

**An Analysis of the Relationship Between Substrate Permeability and
its Impact on Invertebrate Communities within Prairie Creek.**

Senior Thesis

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Abstract

Road construction of the Redwood National Park bypass resulted in a large influx of fine sediments into the Prairie Creek drainage during a storm in October 1989. I studied the relationship of invertebrate communities with substrate size and permeability, within the drainage during the spring of 1996. Three impacted and three unimpacted tributaries from those previously used to assess the impacts on amphibians by Welsh and Ollivier (1992) were used as control and experimental streams. I took five samples from each of six streams during late spring, 1996. Seven metrics were used to show whether there was a difference in invertebrate communities between impacted and unimpacted streams. Boyes Creek and Brown Creek consistently scored poorly. Certain sensitive taxa, such as Perlidae and Heptageniidae, were not common in Brown Creek and Boyes Creek. Invertebrate and sediment data suggest that Big Tree Creek, once considered impacted, has made a recovery. Shannon-Wiener diversity plotted against Fredle Index values (permeability index) for all six streams yielded a P value of 0.189, but was correlated stronger ($P=0.002$) when Boyes Creek and Brown was excluded from the regression analysis.

Introduction

Nonpoint sources of pollution and disturbance is a major factor involved in the degradation of aquatic resources on public land. Siltation of lotic habitats has been identified as a major limiting factor for vertebrates and invertebrates. Gravel spawning fish, such as salmonids, have been the most studied of all the organisms affected. The majority of research on the relationship between salmonid production and substrate has dealt with the adverse effects of embeddedness on the spawning activity of fish. Reiser and White (1988), Chapman (1988), Phillips and colleagues (1975), and Everest and colleagues (1987), all came to the same conclusions about embeddedness of substrate used for spawning; fine sediments that fill the interstitial spaces of gravel cut down on flow through the redd, which brings needed oxygen for the eggs and fry of salmonids. The gravel also provides eggs and fry protection from predation. Invertebrates also need the protection and oxygen provided by the interstitial spaces. Pennak and Van Gerpan (1947) is often cited for the generalization that invertebrate abundance increases are associated with

increasing particle size. Amphibians have been impacted by inorganic sedimentation as well. Concentration of silt has been positively correlated with decreased salamander densities in the Pacific Northwest (Hawkins and others 1983). Welsh and Ollivier (1992) found significant decreases in densities of salamanders, tailed frogs, and red-legged frogs within silted streams in Prairie Creek State Park, CA.

Fine sediments have acute as well as chronic effects on the biota. Newcombe and MacDonald (1991) looked at both concentration of fines and duration of exposure in their review of seventy papers published on the effects of inorganic suspended sediments on freshwater fish, marine fish, and other organisms such as benthic invertebrates. They stated that the concentration of fines alone is a poor measure, but that the combination of duration of exposure and concentration is a better measure of the impacts on the biota.

There are two reasons that macro-invertebrates are an excellent choice for indicators of biological health within a stream environment. The first reason is that macro-invertebrates are long lived, sedentary, and show extreme sensitivities to pollution making them one of the best choices for showing the chronic effects of pollution (Hellawell 1986).

Sedimentation affects most invertebrates to a greater degree, as compared to the impact on fish. The life history stage, egg-to-emergence, is the most critical period for salmonid survival. Emerged salmonids can react to conditions such as excess suspended solids, which interferes with the gills' ability to intake oxygen, by migrating out of the area (Fagerlund and others 1995). In contrast, invertebrates spend most of their life in the interstitial spaces of the gravel. Some insects spend two to three years in the larval stage prior to their short adult lives (Merritt and Cummins 1984), and therefore are susceptible to the effects of sedimentation for a greater percentage of their lives.

More research is needed if invertebrates are to be used as indicators of biological health within streams. Research on invertebrates has not been as extensive as research on fish. Minshall (1984) pointed out the lack of knowledge about substrate-aquatic insect relationships. Field studies have attempted to expand on Pennak and Van Gerpan's work in 1947, but have yielded contradicting results. More consistent results have come from laboratory methods. Other factors, not well understood, seem to be the reason for the difference between laboratory and field methods. In particular, Minshall (1984)

addressed the lack of research done to determine the importance of substrate pore space as a feature important to the microdistribution of insects.

The second reason macro-invertebrates are an excellent choice as indicators of biological health is that they are a food source to fish and amphibians. Insect drift makes up a large proportion of the diet of salmonids. Changes in invertebrate biomass and species composition will affect salmonid production in a variety of ways. A simple decrease in invertebrate biomass decreases the food available to fish, thereby decreasing their production.

Prey size is important to salmonid production. Larger prey makes foraging more efficient for fish. Feeding on small food items requires more energy. The larger organisms, such as the stonefly families *Taeniopterygidae*, and *Perlidae*, need large pore sizes within the substrate to survive (Stewart and Stark 1988).

Changes in the invertebrate communities can involve more complex factors such as intraspecific and interspecific competition among fish. A study by Bozek, DeBrey, and Lockwood (1994) found that while there is a diet overlap among size classes, large trout preferred large prey. They further hypothesized that a high proportion of small items in the diets of adult cutthroat trout within their study area, and their slow growth, indicated that food may be limiting for adults, as well as evidence of high intraspecific competition between adults and smaller size classes.

An increase in embeddedness within a stream can sometimes affect interspecific competition among fish. Sculpins have been shown to reduce food resources, food consumption, and the production of trout (Brocksen and others 1968) as stated by Brusven and Rose (1981). Brusven and Rose (1981) found that increased cobble embeddedness resulted in increased predation by the sculpin *Cottus* upon the stonefly *Hesperoperla pacifica*, and the caddis *Rhyacophila vaccua*, by altering the refuge provided to them by the interstitial spaces. These large organisms would be a preferred food item for any salmonid.

Habitat is the limiting factor for invertebrates even in the presence of predation by fish. Brusven and Haro (1994) studied the effects of cobble embeddedness on the micro-distribution of the sculpin *Cottus belingi* and its stonefly prey. The results support their hypothesis that higher predator densities influence prey densities less than the structural habitat quality of the unembedded-cobble patches. They found that sculpin and stonefly densities

were significantly greater in unembedded substrate. Stonefly densities were greater in unembedded substrate, even though their predators also occurred in greater numbers.

A great deal of variability exists for physical and chemical sensitivity to siltation between different invertebrate taxa. A number of investigators have reported that certain taxa occur on only one type or size of substrate (Minshall 1984). Hellawell (1986) points out that while some genera, such as the mayfly *Baetis*, may be unaffected by sedimentation, because they tend to live on top of stones. Others such as the caddis fly *Hydropsyche* and the dipteran *Simulium*, may disappear in the presence of fine sediments. Stoneflies (Plecoptera), many mayflies (Ephemeroptera), and caddisflies live in the interstitial spaces of the substrate (Minshall 1984). It appears that heterogeneity of substrate size correlates with increased diversity (Minshall 1984). Increased sedimentation may significantly diminish the size and availability of adequate micro-habitat patches for insects by decreasing both the total surface area of the substrate, and pore sizes, within the hyporheic zone (Brusven and Haro 1994). Lemly (1982) concluded that inorganic sedimentation disrupts normal feeding on filter-feeding taxa and lowers pH levels in the bed load. This acidification eliminates pH sensitive species of Plecoptera and Ephemeroptera.

Pore space is the most important variable when sampling substrate, therefore special techniques must be employed. Platts and others (1983) discussed the various substrate quality indexes for evaluating spawning habitat. It was stressed that the geometric mean of substrate size would be a poor measure. A stream with all gravel might have the same geometric mean as one with cobble completely embedded with silt. The Percent Fines method yielded incomplete information as well. Platts concluded that the Fredle Index is the best for predicting the permeability of the substrate. The formula is outlined on page 20 of Platts and others (1983). The procedure uses a measure of the central tendency of the distribution of sediment particle sizes in a sample and the dispersion of sediment sizes in relation to the central value. Phillips and others (1975) as stated in Platts and others (1983) found there was a positive correlation between high Fredle Index numbers and survival-to-emergence for coho and steelhead. Despite the similarities between the habitat requirements of invertebrates and salmonid fry, previous research on invertebrates have not used the Fredle Index.

Cummins (1973) classified macro-invertebrate genera into functional groups based on feeding behavior; Predators (engulfers); shredders; collectors (suspension and deposit feeders); and scrapers (grazers). Sediment probably affects individuals belonging to the same functional group similarly (Minshall 1984). Invertebrates orders can encompass many functional groups, therefore any macro-invertebrate study must identify the invertebrates to genus.

Once invertebrate samples are identified to the taxonomic level desired, the data must be analyzed to detect differences among samples. A great number of methods and their component metrics are employed to characterize the health of an invertebrate community within streams. Taxa richness is one of the most reliable indicators of degradation for aquatic macroinvertebrates (Kerans and Karr 1994). Species richness and evenness both affect the diversity of the community. Increased diversity has long been associated with community health and stability. A popular and simple metric is the Shannon-Wiener species diversity Index (H'). It employs both diversity and evenness in its formula. An unhealthy system would show a few tolerant taxa that dominant the total abundance, thereby decreasing H' (Plafkin and others 1989). However, biologists are developing more complex and multimetric indexes such as the benthic index of biotic integrity (B-IBI; Kerans and Karr 1994), and rapid bioassessment (RBP III; Plafkin et al. 1989).

Fore and others (1996) tested several metrics, currently used to evaluate macroinvertebrate biomonitoring data, for their ability to show differences between sites degraded by human activities and those unaffected. They constructed their own B-IBI and compared it to RBP III protocol and well as multivariate methods. Total abundance did not show significant differences between disturbed and undisturbed sites. Feeding ecology (scrapers; gatherers, shredders; predators; filterers) metrics failed to distinguish the most and least disturbed sites. Percentage of the dominant taxa is a simple measure of redundancy. Any number of dominant taxa may be used in this calculation. Fore and others (1996) tested one to five dominant taxa and found that using three taxa in the metric yielded the best information regarding the difference between impacted and unimpacted sites.

The EPT Index represents the total number of Plecoptera, Trichoptera, and Ephemeroptera taxa. It is considered a universal metric applicable in many stream systems (Plafkin and others 1989). These insect orders are generally regarded as sensitive and loss of taxa in these groups regarded as an

indication of perturbation (Idaho, Dept. of Environmental Quality 1996). There are exceptions to the rule such as *Baetis* (Hellawell 1986).

Fore and others (1996) used the individual orders within the EPT Index in their own B-IBI. Testing of the RBP III protocol (Plafkin and others 1989) revealed that only four of the metrics could distinguish between the most and least disturbed sites; taxa richness; Diversity index (H'); EPT taxa; and percentage of EPT taxa among the total abundance (Fore and others 1996).

For tolerance and intolerance indexes, Fore and others (1996) confirmed the generality that tolerance metrics should be expressed as a percentage of the total abundance and intolerance metrics be expressed as taxa richness. Barbour and others (1996) found that the percentage of Diptera in the total abundance was able to distinguish between sites of varying disturbance. Barbour also found three other metrics that worked well; number of taxa; %dominant taxon; and number of EPT taxa.

Timing of invertebrate sampling is critical in order to evaluate overall biological condition, optimizing the use of the benthic communities' capacity to reflect integrated environmental effects over time. Ideally, the optimal biological sampling season will correspond to recruitment cycles of the invertebrates. Sorting and identifying later instars can be done quicker and with more confidence. Peak emergence of invertebrates occurs in the spring and fall, although onset and duration vary across the United States (Plafkin and others 1989).

Study Site

Prairie Creek lies within Redwood National Park and Prairie Creek State Park in the vicinity of Orick, California. A series of storms in October, 1989, delivered fine sediments from the US Highway 101 bypass project (Caltrans) into the Prairie Creek drainage. Failure to winterize the construction site before the rains started in 1989 resulted in a large influx of fine sediments, and continues to impact the drainage (Redwood National Park 1991).

Scientists from Redwood National Park, Humboldt State University, and the US Forest Service, have been monitoring the effects of the fine sediments on the physical and biological habitat within Prairie Creek and its tributaries. Extensive work has been done on salmon egg survival (Redwood National Park

1991), and amphibians (Welsh and Ollivier 1992). Welsh and Ollivier chose nine tributaries of Prairie Creek, and Little Lost Man Creek, a tributary of Lost Man Creek for their study on amphibians. A comprehensive invertebrate analysis was done on Prairie Creek (Strange 1988) has provided excellent baseline information on invertebrate species composition prior to the main delivery of sediment into the drainage in 1989. Lost Man Creek and its tributaries, which are south of the bypass in Redwood National Park, were not impacted from the bypass project. The only invertebrate research done after 1989 should be considered inadequate, since the invertebrates were identified only to order (Redwood National Park 1991).

Materials and Methods

I chose the same tributaries used by Welsh and Ollivier (1992) to evaluate invertebrate-substrate relationships. I selected six of the ten creeks used in their study, three impacted, and three unimpacted. Corkscrew Creek and Good Creek are first-order streams, while Brown and Big Tree are second-order streams. Boyes Creek and Little Lost Man Creek are third and fourth order streams respectively. Figure 1, which was generated from GIS software (ArcInfo), shows the location of these streams in relation to the Highway 101 bypass. Any attempt to designate sections of Prairie Creek below Ten Tapo Creek, as control or as experimental, would not be scientifically sound. Impacted and unimpacted tributaries alternate along a downstream continuum, depositing sediment into Prairie Creek. However, distinct differences in the amount of fine sediments did occur when comparing the tributaries of Prairie Creek. These streams are of similar size, physical structure, orientation, and have similar vegetative cover (Welsh and Ollivier 1992).

I did not do a dry run of the field sampling, to determine the minimum number of sampling sites, due to time constraints. Instead, five sites were sampled per creek from May 26 to June 11 1996. According to Rosenberg and Resh (1993), "It would take hundreds of samples to estimate total populations to a high degree of accuracy". Three samples per location would be considered a minimum. Five samples would increase the statistical power of the samples with relatively little additional effort, whereas increasing the sample size from 5-60 yields only slightly more statistical power (Platts and others 1983).

Impact of HWY 101 Bypass upon Aquatic Macro Invertebrate Communities of Prairie Creek State Park

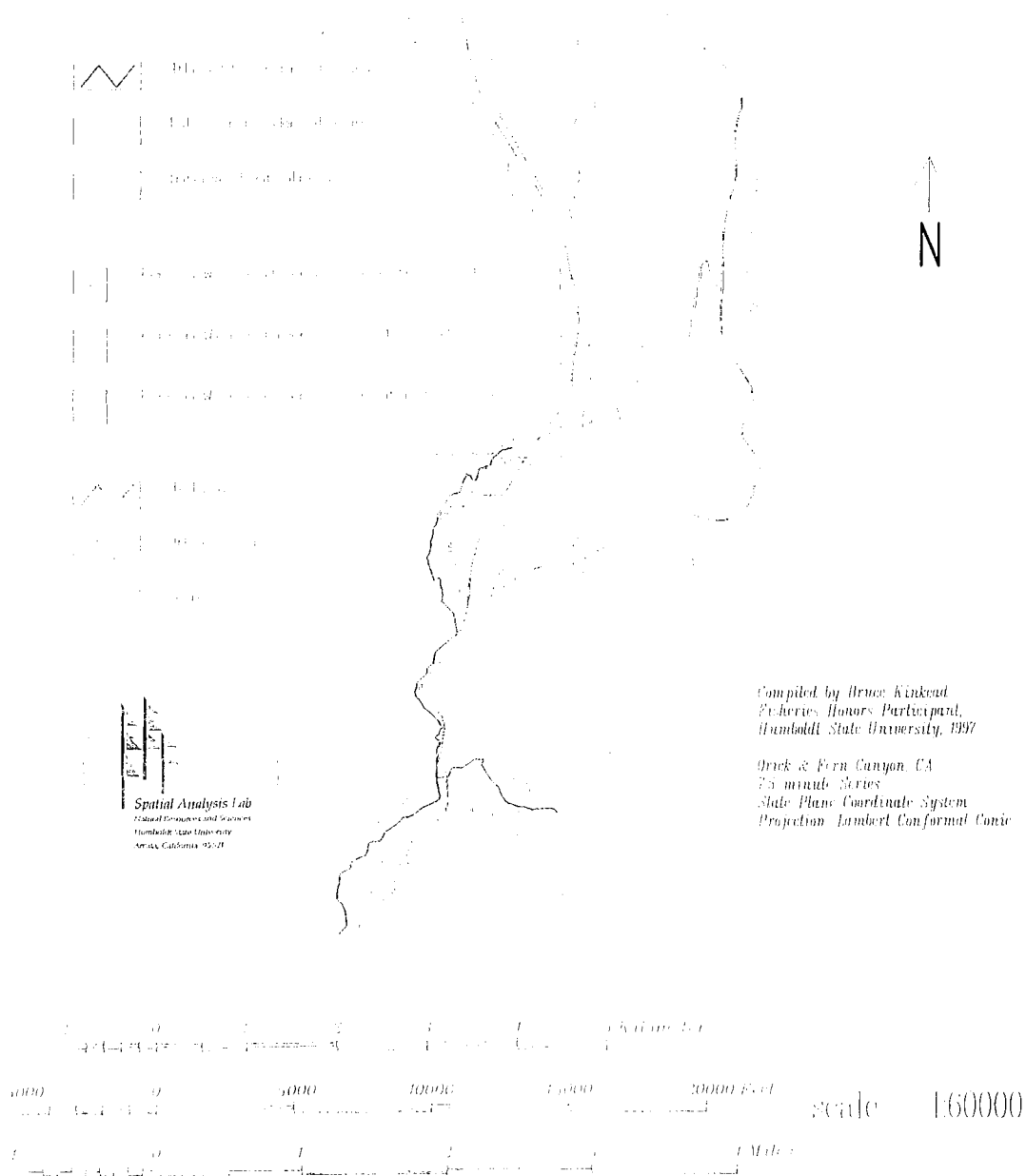


Figure 1. GIS map generated on ArcInfo to show spatial relationships of six tributaries of Prairie Creek and the HWY 101 bypass, along with invertebrate sampling locations, Humboldt County, CA, 1997.

Sampling was initially scheduled for early spring to take advantage of the timing of peak emergence of invertebrates during the spring. However, sampling was rescheduled for May 26th - June 11, because the initial sampling device, the Hess sampler, proved to be inadequate. Due to the embeddedness of the cobble, it was impossible to push the Hess sampler far enough into the substrate to allow for water flow through the sampler.

I used a Phibbs sampler for invertebrate sampling. It has the same frame as the more popular Surber sampler, except it has foam under the bottom of the frame. The foam rests on top of the substrate trapping any organisms that might otherwise swim or crawl away. Methods as outlined in Platts and others (1983) were followed for the invertebrate sampling. Samples were preserved in 70% ethyl alcohol, as outlined in Lind (1985), and transferred to Humboldt State University to be identified and quantified.

I paid careful attention in selecting sampling sites that had minimal physical, chemical, and biological differences other than the substrate. Site locations are shown in Figure 1). Water velocity, depth, presence of moss or other aquatic plants, temperature, and type of habitat, are all things that influence the distribution of invertebrates (Minshall 1984). I used pool tail crests as the habitat type to best show differences between silted streams and unsilted, as recommended by Platts and others (1983). At each sampling station, temperature, velocity, and depth were measured. I took pictures at each sampling station. Differences in canopy, aquatic vegetation, riparian vegetation or anything else of note were recorded.

I sampled the substrate with a 100 point grid similar to those commonly used to quantify fines as a percentage of the total substrate. The wire grid was made to fit inside the Phibbs Sampler. The grid was then placed on top of the substrate once the sampler has been pressed in. I used a viewing tube to cut down on glare in order to quantify the substrate. Percentages of the following substrate size classes were recorded prior to invertebrate sampling: <0.5mm; 0.5-2mm; 2-4mm; 4-8mm; 8-16mm; 16-32mm; 32-64mm; and >64mm.

I used a standard dissecting microscope to identify the macro-invertebrates to the lowest possible taxon. Keys from the following publications were used to identify the organisms; Lauck (1993); Merritt and Cummings (1984); Thorp and Covich (1991); Stewart and Stark (1988); Wiggins (1996); and Usinger (1956).

I statistically evaluated the invertebrate data, as outlined in Platts and others (1983), for total abundance, richness, and the Shannon-Weiner diversity index. One-way anova analysis was performed to see if there was a significant difference between diversities of the six selected streams. Three other metrics were used to evaluate invertebrate sampling data, as outlined in Idaho Division of Environmental Quality (1996): Percent Ephemeroptera, Plecoptera, and Trichoptera (EPT); EPT taxa, a measure of the EPT taxa richness; and Percent Dominance of three taxa. I modified the Percent EPT Index by excluding the genus *Baetis* because of its ability to tolerate sedimentation (Hellawell 1986). I calculated abundance's of certain sediment sensitive taxa, such as stoneflies (Plecoptera) and clinging mayflies of the family Heptageniidae, to show differences among streams.

Evaluation of the substrate was done by calculating Fredle Index values for each sampling site using the formula on page 20 of (Platts and others 1983). Regression analysis was first done on all six streams to see if there was a significant linear correlation between the variables for substrate porosity (Fredle Index) and invertebrate composition (Shannon-Wiener diversity). Since Anova analysis revealed a difference between Boyes Creek and Brown Creek, and the other four streams sampled, I decided to split up the six streams for further regression analysis. First, data from Big Tree, Corkscrew, Good, and Little Lost Man were lumped together, and a second regression line was created. Because invertebrate composition, as well as substrate, can be linked to the velocity of the current (Minshall 1984), a third regression line was created which excluded Little Lost Man Creek. Finally, I created a fourth regression line using data from Boyes Creek and Brown Creek. Excel 5.0 software for Macintosh was used for all statistical analysis.

Results

Raw values of substrate sampled are shown Appendix A. Percent fines and Fredle index values, along with two values (Geometric mean and S_0) used to calculate the Fredle values are shown in Table 1. Other habitat parameters, depth, velocity, temperature, canopy, and presence of aquatic vegetation are shown in Table 2. Measurements of temperature and canopy concur with a previous study on amphibians (Welsh and Ollivier 1992) that habitat is very similar within the study area. Aquatic vegetation capable of providing habitat for invertebrates was not found at any of the sites within Boyes Creek and Corkscrew Creek, while it was found at all five sites in Brown Creek (Table 2). The one striking difference among the six streams studied was depth and velocity that are a function of discharge. Velocities are comparable at Boyes Creek and Little Lost Man Creek that have higher stream discharges. Moderate velocities were measured at Brown Creek and Big Tree Creek, while the lower velocities were measured at Corkscrew and Good Creek.

Raw data of invertebrate abundance's are shown in Appendices B - G. The seven metrics used to evaluate the invertebrate data: total taxa; total number of organisms; Shannon-Wiener Index; number of EPT taxa; percent sediment intolerant EPT taxa, percent Diptera; and percent dominance of three taxa is summarized in Tables 3 - 8. Mean values for Shannon-Wiener diversity are shown in Figure 2. Good Creek, Corkscrew Creek, and Big Tree Creek have comparable mean values for Shannon-Wiener diversity (2.6, 2.58, and 2.54). Little Lost Man Creek is slightly lower at 2.38. Boyes Creek (2.27) and Brown Creek (2.16) were even less diverse. One-way Anova analysis of all six streams shows that there are significant differences ($P=0.009$) between the diversities sampled (Table 9). There were no significant differences in diversity between Big Tree Creek and the three streams identified as unimpacted by Welsh and Ollivier (1992). Anova analysis yielded a P-value of 0.255 (Table 10).

Results from the other six metrics are graphically shown in Figures 3-6; total abundance; total taxa; EPT abundance; percent EPT; percent Diptera; and percent dominance of 3 taxa. The mean values for six of these metrics for the six streams are ranked in order of good to bad and summarized in Table 11. Fore and others (1996) demonstrated that total abundance of organisms is not an indicator of stream health, and therefore left out of this summary.

Table 1: Fredle Index values calculated from substrate samples taken from six Prairie Creek tributaries, Humboldt County, CA, on May 26 - June 11, 1996.

Creek	Station	% Fines (<2mm)	Geometric Mean (mm)	$S_o (D_{75}/D_{25})$	Fredle Index
Corkscrew	1	8	35.13	4	8.78
	2	11	18.61	4	4.65
	3	26	34.52	32	1.08
	4	10	40.36	8	5.05
	5	14	50.21	8	6.28
Good	1	2	40.82	8	5.10
	2	4	64.54	4	16.14
	3	5	28.52	4	7.13
	4	2	19.01	4	4.75
	5	4	30.40	4	7.60
Little Lost Man	1	12	41.76	4	10.44
	2	0	51.96	4	12.99
	3	2	34.34	8	4.29
	4	2	19.01	4	4.75
	5	4	30.40	4	7.60
Boyes	1	41	8.93	8	1.12
	2	43	11.76	8	1.47
	3	28	59.50	32	1.86
	4	31	25.77	32	0.81
	5	32	23.03	32	0.72
Brown	1	8	93.20	8	11.65
	2	3	136.02	2	68.01
	3	10	56.82	4	14.72
	4	6	92.10	16	5.76
	5	13	26.47	16	1.65
Big Tree	1	12	45.18	32	1.41
	2	11	24.11	8	3.01
	3	2	44.00	4	11.00
	4	8	87.32	4	21.83
	5	8	50.42	4	12.61

Table 2. Depth, velocity, water and air temperature, canopy, and presence of aquatic vegetation within the sample measured at six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Creek	Sample	Depth (cm)	Velocity (fps)	Water temp (C)	Air temp (C)	Aquatic Veg.	Canopy (%)
Good	1	6	0.37	10	15	algae	90
	2	7	0.20	10	16	moss	90
	3	6	0.23	10	14	moss	95
	4	5	0.20	10	13	none	95
	5	9	0.53	10	11	none	95
Corkscrew	1	3	0.08	11	13	none	90
	2	1	0.05	12	15	none	95
	3	2	0.05	12	15	none	90
	4	2	0.05	12	18	none	90
	5	3	0.05	11	14	none	90
Little Lost Man	1	16	0.68	12	18	algae	80
	2	9	1.40	13	18	algae	85
	3	14	0.70	13	16	none	95
	4	13	1.50	13	15	none	90
	5	13	0.13	12	13	none	90
Boyes	1	15	1.90	12	21	none	80
	2	13	0.73	12	19	none	90
	3	14	0.90	12	19	none	80
	4	15	0.90	13	15	none	80
	5	9	0.53	12	12	none	95
Brown	1	16	0.55	9	14	algae/moss	90
	2	12	0.43	11	14	algae	95
	3	13	0.75	11	15	algae/moss	90
	4	9	0.63	11	16	algae	85
	5	14	0.17	11	17	algae	70
Big Tree	1	11	1.40	9	18	none	70
	2	12	1.70	8	12	none	65
	3	10	0.53	12	16	moss	95
	4	10	0.12	12	16	none	90
	5	11	1.10	11	16	none	70

Table 3. Summary of bioassessment metrics tested at Good Creek, Prairie Creek State Park, Humboldt County, CA, May 29 1996.

Good Creek										
	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	St Dev	StError	95% Conf. Int.	
Total Taxa	25	29	18	16	20	22	5.3	2.4	20	23
Total Organisms	260	287	33	25	98	141	125	55.9	114	167
Shannon-Wiener	2.57	2.64	2.62	2.53	2.64	2.60	0.047	0.02	2.59	2.61
No of EPT	15	17	10	7	12	12	4.0	1.8	11	13
% Intolerant EPT ^{/a}	0.727	0.488	0.636	0.400	0.633	0.577	0.131	0.058	0.549	0.605
% Diptera	0.112	0.052	0.061	0.200	0.041	0.093	0.066	0.029	0.079	0.107
% Dominance (3 taxa)	0.473	0.401	0.394	0.360	0.408	0.407	0.041	0.018	0.398	0.416

^{/a} Intolerant EPT excludes *Baetis*.

Table 4. Summary of bioassessment metrics tested at Big Tree Creek, Prairie Creek State Park, Humboldt County, CA, June 11 1996.

Big Tree Creek										
Metric	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	St Dev	StError	95% Conf. Int.	
Total Taxa	15	18	19	31	26	22	6.5	2.9	20	23
Total Organisms	50	84	81	182	195	118	66	29.3	104	132
Shannon-Wiener	2.32	2.39	2.58	2.88	2.51	2.54	0.22	0.10	2.49	2.58
No of EPT	12	10	14	18	16	14	3.2	1.4	13	15
% Intolerant EPT ^{/a}	0.700	0.417	0.815	0.522	0.533	0.597	0.158	0.071	0.564	0.631
% Diptera	0.100	0.131	0.111	0.055	0.031	0.086	0.041	0.019	0.077	0.094
% Dominance (3 taxa)	0.520	0.548	0.444	0.429	0.538	0.496	0.055	0.025	0.484	0.508

^{/a} Intolerant EPT excludes *Baetis*.

Table 5. Summary of bioassessment metrics tested at Corkscrew Creek, Prairie Creek State Park, Humboldt County, CA, June 11 1996.

Corkscrew Creek										
Metric	Site 1	Site 2	Site 3	Site 4	Site 5 ^b	Mean	St Dev	StError	95% Conf. Int.	
Total Taxa	19	24	18	17	11	20	3.1	1.4	19	20
Total Organisms	58	114	53	36	28	65	34	15	58	72
Shannon-Wiener	2.59	2.62	2.43	2.67	1.86	2.58	0.103	0.05	2.56	2.60
No of EPT	13	17	11	9	6	13	3.4	1.5	12	13
% Intolerant EPT ^a	0.672	0.386	0.358	0.361	0.250	0.444	0.152	0.068	0.412	0.477
% Diptera	0.052	0.237	0.132	0.167	0.464	0.147	0.077	0.034	0.130	0.163
% Dominance (3 taxa)	0.466	0.509	0.509	0.389	0.679	0.468	0.057	0.025	0.456	0.480

^a Intolerant EPT excludes *Baetis*.

^b Site 5 was excluded from summary statistics because of a possible loss of some of the sample due to the sampler not sealing.

Table 6. Summary of bioassessment metrics tested at Brown Creek, Prairie Creek State Park, Humboldt County, CA, June 10 1996.

Brown Creek										
Metric	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	St Dev	StError	95% Conf. Int.	
Total Taxa	25	27	21	15	18	21	4.9	2.2	20	22
Total Organisms	372	137	247	83	198	207	111	50	184	231
Shannon-Wiener	1.74	2.54	1.96	2.21	2.34	2.16	0.312	0.140	2.09	2.23
No of EPT	15	13	10	12	10	12	2.1	0.95	11.5	12.5
% Intolerant EPT ^a	0.317	0.482	0.332	0.518	0.475	0.425	0.093	0.042	0.405	0.445
% Diptera	0.051	0.066	0.146	0.265	0.116	0.129	0.085	0.038	0.111	0.147
% Dominance (3 taxa)	0.739	0.255	0.433	0.205	0.253	0.377	0.220	0.099	0.330	0.424

^a Intolerant EPT excludes *Baetis*.

Table 7. Summary of bioassessment metrics tested at Little Lost Man Creek, Prairie Creek State Park, Humboldt County, CA, June 10 1996.

Little Lost Man Creek										
Metric	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	St Dev	StError	95% Conf. Int.	
Total Taxa	34	36	32	38	27	33	4.2	1.9	33	34
Total Organisms	535	655	458	544	299	498	132	58.9	470	526
Shannon-Wiener	2.59	2.51	2.37	2.40	2.25	2.43	0.129	0.06	2.40	2.45
No of EPT	19	20	16	19	11	17	3.7	1.6	16	18
% Intolerant EPT ^{/a}	0.404	0.299	0.253	0.267	0.197	0.284	0.076	0.034	0.268	0.300
% Diptera	0.135	0.220	0.109	0.175	0.187	0.165	0.044	0.020	0.156	0.174
% Dominance (3 taxa)	0.497	0.560	0.576	0.607	0.492	0.546	0.050	0.023	0.536	0.557

^{/a} Intolerant EPT excludes *Baetis*.

Table 8. Summary of bioassessment metrics tested at Boyes Creek, Prairie Creek State Park, Humboldt County, CA, May 26 1996.

Boyes Creek										
Metric	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	St Dev	StError	95% Conf. Int.	
Total Taxa	23	17	20	13	16	18	3.8	1.7	17	19
Total Organisms	161	141	52	56	63	95	52	23	84	106
Shannon-Wiener	2.45	2.25	2.53	1.98	2.16	2.27	0.221	0.099	2.23	2.32
No of EPT	12	7	10	8	11	9.6	2.1	0.93	9.2	10.0
% Intolerant EPT ^{/a}	0.298	0.213	0.346	0.214	0.397	0.294	0.081	0.036	0.276	0.311
% Diptera	0.248	0.461	0.192	0.393	0.079	0.275	0.154	0.069	0.242	0.307
% Dominance (3 taxa)	0.559	0.567	0.500	0.661	0.651	0.588	0.068	0.030	0.573	0.602

^{/a} Intolerant EPT excludes *Baetis*.

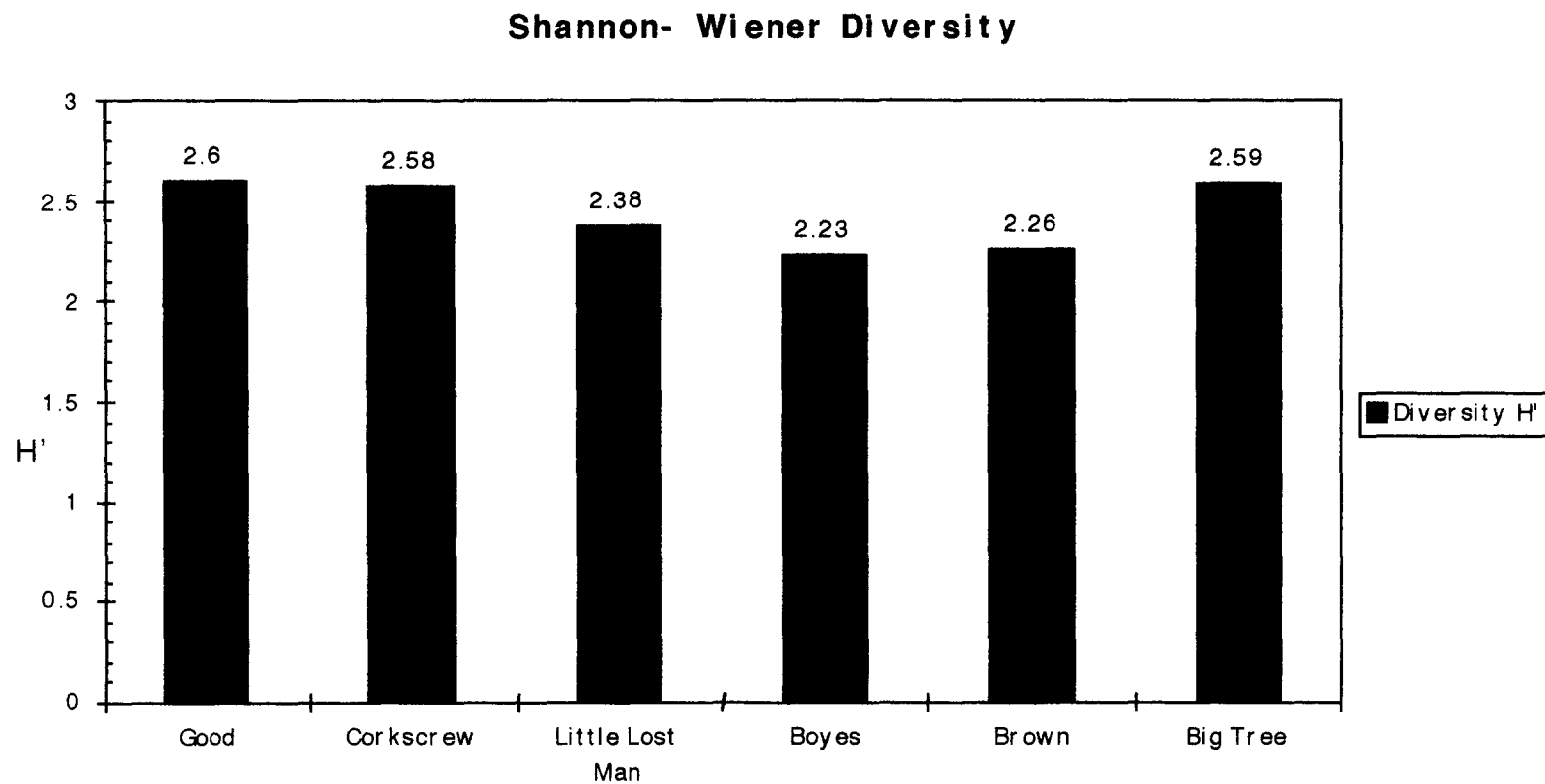


Figure 2. Mean Shannon-Wiener Diversity (H') of macroinvertebrates for six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Table 9. One-way anova analysis of Shannon-Wiener Diversity of macroinvertebrates for six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Anova: Single Factor						
SUMMARY						
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
Corkscrew	4	10.31	2.58	0.01075833		
Good	5	13	2.60	0.00235		
Big Tree	5	12.68	2.54	0.04723		
LLM	5	12.12	2.42	0.01718		
Brown	5	10.79	2.16	0.09892		
Boyes	5	11.37	2.27	0.04913		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.77810569	5	0.15562114	4.01483561	0.00915201	2.64000022
Within Groups	0.891515	23	0.03876152			
Total	1.66962069	28				

Table 10. One-way anova analysis of Shannon-Wiener diversity of macroinvertebrates for four tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Anova: Single Factor						
SUMMARY						
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
Corkscrew	4	10.31	2.58	0.010758		
Good	5	13	2.60	0.00235		
Big Tree	5	12.68	2.54	0.04723		
LLM	5	12.12	2.42	0.01718		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.089801	3	0.029934	1.500105	0.255004	3.28738281
Within Groups	0.299315	15	0.019954			
Total	0.389116	18				

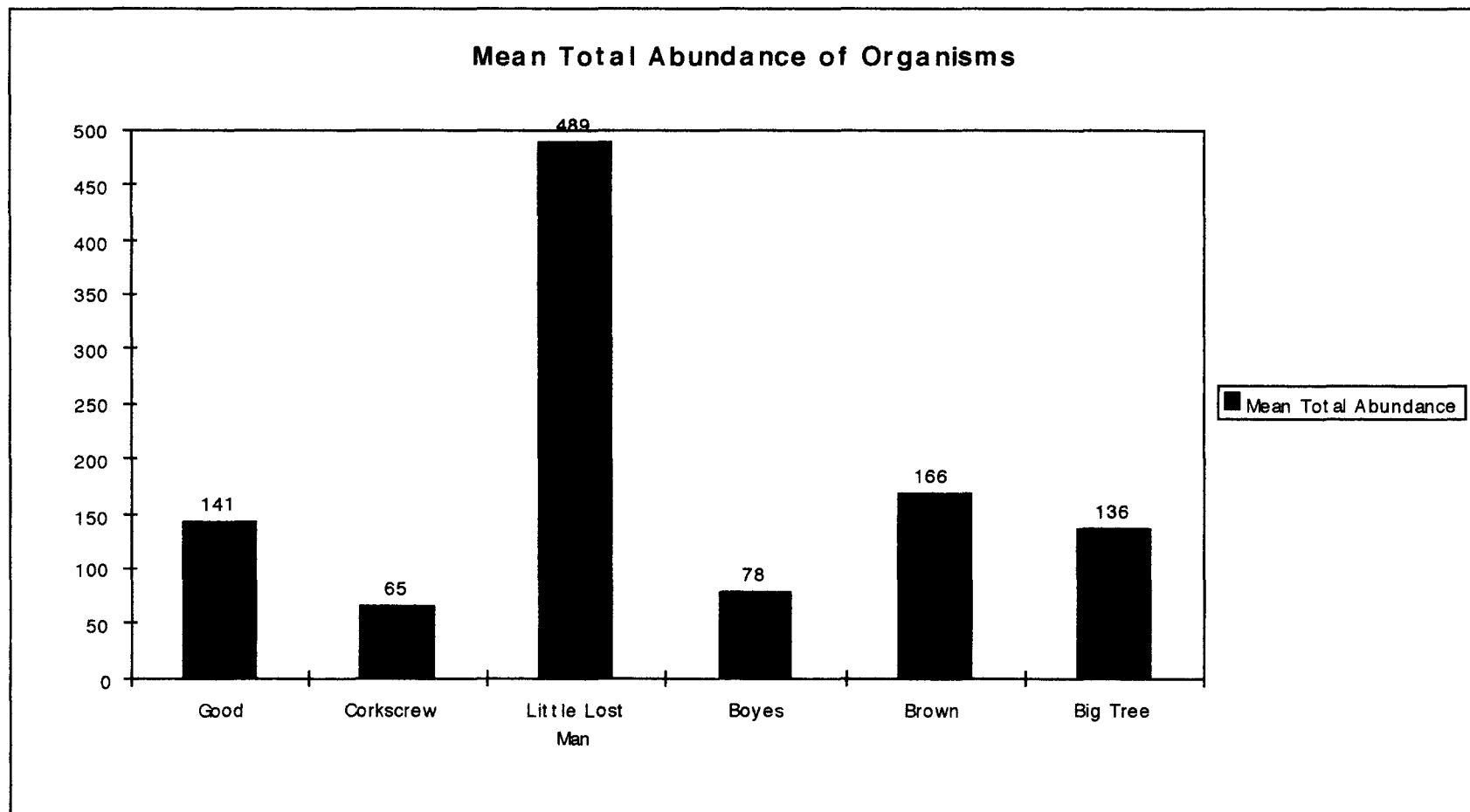


Figure 3. Mean total abundance of macroinvertebrates in six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

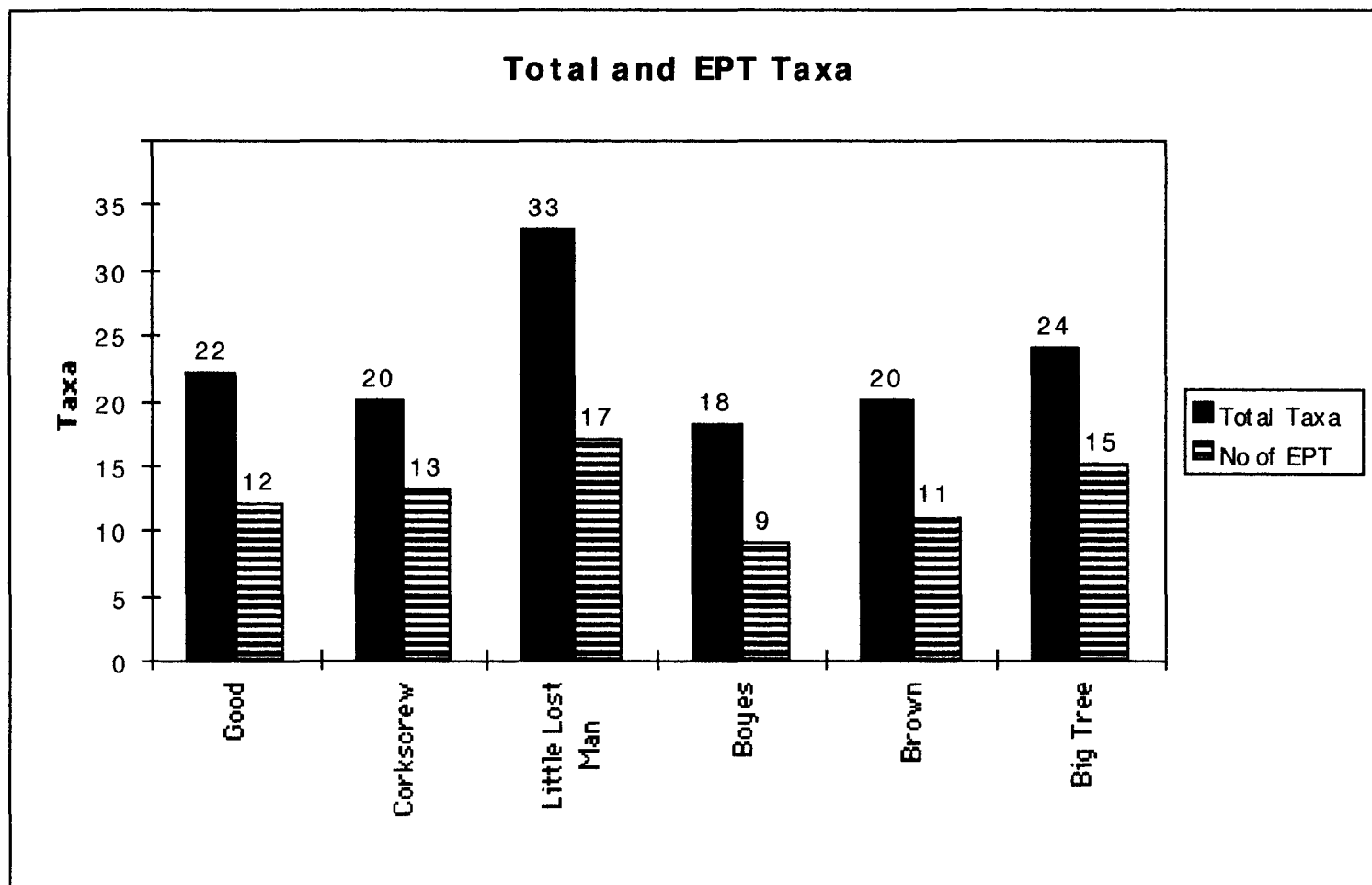
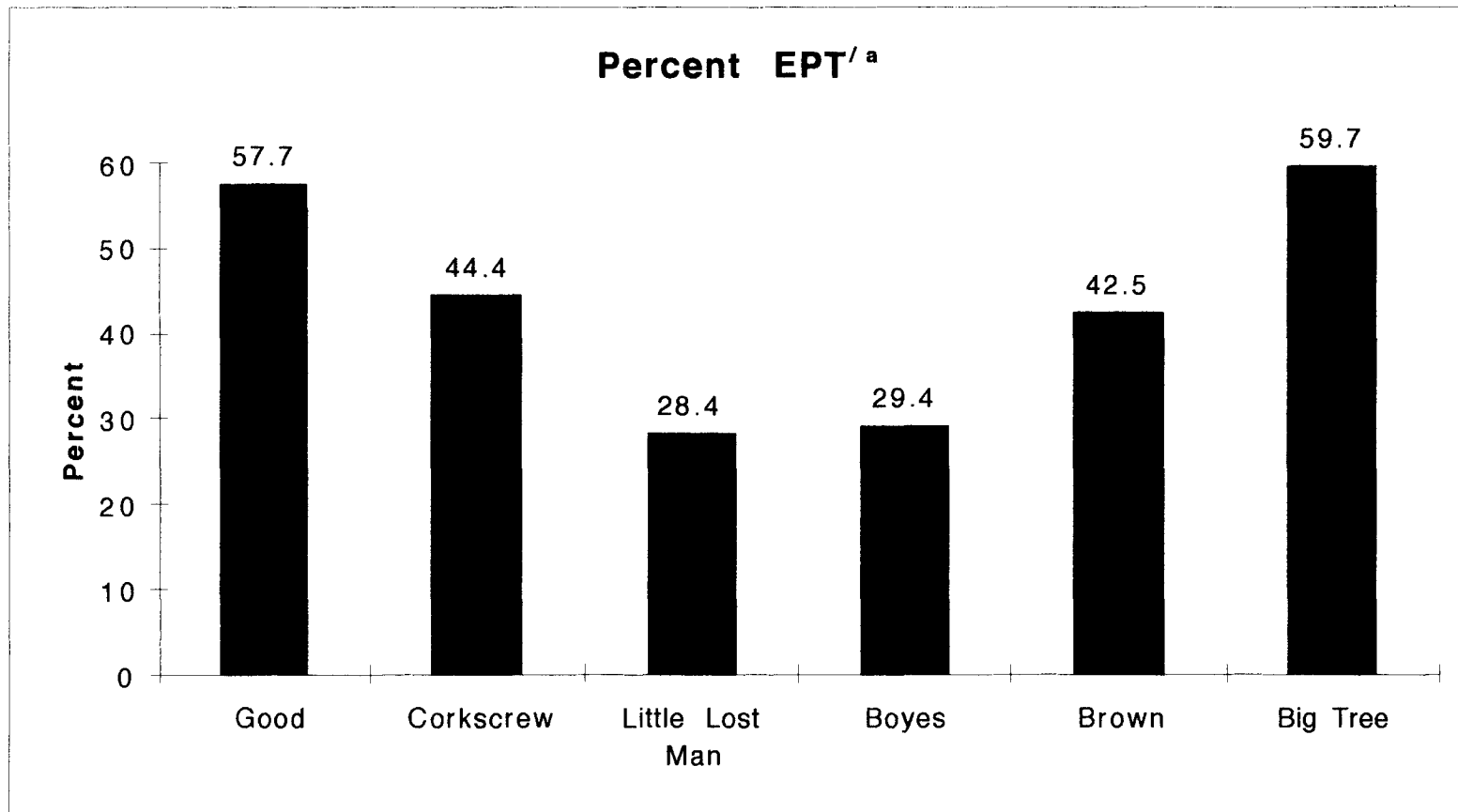


Figure 4. Mean total taxa and EPT taxa in six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.



^{/a} excludes *Baetis*

Figure 5. Mean percent EPT in six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

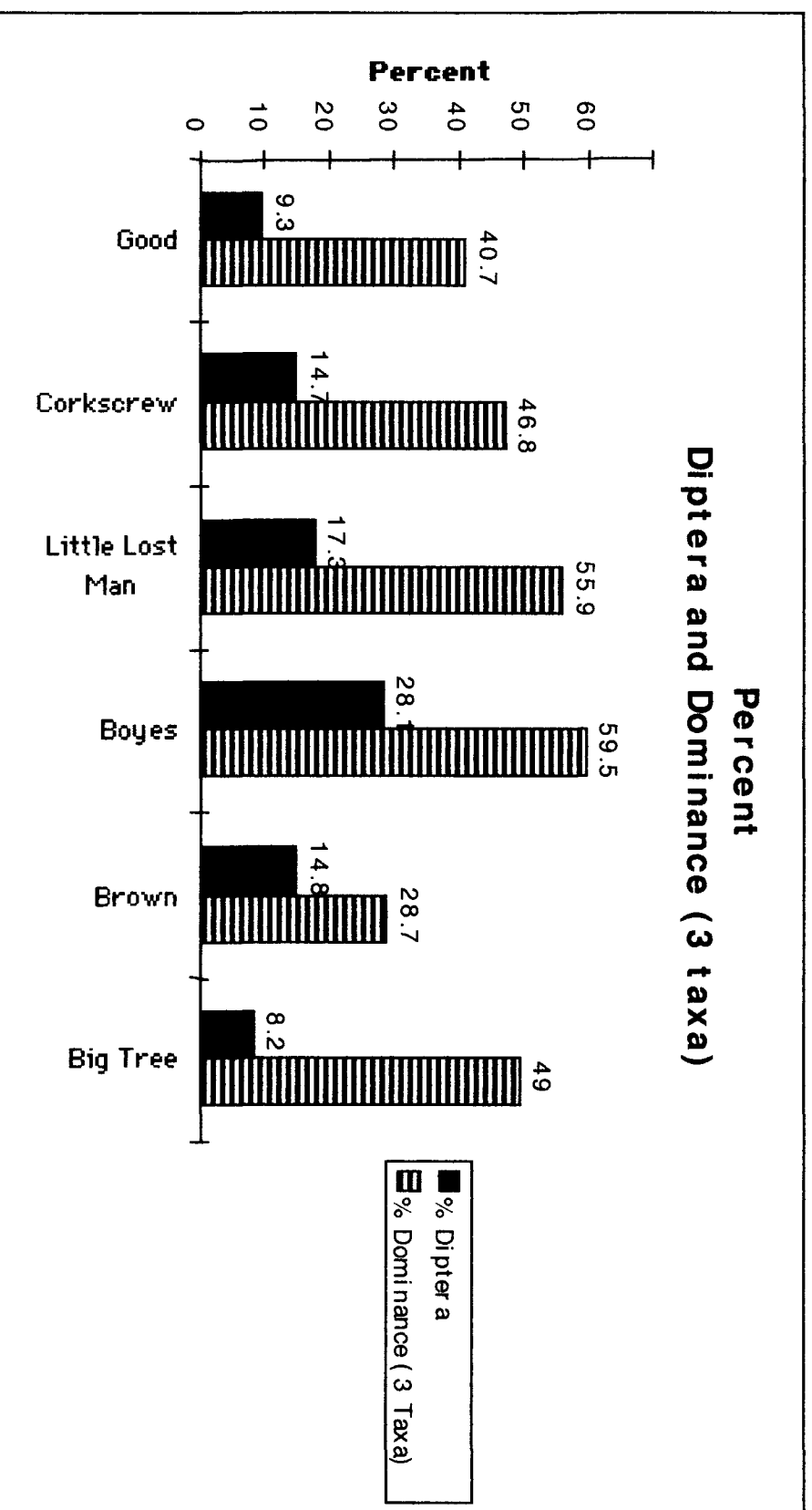


Figure 6. Percent: Diptera; and Dominance of 3 taxa for six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Table 11. Rankings of six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996, using six metrics used to evaluate the health of invertebrate populations.

	Stream					
Metric	Good	Corkscrew	Big Tree	Little Lost Man	Brown	Boyes
Total Taxa	2	5	2	1	4	6
Shannon-Wiener Diversity	1	2	3	4	6	5
No of EPT	4	2	2	1	4	6
% EPT ^{1/a}	2	3	1	5	4	6
% Diptera	2	4	1	5	3	6
% Dominance (3 taxa)	2	3	4	5	1	6

^{1/a} Intolerant EPT excludes *Baetis*.

The six streams show differences in dominant taxa (Appendices B - G). *Baetis* was found in all samples except one site in Good Creek. In fact, it was the most abundant taxon in Little Lost Man Creek, Big Tree, and Brown Creek. *Baetis* was the second most abundant in Boyes Creek. Chironomidae was found in all samples except site 1, Big Tree Creek. Chironomids dominated in Corkscrew Creek and Boyes Creek, and was the second most common in Little Lost Man Creek. *Yoraperla* was the most dominant taxon in Good Creek. Table 12 shows the three most dominant taxa for each stream sampled.

Table 12. The three most dominant invertebrate taxon and the total abundance of those taxon found in six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

	Good	Corkscrew	Little Lost Man	Big Tree	Brown	Boyes
most dominant taxa	<i>Yoraperla</i>	Chironomidae	<i>Baetis</i>	<i>Baetis</i>	<i>Baetis</i>	Chironomidae
total abundance	119	51	852	130	411	106
2nd most dominant	Juga	<i>Anisogammarus</i>	Chironomidae	<i>Rithrogena</i>	<i>Rithrogena</i>	<i>Baetis</i>
total abundance	54	33	295	69	171	91
3rd most dominant	<i>Anisogammarus</i> / <i>Acar</i>	<i>Baetis</i>	<i>Zapada</i>	<i>Zapada</i>	Chironomidae	<i>Optioservus</i> larvae
total abundance	50/50	28	212	43	87	40

The order Plecoptera showed significant differences between impacted sites and unimpacted streams (Appendices B - G, Figure 7). *Calinueria* was common throughout the study area, except in Boyes Creek, where only one was found at site 3. Site 3 had the highest Fredal value (1.86) of the five samples on Boyes Creek (Table 1). *Yoraperla* was common in Good Creek and Big Tree Creek, in fact, it was the most dominant taxon in Good Creek. Samples in Boyes Creek and Little Lost Man Creek only included two *Yoraperla* and one at Brown Creek. *Capnia* was very common in Good Creek where a total of 49 were found. *Capnia* was rare in Boyes Creek where only one was sampled at site 5, and in Little Lost Man Creek where only site 3 included *Capnia*. *Zapada* was found in all six streams, but was most common in Little Lost Man Creek where they were the third most dominant taxon. The lowest relative abundance of *Zapada* was found in Boyes Creek. *Sweltsa* was common in all streams including Boyes Creek.

The order Ephemeroptera showed similar differences between Boyes Creek and Brown Creek, and the other four streams (Appendices B - G, Figure 8). *Cinygmula* was absent in Boyes Creek and Brown Creek, and common in the other four streams. Other members of the family Heptageniidae such as *Rithrogena*, *Epeoris*, *Heptagenia*, and *Ironodes* were more common in Good Creek, Little Lost Man Creek, Corkscrew Creek, and Big Tree Creek (Figure 8). *Paraleptophlebia* was found in all six streams and the most common mayfly in Good Creek. They were less abundant in Brown Creek and Boyes Creek.

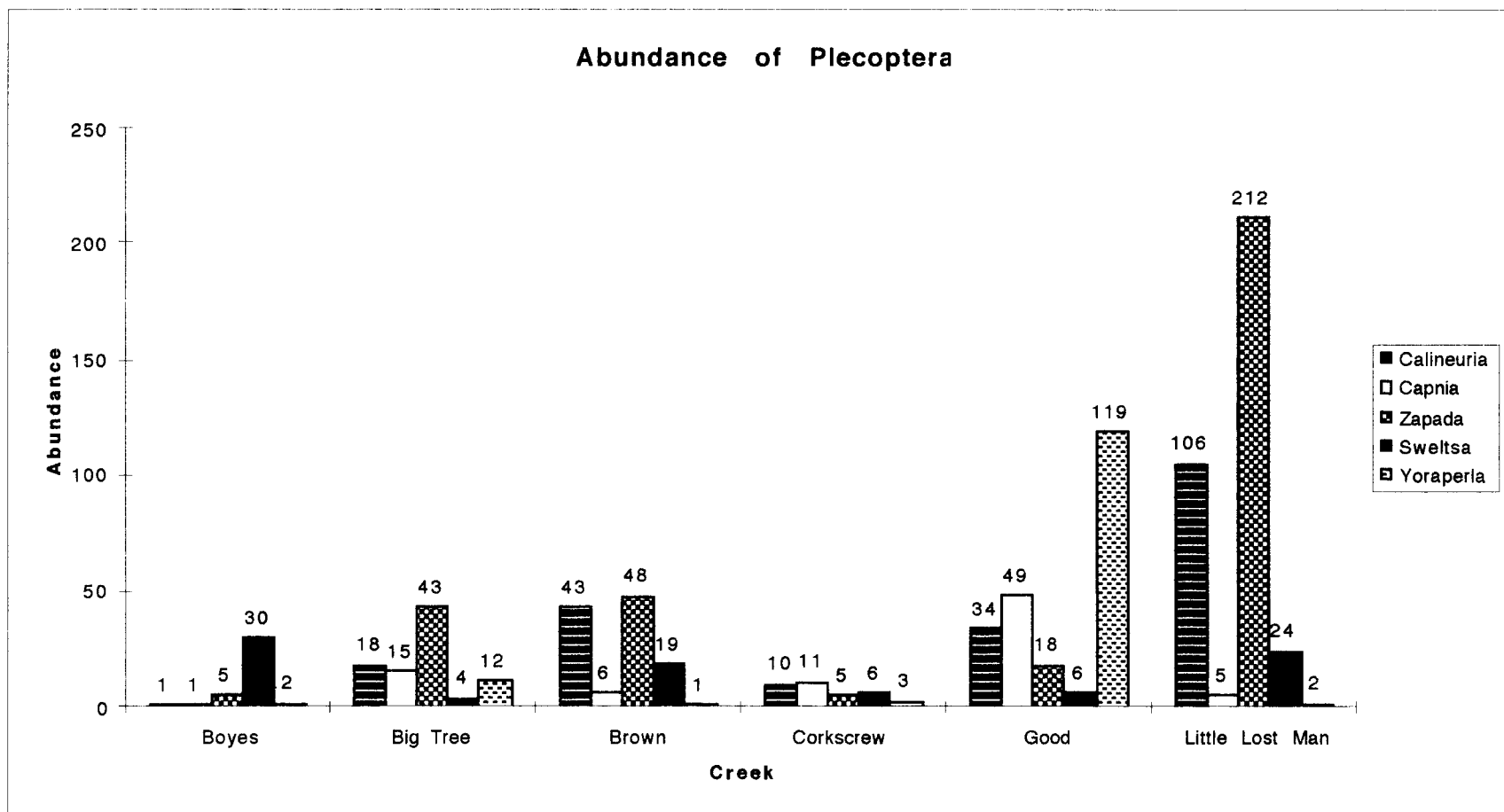


Figure 7. Plecopteran abundance in six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

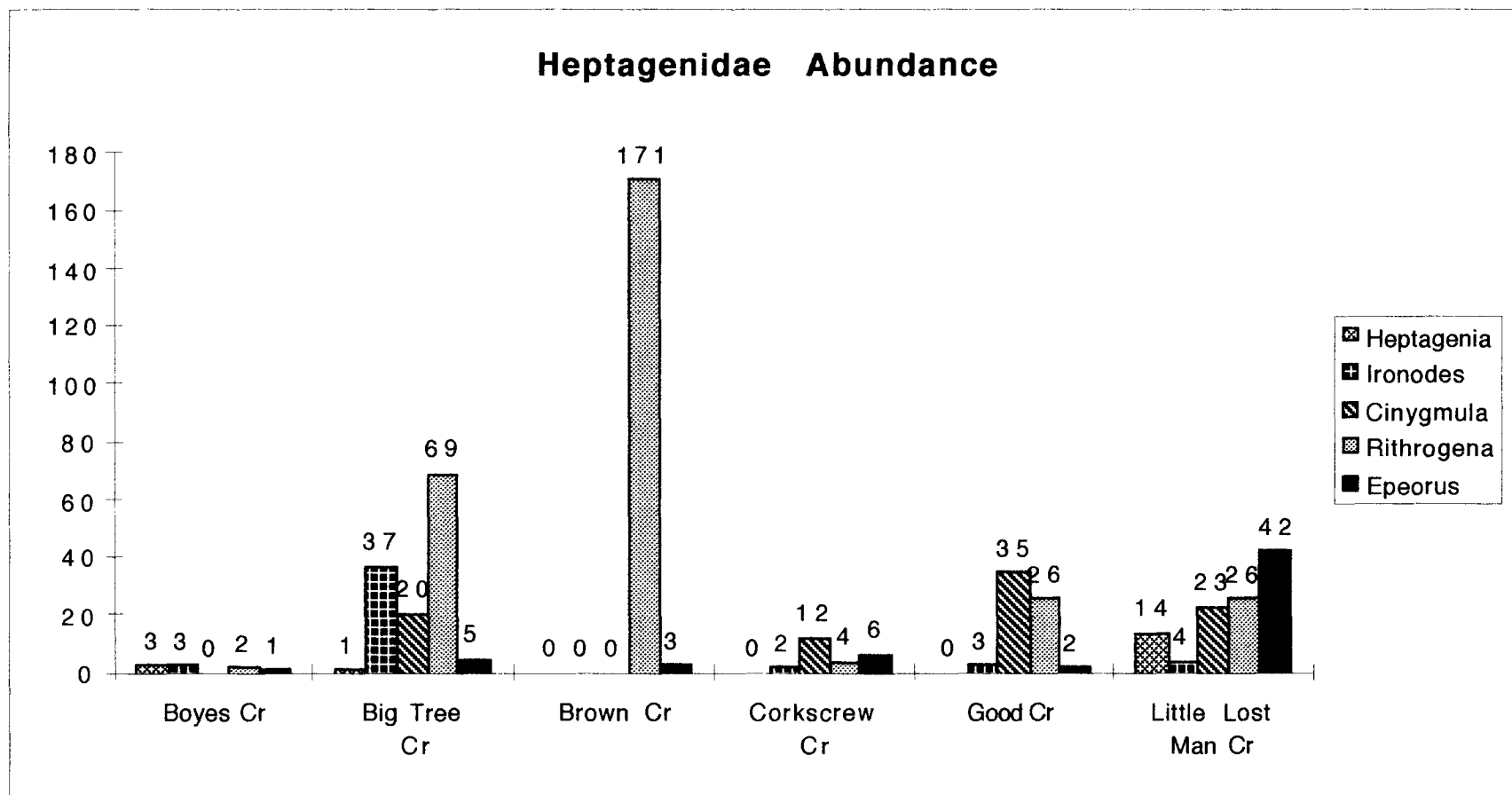


Figure 8. Heptagenidae abundance in six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Five of the six streams contained seven genera of Trichoptera, except Big Tree Creek, which had only five. *Rhyacophila* was found in all six streams sampled. It was the most numerous Trichopteran at Good Creek, Little Lost Man Creek, Boyes Creek, and Brown Creek. *Glossosoma* was the most abundant in Corkscrew Creek and Big Tree Creek. Net spinning members of the family Hydropsychidae (*Hydropsyche*, *Parapsyche*, and *Himalopsyche*) were found in all streams except Little Lost Man Creek.

Elmidae, or riffle beetles, dominated sampling of the order Coleoptera. *Optioservus* was the most abundant in five of the six streams. *Optioservus* was the second most numerous in Good Creek behind *Heteroliminus*. *Eubrianix*, a member of the family Psephenidae, or commonly called water pennies, was found in Good Creek and Little Lost Man Creek.

Common non-insect invertebrates included *Anisogammarus*, Gastropoda, Acari, and Oligochaeta. *Anisogammarus* was one of the three dominant taxa found in the two smaller streams, Good and Corkscrew. They were not found at all in Brown and Little Lost Man Creek. Acari (water mites) were common in all streams except Boyes Creek, where only 3 were sampled. The gastropod *Juga* was common in all six streams, and the second most common taxon in Good Creek. Oligochaetes were not found in Good Creek and only one was found in Brown Creek samples. Moderate numbers were found in the other four streams.

Organisms that use filtering as a means of collecting organic particulates were found in all six streams. The largest abundance of *Simulium* occurred in Big Tree Creek, with Boyes Creek and Corkscrew Creek having the lowest abundance's.

Amphibians caught within the samples were recorded at the time of sampling and released. Table 13 summarizes all amphibian sightings. Tailed frogs (*Ascaphus truei*) were all tadpoles except one adult at site 4, Big Tree Creek. All salamanders were small unknown larvae except Corkscrew Creek, site 3. Field notes described it as four inches long, with gills, and silvery speckles on the underside.

Table 13. Amphibians sampled in six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Stream	Organism	Site #				
		1	2	3	4	5
Good	Tailed Frog				1	
	Salamander					
Corkscrew	Tailed Frog					
	Salamander	1	3	1		
Little Lost Man	Tailed Frog					
	Salamander				1	
Boyes	Tailed Frog					
	Salamander					
Brown	Tailed Frog					
	Salamander					2
Big Tree	Tailed Frog				1	1
	Salamander				1	1

The final objective of the project was to determine how closely substrate porosity, as measured by the Fredle Index, was linked to invertebrate diversity by performing regression analysis. Site 5 of Corkscrew Creek was once again not included, as was site 2 of Brown Creek because its Fredle Index value of 68.01 (Table 1) was a clear outlier. Linear regression analysis of the remaining 28 locations yielded a positive relationship, but it was not significant; $P=0.188$. (Table 14 and Figure 9). A closer look at the line fit revealed that many of the diversity outliers came from Boyes Creek and Brown Creek. Additional regression analysis was done on the nineteen sites from the other four streams; Big Tree; Corkscrew; Good; and Little Lost Man. The result (Table 15 and Figure 10) was a much closer line-fit that was significant ($P=0.002$). Exclusion of Little Lost Man Creek because of its greater size and distance from Big Tree, Good, and Corkscrew yielded an even closer line fit ($P=0.001$) than when Little Lost Man Creek was included (Table 16 and Figure 11). A regression analysis of Boyes Creek and Brown Creek revealed why the regression line for all six streams were more scattered than the line excluding these two streams. Table 17 shows that a significant ($P=0.033$) negative relationship exists between Fredle Index values and diversity. This is graphically shown in Figure 12.

Table 14. Linear regression analysis summary of Shannon-Wiener diversity index values (Tables 3-8) plotted against Fredle Index values (Table 1) for six tributaries of Prairie Creek, May 26 - June 11, 1996.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.25586687							
R Square	0.06546785							
Adjusted R Square	0.02952431							
Standard Error	0.22804727							
Observations	28							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.09472333	0.09472333	1.82140783	0.1887806			
Residual	26	1.35214453	0.05200556					
Total	27	1.44686786						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	2.38199434	0.06978592	34.1328806	4.002E-23	2.23854724	2.52544144	2.23854724	2.52544144
Fredle	0.01091835	0.00809009	1.34959543	0.1887806	-0.0057111	0.02754777	-0.0057111	0.02754777

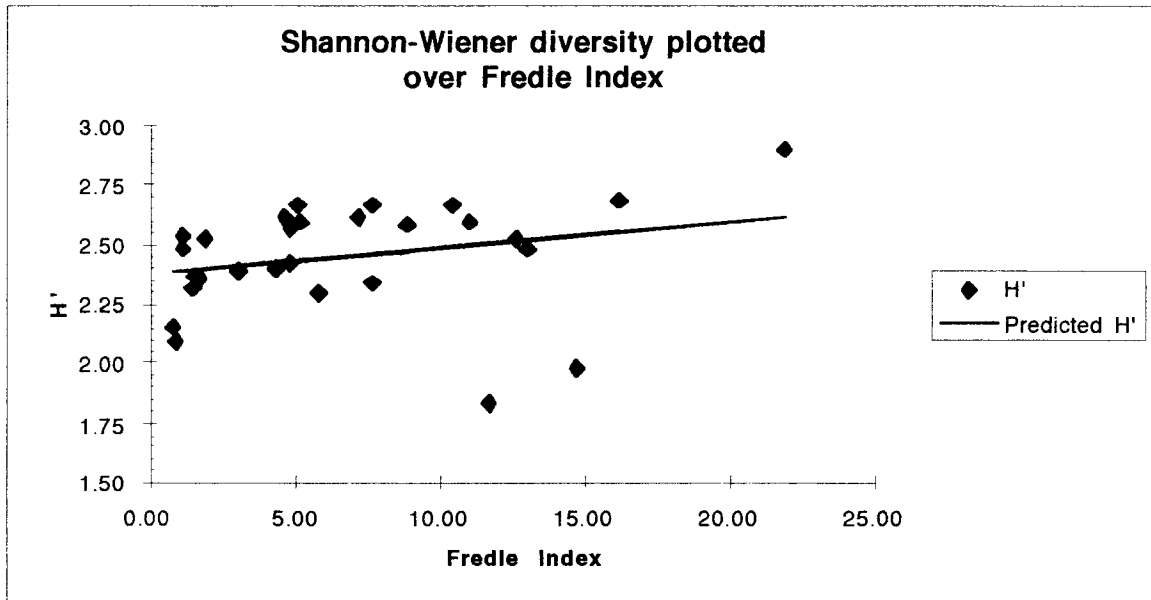


Figure 9. Regression analysis of Shannon-Wiener diversity (Tables 3-8) plotted over Fredle Index values (Table 1) for six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Table 15. Linear regression analysis summary of Shannon-Wiener diversity index values (Tables 3-8) plotted against Fredle Index values (Table 1); for Big Tree Creek; Corkscrew Creek; Good Creek; and Little Lost Man Creek, Humboldt County, CA, May 26 - June 11, 1996.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.66232148							
R Square	0.43866975							
Adjusted R Square	0.40565032							
Standard Error	0.1116857							
Observations	19							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.16571558	0.16571558	13.2852018	0.00200383			
Residual	17	0.21205284	0.0124737					
Total	18	0.37776842						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	2.41338245	0.04708546	51.2553631	4.4774E-20	2.31404067	2.51272423	2.31404067	2.51272423
Fredle	0.01821273	0.00499679	3.64488708	0.00200383	0.00767041	0.02875504	0.00767041	0.02875504

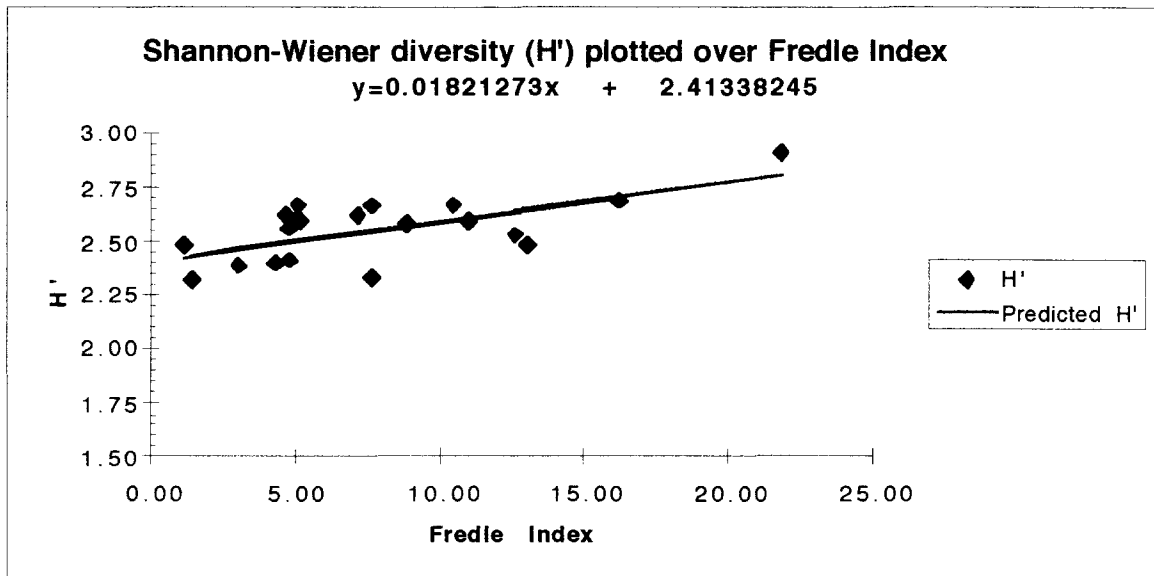


Figure 10. Regression analysis of Shannon-Wiener diversity (Tables 3-8) plotted over Fredle Index values (Table 1) for; Good Creek; Corkscrew Creek; Little Lost Man Creek; and Big Tree Creek, Humboldt County, CA, May 26 - June 11, 1996.

Table 16. Linear regression analysis summary of Shannon-Wiener diversity index values (Tables 3-8) plotted against Fredle Index values (Table 1); for Big Tree Creek; Corkscrew Creek; and Good Creek, Humboldt County, CA, May 26-June 11, 1996.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.76292751							
R Square	0.58205839							
Adjusted R Square	0.54722992							
Standard Error	0.09407266							
Observations	14							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.14789688	0.14789688	16.7121449	0.00150419			
Residual	12	0.10619598	0.00884966					
Total	13	0.25409286						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	2.44715824	0.04318859	56.6621452	6.0236E-16	2.35305838	2.54125809	2.35305838	2.54125809
Fredle	0.01824755	0.00446363	4.08804903	0.00150419	0.00852213	0.02797296	0.00852213	0.02797296

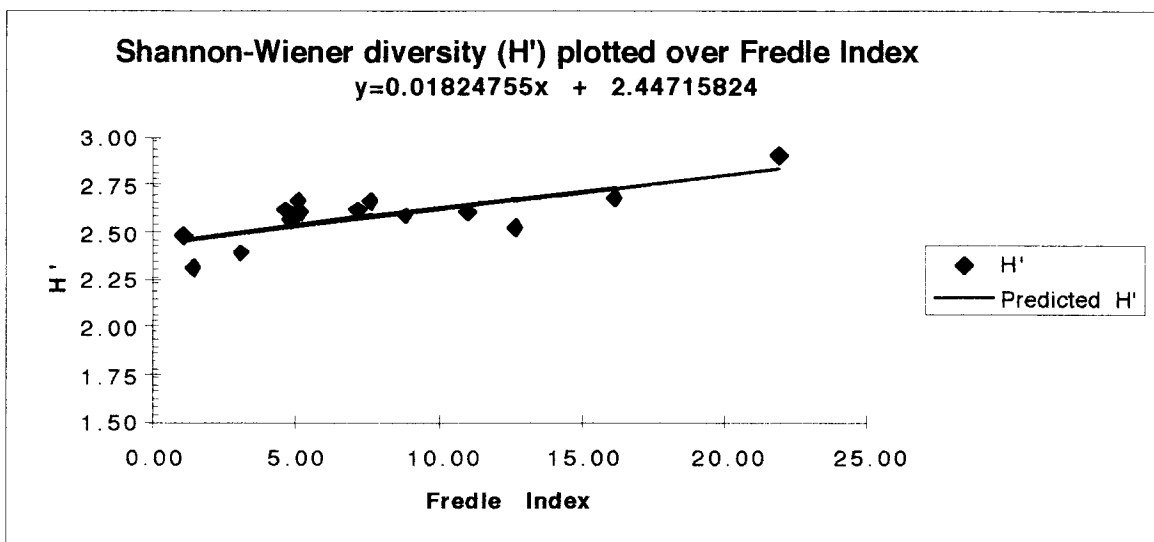


Figure 11. Regression analysis of Shannon-Wiener diversity (Tables 3-8) plotted over Fredle Index values (Table 1) for; Good Creek; Corkscrew Creek; and Big Tree Creek, Humboldt County, CA, May 26 - June 11, 1996.

Table 17. Linear regression analysis summary of Shannon-Wiener diversity (Tables 3-8) plotted against Fredle Index values (Table 1), for Boyes Creek and Brown Creek, Humboldt County, CA, May 26 - June 11, 1996.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.70631737							
R Square	0.49888422							
Adjusted R Square	0.42729626							
Standard Error	0.18197091							
Observations	9							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.23076167	0.23076167	6.96882784	0.03343058			
Residual	7	0.23179389	0.03311341					
Total	8	0.46255556						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	2.38507378	0.08128673	29.3414913	1.3755E-08	2.19286135	2.5772862	2.19286135	2.5772862
Fredle Index	-0.0323356	0.01224902	-2.6398538	0.03343058	-0.0612999	-0.0033713	-0.0612999	-0.0033713

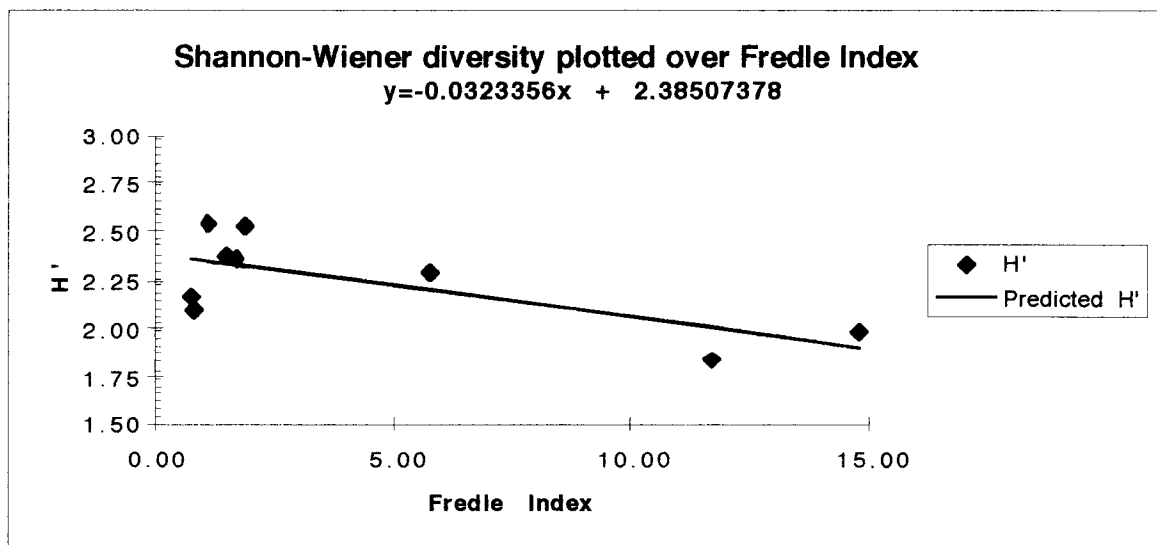


Figure 12. Regression analysis of Shannon-Wiener diversity (Tables 3-8) plotted over Fredle Index values (Table 1), for Boyes Creek and Brown Creek, Humboldt County, CA, May 26 - June 11, 1996.

Discussion

Shannon-Weiner diversity (H') data suggests lower diversity in impacted streams. The three streams identified as impacted by Hwy. 101 (Welsh and Ollivier 1992); Good Creek; Corkscrew Creek; and Little Lost Man Creek, are in better shape compared to two of the streams identified as impacted. Boyes Creek is dominated by fine sediments (Table 1) and scored very poorly on all the metrics used to evaluate the health of the invertebrate populations (Table 11). Brown Creek also had results indicating continuing problems. Data from Big Tree Creek indicates there is very little difference between it and the control streams.

I did not evaluate the substrate as intensely as Redwood National Park (1991) to assess salmonid spawning habitat. All five sites in Boyes Creek had Fredle values of less than 2.0 (Table 1), which suggests limited spawning habitat. Data from Boyes Creek stands out as five of the lowest eight Fredle Index values, and five of the highest percent fines. Phillips and others (1975) predicted survival-to-emergence rates for coho with f values of 2, 4, and 8, to be 30, 60, and 88 percent. The f values of the other five streams were considerably better (Table 1). Little Lost Man Creek, and Good Creek, had Fredle values of at least 4.0 at all five sites.

The substrate sampling methodology of using a grid to quantify the substrate was not the best method, but rather a compromise. A McNeil sampler used with a set of sieves to calculate percent weight of each size class would have been the most accurate method to calculate Fredle values (Platts and others 1983). Using the grid allowed me to sample the substrate quickly, and without harming the invertebrates, but only counted surface gravels.

A large source of variation for invertebrate composition comes from the variability in habitat (Minshall 1984). Despite the desire to find thirty similar sites with the only difference being substrate, sites showed habitat differences. Streams in the study area had similar riparian vegetation (Welsh and Ollivier 1992), canopy and temperature (Table 2). However, Corkscrew Creek and Good Creek are first order streams (Figure 1), while Boyes Creek and Little Lost

Man Creek are third order streams. Big Tree Creek and Brown Creek are second-order streams. Table 2 shows the difference in depths and velocities in different stream orders. Insects occupy different habitats depending the velocity of the current and their morphology. The mayfly *Drunneta*, with its stout protibia, and perlid stoneflies are able to hold on in very swift currents (Minshall 1984). The difference in velocities measured at the six streams should therefore be considered a factor in variance of invertebrate composition. Since I only sampled pool-tail crests, a limited number of potential sample sites existed. Pools were not abundant in the smaller streams, and water depths had to allow for flow to go through the front of the sampler and into the net. In most cases, it was take the first five pools found.

Many characteristics of the substrate, other than porosity, could have led to increased differences in invertebrate composition. Substrate stability refers to the degree of resistance to movement. Increased instability results from higher peak flows and smaller particles. Stability also affects the amount of detritus trapped between the particles. Reduced taxa richness and abundance are commonly associated with shifting sand, although certain species (e.g., mayfly *Baetis* and the midge *Chironomus*) apparently prefer this substratum (Minshall 1984). Substrate heterogeneity also contributes to a greater variety of living spaces, and hence, a greater diversity of invertebrates (Minshall 1984). Minshall (1984) points out that shape and texture of the particles also plays a role in trapping detritus and providing refuge to invertebrates..

It is noteworthy that Big Tree Creek's mean H' (2.54) was comparable to Corkscrew Creek (2.58) and Good Creek (2.6), and well above Little Lost Man Creek (2.38). Anova analysis showed significant differences ($P=0.009$) among the six streams, but no significant differences ($P=0.255$) when Boyes Creek and Brown Creek were eliminated from the calculation. This leads to the possibility that Big Tree Creek has recovered to the point where differences between it and the control streams cannot be detected.

Other metrics showed similar results to H' . Little Lost Man Creek had the highest total taxa, and highest mean abundance (498), not surprising since it had the highest discharge and velocities (Table 2). Grubaugh and others (1997

linked higher macroinvertebrate production to higher stream orders. In contrast, Boyes Creek had the lowest total taxa, and a mean abundance (98), significantly lower, despite its comparable size. Little Lost Man also had the highest EPT taxa (Table 11). Good Creek and Big Tree also did well overall with the other metrics (Table 11). Big Tree scored the highest for percent EPT, with Good and Corkscrew rating second and third respectively. Big Tree Creek had the lowest percent Diptera, with Good Creek the second lowest. The expected trend is increasing percent Diptera in the presence of disturbance (Fore and others 1996). Boyes Creek had the highest percentage of Diptera (Table 11). Percent dominance of three taxa (Table 11) showed results inconsistent with the other metrics in regard to Brown Creek, which had the lowest value. Boyes Creek had the highest value of the six streams. The expected trend with percent dominance is increasing dominance with increasing disturbance. Overall, Good Creek and Big Tree Creek did the best, followed in order by Corkscrew Creek, Little Lost Man Creek, Brown Creek, and Boyes Creek. Boyes Creek finished last in every metric except diversity in which it was 5th (Table 11).

A strong argument could be made that results from Good Creek and Corkscrew Creek indicate they are in the most pristine condition. Some headwaters streams are naturally unproductive, even in their most pristine condition (Plafkin and others 1989). Both streams are first order streams (Figure 1), and Corkscrew Creek had the lowest velocities measured (Table 2). Corkscrew Creek and Good Creek consistently scored better than Little Lost Man Creek, as well as the two the impacted streams, Boyes Creek and Brown Creek. This in spite of being first order streams.

An analysis of the individual taxa within the six streams shows certain taxa are quite abundant regardless of habitat quality, while others decline rapidly in the presence of siltation. Thorne and Williams (1997) showed that EPT taxa richness is one of the better component metrics for evaluating invertebrate data. The lowest EPT found was in Boyes Creek and Brown Creek (Figure 4). A closer look into these orders shows an even stronger trend.

"Clinging" invertebrates are very abundant in the unimpacted streams, but almost absent from the impacted streams. Figure 8 shows abundance's of

individual genera in the family Heptageniidae. Only nine specimens of Heptageniidae were found in Boyes Creek. Brown Creek was almost exclusively early instars of *Rithrogena*, which was found in all six streams. *Cinygmula* showed the greatest preference for the unimpacted streams, including Big Tree Creek (Figure 8). Little Lost Man Creek, as well as Big Tree Creek, had all five taxa with more evenness. *Calinueria* was common in all six streams except Boyes Creek, especially Little Lost Man Creek. Like other members of the stonefly family Perlidae, it needs large interstitial spaces to survive (Stewart and Stark 1988). *Yoraperla* was not a common stonefly in Boyes Creek, Brown Creek, and Little Lost Man Creek. It was the most common taxon in Good Creek. *Yoraperla* prefers clean headwater streams (Stewart and Stark 1988). Since Little Lost Man Creek and Boyes Creek are larger streams, *Yoraperla* would not be expected to be present in large numbers. It was a little surprising that only one specimen of *Capnia* was found in Boyes Creek. *Capnia* needs looser particles in order to slither through (Minshall 1984), and Boyes Creek had plenty of sand. *Capnia* was more abundant in all of the other five streams, specifically Good Creek, where 49 were found. Perhaps the amount of fine sediments found in Boyes Creek was within the tolerance range, but not within the preference range.

In contrast to the other Plecopterans, the lowest abundance's for *Sweltsa* were in Good Creek and Big Tree Creek, while the highest abundance was in Boyes Creek. Tolerance values assigned to the other Plecopterans range from 1 -2 (Idaho, Dept. of Environmental Quality 1996), with 1 being the most sensitive. *Sweltsa* received a TV rating of 1. However, *Sweltsa* was the only Plecopteran that thrived in the habitat that was marginal for other stoneflies.

A special note about *Sweltsa* must be made at this time. Strange (1988) incorrectly identified *Sweltsa* as *Suwalia* in his thesis. These chloroperlids are very tough to distinguish and a picture in Stewart and Stark (1988) may have contributed to the mistake. Figure 11.20E shows black clothing hairs laterally on thoracic sterna that distinguish *Sweltsa* from other Chloroperlidae. A phone call to Dr. David Lauck (Lauck 1997) confirmed my suspicions. According to Lauck, these hairs are not as numerous as shown in the picture. Also *Suwalia* is found

at higher elevations, while *Sweltsa* is found in coastal streams. John Lee, a former graduate student of Dr. Lauck's was kind enough to take a look at my specimens and confirm that they were *Sweltsa* (Lee 1997). He was also very helpful to me for identifying some Dipteran pupae.

Species composition and abundance's for the order Trichoptera (Appendices B - G) were less distinguishing among the six streams studied. Taxa richness for the order was very even for the six streams (Appendices B - G). The only Trichopteran that showed any sensitivity to the fine sediments in the three impacted streams was *Neophylax*, a large cased caddis. It was not found in Brown Creek (Appendix G) and Big Tree Creek (Appendix F), and only two were found in Boyes Creek (Appendix E). They were very common in Little Lost Man Creek (Appendix D). There was no identification of taxa that occurred only in unimpacted streams.

Lemly (1982) reported that three taxa, *Rhyacophila spp.*, *Heptagenia spp.*, and *Rithrogenia spp.*, have shown significant drops in abundance when sedimentation caused a drop in pH at the water-substrate interface. None of these taxa showed a significant drop in numbers in Boyes Creek.

Moderately sensitive taxa showed no significant differences among the six streams, with two exceptions. Acari was common throughout the study area (Appendices B-G), but only two were found in Boyes Creek (Appendix E). *Anisogammarus* was common everywhere except in Little Lost Man Creek, where none were sampled. Elmid beetles and Gastropods were common throughout and showed no significant differences among streams.

There were significant differences in highly tolerant taxa such as Chironomids. Chironomidae was the dominant taxon for Boyes Creek and Corkscrew Creek, but was not one of the three dominant taxa for Good Creek and Big Tree Creek.

Amphibian sightings (Table 13) showed a similar trend seen in the substrate and invertebrate data analysis. Boyes Creek was the only stream sampled where no amphibians were sighted. Corkscrew Creek and Big Tree Creek had the most amphibian sightings.

None of the studies, reported by Minshall (1984), in which pore space has been determined in relatively natural setting (Williams and Mundie 1978; Khalaf and Tachet 1980; Williams 1980), have shown a significant correlation between pore space and the numbers or kinds of insects. Minshall (1984) indicated that under natural conditions this feature probably is complicated by other factors. All three of these studies placed substrates of known composition into natural conditions and allowed for colonization to occur. There are too many factors involved in macroinvertebrate distribution, as pointed out by Minshall (1984), to oversimplify the experiment.. Williams and Mundie (1978) used three types of substrate placed in a flow controlled channel. Williams (1980) used four types of substrate in wire baskets, placed into a natural streambed. In each case, porosity, mean size, and heterogeneity was measured. Laboratory experiments are great for isolating the variables, but do not simulate nature very well.

Significant correlation was not found in this study when all six streams were included in the regression ($P=0.188$). However, when Boyes Creek and Brown were eliminated from the calculation, significant correlation was found ($P=0.002$). If these two streams are still impacted by the Hwy. 101 bypass, the delivery of fine sediments into the watershed may not be the only pollutant. Toxic petroleum products and other pollutants may be adding to the problem. The headwaters of Boyes Creek crosses the highway in three places (Figure 1), and the headwaters of Brown Creek lies very close to the highway as well. However, the headwaters of Big Tree Creek is further from the bypass (Figure 1). The regression that included Good, Corkscrew, and Big Tree were the most correlated ($P=0.015$). These three streams have more in common when compared to Little Lost Man Creek. They are closer in proximity and size. Little Lost Man Creek samples had much higher velocities (Table 2), and it has its own influences from surrounding roads. All five sites were below the bridge crossing the stream (Figure 1). Therefore, it should not be surprising that the regression line would be closer with Little Lost Man Creek excluded.

The negative relationship of Shannon-Wiener diversity and substrate porosity as measured by the Fredle index, for Boyes and Brown Creek (Table

17, Figure 12) is the opposite of what was expected. Low diversity on site 1 (1.74) and site 3 (1.96) of Brown Creek (Table 6), along with high Fredle Index values (Table 1), account for the negative slope of the regression line. If I had included site 2 of Brown Creek, which had the outlying Fredle Index value of 68.01, the regression would have been quite different. A positive slope resulted when site 2 was included (Appendix H). One value drastically changed the regression equation and the P value. Another fact that I would like to point out is that site 1 and site 3 had the highest abundance's on Brown Creek (Table 6). High abundance's of the dominant organisms, *Baetis* and *Rithrogena* (Appendix F), caused the very low diversity values, rather than a low number of taxa (Table 6). For these reasons, I do not want to draw any conclusions about the slope of the regression line for Boyes Creek and Brown Creek.

Much of the analysis of the substrate and invertebrate data suggests that Big Tree Creek is more closely associated with the unimpacted streams at this point in time. Anova analysis of Shannon-Wiener diversity and the regression analysis support this hypothesis. All the other metrics, except percent dominance, agree. Analysis of individual taxa shows no clear differences between Big Tree Creek and the unimpacted streams.

In sharp contrast to Big Tree Creek, Boyes Creek is clearly a disturbed site. All the methods utilized in this study clearly show a distinction between Boyes Creek and the other streams. Brown Creek shows evidence of human disturbance, but to a lesser degree. The distance from the Hwy. 101 bypass to the headwaters of these streams appears be critical in how the streams continue to be affected by the road construction.

A more comprehensive study of porosity-diversity relationships is needed. If the sole purpose of this study had been to evaluate this relationship, more significant results might have been possible. Since a second objective was to evaluate the continued impact of the Hwy. 101 bypass, sampling sites were more diverse than what would be optimum. Thirty riffles sampled in the same stream would have accomplished optimal conditions for such a study.

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Appendix A. Peeble counts taken within invertebrate sampler for six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Corkscrew Creek

Substrate size	Site 1		Site 2		Site 3		Site 4		Site 5	
(mm)	Raw count	%	Raw	%	Raw	%	Raw	%	Raw	%
<0.05	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
0.05-2	6	7.9	10	10.5	30	26.3	10	9.8	15	14.2
2-4	2	2.6	8	8.4	4	3.5	6	5.9	3	2.8
4-8	3	3.9	7	7.4	8	7.0	8	7.8	5	4.7
8-16	10	13.2	19	20.0	10	8.8	10	9.8	6	5.7
16-32	31	40.8	41	43.2	16	14.0	18	17.6	13	12.3
32-64	11	14.5	10	10.5	22	19.3	26	25.5	26	24.5
64-128	13	17.1	0	0.0	24	21.1	24	23.5	38	35.8
>128	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total count	76		95		114		102		106	

Good Creek

Substrate size	Site 1		Site 2		Site 3		Site 4		Site 5	
(mm)	Raw count	%	Raw	%	Raw	%	Raw	%	Raw	%
<0.05	0	0.0	0	0	0	0.00	0	0.00	0	0
0.05-2	2	2.4	4	4	5	5.26	2	2.35	3	4
2-4	7	8.5	0	0	3	3.16	4	4.71	4	6
4-8	8	9.8	3	3	5	5.26	17	20.00	6	9
8-16	17	20.7	4	4	30	31.58	20	23.53	13	19
16-32	13	15.9	15	16	20	21.05	32	37.65	19	28
32-64	13	15.9	20	21	26	27.37	10	11.76	17	25
64-128	22	26.8	50	52	6	6.32	0	0.00	6	9
>128	0	0.0	0	0	0	0.00	0	0.00	0	0
Total count	82	100	96	100	95	100	85	100	68	100

Little Lost Man Creek

Substrate size	Site 1		Site 2		Site 3		Site 4		Site 5	
(mm)	Raw count	%	Raw	%	Raw	%	Raw	%	Raw	%
<0.05	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
0.05-2	10	12.3	0	0.0	2	2.4	16	17.4	16	17.4
2-4	0	0.0	4	5.6	5	6.0	4	4.3	4	4.3
4-8	3	3.7	2	2.8	28	33.3	10	10.9	10	10.9
8-16	7	8.6	6	8.3	13	15.5	2	2.2	2	2.2
16-32	18	22.2	22	30.6	8	9.5	8	8.7	8	8.7
32-64	27	33.3	10	13.9	7	8.3	32	34.8	32	34.8
64-128	16	19.8	28	38.9	21	25.0	20	21.7	20	21.7
>128	0	0.0	0	0.0	0	0.0	0		0	0.0
Total count	81		72		84		92		92	

Appendix A continued. Peeble counts taken within invertebrate sampler for six tributaries of Prairie Creek, Humboldt County, CA, May 26 - June 11, 1996.

Boyes Creek

Substrate size	Site 1		Site 2		Site 3		Site 4		Site 5	
(mm)	Raw count	%	Raw	%	Raw	%	Raw	%	Raw	%
<0.05	0	0.0	5	4.4	0	0.0	1	1.2	0	0.0
0.05-2	40	40.8	44	38.6	21	27.6	26	30.2	29	31.9
2-4	12	12.2	15	13.2	0	0.0	11	12.8	10	11.0
4-8	14	14.3	15	13.2	2	2.6	5	5.8	7	7.7
8-16	13	13.3	15	13.2	3	3.9	9	10.5	10	11.0
16-32	15	15.3	9	7.9	9	11.8	10	11.6	9	9.9
32-64	4	4.1	7	6.1	14	18.4	11	12.8	18	19.8
64-128	0	0.0	4	3.5	16	21.1	13	15.1	8	8.8
>128	0	0.0	0	0.0	11	14.5	0	0.0	0	0.0
Total count	98		114		76		86		91	

Big Tree Creek

Substrate size	Site 1		Site 2		Site 3		Site 4		Site 5	
(mm)	Raw count	%	Raw	%	Raw	%	Raw	%	Raw	%
<0.05	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
0.05-2	12	12.0	9	10.8	2	2.0	6	8.3	8	8.0
2-4	6	6.0	7	8.4	6	6.1	0	0.0	6	6.0
4-8	8	8.0	12	14.5	10	10.2	3	4.2	4	4.0
8-16	8	8.0	12	14.5	8	8.2	2	2.8	4	4.0
16-32	21	21.0	13	15.7	10	10.2	11	15.3	18	18.0
32-64	18	18.0	30	36.1	44	44.9	12	16.7	26	26.0
64-128	23	23.0	0	0.0	18	18.4	20	27.8	34	34.0
>128	4	4.0	0	0.0	0	0.0	18	25.0	0	0.0
Total count	100		83		98		72		100	

Brown Creek

Substrate size	Site 1		Site 2		Site 3		Site 4		Site 5	
(mm)	Raw count	%	Raw	%	Raw	%	Raw	%	Raw	%
<0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0
0.5-2	6	7.6	2	2.6	8	10.4	5	6.2	12	13
2-4	2	2.5	1	1.3	3	3.9	6	7.4	15	16
4-8	2	2.5	3	3.9	0	0.0	6	7.4	5	5
8-16	3	3.8	4	5.2	8	10.4	9	11.1	3	3
16-32	9	11.4	4	5.2	4	5.2	6	7.4	29	31
32-64	20	25.3	7	9.1	22	28.6	10	12.3	26	27
64-128	10	12.7	8	10.4	32	41.6	8	9.9	5	5
>128	27	34.2	48	62.3	0	0.0	31	38.3	0	0
Total count	79		77		77		81		95	

Appendix B. Abundance of benthic invertebrates from Good Creek, May 29, 1996.

		Good Creek					Total
		Site 1	Site 2	Site 3	Site 4	Site 5	
Ephemeroptera	<i>Baetis</i>	10	23	1		6	40
	<i>Attenella</i>	3					3
	<i>Cinygmula</i>	1	23	2	1	8	35
	<i>Epeorus</i>	2					2
	<i>Heptagenia</i>		9				9
	<i>Ironodes</i>	2		1			3
	<i>Rithrogena</i>	21	6	1			28
	<i>Paraleptophlebia</i>	26	16			2	44
	<i>Ameletus</i>					1	1
Plecoptera	<i>Capnia</i>	19	28			2	49
	<i>Sweltsa</i>		2			4	6
	<i>Zapada</i>	14	1	1	1	1	18
	<i>Malenka</i>	3	3			1	7
	<i>Yoraperla</i>	76	34	2	2	5	119
	<i>Calineuria</i>	11	3	3	1	16	34
	<i>Glossosoma</i>		3	5	3	13	24
Trichoptera	<i>Hydropsyche</i>		1				1
	<i>Ochrotrichia</i>	3	1	1			5
	<i>Lepidostoma</i>				1		1
	<i>Neophylax</i>		2				2
	<i>Wormaldia</i>	2	3				5
	<i>Rhyacophila</i>	6	5	5	1	9	26
	<i>Optioservus</i> larvae	7	3	1	1	6	18
Coleoptera	<i>Acneus</i> adult				1		1
	<i>Acneus</i> larvae		3				3
	<i>Eubrianax</i> larvae		2				2
	<i>Heterliminus</i> larvae	8	4	1		11	24
	Chironomidae	21	10	1	3	3	38
Diptera	<i>Simulium</i>	4	1				5
	<i>Prinocera</i>			1			1
	<i>Hexatoma</i>	2					2
	<i>Chelifera</i>	2	4		2	1	9
	<i>Smynthurides</i>			1	1	1	3
Collembola	<i>Morulina</i>					1	1
	<i>Anisogammarus</i>	9	39			2	50
Amphipoda		6	12	2	1		50
Acari							
Gastropoda	<i>Juga</i>	1	42	3	3	5	54
	<i>Physa</i>				2		2
Ostracoda			3	1			4
Annelida	<i>Hirudinia</i>	1	1		1		3

Appendix C. Abundance of benthic invertebrates from Corkscrew Creek, June 11, 1996.

		Corkscrew Creek					Total
		Site 1	Site 2	Site 3	Site 4	Site 5	
Ephemeroptera	<i>Baetis</i>	9	13	2	2	2	28
	<i>Ephemerella</i>		1		2		3
	<i>Serratella</i>		1				1
	<i>Cinygmula</i>	6	5			1	12
	<i>Epeorus</i>		4				4
	<i>Heptagenia</i>	4	2	2			8
	<i>Rithrogena</i>	3	1				4
	<i>Paraleptophlebia</i>	3	5	2	2		12
	<i>Ameletus</i>			1	2		3
Plecoptera	<i>Capnia</i>	3		7	1		11
	<i>Sweltsa</i>	1	2	2	1		6
	<i>Zapada</i>	1	2	1		1	5
	<i>Calinueria californica</i>	1	6		2		9
	<i>Yoraperla</i>		2		1		3
Trichoptera	<i>Glossosoma</i>	12	6	1	2	3	24
	<i>Hydropsyche</i>		1				1
	<i>Ochrotrichia</i>		1				1
	<i>Apatania</i>					1	1
	<i>Neophylax</i>	1		1		1	3
	<i>Wormaldia</i>	1	1				2
	<i>Rhyacophila</i>	3	4	1			8
Coleoptera	<i>Optioservus</i> larvae	1		3	1		5
	<i>Narpus</i> larvae		1	1	1	1	4
Collembola	<i>Smythurides</i>	1		1			2
Diptera	Chironomidae	3	24	7	4	13	51
	<i>Simulium</i>		1				1
	Chelifera		2		2		4
Amphipoda	<i>Anisogammarus</i>	2	21	5	2	3	33
Acari			2	2	1		5
Gastropoda	Gastropoda	2	6	13	5		26
Annelida	Oligochaeta	1			5	1	7
	Hirudinia					1	1

Appendix D. Abundance of benthic invertebrates from Little Lost Man Creek, June 3, 1996.

		Little Lost Man Creek					Total
		Site 1	Site 2	Site 3	Site 4	Site 5	
Ephemeroptera	<i>Baetis</i>	110	239	197	220	86	852
	<i>Ephemerella</i>	8	3	4	5		20
	<i>Drunella coloradensis</i>		8		3	2	13
	<i>Drunella spinifera</i>		1				1
	<i>Attenella</i>	1	13	7	2		23
	<i>Serratella</i>	2	10	14	7		33
	<i>Cinygmula</i>		5	4	4	10	23
	<i>Epeorus</i>		28	4	7	3	42
	<i>Heptagenia</i>	1		1	1		3
	<i>Ironodes</i>		2		2		4
	<i>Rithrogena</i>	7	7	2	10		26
	<i>Paraleptophlebia</i>	22	17	22	18	7	86
	<i>Ameletus</i>	10			3	6	19
Odonata	<i>Gomphus</i>	1					1
Plecoptera	<i>Capnia</i>			5			5
	<i>Sweltsa</i>	13	5	4	2		24
	<i>Paraperla</i>			1			1
	<i>Zapada</i>	92	45	13	41	21	212
	<i>Yoraperla</i>	1	1				2
	<i>Calineuria</i>	29	26	23	23	5	106
	<i>Kogotus</i>		2				2
	<i>Isoperla</i>		1				1
Trichoptera	<i>Glossosoma</i>				1	1	2
	<i>Ochrotrichia</i>	1	3				4
	<i>Lepidostoma</i>	2					2
	<i>Apatania</i>	2					2
	<i>Neophylax</i>	16	1	4	6		27
	<i>Wormaldia</i>	4			1	2	7
	<i>Rhyacophila</i>	4	18	8	9	2	41
Coleoptera	<i>Optioservus</i> larvae	26	22	18	21	21	108
	<i>Optioservus</i> adult	13	5	5	8	3	34
	<i>Zaitzevia</i> larvae	3	6	13	7	6	35
	<i>Zaitzevia</i> adult	4	13	4	2	3	26
	<i>Eubrianax</i> larvae	1					1
	<i>Heterliminus</i> larvae	1	2	12	4	4	23
	<i>Heterliminus</i> adult		6	1	2		9
	<i>Ordobrevia</i> larvae			5	5		10
	<i>Ordobrevia</i> adult			8	1	3	12

Appendix D continued. Abundance of benthic invertebrates from Little Lost Man Creek,
June 3, 1996.

Diptera	Chironomidae	64	83	39	69	40	295
	<i>Simulium</i>		9		1	1	11
	<i>Dixidae</i>	1			3		4
	<i>Hexatoma</i>	2	1			11	14
	<i>Limophila</i>		38	4	10	1	53
	<i>Limonia</i>			1			1
	<i>Tipula</i>	1	1		5	1	8
	<i>Chelifera</i>		5	2	3	1	11
	<i>Glutops</i>	2	3	1	1		7
	<i>Ptychoptera</i>				1		1
	Ceratopogonidae pupae	2	4	3	2	1	12
Ostracoda	Ostracoda			1			1
Acari		56	20	28	31	54	189
Gastropoda	Gastropoda	19					19
Annelida	Oligochaeta	14	2		3	3	22
Collembola	<i>Morulina</i>					1	1

Appendix E. Abundance of benthic invertebrates from Boyes Creek, May 26, 1996.

		Boyes Creek					Total
		Site 1	Site 2	Site 3	Site 4	Site 5	
Ephemeroptera	<i>Baetis</i>	35	15	14	5	22	91
	<i>Ephemerella</i>	5		2	3		10
	<i>Drunella coloradensis</i>	2			1		3
	<i>Attenella</i>	2	1				3
	<i>Serratella</i>	3			1	4	8
	<i>Epeorus</i>			1			1
	<i>Ironodes</i>	1		2			3
	<i>Rithrogena</i>				2		2
	<i>Paraleptophlebia</i>	5	4	1			10
	<i>Ameletus</i>		17				17
Plecoptera	<i>Capnia</i>					1	1
	<i>Sweltsa</i>	14	4		3	9	30
	<i>Zapada</i>	3				2	5
	<i>Yoraperla</i>	1				1	2
	<i>Calineuria</i>			1			1
	<i>Isoperla</i>					1	1
Trichoptera	<i>Glossosoma</i>			1		1	2
	<i>Hydropsyche</i>			1		3	4
	<i>Ochrotrichia</i>	1					1
	<i>Neophylax</i>			2			2
	<i>Wormaldia</i>		1				1
	<i>Rhyacophila</i>	11	3	7	1	2	24
	<i>Farula</i>				1	1	2
Coleoptera	<i>Optioservus</i> larvae	19	9	4	8		40
	<i>Optioservus</i> adult	3	5				8
	<i>Zaitzevia</i> larvae	2					2
	<i>Heterliminus</i> larvae	1					1
	<i>Narpus</i> larvae				1		1
Diptera	Chironomidae	36	41	5	22	2	106
	<i>Simulium</i>			1		1	2
	<i>Hexatoma</i>		1	1			2
	<i>Chelifera</i>	2	22	1		2	27
	<i>Ptychoptera</i>	1					
	<i>Glutops</i>		1				1
	Culicidae	1		1			2
	Ceratopogonidae pupae			1			1
Amphipoda	<i>Anisogammarus</i>	6	10	1	1		18
Acari	Hydracarina		3				3
Gastropoda	Gastropoda	4	3	4	7	10	28
Annelida	Oligochaeta	3	1	1		1	6