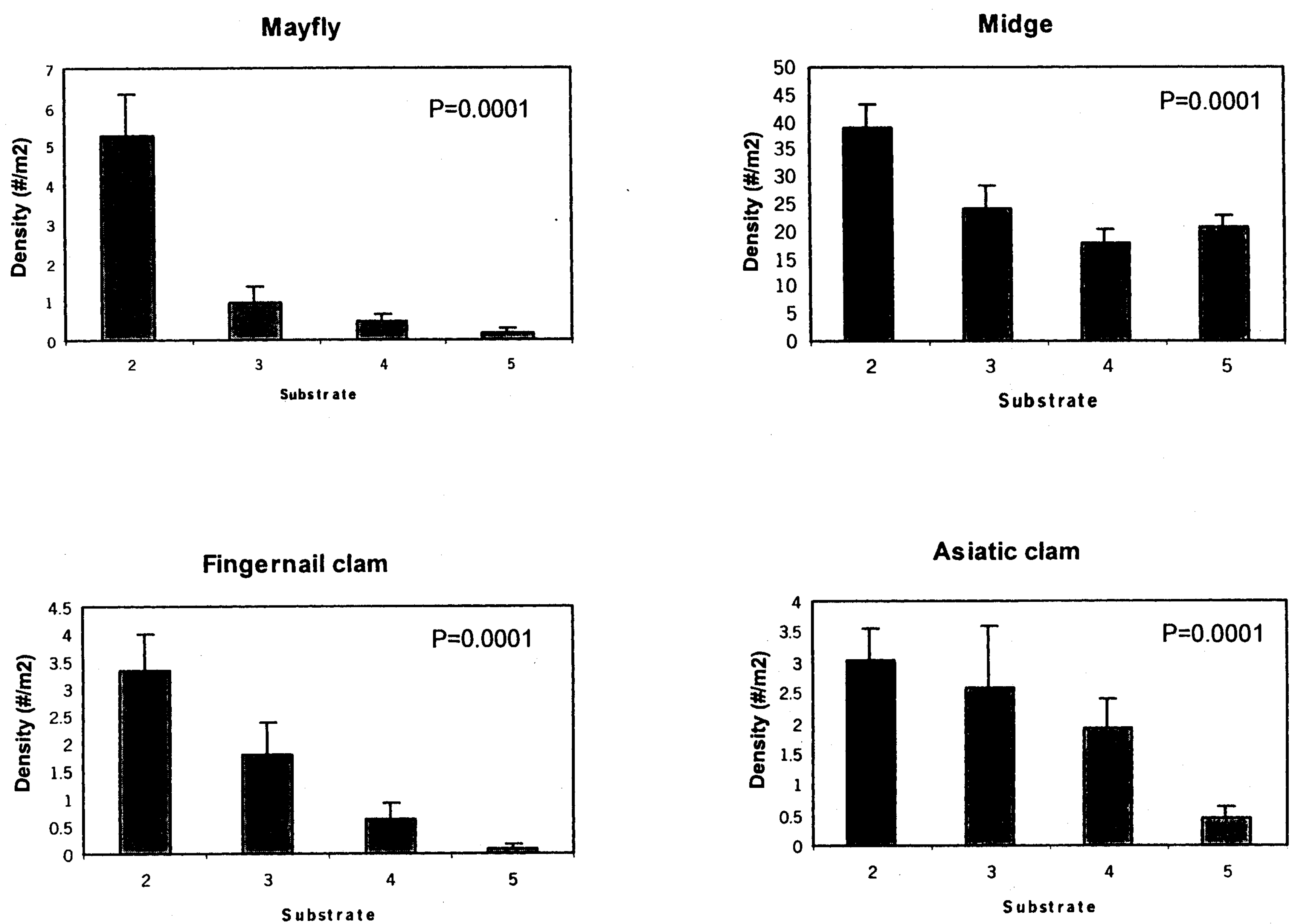

Figure 8. Mean densities of mayflies, midges, fingernail clams, and Asiatic clams in four substrate classes as determined by November 1997 and 1998 sampling in La Grange Reach, Illinois River. P-values result from Kruskal-Wallis ANOVAs.

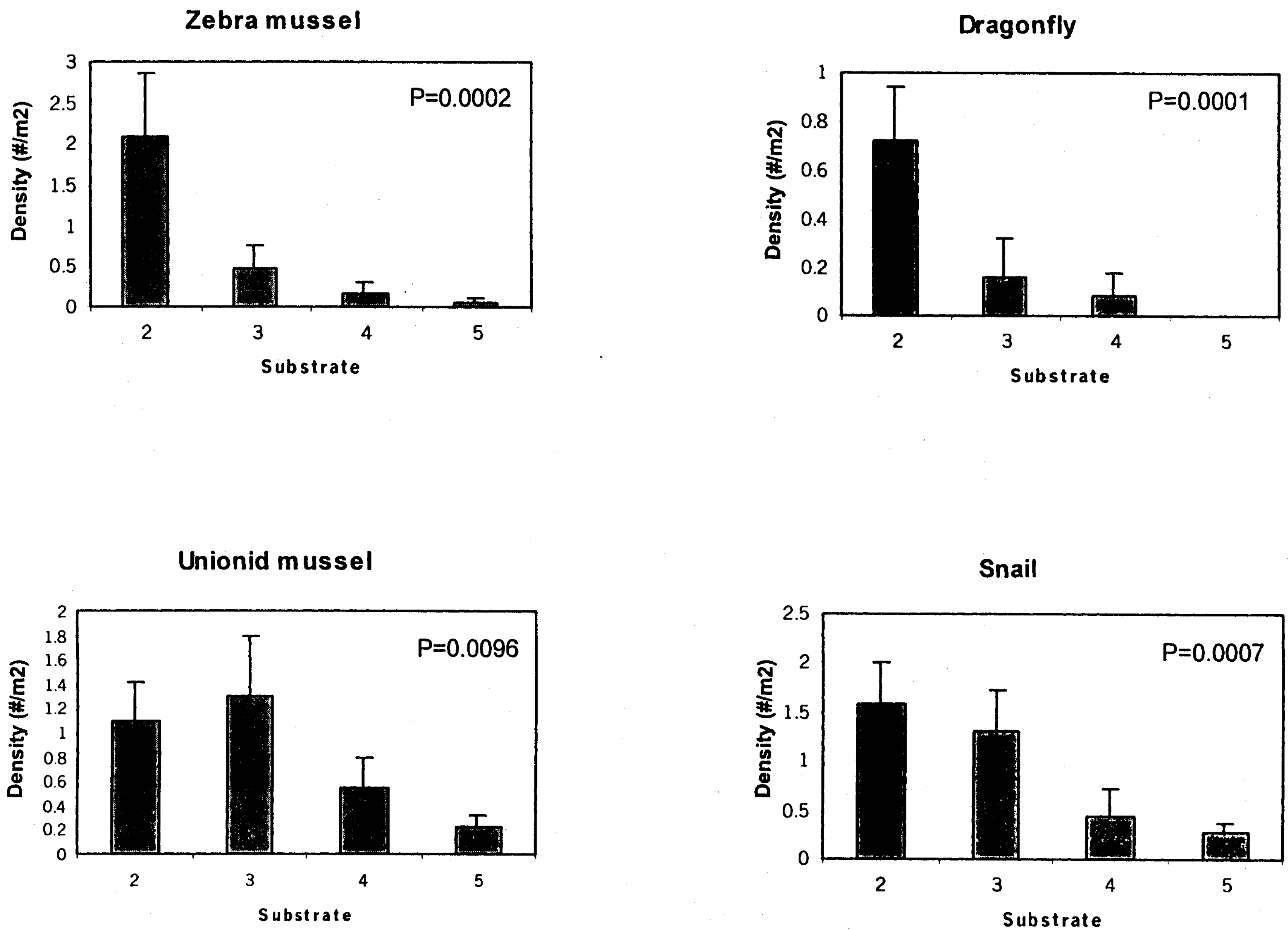

Figure 9. Mean densities of zebra mussels, dragonflies, Unionid mussels, and snails in four substrate classes as determined by November 1997 and 1998 sampling in La Grange Reach, Illinois River. P-values result from Kruskal-Wallis ANOVAs.