

**Evaluating the Biological Condition of
Bellevue Streams Using Invertebrates and Diatoms**

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Summary

To protect its natural resources, the City of Bellevue periodically evaluates the biological condition of its streams by sampling habitat features, water quality, invertebrates, or fish. This study compared the results of biological assessment based on invertebrates for samples collected in 1998 with those collected in 2001. Diatom samples were also collected in 2001 and evaluated for their association with human disturbance.

1. Biological condition was assessed using a benthic index of biotic integrity (B-IBI) based on stream invertebrates. The biological condition of the invertebrate assemblage declined significantly for 12 sites sampled in 1998 and 2001. Sites in the headwaters of Coal Creek that represented the best biological condition in 1998 declined dramatically. The total number of different species declined as did the number of mayfly, caddisfly, and clinger species. The relative abundance of predator individuals also declined.

2. Although invertebrate metrics and index values changed from 1998 to 2001, sites were ranked in the same order in terms of biological condition. For both years, the metrics and index were significantly correlated with human disturbance measured in terms of riparian disturbance and condition. Coal Creek, Lewis, and the most upstream site on Kelsey were still the best in terms of biological condition. On Goff Creek, B-IBI values changed, but the site within the bypassed area still had the highest values compared to sites upstream and downstream.

3. Biological metrics derived from diatom samples were not significantly associated with human disturbance as quantified for this study. However, the metrics did tend to consistently rank sites in a different order suggesting that diatoms may be responding to other factors not quantified for this study such as nutrients or toxics. In addition, diatom metric values tended to indicate poor condition when compared with values observed in other regions.

4. Diatom metrics were precise in terms of yielding similar values for site visits one month apart. Although precise, diatom metrics failed to show differences between sites upstream and downstream of four road crossings with heavy traffic.

Introduction

Streams draining urban landscapes are influenced by erosion from cleared land, toxic chemicals from industrial processes or road surfaces, dramatic fluctuations in water flow due to impervious surfaces and many other human activities. These human influences are reflected in the biological assemblage that live in the stream. A variety of monitoring tools and protocols have been developed by state and federal agencies to evaluate the biological condition of streams (Davis and Simon, 1995). The City of Bellevue uses these methods to identify problems in stream segments and to improve management practices.

Invertebrates are reliable indicators of biological condition because they integrate many of the human activities that influence or alter flow regime, the sources or processing of nutrients, the hydrological condition of the channel or the chemical water quality of a stream. Unlike fish, invertebrates spend most of their life cycle in the stream reach where they are found. For most, their winged adult stage is a very brief segment of their lives. Like fish, they need many of the same elements to successfully reproduce: cold, clear water, a mix of small cobble and gravel, and natural flow regimes without excessive droughts or floods.

Typically fish or invertebrates are used as biological indicators of stream condition; however, this situation is rapidly changing as algae sampling is included as part of routine site assessments. Many studies have demonstrated the usefulness of algae, and particularly diatoms, as biological indicators (Leland, 1995; Cuffney et al., 1997; Carpenter and Waite, 2000; Hill et al., 2000). Recent studies have also shown that algae are often closely associated with direct measures of human disturbance such as land cover, land use, or riparian disturbance (Kutka and Richards, 1996; Chessman et al., 1999; Pan, et al., 1999; Stewart et al., 1999; Carpenter and Waite, 2000; Leland and Porter, 2000).

The importance of algae to riverine ecology is easily appreciated when one considers that they are primary producers that convert inorganic nutrients into biologically active organic compounds while providing physical habitat for other organisms. As primary producers, algae transform solar energy into food from which many invertebrates obtain their energy. Algae also transform inorganic nutrients, such as atmospheric nitrogen, into organic forms, such as ammonia and amino acids, that can be used by other organisms. Algae stabilize the substrate and create mats that form structural habitat for fish and invertebrates. Some invertebrates use algae to construct cases. "Algae" is a general term that includes blue-green and red algae, diatoms and other groups. Algae are typically microscopic, single-celled organisms that photosynthesize their food. Diatoms differ from other "soft" algae in that they create intricate cases, or frustules, from silica. Taxonomists can use the frustule patterns to identify diatoms to species.

Biological assessments based on multimetric indices are increasingly used in the United States to monitor and manage surface waters (Ransel, 1995; Davis et al., 1996; Karr and Chu, 1999). Multimetric indexes typically combine selected biological attributes, called metrics (e.g., the number of mayfly taxa or the relative abundance of predators) to evaluate the impact of human activities on aquatic systems (Davis and Simon, 1995; Barbour et al., 1998; Karr and

Chu, 1999). The benthic index of biotic integrity (B-IBI) developed for the northwestern USA and Japan includes 10 invertebrate metrics selected for their association with urbanization, timber harvest, recreation and pollution (Rossano, 1996; Karr, 1998, 1999; Fore et al., 2001).

The development of biological metrics and indexes for algae is fairly recent and they have yet to be extensively tested or applied (Stevenson and Bahls, 1999). Recent efforts to develop biomonitoring tools for algal assemblages indicate that some diatom attributes are robust indicators of biological condition and human influence (Cuffney et al., 1997; Hill et al., 2000; Fore, 2002; Fore and Grafe, in press). Although a multimetric index has not been developed for wadeable streams in the Pacific Northwest, I tested a set of metrics that were significantly associated with multiple types of human disturbance across different geographic regions.

In 1998, 13 Bellevue stream sites were sampled for invertebrates. B-IBI and its component metrics were consistently correlated with human disturbance measured in terms of the type of vegetation and density of development surrounding the stream site, the intensity of urbanization upstream, flow regime and the presence of chemical pollution (Fore, 1999). That study also found that biological metrics and the B-IBI were sensitive to small differences within streams. Along Kelsey Creek, riparian vegetation and canopy cover was associated with better biological integrity. Along Goff Creek, biological integrity improved where high flows were removed with a bypass pipe and large trees rather than buildings were alongside the creek.

This document describes results of biological sampling to 12 of the same 13 sites in 2001. Invertebrates were sampled in order to assess whether sites had changed in three years. Diatoms were also sampled to determine if they were associated with human disturbance in a similar way or whether they ranked sites differently. Five additional sites were also sampled for diatoms to test whether diatom assemblages differed upstream and downstream of road or highway crossings with heavy traffic.

Methods

Study sites

Coal Creek, Kelsey Creek, Goff Creek, and Lewis Creek basins were sampled in 1998 and 2001 for invertebrates; Richards Creek was sampled in 1998 only (Figure 1). Invertebrates were collected from 13 stream sites in September 1998. In 2001, 12 of these sites and one new site in Coal Creek basin were sampled for invertebrates (Table 1). Five sites were sampled on Kelsey Creek (mainstem), four sites on Coal Creek, three sites on Goff Creek, and one each on Lewis and Richards Creeks.

Diatoms were sampled at each of the sample sites in 2001 and at six additional sites. Additional diatom sampling sites were selected to test for upstream/downstream differences at road or highway crossings with high numbers of vehicle trips per day. Upstream and downstream sites were compared at two locations on Kelsey Creek at 148th Ave. SE and NE 8th; on Lewis Creek at I-90; and on Yarrow Creek at I-405. In total, diatoms were collected at 19 sampling sites. Diatoms were collected in September and October to estimate variability associated with repeat sampling. All sites were visited twice except the Byrne property on Kelsey (KelByrne) and the mine site on Coal Creek (CoalMine).

Ranking of Sites

For the 1998 study, the 13 original stream sites were ranked according to the intensity of human disturbance at the site and in the watershed. Disturbance ranks were derived from four relative ranks of riparian condition at the site, riparian condition upstream, flow alteration, and water chemistry. Relative ranks were assigned to the 13 sites and the sum of the ranks was the measure of human disturbance used to test biological metrics (Table 2; see Fore 1999 for details). Coal and Lewis Creeks had the least development surrounding stream sites and upstream areas. Kelsey, Goff and Richards Creeks were heavily developed with houses, multifamily buildings and businesses within 20 m of the creek and dense development throughout the watershed.

Sites were ranked according to their riparian condition at the site. Sites with natural vegetation, large cobble in the stream, and an absence of buildings in the riparian area had the lowest rank indicating the least disturbance. In contrast, sites with English ivy, lawn or shrubs in the riparian area, sediment in the channel, and buildings near the stream received higher relative ranks. Sites were ranked according to the riparian condition upstream on the basis of the intensity of development and the presence of riparian vegetation. Hydrographic charts, property owner complaints of flooding or subsidence, and evidence of dry channels were used to rank sites according to flow alteration. Water quality information was not available for the sites; however, Coal Creek was affected by coal mine wastes and drainage from mines and tailing areas, especially in the upstream sites. Urban stormwater run-off is most concentrated in the more densely urban areas, such as Kelsey and Richards Creeks.

City of Bellevue Watersheds

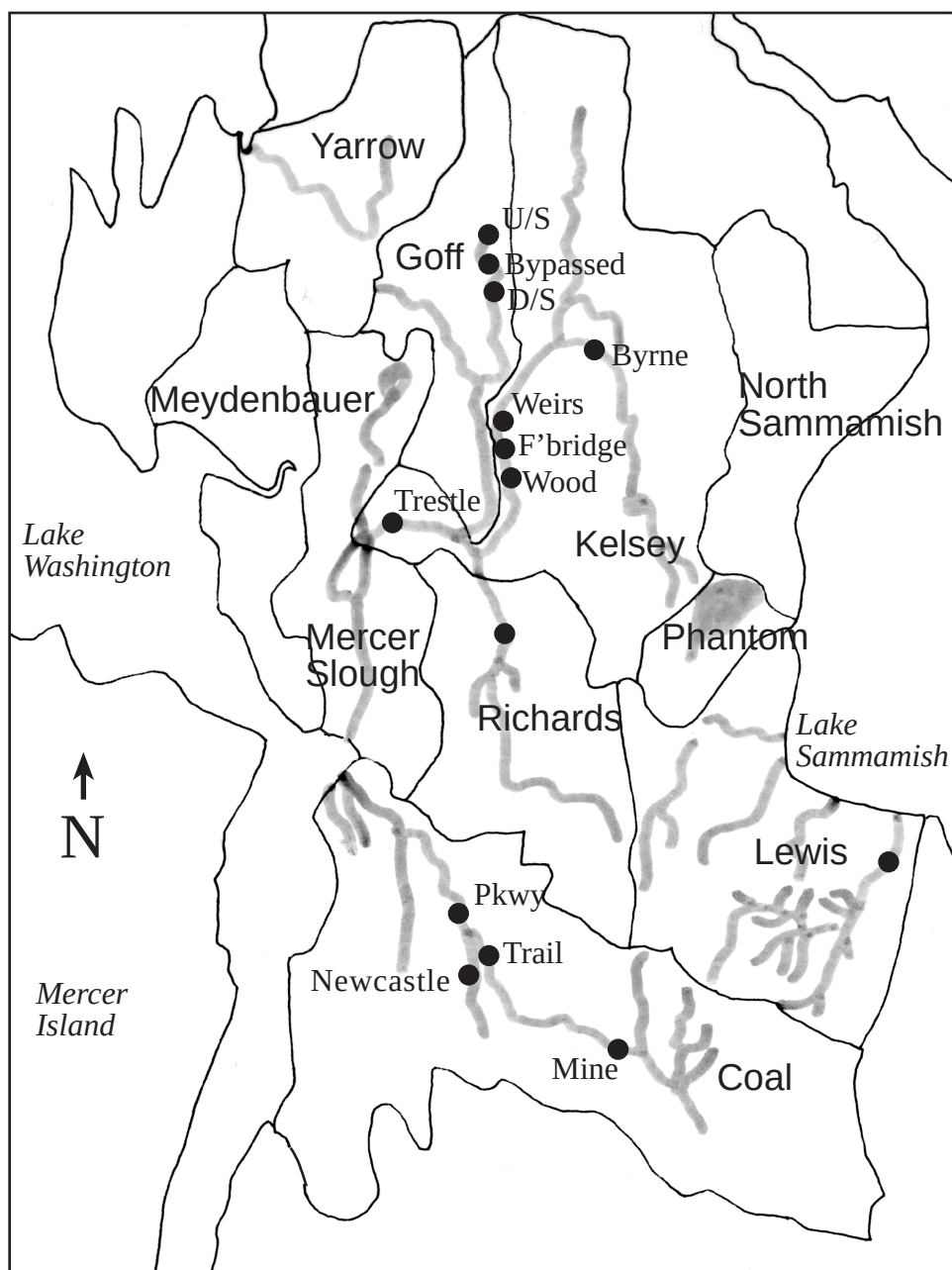


Figure 1. Watershed boundaries, major stream channels, and locations of 14 invertebrate stream sampling sites. See Table 1 for exact locations of sites.

Table 1. Watershed name, site name, whether site was sampled for diatoms in 2001, identification of sites as either upstream (u/s) or downstream (d/s) if part of a paired comparison, whether the site was sampled for invertebrates, site description and location are shown.

Stream	Site name	Diatom	Diatom compare?	Inverts.	Location	Comments
Goff	GoffUsBp	yes		yes	NE 28th, E. of 130th Ave. NE	U/S of bypass
Goff	GoffInBp	yes		yes	2606 130th Ave. NE	In bypass area
Goff	GoffDsBp	yes		yes	E. of 130th Ave. NE, S. of NE 24th, N. of 520	D/S of bypass
Kelsey	KelByrne	yes		yes	Byrne, 1408 143rd Pl. NE	Large cedars
Kelsey	KelWeirs	yes	d/s	yes	Glendale GC, in step weirs	Lawn to water's edge
Kelsey	KelGCfb	yes		yes	Glendale GC, below step weirs, below footbridge	Lawn to water's edge
Kelsey	KelGCwd	yes		yes	Glendale GC, in wooded area near T16	5' riparian buffer
Kelsey	KelTrstl	yes		yes	SE 8th @ Woodridge entrance at train trestle	Sample taken slightly upstream in 2001
Coal	CoalMine	yes		yes	Off Newcastle Rd., access road to regional detention site	Visible scum an odor
Coal	CoalTrail	yes		yes	Above Coal Cr. Pkwy, Coal Creek Trail .25m u/s	Park with natural riparian
Coal	CoalPkwy	yes		yes	Below Coal Cr. Pkwy @ water pipe into 128th Ave. SE	Lots of sediment
Coal	CoalNCTB	yes		2001	Newcastle trib just upstream of detention facility	No sample in 1998
Lewis	Lewis	yes	u/s	yes	Lakemont Blvd. @ I-90	
Richards	Richards			1998	Richards Rd. u/s of SE 18th, behind condos	No sample in 2001
Yarrow	YarrUs	yes	u/s		u/s of I-405, west of 116th, downstream of culvert	
Yarrow	YarrDs	yes	d/s		d/s I-405, across from BSC entry, upstream	
Lewis	LewisDs	yes	d/s		d/s I-90, east of W. Lk Sam PK SE d/s of culvert	
Kelsey	Kel148Us	yes	u/s		u/s 148 th Ave SE, regional detent. site	
Kelsey	Kel148Ds	yes	d/s		d/s 148 th Ave SE, Christian Reformed Church u/s footbridge	
Kelsey	KelNE8Us	yes	u/s		u/s NE 8th , strip chart location, "Foochek"	

Table 2. Stream sites sampled in 1998 were ranked according to (1) riparian condition and intensity of human development at the site, (2) riparian condition upstream of the site, e.g., canopy tree cover vs. urban development, (3) effect of storms on stream flows, (4) and water chemistry. For each variable, sites were assigned a rank according to their relative condition; lower rank numbers indicate better relative condition. Ranks for the four variables were summed to obtain a disturbance rank. Percent impervious surface area upstream of the sampling site is also shown.

Stream	Site name	Rip. Condition at site	Rip. Condition upstream	Flow	Water chemistry	Condition rank	% Impervious surface
Coal	CoalMine	1	1	1	2	5	17
Coal	CoalTrail	1	2	1	1	5	21
Coal	CoalPkwY	2	3	1	1	7	22
Lewis	Lewis	2	3	2	1	8	30
Richards	Richards	4	4	3	1	12	61
Kelsey	KelByrne	3	4	3	1	11	43
Kelsey	KelWeirs	6	4	3	1	14	48
Kelsey	KelGCfb	5	4	3	1	13	47
Kelsey	KelGCwd	5	4	3	1	13	46
Kelsey	KelTrstl	7	4	4	2	17	42
Goff	GoffUsBp	5	4	3	1	13	18
Goff	GoffInBp	3	4	1	1	9	20
Goff	GoffDsBp	5	4	3	1	13	21

Impervious surface area in the upstream watershed was also available for the 13 original sites. A related analysis (not reported here) evaluated impervious surface area within 100 feet of the stream reach and supported the qualitative ranking of sites according to riparian and upstream condition done here.

Invertebrate and Diatom Sampling

Invertebrates were collected using a Surber sampler (0.3 m x 0.3 m) with a 500 μ mesh net. Samples were taken from riffles whenever possible, but glides were substituted when riffles were unavailable. All samples were collected from the center of the riffle. At each stream site, three replicate samples were collected from sequential riffles (where possible). Within each riffle, three Surber samples were collected within 10 to 20 meters and combined into a single sample. The total sampling area was approximately one m² at each site. Macroinvertebrates were preserved in alcohol. Taxonomic identification by a professional laboratory was to species for most insects, genus for chironomids, and order or higher for non-insects.

Periphyton refers to the slippery green material typically found clinging to rocks on a stream bottom. Periphyton is composed of diatoms and “soft” algae which may include red, green or blue-green algae. Within the periphyton can also be found bacteria and fungi, but these are typically not identified as part of sampling. Although many studies identify the soft, or non-diatom, algae, relatively few metrics have been developed for this group. In addition, taxonomic identification is typically limited to the genus level. In contrast, because of their hard silica cases, diatoms can be identified to species and much is known about their ecological preferences and requirements (Van Dam et al., 1994). For this study, periphyton was sampled, but only the diatoms were identified. Periphyton was collected from rock surfaces using a brush and syringe. Samples were taken from riffle areas and preserved with Lugol’s solution. A minimum of 800 diatom valves were identified to species by a professional taxonomist.

Data analysis

A multimetric index, the benthic index of biological integrity (B-IBI), was used to summarize invertebrate data. B-IBI is composed of ten metrics representing multiple levels of biological organization such as taxonomic composition and feeding ecology (Table 3; Appendix I). To calculate B-IBI, metric values of the three replicates taken at each site were averaged. Because each metric has its own range of potential values, each metric is given a score before it is incorporated into B-IBI. A score of 5 indicates values expected in sites with minimal human disturbance; a score of 3, moderate human disturbance; and a score of 1, severe degradation. The sum of metric scores at a site is the final index. Relatively undisturbed sites thus have high B-IBIs, degraded sites low B-IBIs. The index ranges from 50 (10 metrics times a score of 5) indicating the best condition to 10 (10 metrics times a score of 1) indicating the most degraded biological condition.

A multimetric index for diatom stream samples has not been developed for the Pacific Northwest. Instead, I used 11 metrics to summarize the diatom data that were significantly associated with human disturbance in Idaho rivers and mid-Atlantic streams (Table 4; Appendix

Table 3. Biological metrics for stream invertebrates, response to human disturbance, and scoring criteria used to integrate into multimetric index.

Metric	Response	Scoring criteria		
		1	3	5
Taxa richness and composition				
Total number of taxa	Decrease	[0, 20)	[20, 40]	> 40
Number of mayfly taxa	Decrease	[0, 4]	(4, 8]	> 8
Number of stonefly taxa	Decrease	[0, 3]	(3, 7]	> 7
Number of caddisfly taxa	Decrease	[0, 5)	[5, 10)	≥ 10
Number of long-lived taxa	Decrease	[0, 2]	(2, 4]	> 4
Tolerance				
Number of intolerant taxa	Decrease	[0, 2]	(2, 3]	> 3
% of individuals in tolerant taxa	Increase	≤50	(19, 50)	[0, 19]
Feeding ecology				
% of predator individuals	Decrease	[0, 10)	[10, 20)	≥20
Number of clinger taxa	Decrease	[0, 10]	(10, 20]	> 20
Population attributes				
% dominance (3 taxa)	Increase	≤75	[50, 75)	[0, 50)

Table 4. Diatom metrics are shown with their predicted response to disturbance, whether they were significantly correlated with human disturbance in Idaho or the mid-Atlantic, and their correlation with site condition in Bellevue for the first and second visits. All correlation coefficients are shown, significant correlations are indicated (* $p < 0.05$, Spearman's r).

Metric	Response to human disturbance	Idaho rivers	Mid-Atlantic streams	Bellevue Visit 1	Bellevue Visit 2
Tolerance & intolerance					
% intolerant	Decrease	✓	✓	-0.63 *	-0.29
% very tolerant	Increase	✓	✓	0.22	0.28
% salt tolerant	Increase		✓	-0.09	-0.19
% tolerant of low oxygen	Increase	✓	✓	0.46	0.11
% requiring high oxygen	Decrease	✓		-0.27	-0.01
Autecological guild					
% eutrophic	Increase	✓	✓	-0.39	-0.68 *
% nitrogen heterotrophs	Increase	✓	✓	0.39	-0.28
% polysaprobic	Increase	✓	✓	0.09	0.28
% alkaliphilic	Increase	✓	✓	-0.11	-0.71 *
Morphometric guild					
% very motile	Increase	✓	✓	-0.07	-0.17
Individual condition					
% deformed cells	Increase	✓	NA	-0.41	0.71 *

II). In previous studies, intolerant diatoms were observed to decrease with human disturbance while tolerant diatoms increased (Fore and Grafe, in press; Fore, 2002). In addition, diatom species known to be specifically tolerant of salt, nutrient enrichment, low oxygen, or alkaline conditions all increased with human disturbance. Some diatom species are capable of moving enough to avoid being buried by moving sand and sediment. These motile species increased with human disturbance related to erosion. At stream sites contaminated by heavy metals, some diatoms formed abnormal cells. I predicted that deformed cells would increase at sites downstream of heavy traffic due to zinc from brake pads.

Biological metrics and indexes for invertebrates and diatoms were used to test the following series of questions.

1. *Has biological condition improved or declined from 1998 to 2001?* Invertebrate metrics and B-IBI were compared for the 12 sites that were sampled in both years. Graphical comparison of metric and index values for each year and a paired *t*-test were used to evaluate differences.
2. *Were sites still ranked in the same order in terms of biological condition?* Pearson's correlation coefficient was calculated for B-IBI values to determine if sites were similarly ranked in 1998 and 2001. Graphical analysis was used to identify site changes.
3. *Were invertebrate and diatom metrics associated with disturbance rank?* B-IBI and its 10 component metrics were tested for correlation with disturbance rank for both years. For diatoms, 11 metrics were tested for correlation with disturbance rank. A nonparametric test (Spearman's *r*) was used to avoid concerns about distribution of the ranked disturbance measure and the invertebrate metrics. One sided tests were used because a significant correlation in the opposite direction predicted would not be meaningful.
4. *Did the diatom metrics consistently rank sites in the same order for the first and second visits?* I used Kendall's test of concordance to test whether the 11 metrics tended to rank the sites in a similar order across sites. I used graphical analysis to evaluate whether sites were similarly ranked for different visits.
5. *Were changes in diatom metrics observed for sites upstream and downstream of road crossings with heavy traffic?* Four site pairs were used to test for differences in the 11 diatom metrics. Sites were compared graphically.
6. *Were diatom metrics too variable to detect differences between sites?* I used components of variance analysis to estimate the relative proportion of signal (site differences) to noise (differences associated with repeat sampling). I estimated variance components using Anova and calculated the relative percentages of variance associated with site differences and repeat sampling.

Results

Invertebrates

When 1998 and 2001 B-IBI values were compared for each site using a paired t -test, B-IBI values were significantly lower in 2001 ($p < 0.05$). B-IBI declined dramatically at the upstream Coal Creek sites; the most upstream site had a B-IBI of 32 in 1998 compared with 18 in 2001. (Table 5; Figure 2). The trailhead site on Coal Creek also declined, but not as precipitously (Figure 3). On Kelsey and Lewis Creeks, B-IBI values declined at most sites between 2 and 4 points. The wooded site on the golf course on Kelsey did not change. B-IBI at the trestle site on Kelsey increased slightly; however, the sampling location also changed. In 2001, the site was located upstream in a reach that was slightly less disturbed than the site sampled in 1998.

Several component metrics showed a similar pattern to the B-IBI in that they changed toward values indicating a more disturbed biological condition. Total taxa richness, mayfly, stonefly, intolerant, and clinger taxa richnesses all declined from 1998 to 2001 (Figures 4 and 5). Percentage predators was also lower at several sites in 2001. Other metrics including long-lived taxa richness, percentage tolerant individuals and percentage dominance were similar across years (Figure 6).

Although changes in B-IBI values were dramatic at some sites, the index ranked the sites in a similar order in 1998 and 2001. B-IBI values for 1998 and 2001 were significantly correlated ($p < 0.01$, $r^2 = 0.58$). Upstream sites on Coal and Kelsey and the site on Lewis had the highest B-IBI values in both years. Although B-IBI values for Goff Creek changed at all three sites from 1998 to 2001, the site within the bypassed area still scored highest.

B-IBI was significantly correlated with disturbance in both years, although the correlation coefficient was larger in 1998 due to the higher B-IBI values in upper Coal Creek (Table 6). Most of its component metrics were also significantly correlated with disturbance. In 1998 all metrics except percentage dominance were correlated with disturbance. In 2001, percentage dominance was again not significantly correlated with disturbance and neither were three other metrics: mayfly taxa richness, percentage tolerant individuals and percentage predators.

Only two metrics were significantly associated with percent impervious surface area in 1998; these were mayfly and intolerant taxa richness. In 2001, none of the metrics were significantly correlated with impervious surface area.

Diatoms

For diatom samples, laboratory analysis of 36 stream samples yielded 236 species in 38 genera. An average of 855 valves were identified from each sample. The data included a unique observation of the rare genus *Nupela* at the Kelsey trestle site. Sites on average had approximately 44 different species and ranged from 18 to 85. High diversity is fairly typical for diatoms. For Idaho river, average taxa richness at a site was 43 based on a similar 800-valve

Table 5. B-IBI (benthic index of biotic integrity) scores for 14 Bellevue stream sites sampled in 1998 and 2001.

Stream	Site name	B-IBI 1998	B-IBI 2001
Coal	Mine/retention pond	32	18
	Trailhead	30	20
	Newcastle Trib	NA	22
	D/S of Parkway	22	16
Lewis	Lakemont & I-90	24	22
Richards	Richards	16	NA
Kelsey	Byrne property	20	16
	Step weirs	12	10
	Golf Course, footbridge	12	10
	Golf Course, wooded area	16	16
	Trestle	16	18
Goff	U/S bypass	10	14
	In bypassed area	18	16
	D/S bypass	16	14

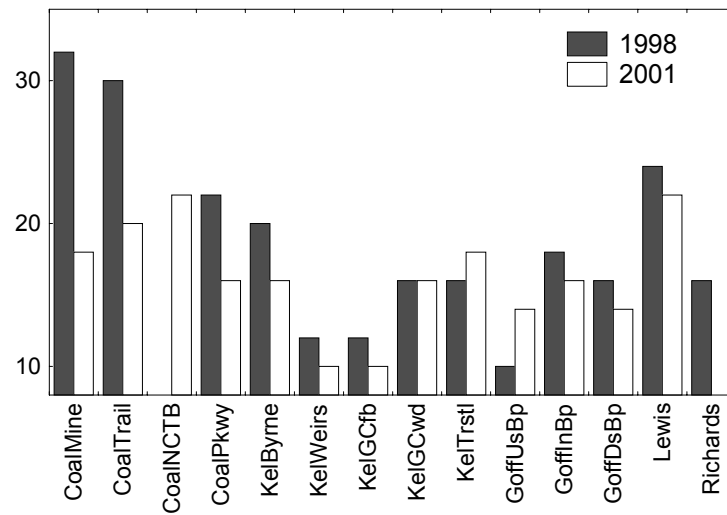
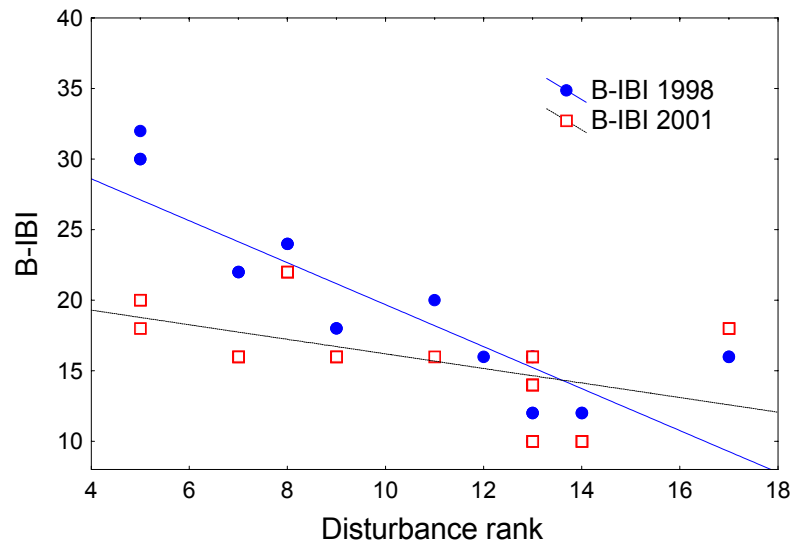


Figure 2. B-IBI declined significantly with disturbance for both years (upper panel). B-IBI values for all Coal Creek sites declined; other creeks varied (lower panel).

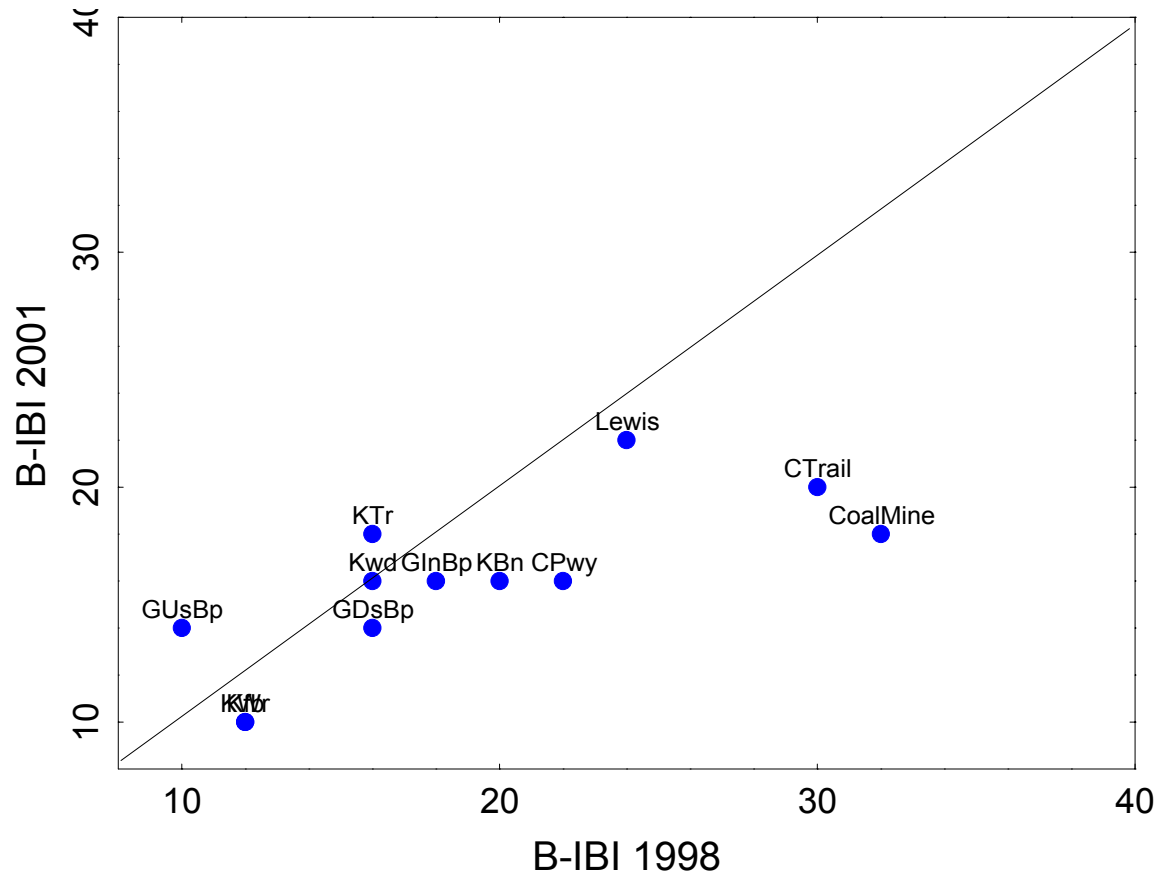


Figure 3. B-IBI values changed the most at the Coal Creek sites and the Kelsey Byrne site between 1998 and 2001. Sites on Lewis, Goff and other Kelsey sites changed less. The line of perfect agreement is shown.

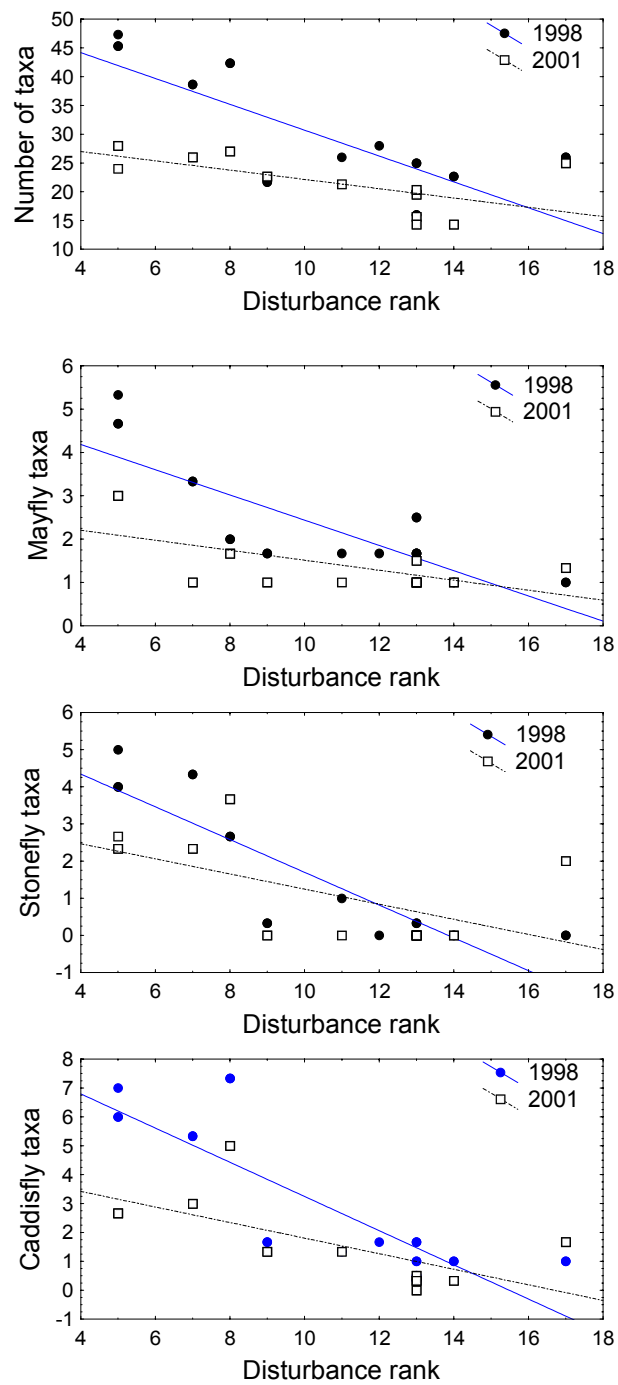


Figure 4. Taxa richness metrics tended to be lower in 2001 than 1998, indicating a decline in biological condition.

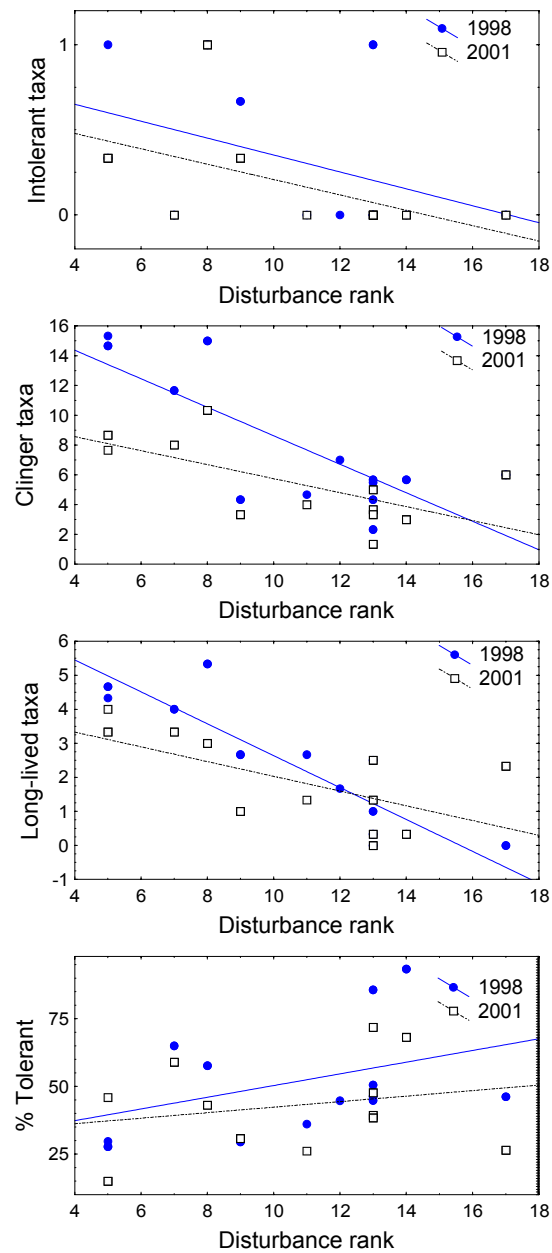


Figure 5. Intolerant and clinger taxa richness declined from 1998 to 2001. Long-lived taxa richness and percentage tolerant individuals were similar across years.

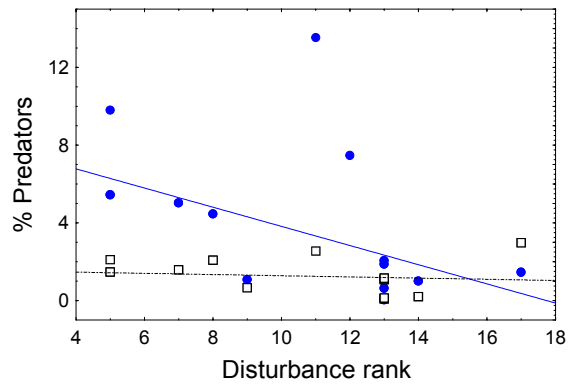
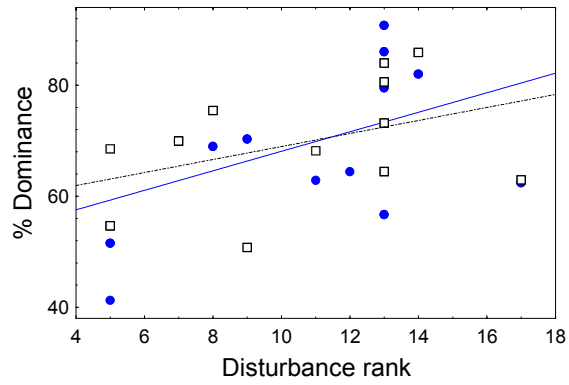


Figure 6. Percentage dominance did not change from 1998 (closed circles) to 2001 (open squares); percentage predators decreased at several sites, indicating a decline in biological condition.

Table 6. Correlation coefficients for invertebrate metrics and B-IBI with site condition rank. Only significant correlations are shown (Spearman's r , $p < 0.05$, 1-sided test).

Metric	1998	2001
$N =$	13	12
Total number of taxa	-0.70	-0.66
Number of mayfly taxa	-0.83	
Number of stonefly taxa	-0.88	-0.64
Number of caddisfly taxa	-0.82	-0.68
Number of long-lived taxa	-0.91	-0.69
Number of intolerant taxa	-0.52	-0.70
% of individuals in tolerant taxa	0.50	
% of predator individuals	-0.65	
Number of clinger taxa	-0.55	-0.62
% dominance (3 taxa)		
B-IBI	-0.84	-0.58

count; for mid-Atlantic streams the average was 28 due to a smaller 500-valve count (Fore, unpublished data).

Diatom metrics used in previous studies were not consistently correlated with disturbance (see Table 4). For the first set of samples collected in September, only the percentage of valves belonging to intolerant taxa was significantly correlated with disturbance. For the second set of samples collected in October, three metrics were significantly correlated with disturbance; these were percentage of valves belonging to eutrophic and alkaliphilic species and percentage deformed cells.

Diatom metrics tended to rank sites similarly when metric ranks were compared for samples collected in September (Kendall's $W=0.83$; $\chi^2_{18}=164.5$, $p<0.01$). Metric also tended to rank sites similarly for samples collected in October (Kendall's $W=0.86$; $\chi^2_{16}=151.7$, $p<0.01$). I averaged the ranks for all metrics for each site using metric data for the first visit and then again for the second visit. When the average metric ranks were compared for both visits, diatoms at the Goff sites above and below the bypass, at the Kelsey Byrne and trestle sites, both sites on Lewis, and sites on Coal Creek at the detention site and below the Coal Creek Parkway tended to indicate better condition (Figure 7). Other sites tended to group together with the three golf course sites on the Kelsey Creek tending to indicate the most disturbed conditions.

Diatom metrics failed to show consistent differences between sites upstream and downstream of road crossings with heavy traffic (Figure 8). Metric values for first and second visits were fairly similar at all sites indicating that there were no problems associated with obtaining repeatable measures from the diatom assemblage. Metric values for upstream/downstream site pairs tended to be more similar to each other than to other site pairs, which further indicates that site differences were measurable using diatoms. Nonetheless, no consistent differences were observed for upstream vs. downstream locations.

Components of variance analysis partitioned the variability of each metric associated with differences in sites (the 'signal') and differences associated with site visit (the 'noise'). Most metrics had a higher percentage of variability associated with site differences than with site visit; exceptions were percentages of valves belonging to intolerant and nitrogen heterotrophic species and percentage deformed cells (Figure 9).

When the eight sites on Kelsey Creek were plotted from upstream to downstream, the trends varied according to metric (Figure 10). One metric indicated improvement in biological condition moving downstream (percentage tolerant); two metrics indicated declined downstream (percentage requiring high oxygen and percentage eutrophic); three metrics indicated decline initially and then improvement further downstream (percentage intolerant, percentage salt tolerant, and percentage tolerant of low oxygen). Typically the change in direction of condition occurred at NE 8th.

In general, the diatom metrics indicated better biological condition at sites on Lewis rather than Kelsey, as expected. The exceptions to this pattern were percentage alkaliphilic and eutrophic which were both high, indicating greater disturbance, at the Lewis sites.

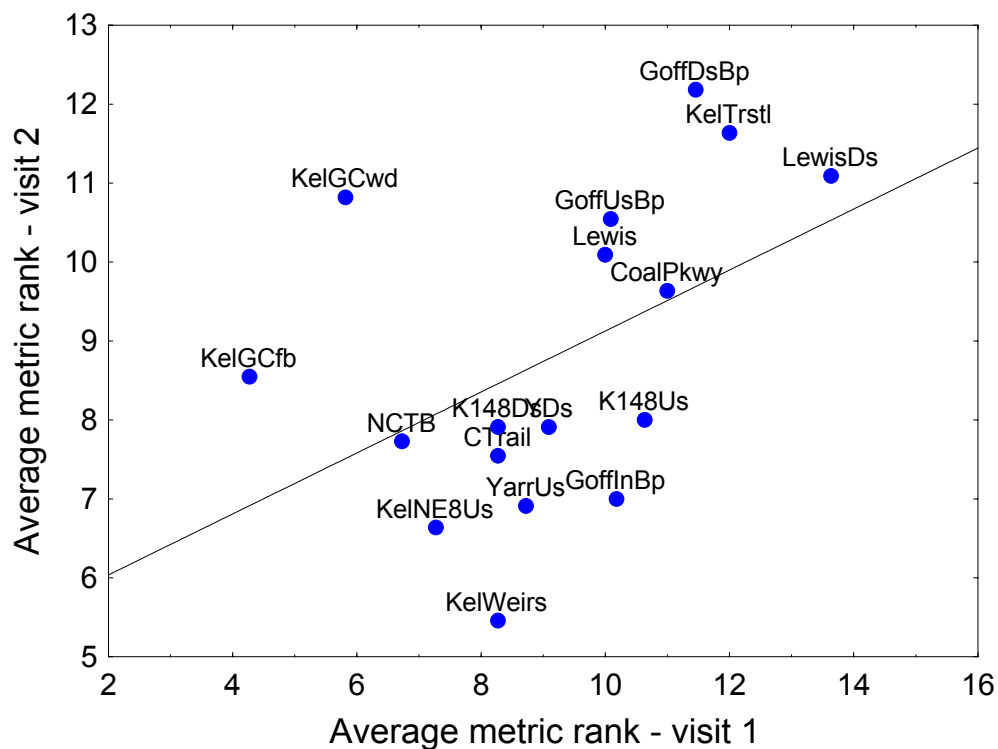


Figure 7. Agreement between site ranks for September and October diatom samples. Samples sites were ranked according to 11 diatom metrics. Ranks were averaged for each site and the site rank for each visit is shown. High rank values indicate better biological condition. CoalMine and KelByrne sites had high rank values for the single site visit, but are not shown.

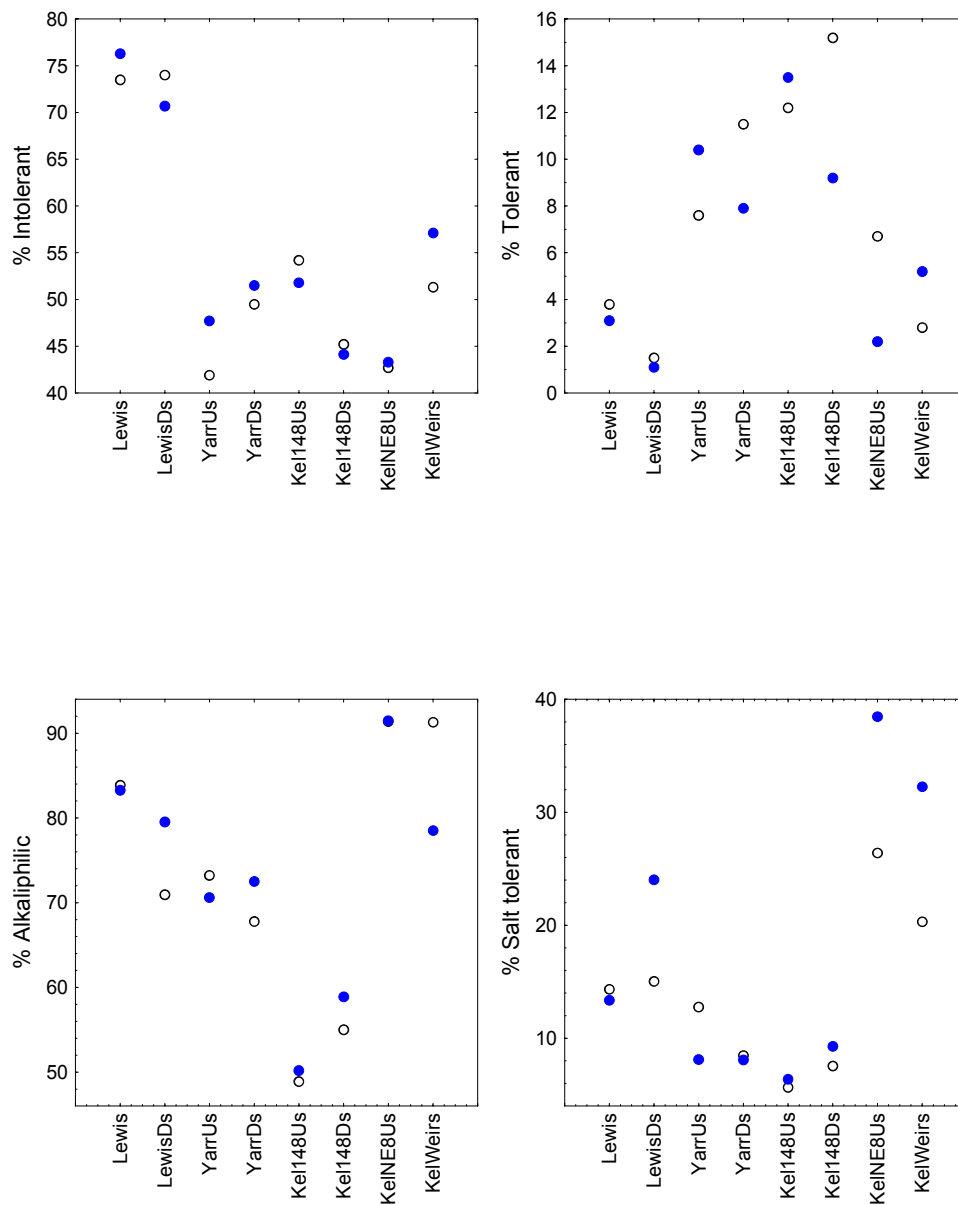


Figure 8. Diatom metric values for four pairs of sites upstream and downstream of road crossings with heavy traffic. Open circles indicate a September sample and closed circles indicate October.

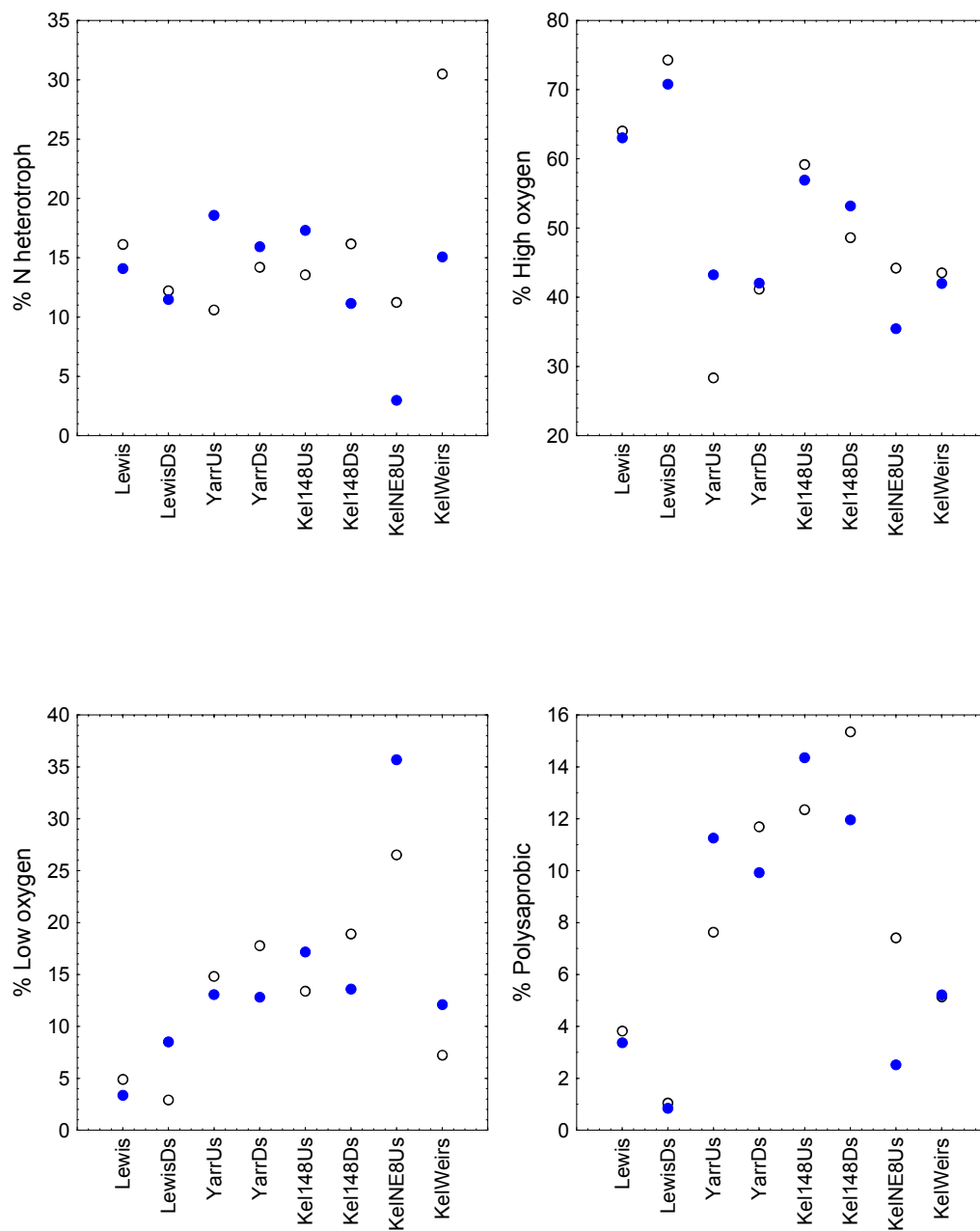


Figure 8. Continued.

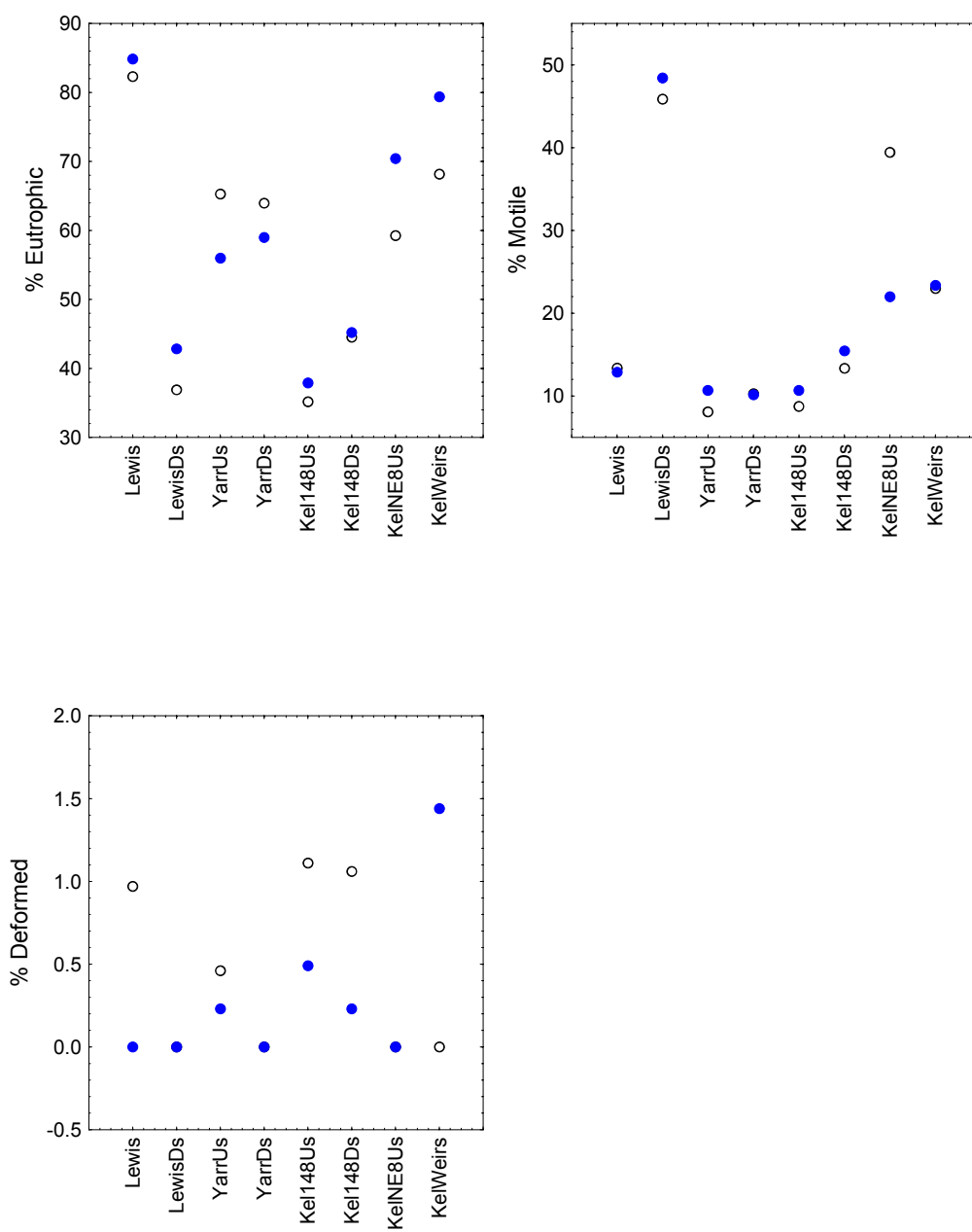


Figure 8. Continued.

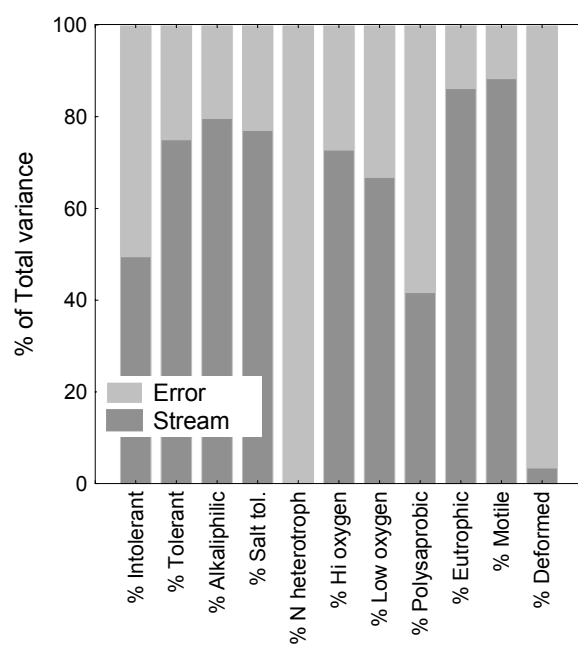
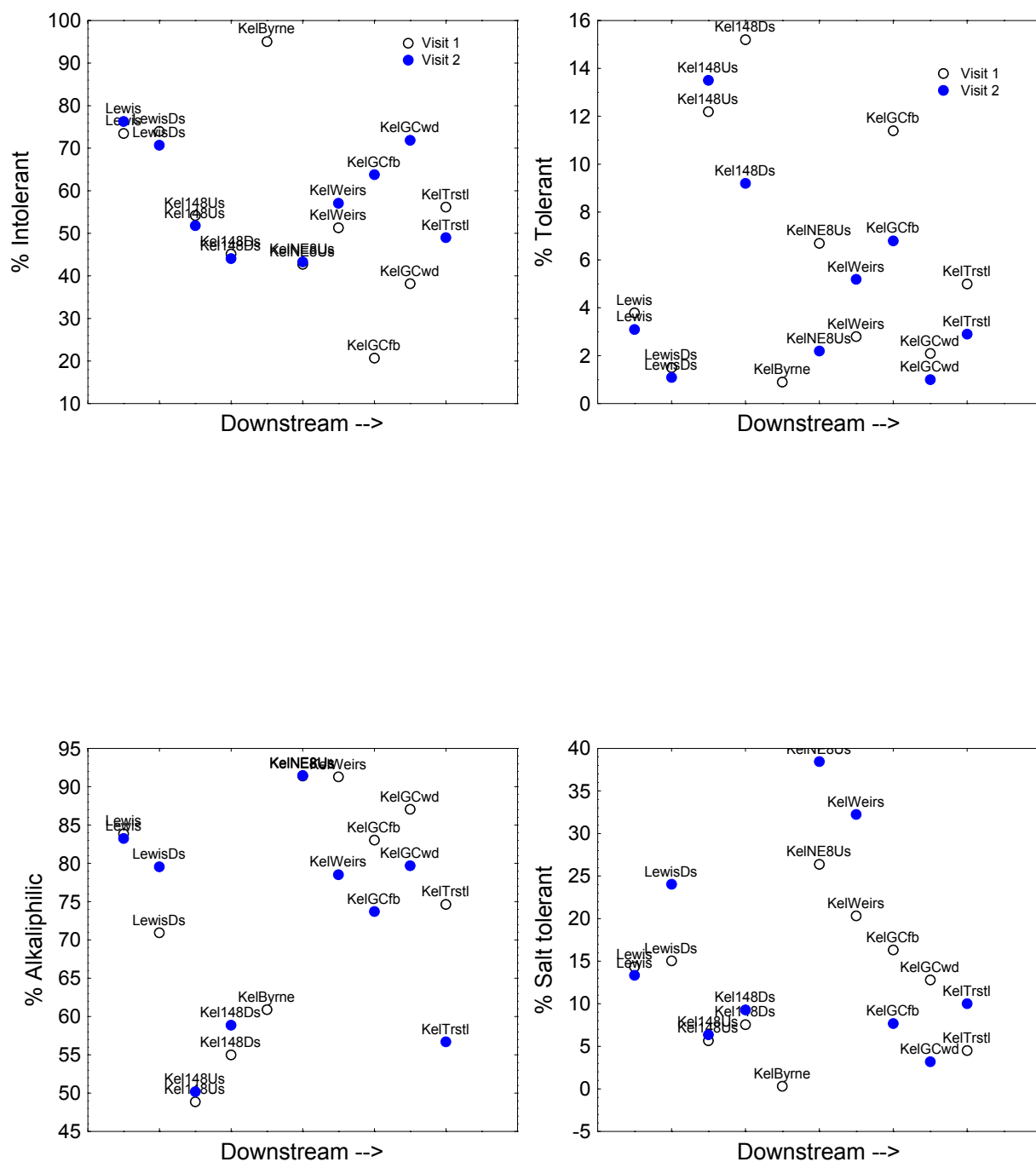


Figure 9. Components of variance for 11 diatom metrics. Stream component represents the differences between sampling sites. Error represents the differences between repeat visits to the same site in different months.



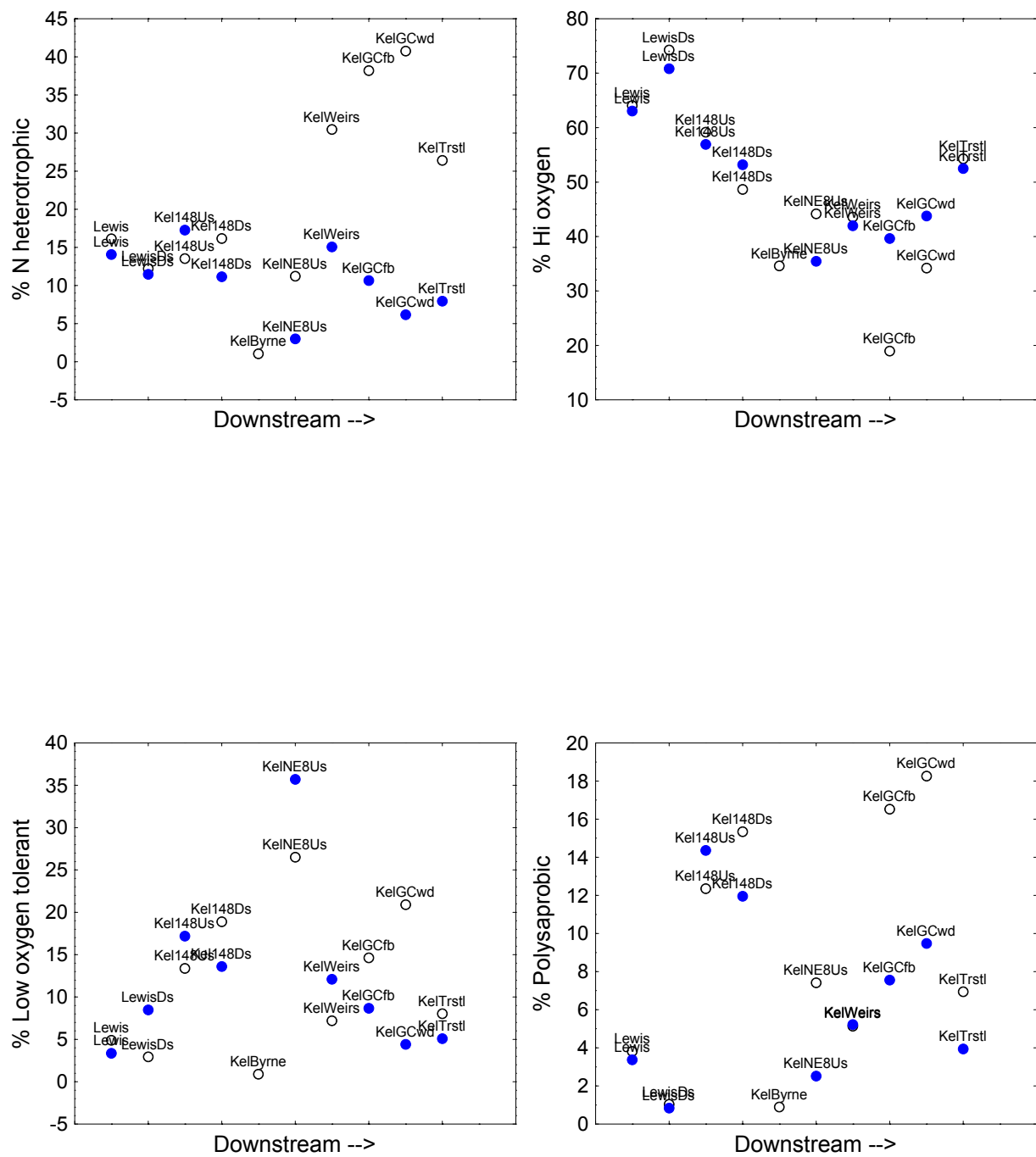


Figure 10. Continued.

For several diatom metrics, the KelByrne site was a consistent outlier indicating better biological condition than sites upstream or downstream. Along with the Lewis sites, the KelByrne site tended to have lower percentages of tolerant diatoms and higher percentages of intolerant diatoms. In contrast, the site at NE 8th had some of the highest values for alkaliphilic, salt tolerant, low oxygen tolerant, and eutrophic diatoms indicating the greatest disturbance.

In general, metric values for different site visits tended to be similar within each site. The exception was the golf course sites which tended to be more variable, particularly for nitrogen heterotrophs. For samples collected on the first visit, nitrogen heterotrophs were much higher at three sites on the golf course and downstream at the trestle site. Nitrogen heterotrophs are typically associated with excessive nitrogen, for example, from fertilizer.

Discussion

The most dramatic change from 1998 to 2001 was the drop in B-IBI values for the three sites on Coal Creek. Typically a change of approximately seven points is a strong indicator of a change in biological condition (Fore et al., 2001). The most upstream site changed from 32 to 18, 14 points. Downstream at the park site (CoalTrail) the index changed from 30 to 20. The greatest change from 1998 to 2001 occurred at the upstream sites. The observed change could have been caused by water quality changes associated with a spill from surrounding roads or mined areas; or the stream could have run dry in the summer. The exact cause could not be determined.

B-IBI declined at six of the other nine sites that were sampled in both years. The change in B-IBI was less extreme for these sites, perhaps because the index did not have as far to go; index values on Kelsey and Goff were less than or equal to 20 (B-IBI ranges from 10 to 50). Though the upland area near the Lewis site experienced prolonged disturbance during the construction of the Lakemont Bypass from 1997 until 1999, B-IBI changed only two points from 24 to 20.

The B-IBI is a summary measure of ten biological attributes. The pattern of decline summarized in the index was more dramatically apparent when some of the component metrics were considered. The total number of taxa was higher at nearly every site in 1998. Similarly, the number of taxa in key groups such as the mayflies, stoneflies, and caddisflies were consistently lower in 2001. The number of clinger taxa declined dramatically at the Coal Creek sites, but were similar for other sites from 1998 to 2001. Clingers often decline in association with an increase in sediment which obstructs their microhabitats within and between the gravel and cobble. Predators also declined. In 1998 the percentage of predators ranged from 5-15% for several sites; in 2001, all sites had fewer than 5% predators. These values are typical of severely degraded sites.

Could some other factor not related to human disturbance have caused the decline in B-IBI? Although the sampling crew changed, the protocol used to collect invertebrates was identical from 1998 to 2001. Members from each crew have sampled together on previous occasions to ensure that methods were similar. The laboratory that identified invertebrates changed between years and the laboratory protocol changed slightly. In 1998, the entire sample was identified. In 2001, a minimum of 500 individuals was identified; however, this represented the entire, or very nearly the entire, sample in most cases. In 1998, a larger number of individuals was identified from each sample, 718 vs. 526 in 2001. The concern here is that larger sample sizes yield more different taxa which can inflate taxa richness measures which in turn may yield higher B-IBI values.

The samples were on average larger in 1998, and could have increased the number of taxa and consequently the B-IBI values. However, the largest change in taxa richness is more typically found from 100 to 300 individuals, not from 500-700 (Li et al., 2001). B-IBI values for other sites on Lewis and Goff Creeks changed less than for Coal Creek sites; these sites serve as a control for evaluating the effect of changes in sample size. Furthermore, not all metrics were

affected. For example, long-lived taxa richness did not change between years. Percentage predators did show a marked change, confirming that biological condition has declined. But, because it is measured as a percentage rather than a count of taxa, it does not depend on the number of individuals counted.

When the disturbance gradient was defined in 1998 to test invertebrate metrics, we knew that the range of conditions was relatively narrow for Bellevue streams. Most watersheds are entirely developed and very little natural area remains. The narrow range of B-IBI values from 10 to 25 (out of a possible 10 to 50 points) supports the idea that these sites represent the degraded end of the spectrum. In 1998, we sampled Coal Creek even though it was outside Bellevue in order to have a less disturbed site for comparison.

In 2001, the potential range of conditions for Bellevue sites seems to have narrowed further given the decline in condition for Coal Creek. Thus, the narrow range of site conditions available for testing may have limited our ability to detect differences between sites using diatom metrics. Diatom metrics were not consistently related to human disturbance measured in terms of riparian vegetation and development. Additional information about water chemistry, nutrients or toxics might provide greater insight into how or why the diatoms responded as they did across sites. It's possible that diatoms respond to different types of human disturbance than invertebrates and that these other stressors were present, but we failed to measure them. If diatoms do respond consistently to other human influences, the combination of macroinvertebrate and diatom metrics may provide additional insight for environmental assessment.

Metric values for diatoms have not been calibrated for wadeable streams in the Pacific Northwest. A multimetric index derived from the metrics evaluated here has been calibrated and applied to large rivers in Idaho and to wadeable streams in the mid-Atlantic region (Fore, 2002; Fore and Grafe, in press). Many of the same metrics were significantly correlated with very different types of disturbance across the two studies; however, the range of metric values that indicated little or no human disturbance varied by as much as a factor of three for several metrics. Metric values that indicated little or no disturbance for Idaho rivers would indicate severe degradation for the mid-Atlantic streams.

We cannot determine how different the metric values for Bellevue streams would be from reference condition because no undisturbed streams were sampled for this study. If we assume that diatoms respond similarly to human disturbance in western Washington as they do in the mid-Atlantic (a very large and unfounded assumption), the range of metric values from Bellevue sites were more similar to disturbed sites than reference sites in the mid-Atlantic. Most of the metric values for Bellevue sites fell in the range of values indicating poorest condition for the mid-Atlantic. This comparison should not be interpreted as an assessment based on diatoms. Additional analysis for the Pacific Northwest must first determine what expected values should be for diatom metrics in the absence of human disturbance.

Although diatom metrics failed to be correlated with human disturbance defined in terms of riparian vegetation and development, the metrics showed some tendency to select the same sites as least disturbed from one visit to the next. The diatom metrics agreed somewhat with the

invertebrate assessment in terms of which sites were least disturbed. The upstream sites on Coal Creek, Lewis and the most upstream site on Kelsey were least disturbed according to the diatom metrics. The diatom metrics disagree with the invertebrate assessment in identifying the Goff sites upstream and downstream of the bypassed area and the Kelsey trestle site as least disturbed.

Estimates of diatom metrics were also relatively precise in that samples taken at different times from the same site were more similar than samples taken from different sites. Although metric values were repeatable from one visit to the next, they failed to detect any differences between sites upstream and downstream of road or highway crossings.

Although biological assessments based on diatoms show some promise as a monitoring tool, it must await additional sampling from regional reference sites before metrics can be interpreted for Bellevue's urban watersheds. In contrast, invertebrate sampling and assessment protocols are well developed and provide a reliable method for assessing the biological condition of urban streams.

Recommendations

Invertebrates

- Repeat the invertebrate sampling in 2002 using the same field staff to determine whether the results from 2001 persist.
- Identify either the entire sample, or a minimum of 700 individuals (rather than 500) to more closely approximate 1998 methods. This could be done for a subset of sites but should include upstream Coal and the Kelsey Byrne sites.
- Alternatively, request that the taxonomist put data from a 500-count subsample in one electronic file and the remainder of the count (or the additional 200) in a second additional electronic file. This could be done for a subset of sites to evaluate the influence of sample size on the observed differences between 1998 and 2001.

Diatoms

- Sample diatoms at minimally disturbed, low elevation streams that would approximate reference conditions for Bellevue stream sites. Example might include Rock, Holder, or Carey Creeks or sites in the upper watershed of the Cedar River.
- Select sites that represent a range of conditions including high urban development, moderate rural or suburban development, and minimally disturbed.
- Collect additional water chemistry information related to phosphorus and nitrogen concentrations, conductivity, and pH. If possible, team with other regional programs collecting water chemistry data.

Acknowledgments

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Appendix I.

Description of invertebrate metrics used in the benthic index of biological integrity (B-IBI)

Biological metrics measure different aspects of stream biology including taxonomic richness and composition, tolerance and intolerance, habit, reproductive strategy, feeding ecology and population structure. The benthic index of biotic integrity, or B-IBI, is composed of ten biological metrics that formalize our scientific understanding of how human activities alter stream biology. Each of the ten metrics tested and developed for the Pacific Northwest is described below.

Total taxa richness. The biodiversity of a stream declines as flow regimes are altered, habitat is lost, chemicals are introduced, energy cycles are disrupted, and alien taxa invade. Total taxa richness includes all the different invertebrates collected from a stream site: mayflies, caddisflies, stoneflies, true flies, midges, clams, snails, and worms.

Mayfly (Ephemeroptera) taxa richness. The diversity of mayflies declines in response to most types of human influence. Many mayflies graze on algae and are particularly sensitive to chemical pollution (e.g., from mine tailings) that interferes with their food source. Mayflies may disappear when heavy metal concentrations are high while caddisflies and stoneflies are unaffected. In nutrient-poor streams, livestock feces and fertilizers from agriculture can increase the numbers and types of mayflies present. If many different taxa of mayflies are found while the variety of stoneflies and caddisflies is low, enrichment may be the cause.

Stonefly (Plecoptera) taxa richness. Stoneflies are the first to disappear from a stream as human disturbance increases. Many stoneflies are predators that stalk their prey and hide around and between rocks. Hiding places between rocks are lost as sediment washes into a stream. Many stoneflies are shredders and feed on leaf litter that drops from an overhanging tree canopy. Most stoneflies, like salmonids, require cool water temperatures and high oxygen to complete their life cycles.

Caddisfly (Trichoptera) taxa richness. Different caddisfly species (or taxa) feed in a variety of ways: some spin nets to trap food, others collect or scrape food on top of exposed rocks. Many caddisflies build gravel or wood cases to protect them from predators; others are predators themselves. Even though they are very diverse in habit, taxa richness of caddisflies declines steadily as humans eliminate the variety and complexity of their stream habitat.

Intolerant taxa richness. Animals identified as intolerant are the most sensitive taxa; they represent approximately 5-10% of the taxa present in the region. These animals are the first to disappear as human disturbance increases. Chironomids are not included in this metric.

Clinger taxa richness. Taxa defined as clingers have physical adaptations such as ventral suckers, dorsoventral flattening, well-developed tarsal claws, or construct retreats that they attach to the substrate; thus, they are able to “cling” to smooth substrates in fast water. These animals require

open areas between rocks and cobble along the bottom of the stream; consequently, they are particularly sensitive to fine sediments that fill these spaces and eliminate the variety and complexity of small habitats. Clingers may use these areas to forage, escape from predators, or lay their eggs. Sediment also prevents clingers from moving down deeper into the stream bed, or hyporheos, of the channel. Chironomids are included in this metric.

Long-lived (semi-voltine) taxa richness. These invertebrates require more than one year to complete their life cycles; thus, they are exposed to all the human activities that influence the stream throughout one or more years. If the stream is dry part of the year or subject to flooding, these animals may disappear. Loss of long-lived taxa may also indicate an on-going problem that repeatedly interrupts their life cycles.

Percent tolerant. Tolerant animals are present at most stream sites, but as disturbance increases, they represent an increasingly large percentage of the assemblage. Invertebrates designated as tolerant represent the 5-10% most tolerant taxa in a region. In a sense, they occupy the opposite end of the spectrum from intolerant taxa. Chironomids are not included in this metric.

Percent predator. Predator taxa represent the peak of the food web and depend on a reliable source of other invertebrates that they can eat. Predators may have adaptations such as large eyes and long legs for hunting and catching other animals. The percentage of animals that are obligate predators provides a measure of the trophic complexity supported by a site. Less disturbed sites support a greater diversity of prey items and a variety of habitats in which to find them.

Percent dominance (3 taxa). As diversity declines, a few taxa come to dominate the assemblage. Opportunistic species that are less particular about where they live replace species that require special foods or particular types of physical habitat. Dominance is calculated by adding the number of individuals in the three most abundant taxa and dividing by the total number of individuals collected in the sample.

Appendix II.

Description of diatom metrics developed and tested for Idaho rivers and mid-Atlantic streams.

Percentage of valves belonging to intolerant species. Species classified as generally intolerant of high nutrients (eutrophic), organics (polysaprobic), temperature (euthermal), salts (euhalobus), toxics, suspended solids, and unstable substrate. Original classifications by Lange-Bertalot (1979) and Lowe (1974) were modified by Bahls (1993) to reflect diatom responses to disturbance in Montana.

Percentage of valves belonging to tolerant species. As above, except generally tolerant of high nutrients (eutrophic), organics (polysaprobic), temperature (euthermal), salts (euhalobus), toxics, suspended solids, or unstable substrate.

Percentage of valves belonging to salt tolerant species. Diatoms were originally classified as salt tolerant based on their tolerance of brackish or marine conditions. Sources of salt (or chlorine) in freshwater streams may be treated wastewater or agricultural run-off (Van Dam et al., 1994).

Percentage of valves belonging to species that are tolerant of low oxygen. Species were originally classified as tolerant of low oxygen levels in the context of organic waste decomposition; however, this attribute may also be relevant to conditions where dams or other channel alterations create stagnate, poorly oxygenated water.

Percentage of valves belonging to species that require high oxygen. As above, except these species require high levels of oxygen (Van Dam et al., 1994).

Percentage of valves belonging to eutrophic species. Trophic state relates to the presence of inorganic nutrients such as nitrogen, phosphorus, silica and carbon. Eutrophic species thrive in condition where inorganic nutrients are high, for example, when fertilizer is present (Van Dam et al., 1994).

Percentage of valves belonging to nitrogen heterotrophic species. Diatoms classified as nitrogen heterotrophs can use amino acids created by other organisms as sources of carbon and nitrogen. They therefore tolerate and thrive in conditions where nitrogen is abundant, for example, due to fertilization (Van Dam et al., 1994).

Percentage of valves belonging to polysaprobic species. Polysaprobic species thrive in condition where biodegradable organic matter is readily available and oxygen concentrations are low. Organic enrichment associated with untreated sewage would increase saprobity (Van Dam et al., 1994).

Percentage of valves belonging to alkaliphilic species. Many diatoms are known to be specifically sensitive to acidic or alkaline conditions. Construction or agriculture on alkaline soils can erode soils and may increase alkalinity. Irrigation and fertilization can also increase soil alkalinity (Van Dam et al., 1994).

Percentage of valves belonging to motile genera. Motile diatoms tolerate silt because they can move across unstable substrates without being buried. We expect them to increase as sediment increases. Motility of diatom genera were assigned by R. J. Stevenson, Michigan State University (personal communication, June 2000). Motile genera included *Cymatopleura*, *Gyrosigma*, *Hantzschia*, *Nitzschia*, *Stenopterobia*, and *Surirella*.

Percentage of deformed valves. Cell deformities have been associated with contamination by heavy metals caused by hard rock mining (McFarland et al., 1997). Diatoms seem to be particularly sensitive to zinc which is found in relatively high concentrations in urban streams due to automobile brake linings and other industrial sources.

Appendix III. Shown for invertebrate samples are stream site, disturbance rank, B-IBI, total taxa, number of mayfly, stonefly, caddisfly, intolerant, clinger, and long-lived taxa, percentages of tolerant taxa and predators, and percentage dominance for 1998 and 2001 sampling events.

Site	Dist. rank	B-IBI 1998	2001	Taxa 1998	2001	Mayfly 1998	2001	Stonefly 1998	2001	Caddisfly 1998	2001	Intolerant 1998	2001
CoalMine	5	32	18	47.3	24.0	5.3	3.0	5.0	2.7	7.0	2.7	1.0	0.3
CoalTrail	5	30	20	45.3	28.0	4.7	3.0	4.0	2.3	6.0	2.7	0.3	0.3
CoalNCTB			22		29.7		1.3		2.3		4.0		0.0
CoalPkwy	7	22	16	38.7	26.0	3.3	1.0	4.3	2.3	5.3	3.0	0.0	0.0
KelByrne	11	20	16	26.0	21.3	1.7	1.0	1.0	0.0	1.3	1.3	0.0	0.0
KelWeirs	14	12	10	22.7	14.3	1.0	1.0	0.0	0.0	1.0	0.3	0.0	0.0
KelGCfb	13	12	10	20.0	14.3	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0
KelGCwd	13	16	16	25.0	20.3	1.7	1.0	0.3	0.0	1.7	0.3	0.0	0.0
KelTrstl	17	16	18	26.0	25.0	1.0	1.3	0.0	2.0	1.0	1.7	0.0	0.0
GoffUsBp	13	10	14	16.0	15.7	1.7	1.0	0.0	0.0	0.3	0.3	0.0	0.0
GoffInBp	9	18	16	21.7	22.7	1.7	1.0	0.3	0.0	1.7	1.3	0.7	0.3
GoffDsBp	13	16	14	20.0	19.5	2.5	1.5	0.0	0.0	0.5	0.5	1.0	0.0
Lewis	8	24	22	42.3	27.0	2.0	1.7	2.7	3.7	7.3	5.0	1.0	1.0
Richards	12	16		28.0		1.7		0.0		1.7		0.0	

Appendix III. Continued.

Site	Clinger		Long lived	% Tolerant		% Pred.		% Dom.		
	1998	2001	1998	2001	1998	2001	1998	2001	1998	2001
CoalMine	15.3	7.7	4.3	4.0	29.8	45.9	9.8	2.1	41.2	68.5
CoalTrail	14.7	8.7	4.7	3.3	27.8	15.0	5.4	1.5	51.5	54.7
CoalNCTB		10.7		4.3		28.5		2.6		58.9
CoalPkwy	11.7	8.0	4.0	3.3	65.0	59.0	5.0	1.6	69.9	69.9
KelByrne	4.7	4.0	2.7	1.3	36.1	26.1	13.5	2.5	62.9	68.2
KelWeirs	5.7	3.0	0.3	0.3	93.4	68.2	1.0	0.2	82.0	85.9
KelGCfb	4.3	3.3	0.0	0.3	85.6	71.9	0.6	0.1	90.8	84.0
KelGCwd	5.7	3.7	1.0	1.3	46.4	38.4	1.9	1.2	56.7	64.5
KelTrstl	6.0	6.0	0.0	2.3	46.2	26.5	1.5	3.0	62.5	62.9
GoffUsBp	2.3	1.3	0.3	0.0	50.5	47.7	0.0	0.1	86.0	73.2
GoffInBp	4.3	3.3	2.7	1.0	29.6	30.8	1.1	0.7	70.3	50.8
GoffDsBp	5.5	5.0	2.5	2.5	44.9	39.4	2.1	1.1	79.5	80.6
Lewis	15.0	10.3	5.3	3.0	57.7	43.1	4.5	2.1	69.0	75.5
Richards	7.0		1.7		44.7		7.5		64.4	

Appendix IV. Shown for diatom sample are site name, visit number, whether the site was part of an upstream/downstream pair, number of valves, number of species, percentages of individuals that belong to species that are intolerant, tolerant, alkaliphilic, salt tolerant, nitrogen heterotrophic, requiring high oxygen, tolerant of low oxygen, polysaprobic, eutrophic, and motile and percentage of deformed individuals.

Site	Visit	Compare	Valves	Taxa	% Int	% Tol	% Alka	% Salt	% Nhet	% Hi ox	% Lo ox	% P sap	% Eutr	% Mot	% Def
CoalMine	1	x	836	38	66.3	2.8	75.5	12.8	15.4	50.1	4.2	2.9	71.2	12.6	0
CoalTrail	1	x	1001	32	56.3	4.1	88.8	17.2	16.1	55.8	7.7	17.0	75.3	14.0	0
CoalTrail	2	x	953	43	54.2	2.0	88.3	28.4	14.7	55.4	10.9	4.6	80.3	19.1	0
CoalNCTB	1	x	831	47	35.1	3.2	88.6	38.8	14.8	32.6	5.2	11.7	76.3	14.2	0.12
CoalNCTB	2	x	884	53	55.5	4.1	83.9	26.7	13.4	52.4	10.5	4.3	78.1	17.9	0
CoalPkwy	1	x	811	34	76.9	2.3	92.0	12.6	7.8	40.1	4.6	7.2	85.8	8.0	0.13
CoalPkwy	2	x	815	42	79.8	2.7	89.0	11.8	8.0	37.6	3.9	3.2	86.1	8.7	0
GoffUsBp	1	x	808	25	40.3	9.7	78.3	0.5	9.7	43.1	9.7	9.9	81.6	1.6	0
GoffUsBp	2	x	839	36	40.4	4.9	63.7	1.4	5.1	37.9	5.1	4.9	63.4	2.4	0
GoffInBp	1	x	927	37	57.3	10.6	74.5	1.5	10.6	35.1	10.6	10.5	80.0	4.1	0.22
GoffInBp	2	x	815	42	37.7	12.3	68.0	2.2	14.5	36.9	13.4	12.3	67.6	5.4	0
GoffDsBp	1	x	820	42	54.6	5.1	79.3	4.9	8.1	37.7	6.0	5.0	76.8	4.6	0
GoffDsBp	2	x	848	32	64.6	3.4	76.5	1.3	4.1	44.5	3.7	3.4	67.9	2.1	0.24
Kel148Us	1	u3	583	70	54.2	12.2	48.9	5.7	13.6	59.2	13.4	12.4	35.2	8.8	1.11
Kel148Us	2	u3	815	85	51.8	13.5	50.2	6.4	17.3	56.9	17.2	14.4	37.9	10.7	0.49
Kel148Ds	1	d3	847	74	45.2	15.2	55.0	7.6	16.2	48.6	18.9	15.4	44.5	13.3	1.06
Kel148Ds	2	d3	861	72	44.1	9.2	58.9	9.3	11.2	53.2	13.6	12.0	45.2	15.5	0.23
KelByrne	1	x	673	18	95.1	0.9	60.9	0.3	1.0	34.6	0.9	0.9	61.1	0.5	0
KelNE8Us	1	u4	837	43	42.7	6.7	91.4	26.4	11.2	44.2	26.5	7.4	59.3	39.4	0
KelNE8Us	2	u4	832	32	43.3	2.2	91.5	38.5	3.0	35.5	35.7	2.5	70.4	22.0	0
KelWeirs	1	d4	817	36	51.3	2.8	91.3	20.3	30.5	43.6	7.2	5.1	68.2	23.0	0
KelWeirs	2	d4	843	33	57.1	5.2	78.5	32.3	15.1	42.0	12.1	5.2	79.4	23.4	1.44
KelGCfb	1	x	992	37	20.7	11.4	83.1	16.3	38.2	19.0	14.6	16.5	78.0	16.7	0
KelGCfb	2	x	807	35	63.8	6.8	73.7	7.7	10.7	39.7	8.7	7.6	66.5	13.8	0.25

Site	Visit	Compare	Valves	Taxa	% Int	% Tol	% Alka	% Salt	% Nhet	% Hi ox	% Lo ox	% P sap	% Eutr	% Mot	% Def
KelGCwd	1	x	827	50	38.2	2.1	87.1	12.8	40.8	34.2	20.9	18.3	74.6	16.3	0
KelGCwd	2	x	907	27	71.9	1.0	79.7	3.2	6.2	43.8	4.4	9.5	71.1	4.9	0.33
KelTrstl	1	x	908	57	56.2	5.0	74.7	4.5	26.4	54.3	8.0	6.9	38.8	6.8	0
KelTrstl	2	x	1118	64	49.0	2.9	56.7	10.0	8.0	52.5	5.1	3.9	44.7	8.1	0.09
Lewis	1	u1	837	24	73.5	3.8	83.9	14.3	16.1	64.0	4.9	3.8	82.3	13.4	0.97
Lewis	2	u1	831	34	76.3	3.1	83.3	13.4	14.1	63.1	3.4	3.4	84.8	12.9	0
LewisDs	1	d1	957	25	74.0	1.5	71.0	15.1	12.2	74.3	2.9	1.0	36.9	45.9	0
LewisDs	2	d1	836	27	70.7	1.1	79.6	24.0	11.5	70.8	8.5	0.8	42.8	48.4	0
YarrUs	1	u2	878	54	41.9	7.6	73.2	12.8	10.6	28.4	14.8	7.6	65.3	8.1	0.46
YarrUs	2	u2	888	64	47.7	10.4	70.6	8.1	18.6	43.2	13.1	11.3	56.0	10.7	0.23
YarrDs	1	d2	838	60	49.5	11.5	67.8	8.5	14.2	41.2	17.8	11.7	64.0	10.3	0
YarrDs	2	d2	866	59	51.5	7.9	72.5	8.1	15.9	42.0	12.8	9.9	59.0	10.2	0