Appendix A

Kenai River Bioassessment: Effects of Storm Drain Outfall on the Benthic Invertebrate Community

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ABSTRACT

The Kenai River is a highly productive system that can be easily accessed throughout most of its eighty miles. This salmon-rich river provides recreation as well as revenues for a wide variety of user groups. However, increased urbanization, loss of wetlands, and greater amount of impervious surfaces throughout it's drainage area has heightened concern that water quality of the Kenai River is being adversely effected. This study concentrates on determining if the benthic invertebrate community shows any adverse effects from sewage and storm drain outfalls. Data collected from above and below five storm drain outfalls did not show significant differences in four biotic metrics, although there was a significant difference found in two metrics at the Soldotna Sewage Treatment Plant outfall. The decrease of sensitive taxa and an increase in the family Chironomidae was noted in the above versus below sewage outfall locations which may reflect organic enrichment. Although differences between individual outfalls were minimal, significant differences in benthic community structures were noted between the uppermost location sampled (River Mile 28) and the sites sampled below urbanized areas. This suggests habitat changes or possible cumulative impacts from water quality degradation. Annual monitoring of critical parameters should be conducted because as urbanization increases, so does the potential for impaired water quality.

INTRODUCTION

The Kenai River has been the focus of much attention in the last few years. Litchfield and Kyle (1992) established baseline data in which to gauge future changes in water quality parameters. Data collected in 1990 and 1991 showed differences in water quality between the more rural upper river and the more urbanized lower river. Several areas of concern were related to the influence of urban run off through storm drains and the effect of urbanization on benthic invertebrate populations. Additional data collected and summarized in a letter to the Kenai River Special Management Area Board (Litchfield 1993) documented total petroleum hydrocarbons entering the river through storm drains. Benthic invertebrate surveys also indicated a noticeable decrease in abundance of sensitive organisms in certain portions of the lower Kenai River compared to previous years, which suggested water quality degradation. In this project we use biological, chemical, and physical indicators to evaluate water quality specifically as is relates to the effect of non-point source contamination entering the Kenai River through outfall drains. In addition, we compare two different bioassessment approaches and recommend future bioassessment methods that are possibly more suitable for this large glacial river.

METHODS

Sampling

Subsurface water was collected 5-7 May, 1997 for nutrient analysis with a plastic bilge pump lowered 0.5 m below the surface at thirteen Kenai River locations. Before the samples were collected, river water was used to rinse pre-cleaned carboys. Samples were kept cool and in the dark until transported to the limnology laboratory in Soldotna for processing. Water samples were analyzed using methods detailed by Koenings et al. (1987). We measured conductivity, pH, alkalinity, turbidity, color, calcium, magnesium, iron, total phosphorus, reactive silicon, and total solids.

Sediment samples were collected from two reference locations and just above and below six outfall locations in the Kenai River and analyzed for toxicity using the Microtox® bacterial bioassay. Triplicate samples were collected from each site and pooled into one clean borosilicate container, and kept cool until analyzed within 12 hours.

The Microtox Solid Phase Test is a photometric technique that uses the response of bioluminescent bacterium to chemical exposure to rate the relative toxicity of sediment and soil (Microtox® 1995). This bioassay has in recent years gained broad support as a relatively inexpensive and rapid technique to screen soils for a variety of toxic materials (Dutka 1996, Becker et. al. 1990). In this test bacteria (*V. fischeri*) are put in direct contact with the sediment for 20 minutes, and then removed from suspension using a filter column. The bacteria are then measured for illuminance and the light output values are used to calculate the percent concentration of the sample to produce an EC_{50} effect. The EC_{50} is defined as the effective concentration that results in 50% reduction in light emission. Sample concentrations greater than 2% are regarded as non-toxic, concentrations between 1% and 2% suggest toxicity, and those below 1% are toxic proportionately as the value declines.

Benthic macroinvertebrate samples were collected 13-15 May, 1997 at thirteen locations between River Mile 28 and River Mile 14, using two sampling techniques. The locations were selected above and below storm drain outfalls, with two reference sites located at River Mile 28 and River Mile 25.8. Three replicate samples were collected from each location in erosional habitat (riffle/cobble) using a modified Surber sampler with a 335 micron mesh net. Five replicate samples were collected from three locations for statistical purposes. To eliminate habitat changes as a variable, riffles/run locations were selected that were similar in cobble size, substrate percent embedded, and water flow and depth. In addition, nine locations were evaluated following procedures outlined in the Rapid Bioassessment Protocols (RBP) for Alaska (Barbour and Major 1997) with the following adjustments. The primary suitable habitat type present in the Kenai River during low water is cobble/riffle. Therefore, samples were pooled from a total of 10 jabs using a D-frame 335 micron mesh dip net. All benthic invertebrates were placed in containers and preserved in 90% ethanol. We also recorded latitude and longitude (GPS), water temperature, substrate size and percent embedded, and water velocity. Habitat Assessment Field Data sheets (Barbour and Major 1997) were completed for the RBP methodology.

The samples collected with the Surber net were sorted and all invertebrates were picked out from substrate and debris. This analysis technique is known as the quantitative Surber method. Large debris and substrate were picked from the pooled samples collected with the D-frame net and a subsample of 300 organisms were identified. All invertebrates were identified to the lowest practical taxon, generally family level and in the case of Ephermeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) to genera level. These three orders are more commonly referred to as the EPT grouping. They are used in the calculation of various metrics due to their overall greater sensitivity to water quality degradation (Hilsenhoff 1988).

Macroinvertebrate Assessment

A number of biotic metrics were calculated for each location including the number of EPT genera, EPT to total individuals ratio, percent dominant taxa, and Family Biotic Index. EPT genera is a measurement of population diversity or richness and given similar habitat conditions, tends to increase as water quality improves. The number of EPT genera can range from 0 - 14, although pristine sites within the Municipality of Anchorage rarely support more than 10 genera (Milner and Oswood 1995). The EPT to total individuals ratio is an enumeration metric that reflects higher water quality as the ratio approaches one. In practice the ratio never attains one due to the presence of chironomids and other dipterans that also occupy pristine water. Another enumeration metric that evaluates community evenness is the percent dominant taxa. It is calculated as the amount that one taxon contributes to the total number of organisms in a sample. Although dominance by one taxon usually reflects impaired water quality, it is important to note the sensitivity of the dominant organism. A community dominated by a specific but highly sensitive taxon will indicate different water quality than dominance by a very tolerant one. The Family Biotic Index (FBI) is used to assess water quality based on the ability of benthic families to tolerate organic pollution (Hilsenhoff 1988). In addition, FBI has been used successfully to indicate other forms of pollution (Resh and Jackson 1993). A family sensitive to water quality impairment is given a score of 0 and a tolerant family a score of 10. The number of individuals within a family are then multiplied by the family sensitivity score and the sum of these scores are then divided by the total number of organisms in the sample to obtain FBI. The FBI ranges from 0-10, with a higher score indicating a greater potential for water quality degradation. The sensitivity scores are listed in Table 1. Although Oligachaeta (worms) were not included in Hilsenhoff's original index, they are given a score of 8 due to their known tolerance to impaired water quality (Milner and Oswood 1995).

Statistical Analysis

Several statistical analyses were used to test for significant changes among sites and above and below outfall locations. Both parametric (paired *t*-test and one-way ANOVA) and non-parametric (Wilcoxon signed rank test and Kruskal-Wallis test) analyses are commonly used when testing for biological diversity (Magurran 1988). The parametric analyses use actual data to test for differences between treatments (i.e., above/below outfalls) while the non-parametric analyses rank the data first, then test for significant differences. The non-parametric analyses are more often used when the distribution of the data is not defined. Due to the natural variability of benthic community structure and distribution within specific locations, the non-parametric statistic may show subtle changes in community assemblages.

RESULTS AND DISCUSSION

General Water Quality and Nutrients

A summary of general water quality parameters and nutrients for the Kenai River are presented in Table 2. Data from four of the sampling locations (River Miles 39, 23, 21, 17) can be compared to historic data collected during similar time periods. For the thirteen locations on the Kenai River conductivity ranged from 63 to 108 µmhos cm^{-1} and averaged 80 µmhos cm^{-1}. Conductivity is an index of total ion content and is usually correlated with the amount of dissolved solids. Although conductivity fluctuated according to site location and influence of major tributaries, the values found were within the range determined in 1990 and 1991 (Litchfield and Kyle 1992). The highest conductivity value (108 µmhos cm^{-1}) was found at River Mile 22, just downstream from the confluence of Soldotna Creek. In early May, water quality in the Kenai River is more influenced by its tributaries due to low flow originating from glacial meltwater and higher flows from snow melt in the watershed. Therefore, tributary inflous drive the river conditions in a greater proportion. The pH ranged from 7.1 to 7.9 units and were well within the State of Alaska Water Quality Standard Regulations (ADEC 1997). The pH range is consistent with benthic invertebrate survival and emergence (Bell 1971) and is also similar to historic (1991-1992) values.

In the Kenai River, turbidity is caused primarily by the suspension of inorganic materials in the water column, and fluctuates greatly. Although a large amount of turbidity in the Kenai River is derived from glacial silt particles, sediment loading from erosion also contributes to turbidity. Although turbidity levels in May were slightly higher in 1997 than in 1990 and 1991, trends could not be ascertained with only one sampling date. Most likely the higher levels are due to natural variations common to the Kenai River during early spring and summer flow conditions.

Total phosphorus (corrected for turbidity interference) ranged from 12 to 54 µg L^{-1}, total iron ranged from 264 to 944 µg L^{-1} and reactive silicon ranged from 1,885 to 5,418 µg L^{-1} for the thirteen Kenai River stations sampled in May, 1997. Total phosphorus and total iron concentrations also were slightly higher in 1997 than for April-May concentrations in earlier studies (Litchfield and Kyle, 1992). This would be expected due to more suspended material in the water column as reflected by the higher turbidity. All values were still within seasonal ranges previously found on the Kenai River. Finally, a one time (May 1997) water quality sample has limited value for status and trend information but it can serve to point out potential changes that might affect benthic invertebrate populations. A monthly sampling schedule during the ice free season would be more useful.

Sediment Analysis

All of the sediment samples collected on the Kenai River in May 1997 and analyzed using the Microtox® Solid Phase Test displayed EC_{50} values greater than 2% (Table 3), indicating no toxicity by this technique. This screening method may be better suited to areas of higher contamination than what we found on the Kenai River.

Benthic Invertebrates

Above Versus Below Outfall

Investigations of aquatic insects to evaluate water quality have been widely used for a number of years (Hilsenhoff 1987; Hilsenhoff 1988; Merritt and Cummins 1996; Rosenberg and Resh 1993). It is important to understand both the advantages and disadvantages of their use especially as it pertains to the Kenai River. Benthic invertebrates are good indicators of localized conditions due to their limited migration patterns (drift), and are specifically well suited for site specific impacts such as upstream versus downstream effects (Plafkin et. al 1989). Most benthic species have a life cycle of one or more years with life stages that are sensitive to impaired water quality. Thus intermittent impacts from sources such as storm drains can be detected by investigating benthic assemblages, whereas water chemistry testing alone may not be sufficient. Benthic invertebrates serve as the primary food source for many species of fish and disturbances to the benthic community may be easier to assess than effects on higher trophic levels. Finally, benthic invertebrates are relatively easy to collect, commonly found in most streams and rivers, and the taxonomy of many groups is well known. Disadvantages involve natural variability in distribution and abundance not related to water quality, including habitat changes and seasonal variations. Also, benthic invertebrates are not sensitive to some pathogens and trace amounts of certain pollutants (Resh 1995). Therefore, assessing water quality using benthic invertebrates is best used in conjunction with chemical and physical investigations.

Results from quantitative benthic sampling at one reference location and above and below the six outfall sites are presented in Table 4. The samples collected at River Mile 25.8 were not used to indicate a reference condition after evaluation of physical parameters (close proximity to a subdivision drain) suggested possible water quality impairment or habitat variability. A graphic representation of the four biometrics calculated along with water quality trends is presented in Figure 1 for the seven sites surveyed.

The results of parametric and non-parametric analyses to test for overall significant differences of benthic assemblages between above and below outfall locations are presented in Table 5. Results of the paired *t*-test and Wilcoxon test indicated no significant differences ($P > 0.05$) between the above and below outfall locations for the four metrics calculated. Considering the above sites as one group and the below sites as another group, there were no significant differences in the community structures at any of the sites as indicated by these biotic metrics. The Kruskal-Wallis analysis was then used to test for significant differences between above and below individual outfall locations to indicate if any site in particular exhibited community changes (Table 6). All sites with the exception of the Sewage Treatment Plant showed non-significant *P*-values.

Two of the four metrics at the Sewage treatment plant outfall, EPT/ total individual ratio and FBI indicated significant differences ($P = 0.0495$) between above and below locations. This site was more heavily dominated by Chironomids that are generally more tolerant of water quality impairment. It is important to note that sensitive EPT genera were also found at this site but in greatly reduced numbers. There was no significant difference in the number of individuals found above compared to below the outfall, but the number of EPT individuals decreased from 1262 to 373 organisms m^{-2}.

Site Differences

The reference site and above outfall locations were then tested using parametric and non-parametric analyses to detect any change that may exist from cumulative impacts. There were significant differences ($P<0.05$) found between sites in three of the four metrics (Table 5). Specifically, significant changes were shown in the EPT/Total Ratio, percent dominant taxa, and FBI between the two most upstream locations and the remainder of the sites (Figure 2). This shows there are definite differences in community structure with decreasing river mile down the Kenai River. Natural variables not associated with water quality impairment include habitat changes and slightly different water chemistry (e.g., pH and conductivity) due to tributary contributions. Possible water quality impairments not associated with outfalls include direct run-off, seepage from septic tanks and contaminated sites. Due to the larger number of chironomids, and presence of EPT genera in the lower portions of the river, one may suspect that the water quality changes are more closely associated with leaching septic tanks rather than toxic contaminates from storm drains due to the organic enrichment effect seen in the benthic community. The increase of chironomids in itself may not be detrimental, due to their importance as a food source to juvenile fish, provided overall water quality is not markedly impaired. The study design for this investigation primarily focused on above and below specific outfalls and not on cumulative impacts. Therefore, while there is an indication in the benthic community assemblages that cumulative impacts are occurring, a more rigorous sampling regime would be necessary to gain better statistical support. The changes in benthic assemblages in the Kenai River are very subtle at this point in time. It is possible that while one outfall in particular doesn't result in significant differences, a series of impacts added together as reflected by the benthic communities may indicate impairment.

Data collected in 1991, 1993 and 1997 from five general locations on the Kenai River are shown in Table 7. The total EPT genera either remained consistent with 1993 for the five locations, although values at River Miles 22 and 18 still were much lower than found in 1991. This trend also holds true for the EPT/total individual ratio and the percent dominant taxa. The EPT/total individual ratio for the other locations remained fairly consistent with 1993 data, although percent dominant taxa increased in value for all locations with the exception of river mile 14. Overall, benthic assemblages in 1997 were consistent with 1993, with a greater number of sensitive organisms found in specific locations. Benthic populations measured by the four biotic metrics calculated continued to display less diversity and richness than found in 1991.

Comparison of Bioassessment Methods

Results from the qualitative benthic invertebrate composite samples are presented in Table 8. A subsample of 300 organisms were picked from 10 jabs that were pooled together. Although the original method called for 20 jabs, it is important to note that only 3% to 4% of the total sample was needed to obtain 300 organisms. The significance of the number of jabs diminishes when the sample obtained contains sufficient numbers of organisms. It would make no significant difference if the 300 sub-sample was obtained from 5,000 individuals with 10 jabs or from 10,000 individuals with 20 jabs. The number of EPT individuals observed at each location ranged from 9 to 45 and averaged 22. For the quantitative method the number of EPT individuals ranged from 25 to 489 and averaged 199 per site. Four biotic metrics were calculated for each location consistent with the replicate samples.

Although habitat sheets were completed by two investigators at each location, the use of these forms to accurately assess Kenai River habitat was questionable because they were established to assess wadeable streams requiring habitat on both banks be evaluated. Even during low water, the Kenai River at most locations cannot be safely waded and logistically, it would be difficult to navigate during low flow conditions. The forms should be modified for application to large rivers. Also, investigator variability would have to be established when giving habitat assessment values based on observed versus measured parameters.

Metrics from the composite subsample method showed less variation than the metrics calculated by the replicate quantitative Surber samples (Figure 3). For example, EPT/total individuals ratio ranged from 0.03 to 0.11 compared to 0.03 to 0.29 using the quantitative replicates. Average percent dominant taxa ranged from 85% to 97% compared to 71% to 98% for the composite subsample method and Surber methods, respectively. Total EPT genera ranged from 2 to 7 in the composite method compared with range of from 6 to 11 for the Surber method. The most obvious differences in methods are seen in the data for sites above River Mile 22.1. For example, at River Mile 28.0 the EPT/total individuals ratio using the composite method was 0.03 compared to 0.22 with the replicate samples and the percent dominant taxa was 96% compared to 77.7%. The values from the composite sample indicated greater water quality impairment than the replicate samples. This is because the sample was dominated by Chironomidae. That is, when a 300 organism subsample was taken Chironomidae were overweighted (EPT of the 300 = 3%) and did not reflect the large number of EPT individuals present (1052/m^2 of a total of 5148/m^2 i.e. 22%) which underestimated the overall number of EPT genera at the site. The subsample composite method did not show the reference condition to be different in benthic community structure compared to the significant differences found with the quantitative replicate approach. The time necessary to accomplish the field portion for the two methodologies is approximately the same, however, processing time for invertebrate identification is approximately twice as long for the quantitative method as opposed to the sub-sample method. This would be shortened if only three replicates were used which Russek (1993) showed to have no effect on metrics (except for the number of EPT) within the Municipality of Anchorage.

The composite method gives a more rapid approach to assess water quality that is useful in many applications, especially when looking at areas with major water quality degradation and in non-riffle/cobble habitats. Also, the composite method allows more comparisons with lower 48 streams. The quantitative Surber method potentially gives a higher resolution and provides statistical comparisons between sites. The quantitative method was able to detect changes in the EPT numbers, but indicated a wide diversity. The changes in benthic community structure suggesting water quality impairment from organic enrichment are subtle at this point in the Kenai River and must be considered within the context of natural variability. The greater the number of organisms observed, and the more replicate samples taken potentially lends to a more definite conclusion of the water quality impairment source. Also, the replicate method allows for statistical analysis to test for changes in benthic assemblages. The Kenai River benthic community is dominated by the family

Chironomidae and a 300 organism subsample may not have been sufficient to characterize and document other key taxa present. Also, it would be important to measure the amount of variation in the metrics as determined in the sub-sampling technique by undertaking replicate sub-samples from the same composite sample. Finally, we found the metric values to be sufficiently different between the two methods therefore historic information would be difficult to interpret if the composite method was used. It is important to note that the composite method was developed for clear wadeable streams. Applying this method to large, glacial rivers without modifications does not work well for comparative purposes.

CONCLUSIONS AND RECOMMENDATIONS

With the exception of the Soldotna Sewage Treatment Plant outfall location, benthic invertebrate populations overall showed no significant changes above versus below specific outfall locations The storm drain outfalls sampled discharges intermittently while the sewage outfall is a continuous flow. Therefore, we would expect less water quality degradation and more time for recovery in areas receiving only occasional impact. There were significant differences in benthic community structures among sites sampled from the upper most reaches sampled (RM 28) down to the lower river reaches (RM 14) suggesting either habitat changes or water quality degradation. To further isolate the causes of the observed changes in benthic communities along the Kenai River, a research project with replicate reference locations and additional replicate samples within location would be recommended. Additional measured habitat parameters would give further support to the possible causes for benthic community changes. Also, localized tolerance values for EPT genera and Chironomidae found in the Kenai River would be useful in determining water quality impairment from sources relevant to this area. As more areas are paved increasing storm drain flow, and outfall from the Soldotna Sewage Treatment Plant increases, there is a greater possibility for detrimental changes to the biotic diversity of the Kenai River. The technology exists for effectively treating and monitoring pollutants before entering the river and this should be considered when new construction is planned.

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Table 1. Tolerances of macroinvertebrate families to changes in water quality based on a scale of 0 - 10, with 0 indicating least tolerant and 10 most tolerant. Adopted from Hilsenhoff (1988).

Scale	Plecoptera (Stoneflies)	Ephemeroptera (Mayflies)	Trichoptera (Caddisflies)	Diptera (True flies)
0	Leuctridae		Glossosomatidae	
	Pteronarcyidae		Rhyacophilidae	
1	Chloroperlidae	Ephemerellidae	Brachycentridae	
	Perlidae			
	Capniidae			
2	Nemouridae			
	Perlodidae			
	Taeniopterygidae			
3				Tipulidae
4		Baetidae	Apatniidae	
		Heptageniidae	Limnephilidae	
			Hydropyschidae	
6				Chironomidae
				Simuliidae
				Empididae
				Ceratopogonidae
8				Oligochaeta (not Diptera)
10				Psychodidae

Table 2. General water quality parameters and nutrient concentrations for Kenai River stations (River Mile 13.9-39) sampled May 5 - 7, 1997.

Location	**Date**	**River Mile**	**Specific conductance (mmhos/cm)**	**pH (Units)**	**Alkalinity (mg L-1)**	**Turbidity (NTU)**	**Color (Pt units)**	**Calcium (mg L-1)**	**Magnesium (mg L-1)**	**Iron (mg L-1)**	**Total-P (mg L-1 P**	**Reactive silicon (mg L-1 Si)**	**Total Solids (mg L-1)**
Bings Landing	5/7/97	39.0	63	7.3	23.5	13.6	8	9.4	1.1	264	18.6	1885	43
Scout Loop access	5/7/97	34.0	84	7.5	35.6	12.0	15	11.3	1.7	521	33.4	3268	68
East Redoubt	5/5/97	28.0	73	7.1	29.7	11.1	9	10.3	1.7	388	24.8	2570	58
Moose Range	5/5/97	25.8	72	7.4	30.4	12.3	12	9.4	1.7	389	31.4	3941	60
Bowers	5/7/97	24.5	91	7.1	38.1	15.4	22	10.3	2.3	944	58.4	5109	82
Swiftwater	5/5/97	23.0	75	7.4	30.5	14.0	9	9.4	1.7	442	24.8	2708	55
Highways Above	5/5/97	22.1	108	7.5	42.0	12.3	12	12.2	2.3	596	51.5	5418	82
Soldotna Bridge	5/5/97	21.2	88	7.7	34.6	11.3	10	10.3	1.7	441	34.4	3774	63
Sewage Treatment Plant	5/5/97	20.5	92	7.6	34.1	13.4	9	11.3	1.7	404	91.3	3586	73
Marydale	5/7/97	17.7	73	7.5	29.0	15.0	12	10.3	1.1	343	36.0	2622	58
Poachers Cove	5/5/97	17.2	76	7.6	30.0	13.7	9	9.4	1.7	363	28.4	2807	60
Big Eddy Park Above	5/5/97	16.7	72	7.9	28.6	12.2	8	9.4	1.1	353	24.4	2629	54
Big Eddy Jetty Below	5/7/97	13.9	73	7.4	29.1	11.3	10	9.4	1.1	328	26.5	2775	49
Mean			80		32	13	11	10	1.6	444	37	3315	62
Range			(63-108)	(7.1-7.9)	(24 - 42)	(11-15)	(8-22)	(9-12)	(1.1-2.3)	(264-944)	(19-91)	(1885-5418)	(43-82)

Table 3. Microtox values (EC_{50}) for sediments collected from 14 locations on the Kenai River May, 1997. EC_{50} is defined as the effective concentration that results in 50% reduction in light emission.

Location	River Mile	EC_{50} (%)	95% Confidence Limits	EC_{50} (%) corrected with reference
East Redoubt	28.0	39.3	27.4 to 56.3	Reference
Moose Range	25.8	17.0	9.8 to 29.7	*
Bowers Above	24.5	4.8	4.0 to 5.9	*
Bowers Below	24.4	29.2	17.4 to 48.8	*
Highways Above	22.1	14.7	5.7 to 37.6	*
Highways Below	21.8	12.1	6.2 to 23.9	*
Soldotna Bridge Above	21.2	27.6	23.3 to 32.8	*
Soldotna Bridge Below	21.1	11.7	10.9 to 12.6	34.8
Sewage Treatment Plant Above	20.5	421	38.9 to 4563.9	*
Sewage Treatment Plant Below	20.4	448	165.9 to 1211.2	*
Marydale Above	17.7	110	10.1 to 1201.9	*
Marydale Below	17.6	4.6	3.8 to 5.5	11.1
Big Eddy Park Above	16.7	21.4	14.5 to 31.5	*
Big Eddy Jetty Below	13.9	73.3	56.3 to 95.3	*

* unable to calculate

Table 4. Summary of quantitative benthic invertebrate samples (3-5 replicates) for Kenai River stations (River Mile 13.9-28), May 1997

River Mile	Location	Total No. Indvs. Observed	Total No. EPT Indv. Observed	Total No. Indv./m2	Total No. EPT Indv./m2	Total No. EPT Genera	Average No. EPT Genera	Average EPT/Total Indv. Ratio	Average Percent Dominant Taxa	Average Family Biotic Index
28.0	East Redoubt	1434	293	5148	1052	10	7.3	0.22	77.7	5.05
*25.8	Moose Range	1541	130	3313	280	8	3.4	0.06	92.0	5.87
24.5	Bowers Above	1927	489	6918	1756	7	5.3	0.29	71.3	4.61
24.4	Bowers Below	1106	213	3971	765	7	5.7	0.19	80.3	5.09
*22.1	Highways Above	2527	85	5433	183	7	3.2	0.04	95.6	5.92
21.8	Highways Below	1579	36	5669	129	6	4.0	0.03	95.0	5.94
21.2	Soldotna Bridge Above	4885	379	10503	815	8	4.6	0.07	92.2	5.67
20.5	Sewage Treatment Above	2598	352	9327	1264	8	6.0	0.14	86.0	5.41
20.4	Sewage Treatment Below	2667	103	9578	373	8	5.3	0.04	96.0	5.88
17.7	Marydale Above	3874	62	13908	223	9	3.3	0.01	98.3	5.94
17.6	Marydale Below	2197	25	7887	90	8	4.3	0.01	97.0	5.99
*16.7	Big Eddy Park Above	2546	222	5474	477	11	6.0	0.08	91.4	5.64
13.9	Big Eddy Jetty Below	1644	199	5902	427	10	6.3	0.06	93.7	5.77
Range		1106-4885	25-489							
Mean		2348	199							

* 5 replicates

Table 5. Results of parametric and non-parametric analyses to test for overall significant differences between above and below outfall sites and site locations for four benthic invertebrate metrics. Values are approximate probabilities (P - value), P - values < 0.05 are significant.

	Parametric		Non - Parametric	
Metric	Paired t-test (above vs below)	One way ANOVA (spatial)	Wilcoxon test (above vs below)	Kruskal-Wallis (spatial)
Number of EPT Genera	0.1275	0.2843	0.1159	0.2779
EPT/Total Individual Ratio	0.3538	**0.0119**	0.1730	**0.0379**
Percent Dominant Taxa	0.4447	**0.0132**	0.4631	**0.0604**
Family Biotic Index	0.2668	**0.0087**	0.1730	**0.0278**

Table 6. Results of Kruskal-Wallis analysis to test for significant differences between above and below individual outfall sites for four benthic invertebrate metrics. Values are approximate probabilities (P -value), $P < 0.05$ are significant.

Location	Outfall Type	River Mile (approx.)	Metric 1 Number of EPT Genera	Metric 2 EPT/Total Individual Ratio	Metric 3 Percent Dominant Taxa	Metric 4 Family Biotic Index
Bowers	Subdivision drain	24.5	0.8166	0.5127	0.5127	0.5066
Highways	Storm drain	21.6	0.2819	0.8815	0.3653	0.8815
Soldotna Bridge	Storm drain	21.0	0.5386	0.2967	0.2938	0.4561
Sewage Treatment Plant	Sewage outfall	20.5	0.7963	**0.0495**	0.0765	**0.0495**
Marydale	Storm drain	17.6	0.6579	0.5127	0.4867	0.2752
Big Eddy	Storm drain	14.5	0.6488	0.8815	0.5486	0.5486

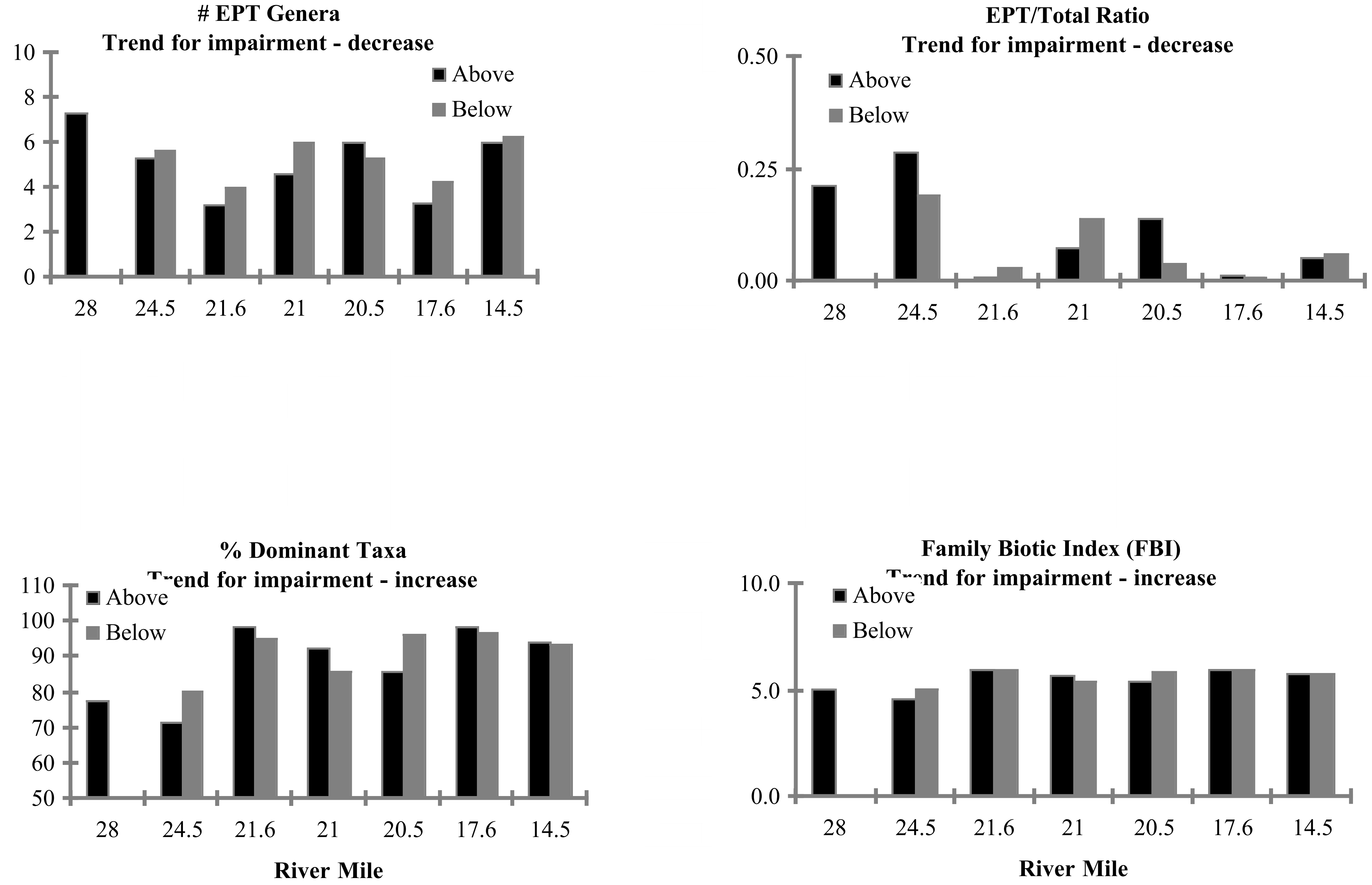
Table 7. Summary of the total EPT genera, EPT/total individual ratio, percent dominant taxa and the Family Biotic Index for Kenai River stations (River Mile 14-25) sampled for benthic invertebrates in 1991, 1993, and 1997.

Metric		Total EPT genera	EPT/total ratio	Percent dominant taxa	Family Biotic Index
Trend for degredation		decrease	decrease	increase	increase
River Mile	Year				
25.0	1991	9	0.05	94	na[1]
25.0	1993	3	0.21	73	5.4
24.5	1997	6	0.19	80	5.1
22.0	1991	9	0.17	80	na
21.6	1993	4	0.09	84	5.9
21.8	1997	4	0.03	95	5.9
21.0	1991	6	0.19	68	na
20.6	1993	3	0.11	6.5	5.7
20.5	1997	6	0.14	86	5.4
18.0	1991	9	0.18	73	na
18.0	1993	2	0.01	95	6.0
17.7	1997	3	0.01	98	5.9
14.0	1993	5	0.02	96	6.1
13.9	1997	5	0.05	94	5.8

1/ na indicates not available.

Table 8. Summary of qualitative benthic invertebrate sampling for 9 locations on the Kenai River in May 1997.

River Mile	Location	Total no. individuals observed	Total no. EPT individuals observed	Percent of total subsampled	No. EPT Genera	EPT/total individual ratio	Percent dominant taxa	Family biotic Index
28.0	East Redoubt	300	10	4	2	0.03	96	5.87
25.8	Moose Range	300	10	4	3	0.03	96	5.89
22.1	Highways Above	296	32	3	5	0.11	89	5.67
21.8	Highways Below	300	19	4	5	0.06	90	5.95
20.5	Sewage Treatment Above	300	45	3	5	0.15	85	5.27
20.4	Sewage Treatment Below	300	28	3	5	0.09	90	5.65
17.7	Marydale Above	301	9	3	2	0.03	97	5.86
16.7	Big Eddy Park Above	300	23	4	7	0.08	92	5.66
13.9	Big Eddy Jetty Below	300	19	3	5	0.06	93	5.73
Mean		**300**	**22**					


EPT Genera
Trend for impairment - decrease

EPT/Total Ratio
Trend for impairment - decrease

% Dominant Taxa
Trend for impairment - increase

Family Biotic Index (FBI)
Trend for impairment - increase

Figure 1. The number (#) of EPT genera, EPT/total ratio, percent (%) dominant taxa, and Family Biotic Index (FBI) versus river mile for seven sites on the Kenai River sampled in May 1997.

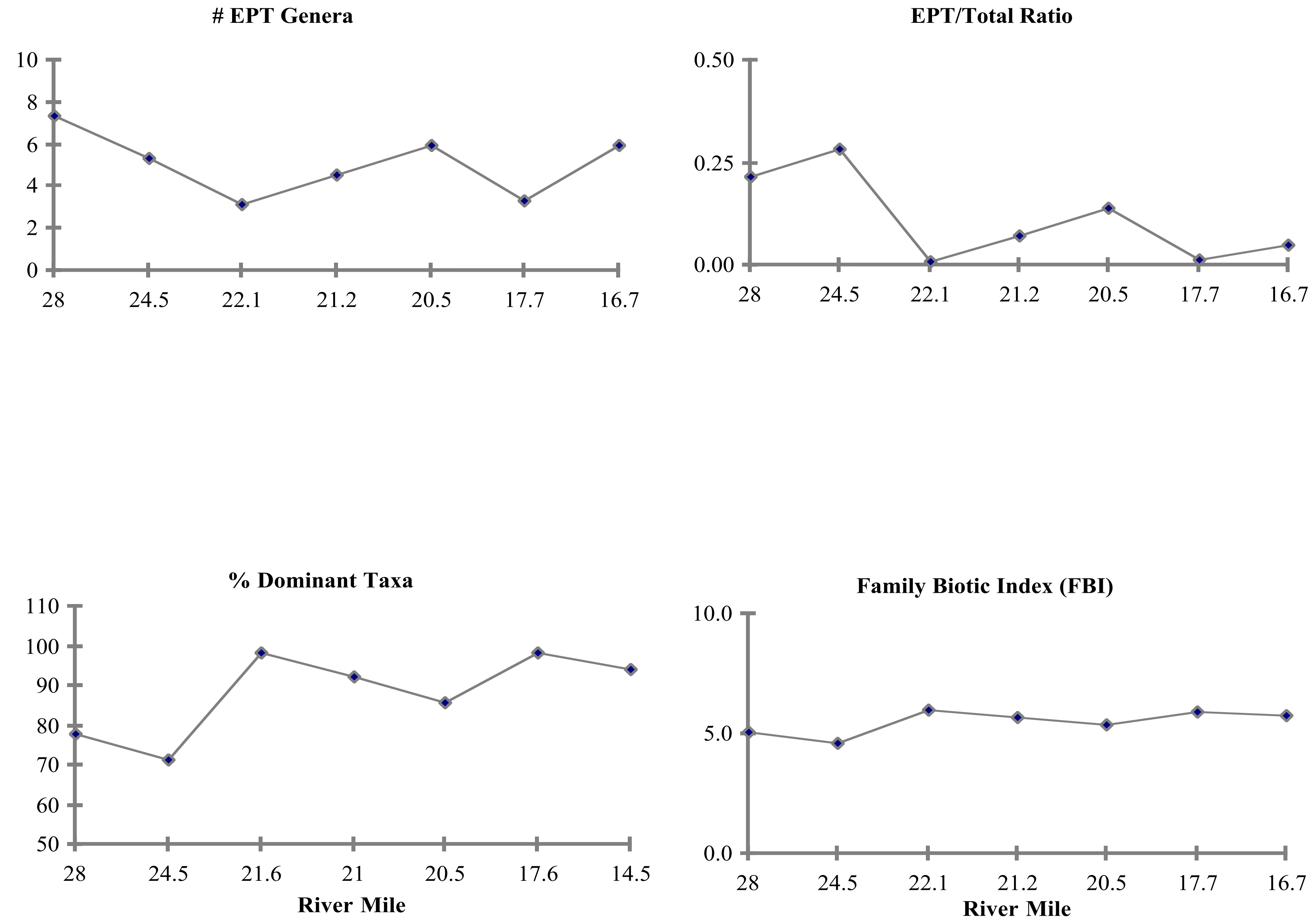


Figure 2. The number (#) of EPT genera, EPT/total ratio, percent (%) dominant taxa, and Family Biotic Index (FBI) versus river mile for the reference site and the above outfall sites in the Kenai River sampled May 1997.

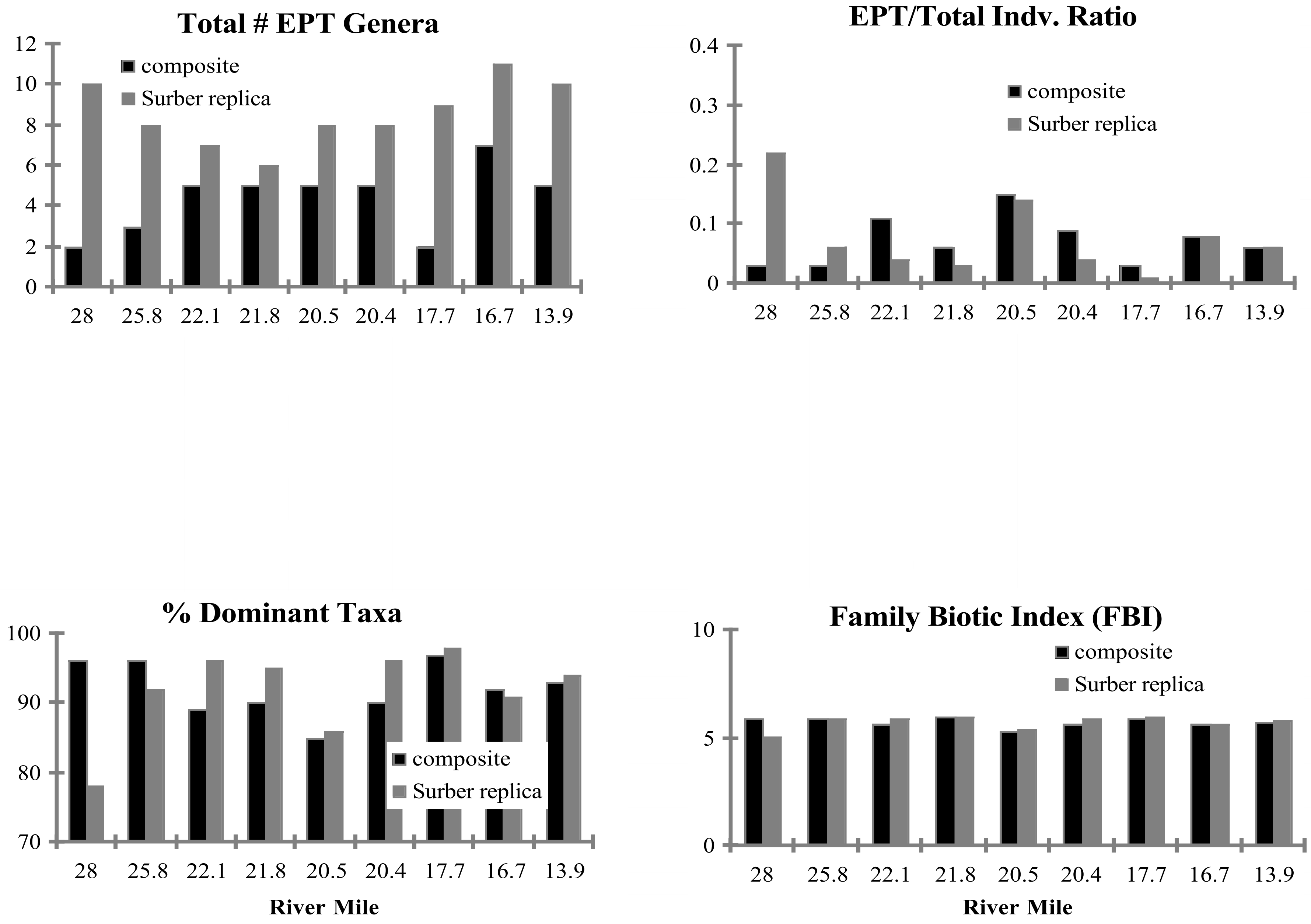


Figure 3. Total number of EPT genera, EPT/toal individual ratio, percent dominant taxa, and Family Biotic Index (FBI) versus river mile for two benthic invertebrate methods at eight sites in the Kenai River sampled May 1997.