BIOLOGICAL ASSESSMENT OF STREAM SITES IN THE CITY OF BELLEVUE, BASED ON MACROINVERTEBRATE ASSEMBLAGES

Report to the City of Bellevue, Washington
Utilities Department
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INTRODUCTION

Recent evidence indicates that even moderate increases in urban development have surprisingly profound effects on the physical integrity of rivers and streams. In a landmark study, Booth and Johnson (1997) demonstrated that the stability of stream channels in King County was threatened when basins contained as little as 10% total impervious surface area, such as roads and rooftops. In the major stream basins of the City of Bellevue, impervious surface area is estimated to range from about 14% to over 44%.

Impervious surfaces in cities and suburbs influence not only the physical structure of stream channels, but the chemical quality of water, and the function of riparian zones as well. These destructive changes are primarily associated with the rapid runoff of stormwater, when precipitation no longer percolates through absorbent soils. Large volumes of water rush to streams through storm drains and gutters, altering natural flow regimes that once were finely balanced with the morphology of the channel. Flooding and scouring events are more frequent and more severe, and these result in the erosion of streambanks, widening of channels, and downcutting. Engineering solutions to floods usually involve altering natural channel morphology; these interventions result in monotonous channel features and the loss of sinuosity, which in turn causes water to surge even faster downstream.

When runoff replaces natural percolation of rainwater into soils, the result is a loss of groundwater recharge. Consequently, base flow in streams may be severely diminished, resulting in warmer water temperatures and even periodic dewatering.

Sediment enters channels from runoff and from eroding streambanks and downcutting. This sediment degrades and destroys the natural diversity of substrates in the streambed. Gravels and cobbles become embedded and cemented in place by fine sediment particles; the spaces in between the pebbles and stones become clogged.

Water quality is also profoundly affected by urban runoff as sediment and chemicals are rinsed from impervious surfaces directly into streams and rivers. Toxic metals in various concentrations are almost always present in urban runoff (USEPA 1983), and pesticides, motor oils, fuels, and other organic compounds are also typical pollutants. Nutrient enrichment and eutrophication result from chemical fertilizers and waste from pets and other animals in runoff, as well as from leaky sewers and septic systems.

Riparian zones support vegetation that shades streams, helping to keep water temperatures cool and supplying leaf litter and woody debris to the channel. Riparian soils are natural filtration areas that typically cleanse percolated water on its way to streams. However, storm drainage networks allow rainwater to bypass riparian filtration. Erosion of streambanks caused by catastrophic flows may decrease the width of riparian zones. In addition, urban development often is accompanied by the replacement of functioning riparian vegetation with lawns or impervious surfaces.

Physical changes to stream morphology and chemical and thermal changes to water quality have profound consequences for aquatic biota. These disruptions result in direct mortality of fish and invertebrates, and indirect mortality due to habitat destruction, shifts in available food resources, and disruption of life cycles.

Aquatic invertebrate communities, comprised of aquatic insects, snails, worms, clams and other organisms, are particularly vulnerable to the habitat disruption and water quality degradation that accompanies urbanization. These animals depend on cold, unpolluted water, natural flow regimes, and diverse, clean benthic substrates to complete their life cycles. Less motile than fish, invertebrates cannot easily escape stressors like pollution or habitat disturbance. In well-functioning streams, aquatic invertebrates live on and under cobbles and gravels. Some cling tightly to these surfaces or feed by scraping algal films from the rocks; when substrates are smothered by sediment, these animals cannot survive. When nutrients create blooms of filamentous algae, dissolved oxygen may become unavailable, especially during nighttime, when plants respire. Sediments may become hypoxic and uninhabitable by all but the most tolerant invertebrates. Riparian vegetation not only provides temperature-regulating shade, but the leaf litter and woody debris they provide are important food sources for many invertebrate species.

Some pollutants, such as heavy metals or pesticides, are directly poisonous to invertebrate animals, and can extirpate many taxa. Catastrophes such as runoff tainted by toxic chemicals, periods of dewatering due to drought or irrigation diversions, or an intense scouring event can result in mortality. Repetitions of such occurrences lead to a depauperate invertebrate fauna.

Changes to habitat and water quality inevitably results in changes to the aquatic invertebrate community; in many cases, the alterations to the biota are fairly specific and predictable. Thus, aquatic invertebrate communities are important indicators of water quality and habitat integrity. In addition to their usefulness as indicators, aquatic invertebrates are also a critical link in food chains that support fish, in particular, insectivorous fish such as salmon. When their environments are stressed, aquatic invertebrate communities exhibit lower diversity, loss of sensitive taxa, dominance by tolerant taxa, disruption of functional balance, blooms of “weedy” or short-lived taxa and other symptoms of stress.

This report summarizes and analyzes data from 7 years of benthic invertebrate collections from 11 sites on 5 streams in the City of Bellevue between 1998 and 2007. The objectives of the study include using the invertebrate biota to detect impairment to biological health, using 2 assessment tools: the B-IBI (Benthic Index of Biological Integrity) (Kleindl 1995, Fore et al. 1996, Karr 1998), a battery of 10 biological metrics (Table 1) which has been calibrated for streams of the Pacific Northwest, and a predictive model (RIVPACS – the River InVertebrate Prediction and Classification System) developed by the Washington Department of Ecology (WADOE). RIVPACS compares the occurrence of taxa at a site with the taxa expected at a similar site with minimal human influence, and yields a score that summarizes the comparison. These assessment tools provide a summary score of biological condition, and the B-IBI can be translated into biological health condition classes (i.e., excellent, good, fair, poor, and very poor) based on ranking criteria used by King County (King County 2008a).

This analysis further seeks to identify associations between a measure of urbanization, the percent impervious area, and B-IBI scores, RIVPACS scores, individual B-IBI metrics and other metric expressions of invertebrate assemblage characteristics. In addition, the report identifies probable stressors which may account for diminished stream health, basing these observations on demonstrated and expected associations between patterns of response of B-IBI metrics and other metric expressions, as well as the taxonomic and functional composition of the benthic assemblages. The analysis examines common stressors associated with urbanization: water quality degradation, changes to natural thermal regimes, loss and impairment of instream habitats due to sediment deposition and altered flow regimes, and disturbance to reach-scale habitat features such as streambanks, channel morphology, and riparian zone integrity.

Table 1. The 10 metrics of the B-IBI and their predicted response to increasing impairment.

Metric	Predicted response to impairment
Mayfly taxa richness	Decrease
Stonefly taxa richness	Decrease
Caddisfly taxa richness	Decrease
Intolerant or sensitive taxa richness	Decrease
Percent tolerant taxa	Increase
Percent predators	Decrease
3 dominant taxa percent	Increase
Clinger taxa richness	Decrease
Long-lived taxa richness	Decrease
Total taxa richness	Decrease

METHODS

Sampling

The City of Bellevue provided oversight for the collection of aquatic invertebrates from 11 sites on 5 streams between 1998 and 2007. The City's standard procedure for sampling is reprinted in Appendix A. Table 2 summarizes the sampling history for each drainage and each site, and Figure 1 maps the drainage and site locations. For each sampling event, 3 or, in some cases, 2 replicate samples were taken at each site using a Surber sampler. Samples were processed and invertebrates identified by contracted taxonomy laboratories.

Data adjustments

The sample processing method used in 1998 differed from that of any other year: all organisms in 1998 sample replicates were taxonomically identified, while in other years, subsamples of 500 - 700 organisms were randomly selected for identification. To make the data from 1998 samples comparable to data from subsequent years, sample sizes were

Table 2. History of macroinvertebrate sampling events at sites on 5 streams in the City of Bellevue, 1998 - 2007.

Drainage	Site	1998	2001	2002	2003	2005	2006	2007
Coal Creek	RM 4.0	•	•	•		•	•	•
	RM 2.3	•	•	•		•	•	•
	RM 1.8	•	•	•				
Goff Creek	RM 1.7	•	•	•				
	RM 1.6	•	•	•				
	RM 1.4	•	•	•				
Kelsey Creek	RM 3.9	•	•	•		•	•	
	RM 1.8	•	•	•		•	•	
Lewis Creek	RM 1.8				•	•		•
	RM 0.8	•	•	•	•	•	•	•
	RM 0.3					•	•	•
Valley Creek	RM 0.2					•	•	

standardized. Sample data collected in 1998 was adjusted by electronic subsampling using a tool (Subsample.exe) developed by scientists at The Western Center for Monitoring and Assessment of Freshwater Ecosystems at Utah State University (Utah State University 2008(b). Five random subsamples were electronically generated from each sample replicate, and metrics, indices, and RIVPACS scores were calculated for each resulting electronic subsample. To obtain a single value or score for each replicate, the five results were averaged. As a result of averaging, some B-IBI metrics yielded fractional values.

Problems with inconsistency in the taxonomic resolution applied to midges (Diptera: Chironomidae) were rectified. In some years, the specimens in this group were identified to genus, species, or species group; in most years, however, they were left at family. Resolution for the midges was raised to family level for all years' data.

A database application (RIALIS v2.1– Rhithron Associates, Inc.) was used to recalculate all B-IBI metrics and scores. This assured that individual taxon attributes were assigned consistently, and that metrics were scored the same way throughout the project. Taxa attributes were generally in agreement with those assigned by King County (King County 2008b); however, there were a few exceptions in the assignment of attributes relative to functional feeding groups and tolerance.

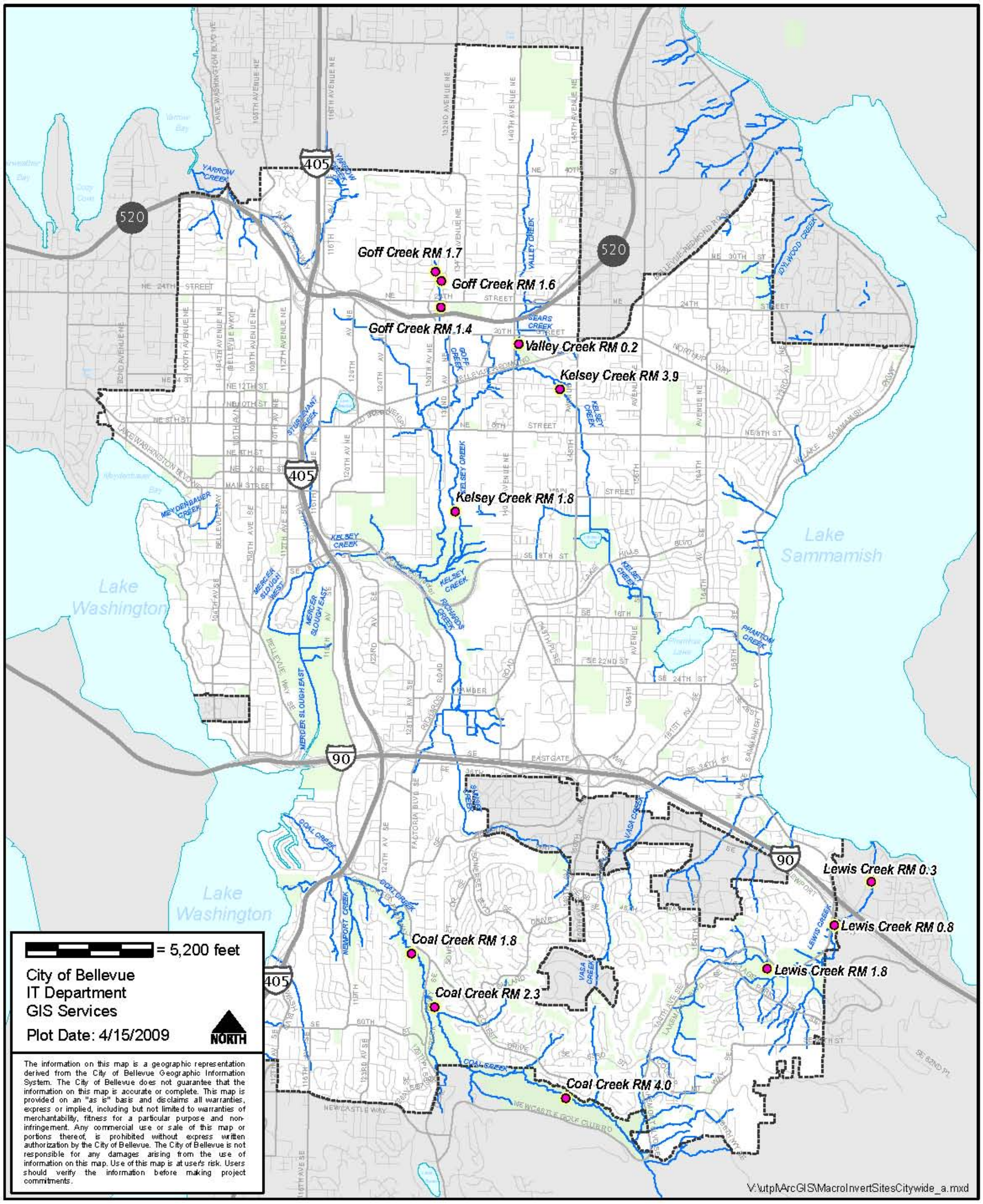

Figure 1. Major drainages and the location of macroinvertebrate sampling sites in the City of Bellevue. 1998 – 2007.

Data analysis

a. Ordination of taxonomic data

The aquatic invertebrate data were explored by means of multidimensional scaling (MDS) (PC-ORD, McCune and Grace 2002), an ordination technique. Replicate sample data were combined into a composite for each sampling event at each site, and relative abundances of taxa were used so that composite sample size did not influence the ordination. Similarities and differences among the benthic assemblages supported at sites and among drainages were examined.

b. Urbanization

The magnitude of urban development influencing each site was calculated from an estimation of the percent of effective (connected) impervious surface area related to each site. Basin boundaries upstream of each site were delineated by City of Bellevue GIS specialists, and all areas draining to a place at or near the sample site were included. Both upstream surface water drainages and all storm water pipes mapped as of November 3, 2008 in the contributing drainage basin were included in the analyses. Effective impervious area values were assigned to each two-foot-by-two-foot area based on a 2007 Digital Terrain Model.

Associations between biological condition as measured by the B-IBI and RIVPACS tools and the percent of impervious surface area were explored. The relationships between individual B-IBI metrics as well as other biological metrics not included in the B-IBI were also evaluated.

c. Analysis of impairment measured by B-IBI and RIVPACS

Comparisons between B-IBI and RIVPACS results were facilitated by the similarity in impairment thresholds for the 2 assessment tools: the impairment threshold for RIVPACS was set by WADOE at 0.73 (WADOE 2006), and the threshold adopted by King County for distinguishing between “good” and “fair” conditions indicated by B-IBI scores is between 72% (B-IBI = 36) and 76% (B-IBI = 38) of maximum score (King County 2008a). In this report, the B-IBI threshold for impairment was considered to be the “good”/“fair” threshold, and 72% (B-IBI = 36) of the maximum score was used for this threshold.

A repeated measures analysis of variance was used to test for differences between years (a random factor) within sites. When significant differences were present, post-hoc tests (multiple t-tests/Fisher’s LSD method) were applied to detect the significantly different years. B-IBI scores for the Valley Creek site were not tested, since scores for the paired replicates did not differ between 2005 and 2006. A t-test for dependent samples was used to test for differences in RIVPACS scores between 2005 and 2006.

d. Narrative ecological analyses

Metric and taxonomic signals for sediment deposition, thermal stress, water quality (including the presence of possible metals contamination), and habitat indicators were investigated and described in narrative interpretations. These interpretations of the taxonomic and functional composition of invertebrate assemblages are based on demonstrated associations between 3 components: assemblage composition, habitat variables, and water quality variables. This information was gleaned from the published literature, the writer's own research and professional judgment, and those of other expert sources (e.g. Wisseman 1998). These interpretations are not intended to replace canonical procedures for stressor identification. Such procedures require substantial surveys of habitat, and historical and current data related to water quality, land use, point and non-point source influences, soils, hydrology, geology, and other resources that were not readily available for this study. Instead, attributes of invertebrate taxa that are well-substantiated in published and unpublished research, and generally accepted by regional aquatic ecologists, are translated into descriptions of probable water quality and instream and reach-scale habitat conditions.

The approach to this analysis uses some assemblage attributes that are interpreted as evidence of water quality and others as evidence of habitat integrity. To arrive at impairment classifications, attributes are considered individually, so information is maximized by not relying on a single cumulative score, which may mask stress on the biota.

Water quality variables are estimated by examining mayfly taxa richness and the Hilsenhoff Biotic Index (HBI) value. Other indications of water quality include the richness and abundance of hemoglobin-bearing taxa and the richness of sensitive taxa. Mayfly taxa richness has been demonstrated to be significantly correlated with chemical measures of dissolved oxygen, pH, and conductivity (e.g. Bollman 1998, Fore et al. 1996, Wisseman 1996). The Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987) has a long history of use and validation (Cairns and Pratt 1993). The index uses the relative abundance of taxa and their associated tolerance values to calculate a score representative of the tolerance of a benthic invertebrate assemblage. Higher HBI scores indicate more tolerant assemblages. In one study, the HBI was demonstrated to be significantly associated with conductivity, pH, water temperature, sediment deposition, and the presence of filamentous algae (Bollman 1998). Filamentous algae is also suspected when certain macroinvertebrates (e.g. LeSage and Harrison 1980, Anderson 1976) are abundant. Nutrient enrichment in streams often results in large crops of filamentous algae (Watson 1988). Hemoglobin-bearing taxa are very tolerant of environments with low oxygen concentrations, since the hemoglobin in their circulating fluids enables them to carry more oxygen than organisms without it. Low oxygen concentrations are often a result of nutrient enrichment in situations where enrichment has encouraged excessive plant growth; nocturnal respiration by these plants creates hypoxic conditions. Sensitive taxa exhibit intolerance to a wide range of stressors (e.g. Wisseman 1996, Hellawell 1986, Barbour et al. 1999), including nutrient enrichment, acidification, thermal stress, sediment deposition, habitat disruption, and other causes of degraded ecosystem health. These taxa are expected to be present in predictable numbers in functioning streams. Sensitive taxa encountered in City of Bellevue samples included the mayfly *Cinygma* sp., caddisflies *Cryptochia* sp. and *Ecclisomyia* sp., stoneflies *Yoraperla brevis*, *Despaxia augusta*, *Kathroperla perdita*, *Paraperla frontalis*, and *Pteronarcys princeps*, and a few others that were only rarely encountered.

Thermal characteristics of the sampled site are predicted by the richness and abundance of cold stenotherm taxa (Clark 1997) which require low water temperatures, and by calculation of the predicted temperature preference of the macroinvertebrate assemblage (Brandt 2001). Hemoglobin-bearing taxa are also indicators of warm water temperatures (Walshe 1947). Dissolved oxygen is associated with water temperature (colder water can hold more dissolved oxygen) and can also vary with the degree of nutrient enrichment. Increased temperatures and high nutrient concentrations can, alone or in concert, create conditions favorable to hypoxic sediments, habitats preferred by hemoglobin-bearers.

Metals sensitivity for some groups, especially the heptageniid mayflies, is well-known (e.g. Clements 1999, Clements 2004, Fore 2003). In the present approach, the absence of these groups in environs where they are typically expected to occur is considered a signal of possible metals contamination, especially when these signals are combined with a measure of overall assemblage tolerance of metals. The Metals Tolerance Index (MTI) (McGuire 1998) ranks taxa according to their sensitivity to metals. Weighting taxa by their abundance in a sample, assemblage tolerance is estimated by averaging the tolerance of all sampled individuals. Higher values for the MTI indicate assemblages with greater tolerance to metals contamination.

The condition of instream and streamside habitats is also estimated by characteristics of the macroinvertebrate assemblages. Stress from sediment deposition is evaluated by caddisfly richness and by clinger richness (Kleindl 1996, Bollman 1998, Karr and Chu 1999). A newer tool, the Fine Sediment Biotic Index (FSBI) (Relyea et al. 2000) is also used. Similar to the HBI, tolerance values are assigned to taxa based on the substrate particle sizes with which the taxa are most frequently associated. Scores are determined by weighting these tolerance values by the relative abundance of taxa in a sample. Higher values of the FSBI indicate assemblages with greater fine sediment sensitivity.

The functional characteristics of macroinvertebrate assemblages are based on the morphology and behaviors associated with feeding, and are interpreted in terms of the River Continuum Concept (Vannote et al. 1980) in the narratives. Alterations from predicted patterns may be interpreted as evidence of water quality or habitat disruption. For example, shredders and the microbes they depend on are sensitive to modifications of the riparian zone vegetation (Plafkin et al. 1989), and the abundance of invertebrate predators is likely to be related to the diversity of invertebrate prey species, and thus the complexity of instream habitats.

RESULTS

a. Ordination of invertebrate assemblages

Results of the ordination study (Figure 2) indicate that Coal Creek and Lewis Creek supported similar invertebrate assemblages, but these were taxonomically distinct from the group of assemblages supported at Goff Creek, Kelsey Creek, and Valley Creek. In the graph, green, purple and yellow symbols represent assemblages collected from the latter group of streams, and red and black symbols represent assemblages collected from Coal and Lewis Creeks.

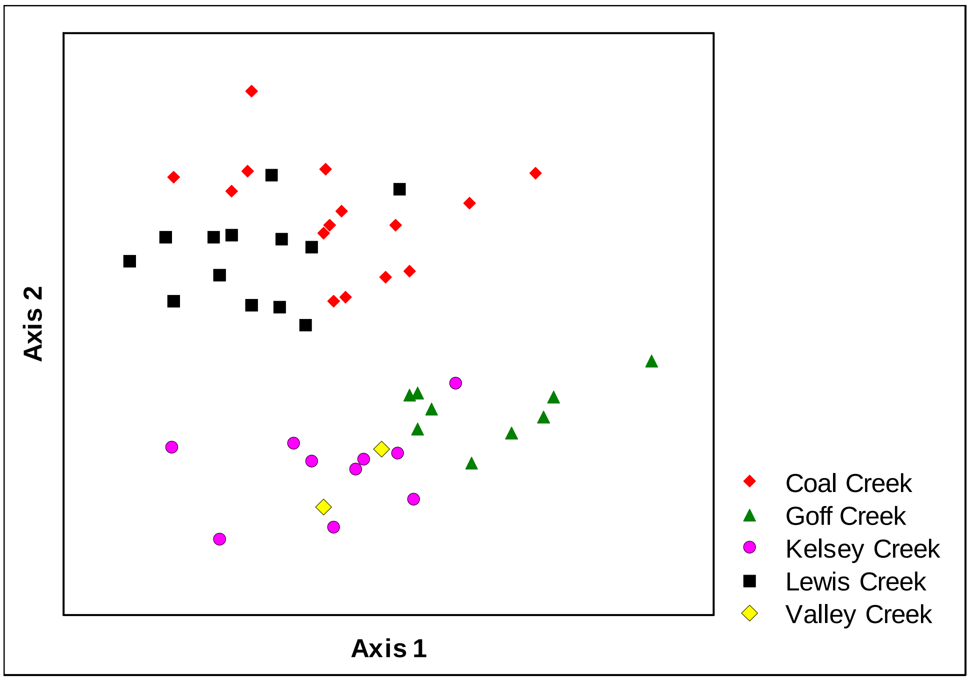

Figure 2. Ordination (MDS) of invertebrate assemblages sampled from City of Bellevue sites 1998 – 2007. Each symbol represents a single site in a single year: thus, symbols represent all of the taxa and their relative abundances from a single composite sample.

The Lewis Creek and Coal Creek assemblages included stoneflies (*Skwala* sp., *Sweltsa* sp., *Despaxia augusta*, and others). Mayflies and caddisflies were more diverse at these sites as well. In contrast, none of the Goff/Valley/Kelsey Creek sites supported any stoneflies in any year. Similarly, *Rhyacophila* spp. were not collected at any of the Goff/Valley/Kelsey sites. Instead, these sites supported more worms, more tolerant snails (Planorbidae), more blackflies (*Simulium* sp.), isopods (*Caecidotea* sp.) and leeches (*Helobdella stagnalis* and others). The Lewis/Coal Creek assemblages included more sensitive taxa and more cold stenotherms. Goff/Valley/Kelsey sites supported simpler, less diverse assemblages.

b. Associations between urbanization and biological characteristics

Both the B-IBI and RIVPACS scores at the City of Bellevue sample sites were significantly correlated with the extent of urbanization as measured by percent impervious surface area. Of the 10 metrics in the B-IBI battery, all but 2 (intolerant taxa richness and percent predators) were significantly associated with urbanization. Table 3 summarizes these results. Of the 11 other biological metrics tested, all but 1 (hemoglobin-bearer richness) was significantly associated with the percent impervious area measure. Table 4 summarizes these relationships for the non-B-IBI metrics.

Table 3. B-IBI scores, RIVPACS scores and individual B-IBI metrics and their associations with percent impervious area: City of Bellevue, 1998 - 2007. Spearman rank correlation coefficients (*r*) and probabilities are given. Correlations were run for all replicates over all years (n = 143 for all tests.)

Metric/Index	Spearman's *r*
Total B-IBI score	-0.39 ***
RIVPACS score	-0.48 ***
Mayfly taxa richness	-0.56 ***
Stonefly taxa richness	-0.40 ***
Caddisfly taxa richness	-0.38 ***
Total taxa richness	-0.33 ***
Intolerant taxa richness	-0.09 n.s.
Long-lived taxa richness	-0.34 ***
Clinger taxa richness	-0.28 ***
Percent predators	0.05 n.s.
Percent 3 dominant taxa	0.18 **
Percent tolerant taxa	-0.16 *

n.s. = not significant
*** $p < 0.10$**
**** $p < 0.05$**
*****$p < 0.001$**

Table 4. Biological metrics other than those included in the B-IBI and their associations with percent impervious area: City of Bellevue, 1998 - 2007. Spearman rank correlation coefficients (*r*) and probabilities are given. Data for invertebrate abundances in samples was not available for samples collected in 2001, 2002, and 2003: otherwise, correlations were run for all replicates in all years (n = 143 for all tests except where indicated.)

Metric	Spearman's *r*
Cold stenotherm richness	-0.14 *
Collector percent	0.28 ***
EPT percent	-0.47 ***
Evenness	0.36 ***
Hemoglobin-bearer richness	-0.03 n.s.
Hilsenhoff Biotic Index	0.29 ***
Margalef D	-0.33 ***
Metals Tolerance Index	0.52 ***
Non-insect percent	0.38 ***
Shannon H	-0.19 **
Abundance of invertebrates in samples	0.25* *(n = 84)*

n.s. = not significant
*** p < 0.10**
**** p < 0.05**
*****p < 0.001**

c. Biological assessments

Table 5 summarizes B-IBI and RIVPACS scores for all replicate samples over the years of study.

B-IBI scores varied from 24% to 72% of the maximum possible score across all City of Bellevue sites in all years. Out of the total of 143 replicate samples, the B-IBI scores for 33% (47 replicates) indicated "very poor" biological conditions. B-IBI scores for 52% of replicates (75) indicated "poor" biological conditions. Scores for 15% of replicates (21) indicated "fair" biological conditions. There were no sites for which B-IBI scores indicated "good" or "excellent" conditions. Thus, impaired biological conditions were indicated for 100% of samples, when B-IBI criteria were applied.

Compared to the B-IBI index, the RIVPACS tool indicated better conditions overall for City of Bellevue sites: scores varied from 0.25 to 0.92. RIVPACS scores indicated impaired biological conditions for 67% of replicates (91), while fully 33% of replicate samples attained scores indicated unimpaired biological condition. Although there was some overlap, both bioassessment tools tended to give higher scores to sites on Coal and Lewis Creeks, while scores for Goff, Valley and Kelsey Creek sites were somewhat lower.

In spite of differences for some samples, total B-IBI scores (transformed so as to be expressed as percent of maximum score) and RIVPACS results were strongly correlated with each other ($r = 0.76$, $p < 0.0001$). Figure 3 illustrates this relationship.

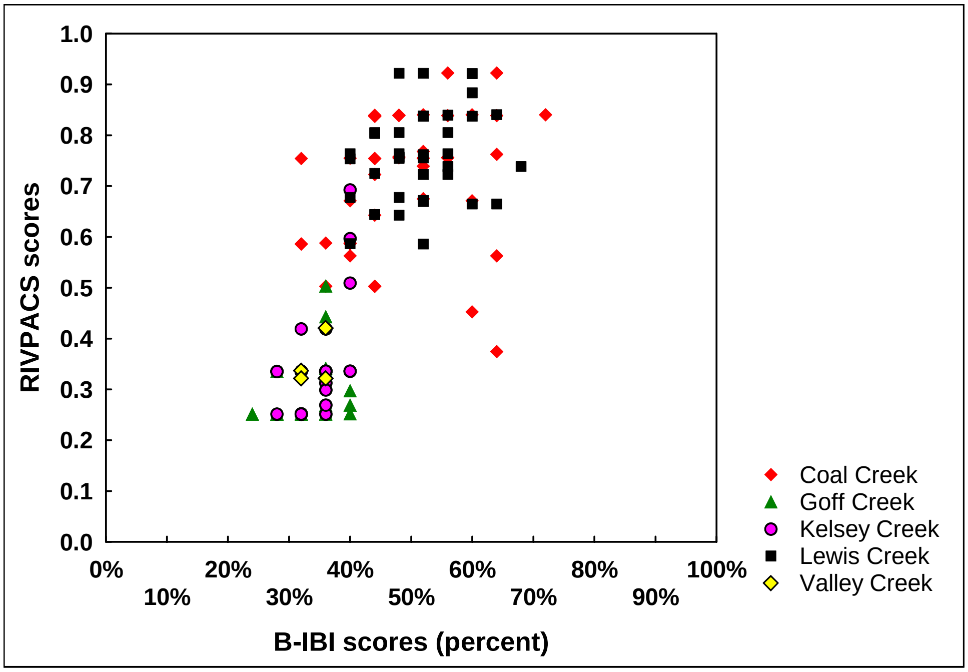

Figure 3. The relationship between total B-IBI scores, expressed as percent of maximum score, and RIVPACS scores for replicate samples from all sampled sites. To facilitate the comparison, B-IBI scores are transformed to percentages. City of Bellevue, 1998 – 2007.

Water-shed	Site	Year	RIVPACS				B-IBI			
			Rep 1	Rep 2	Rep 3	Mean score	Rep 1	Rep 2	Rep 3	Site score
Coal Creek	RM 4.0 Cinder	1998	0.563	0.452	0.375	0.463	32	32	30	32
		2001	0.503	0.838	0.755	0.699	18	22	22	22
		2002	0.754	0.838	0.838	0.810	16	22	22	24
		2005	0.756	0.840	0.840	0.812	28	36	30	26
		2006	0.839	0.755	0.923	0.839	32	26	32	26
		2007	0.672	0.756	0.756	0.728	30	24	28	24
	RM 2.3 Trailhd	1998	0.758	0.768	0.763	0.763	32	26	24	26
		2001	0.503	0.587	0.503	0.531	22	20	22	22
		2002	0.671	0.839	0.587	0.699	20	22	20	24
		2005	0.588	0.840	0.588	0.672	18	26	20	24
		2006	0.923	0.839	0.839	0.867	28	24	28	26
		2007	0.839	0.755	0.839	0.811	24	20	24	24
	RM 1.8 bPark	1998	0.755	0.739	0.675	0.723	26	26	26	26
		2001	0.643	0.562	0.723	0.643	22	20	22	24
		2002	0.587	0.587	0.754	0.643	16	16	22	22
Goff Creek	RM 1.7 Upper	1998	0.312	0.342	0.443	0.366	18	18	18	18
		2001	0.252	0.252	0.252	0.252	16	16	16	18
		2002	0.252	0.252	0.252	0.252	14	12	12	18
	RM 1.6 Bypass	1998	0.252	0.252	0.298	0.267	18	18	20	18
		2001	0.252	0.252	0.336	0.280	20	18	18	20
		2002	0.252	0.252	0.252	0.252	14	14	16	18
	RM 1.5 Lower	1998	0.269	0.269		0.269	20	18		18
		2001	0.336	0.252		0.294	18	14		18
		2002	0.504	0.252	0.336	0.364	18	14	14	18
Kelsey Creek	RM 3.9 Byrne	1998	0.509	0.597	0.693	0.600	20	20	20	20
		2001	0.251	0.335	0.419	0.335	18	16	18	20
		2002	0.251	0.251	0.251	0.251	14	16	16	18
		2005	0.252	0.336	0.336	0.308	16	16	20	18
		2006	0.252	0.336	0.336	0.308	16	16	18	18
	RM 1.8 Glendal	1998	0.313	0.299	0.269	0.294	18	18	18	18
		2001	0.335	0.335	0.252	0.307	16	18	16	18
		2002	0.419	0.335	0.335	0.363	16	14	16	18
		2005	0.251	0.335	0.335	0.307	16	14	14	18
		2006	0.336	0.336	0.336	0.336	20	16	18	20
Lewis Creek	RM 1.8 Upper	2003	0.672	0.756	0.840	0.756	26	26	28	30
		2005	0.665	0.665	0.739	0.690	30	32	34	30
		2007	0.764	0.764	0.764	0.764	24	20	28	24
	RM 0.8 I90	1998	0.723	0.723	0.739	0.728	28	26	28	28
		2001	0.754	0.586	0.670	0.670	20	26	26	28
		2002	0.754	0.587	0.838	0.726	24	20	26	24
		2003	0.838	0.838	0.922	0.866	26	30	30	30
		2005	0.838	0.922	0.922	0.894	26	26	24	26
		2006	0.757	0.841	0.757	0.785	24	32	24	28
		2007	0.677	0.762	0.677	0.705	24	26	20	26
	RM 0.3 Elliott	2005	0.884	0.804	0.643	0.777	30	22	24	26
		2006	0.805	0.805	0.805	0.805	24	28	22	28
		2007	0.645	0.645	0.725	0.672	22	22	22	24
Valley Creek	RM 0.2	2005	0.336	0.421		0.379	16	18		20
		2006	0.322	0.322		0.322	18	16		18

Table 5. RIVPACS and B-IBI scores at City of Bellevue sites in all sampled years. Replicate scores are given, as well as mean RIVPACS scores and B-IBI site scores. To obtain B-IBI site scores, metric values were individually averaged and scored; scores of averaged metric values were summed to obtain site scores.

Macroinvertebrate Sampling Sites

Coal Creek Subbasin

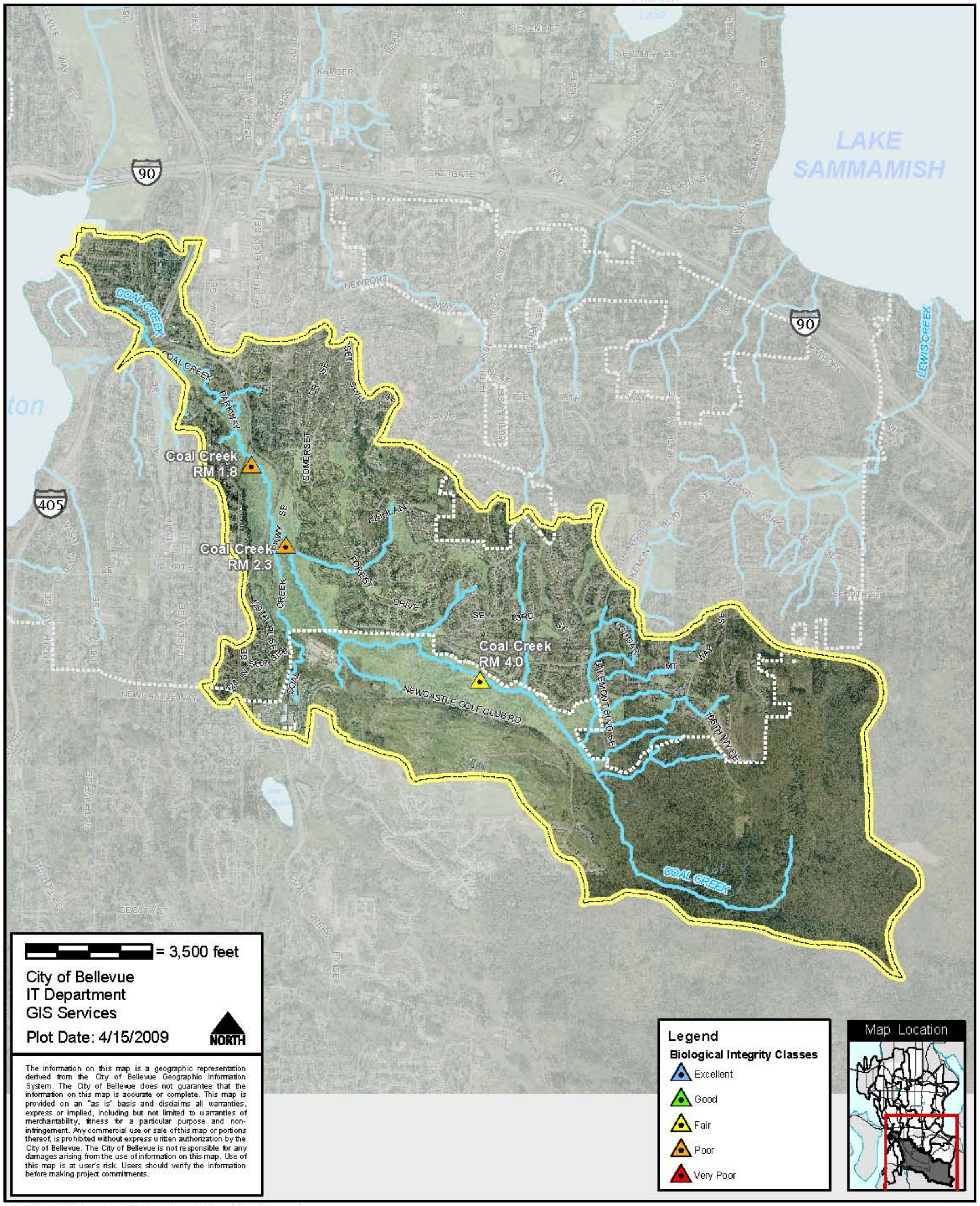

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Figure 4. Coal Creek basin, with 1998-2007 sampling sites. Biological integrity classes based on B-IBI scores (King County 2008a) are indicated by colored triangles.

d. Biological assessments and assemblage characteristics

Coal Creek

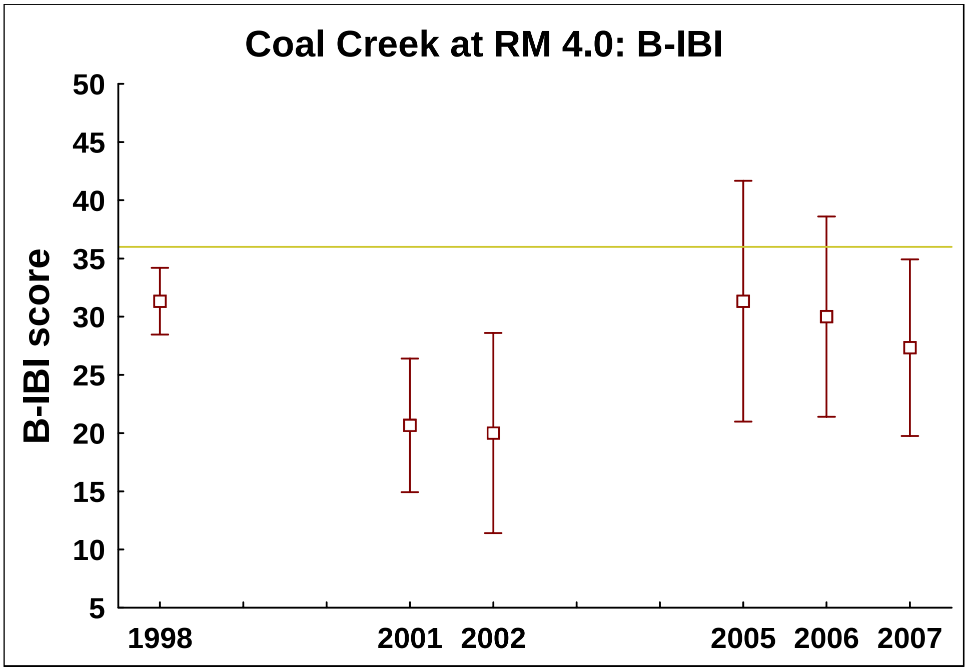
Two sites on Coal Creek were sampled in 6 of the 10 years between 1998 and 2007; a third site was sampled in 1998, 2001, and 2002. Three sample replicates were collected at each sampling event. The map in Figure 4 indicates locations of sites sampled on Coal Creek.

Coal Creek at RM 4.0

1. Bioassessment scores

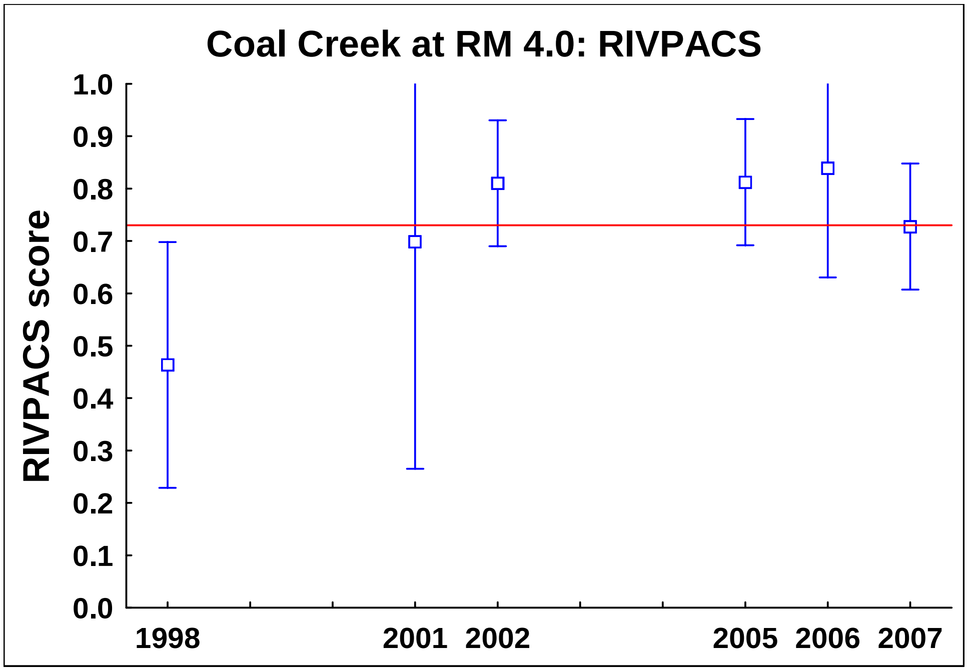
The total B-IBI score (expressed as a percent of maximum score) for sample replicates ranged from 32% to 72% of maximum over the period of study, indicating a range from very poor to fair biological conditions. B-IBI scores were significantly lower ($p = 0.0012$) in 2001 and 2002 compared to other years (Figure 5), and declined slightly between 2005 and 2007. Scores fell below the impairment threshold (below the "good" condition classification, which is represented by the yellow line in Figure 5) most of the time; however, a single replicate attained the threshold value in 2005.

RIVPACS scores ranged from 0.37 to 0.92. While B-IBI scores were generally lower in 2001 and 2002, RIVPACS did not detect worse conditions in those years. Figure 6 demonstrates that RIVPACS scores generally fell above the WADOE threshold for impairment (represented by the red line on the graph). Analysis of variance and post-hoc comparisons indicated a significant difference ($p = 0.004$) between RIVPACS scores in 1998, which were lower than in any other year. There was no significant difference among RIVPACS scores for other years.



Year	Group 1	Group 2
1998		*
2001	*	
2002	*	
2005		*
2006		*
2007		*

Figure 5. B-IBI scores (means and 95% confidence intervals) for Coal Creek at RM 4.0. Three replicate samples were collected in each year of sampling. The yellow line on the graph represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.012$) among years. The table shows the homogeneous groups of mean B-IBI scores resulting from post-hoc tests: B-IBI scores in 2001 and 2002 were significantly lower than scores in all other years. There were no significant differences in B-IBI scores at this site in 1998, 2005, 2006, and 2007.



Year	Group 1	Group 2
1998	*	
2001		*
2002		*
2005		*
2006		*
2007		*

Figure 6. RIVPACS scores (means and 95% confidence intervals) for Coal Creek at RM 4.0. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.004$) among years. The table shows the homogeneous groups of mean RIVPACS scores resulting from post-hoc tests: RIVPACS scores in 1998 were significantly lower than scores in all other years. There were no significant differences in RIVPACS scores at this site in 2001, 2002, 2005, 2006, and 2007.

2. Indicators of ecological condition

a. Water quality

Mayfly taxa richness was lower than expected in all years, and decreased over the study period (Figure 7a). Diversity in this group was highest in 1998, when 6 mayfly taxa were taken in combined replicates; in 2007, only 2 mayfly taxa were collected. This suggests worsening water quality; however, moderately sensitive taxa persisted at the site in all years, such as the caddisfly *Wormaldia* sp. Benthic assemblages were consistently dominated by either the ubiquitous mayfly *Baetis tricaudatus* or by midges.

Metric indicators of water quality not included in the B-IBI battery include the HBI and the MTI. Values for the HBI were lower than the median value for all studied sites, indicating that the site supported a more sensitive assemblage than most studied sites. Values for the MTI over the study period were lower than the median value for all City of Bellevue sites, suggesting that the assemblages collected here were no more metals-tolerant than at most other sites. However, heptageniid mayflies, the bellwether taxa for metals contamination, were not collected at the RM 4.0 site in any year. Other taxa that are considered by some workers to be sensitive to metals, such as the mayfly *Paraleptophlebia* sp. and the stonefly *Sweltsa* sp. were present in all years, and abundant in some years.

b. Thermal condition

The calculated thermal preference for the invertebrate assemblages collected over the study period at the RM 4.0 site ranged from 13.1 to 14.2ºC. One or more cold stenotherm taxa were present in most years, but they were never abundant. These taxa included the stonefly *Despaxia augusta*, which was collected in 4 of the 6 years of sampling, and *Pteronarcys princeps*, which appeared in samples in 2007.

c. Sediment deposition

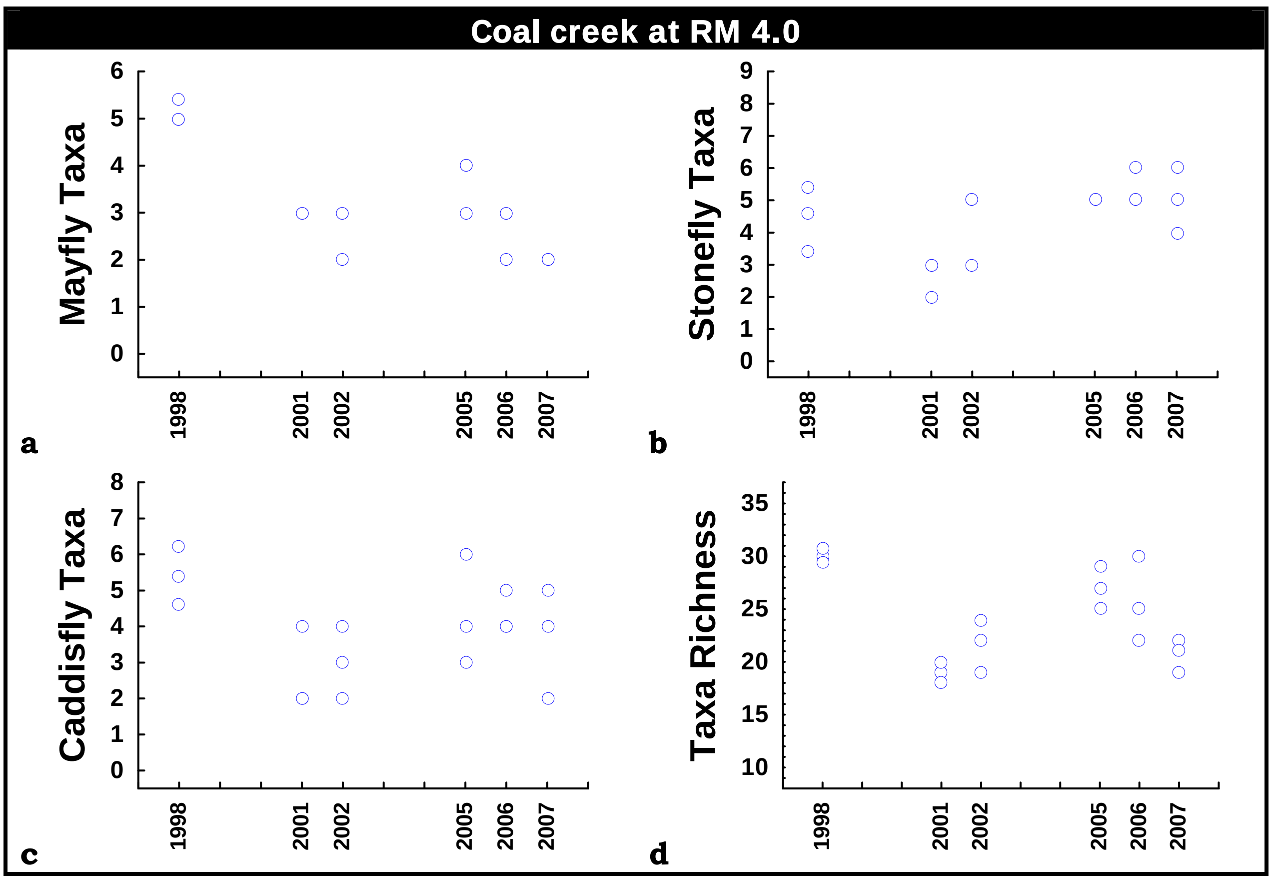
Clinger richness (Figure 7e) was variable over the time period, and was generally lower than expected, suggesting that fine sediment deposition may have limited colonization of stony substrates. The metric displayed a slightly negative trend over the years. Caddisfly richness remained stable in the time period (Figure 7c). In contrast, the FSBI values for the RM 4.0 site trended higher, suggesting improving instream habitat conditions with respect to sediment deposition. Values indicated moderately sediment-tolerant assemblages in all years.

d. Habitat diversity and integrity

Overall taxa richness varied during the study period, but there was a slight negative trend in the number of taxa in sample replicates (Figure 7d); a decline in taxa richness may be related to diminished water quality or loss of instream habitat diversity. Taxa richness was especially low in 2001, 2002 and 2007; diversity in the latter year reversed the positive trend evident in 2005 and 2006. Over the same period, stonefly taxa richness (Figure 7b) exhibited a slight positive trend. Richness in this group may be related to reach-scale habitat features such as streambank stability, riparian zone function, and channel morphology. However, the performance of the stonefly richness metric may also be influenced by changes in water quality.

Semivoltine taxa, which have life cycles that last more than one year, were collected in every year, and richness in the group remained stable (Figure 7g). The elmid beetles (e.g. *Heterlimnius* sp., *Zaitzevia* sp., and others) were important representatives of the group; they were abundant in every year at the RM 4.0 site. Persistence of long-lived organisms at a site implies year-round surface flow, and the absence of periodic catastrophes such as thermal extremes, destructive sediment scours, and toxic pollutants.

Shredders were present in all years, but their small numbers suggest that riparian inputs of large organic material was limited or that hydrologic conditions at the site did not favor retention of this material. Predators increased in abundance over the time period, perhaps indicating improved instream habitat complexity.



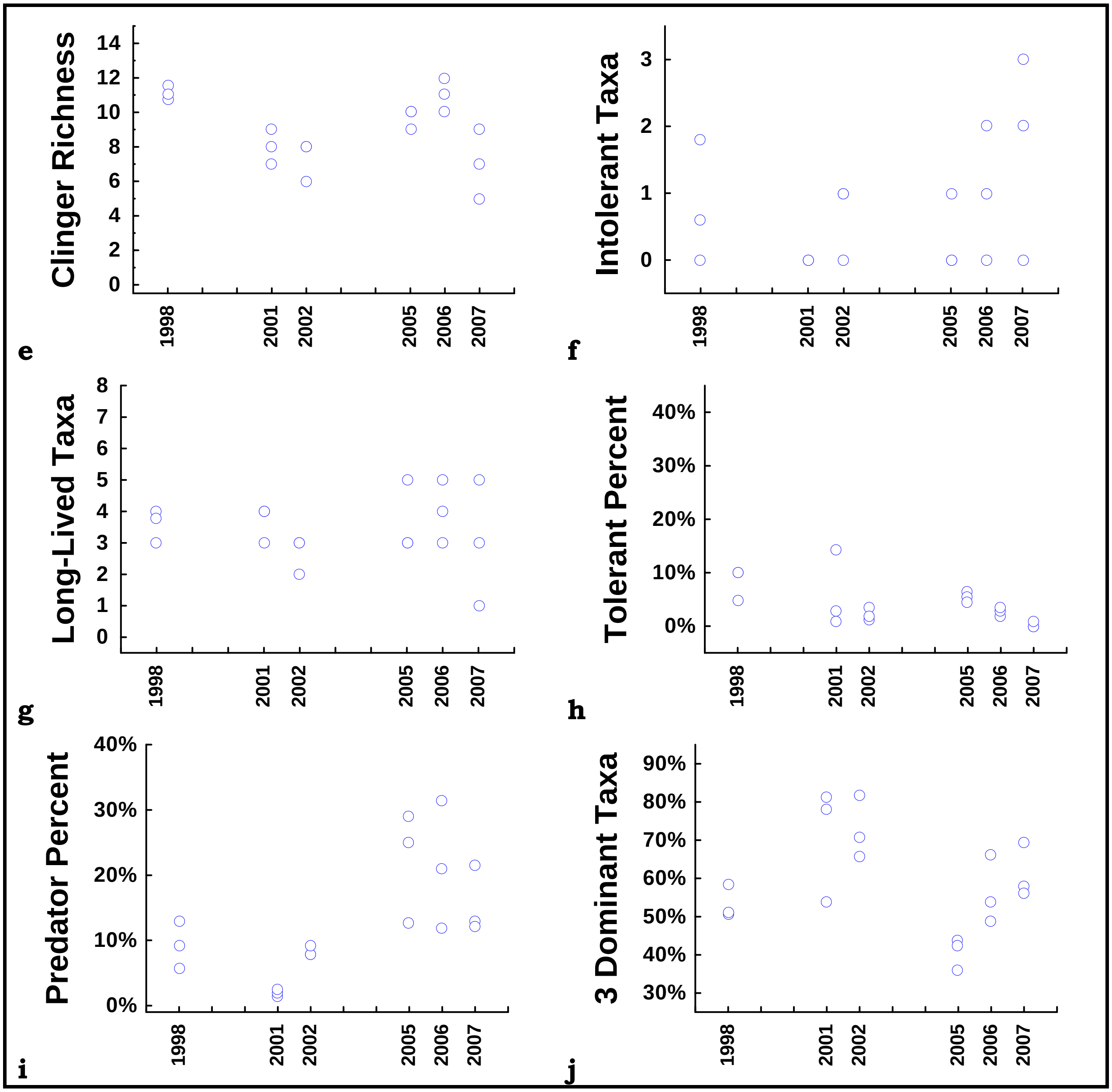


Figure 7 a-j. Performance of B-IBI metrics at Coal Creek RM 4.0. Three replicate samples were collected in each year.

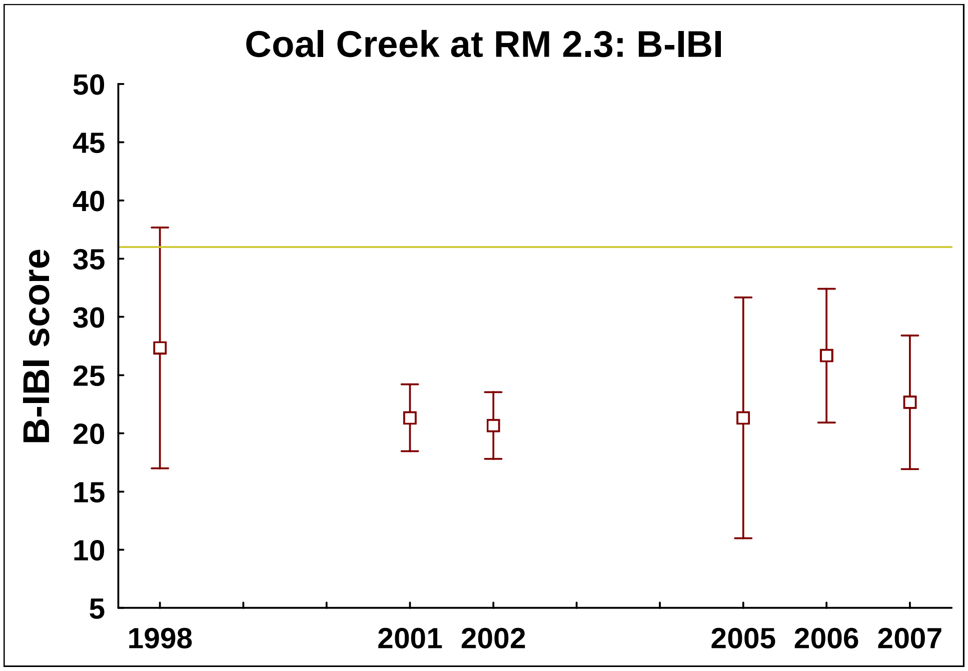
Coal Creek at RM 2.3

The RM 2.3 site was sampled in 6 of the 10 years between 1998 and 2007. Three sample replicates were collected at each sampling event.

1. Bioassessment scores

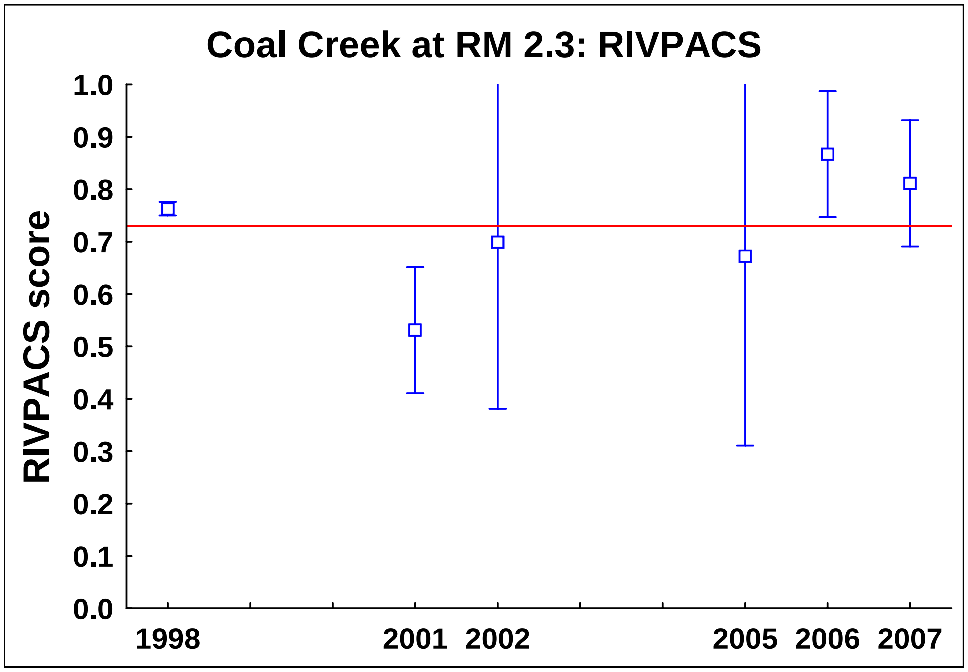
The total B-IBI score (expressed as a percent of maximum score) for replicates ranged from 36% to 56% of maximum over the period of study at Coal Creek at RM 2.3, indicating poor to fair biological conditions. Higher scores in the later years were generally due to small increases in stonefly taxa richness and increasing predator percent. All other individual B-IBI metrics showed negative trends or no trend at all. Repeated measures analysis of variance indicates a significant difference among years ($p = 0.046$), with 1998 and 2006 scoring lower than other years. Figure 8 illustrates the comparison of mean scores, and shows that total B-IBI scores for all replicates in all years were clearly below the impairment threshold.

RIVPACS scores ranged from 0.50 to 0.92, with significant differences among years ($p = 0.007$). RIVPACS scores were lowest in 2001, when all replicates yielded scores below the impairment threshold. RIVPACS scores indicate that this site was unimpaired in 2006 and 2007. Figure 9 illustrates the comparison of mean scores.



Year	Group 1	Group 2
1998	*	
2001		*
2002		*
2005		*
2006	*	
2007	*	*

Figure 8. B-IBI scores (means and 95% confidence intervals) for Coal Creek at RM 2.3. Three replicate samples were collected in each year of sampling. The yellow line on the graph represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.046$) among years. The table shows the homogeneous groups of mean B-IBI scores resulting from post-hoc tests: B-IBI scores in 2001, 2002, and 2005 were significantly lower than scores in all other years. There were no significant differences in B-IBI scores at this site in 1998, 2006 and 2007.



Year	Group 1	Group 2	Group 3
1998	*	*	
2001			*
2002	*		
2005	*		*
2006		*	
2007	*	*	

Figure 9. RIVPACS scores (means and 95% confidence intervals) for Coal Creek at RM 2.3. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.007$) among years. The table shows the homogeneous groups of mean RIVPACS scores resulting from post-hoc tests: RIVPACS scores in 2001 were significantly lower than scores in all other years, and scores in 1998, 2006 and 2007 were significantly higher.

2. Indicators of ecological condition

a. Water quality

Over the study period, mayfly taxa richness declined (Figure 10a), suggesting that water quality deteriorated between 1998 and 2007. Sensitive taxa were rare (Figure 10f). In all recent years, samples were dominated by the ubiquitous mayfly *Baetis tricaudatus*, midges, and the blackfly *Simulium* sp., a compositional pattern suggesting water quality impairment, perhaps related to nutrient enrichment.

The HBI value was consistently lower than the median value for City of Bellevue sites, suggesting that invertebrate assemblages were somewhat less tolerant than those at most other sites. The MTI gave low values in all years, indicating relatively metals-sensitive assemblages. Similar to the RM 4.0 site, the RM 2.3 site did not support heptageniid mayflies. Although *Paraleptophlebia* sp. was prolific in 1998, it was uncommon in all other years. However, the stoneflies *Sweltsa* sp. and *Skwala* sp. were abundant in recent years.

b. Thermal condition

Cold stenotherm taxa were rare in each year in which they occurred. A few specimens of *Despaxia augusta* or *Psychoglypha* sp. were collected in every year except 2006. The calculated thermal preference for assemblages ranged from 13.9 to 14.3ºC.

c. Sediment deposition

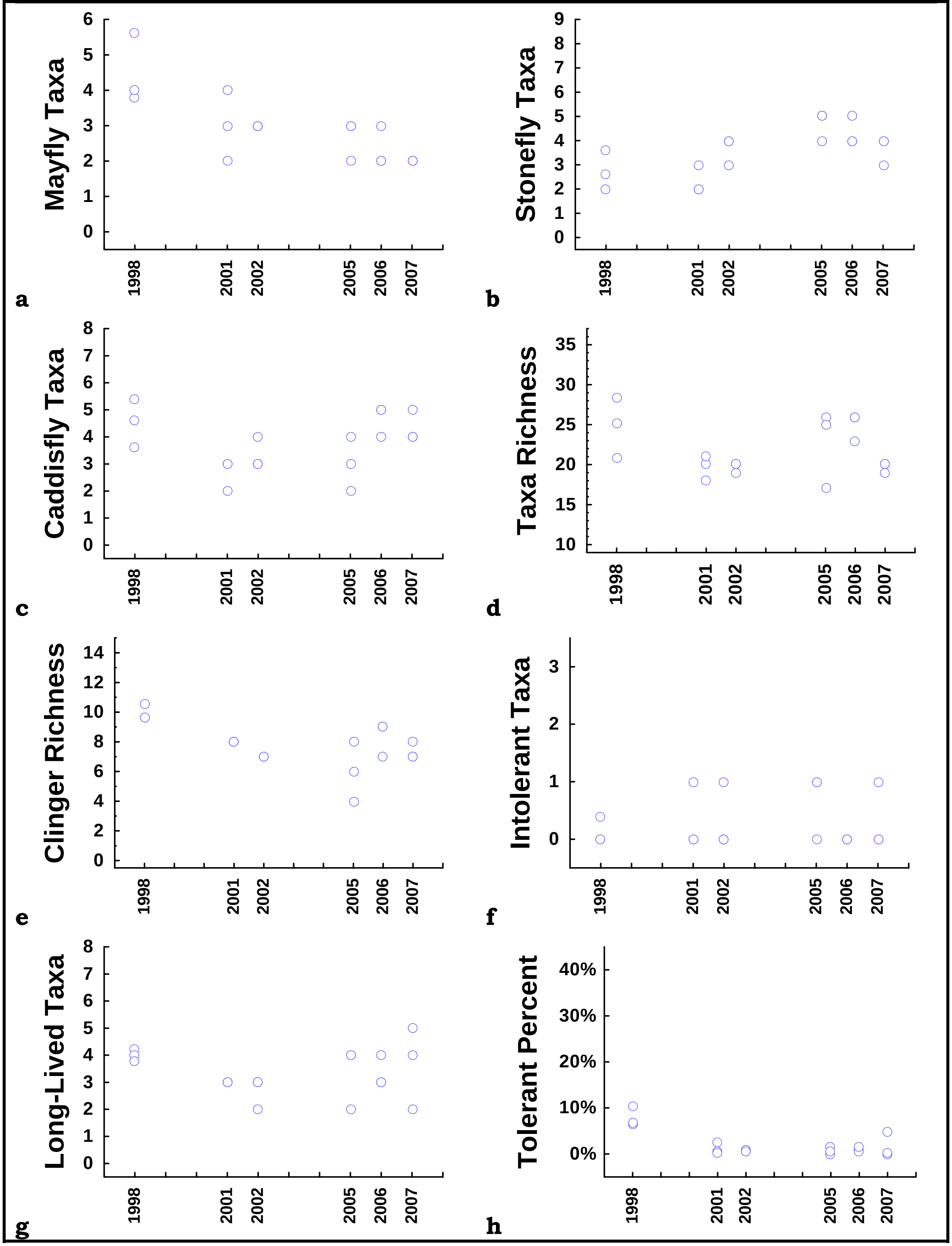
The FSBI value indicates that the RM 2.3 site supported a moderately sediment-tolerant assemblage in every sampled year. Clingers (Figure 10e) were not as diverse here as at the RM 4.0 site. These findings suggest that some fine sediment deposition may have affected instream habitat availability.

d. Habitat diversity and integrity

Similar to the RM 4.0 site, taxa richness at the RM 2.3 location was lower in 2001, 2002 and 2007 than in other years. The variability in taxa richness over the time period suggests that changes in water quality or quantity, or instream habitat conditions may have influenced diversity at these Coal Creek sites. Some improvement in reach-scale habitats over the time period may account for the slowly increasing trend in stonefly taxa richness (Figure 10b). Semivoltine taxa were well-represented in all years (Figure 10g).

Shredder abundance was low in most years, suggesting that large organic material was sparse or not retained in the channel. Riparian inputs may have been limited. Predators were also not as abundant as expected (Figure 10i), suggesting that instream habitats may have been somewhat monotonous.

Coal creek at RM 2.3



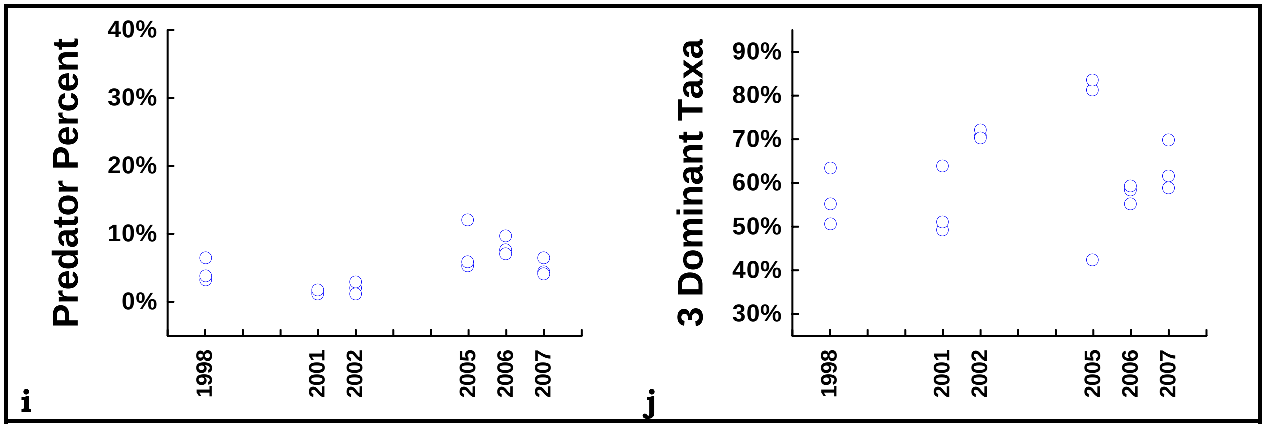


Figure 10a-j. Performance of B-IBI metrics at Coal Creek RM 2.3. Three replicate samples were collected in each year.

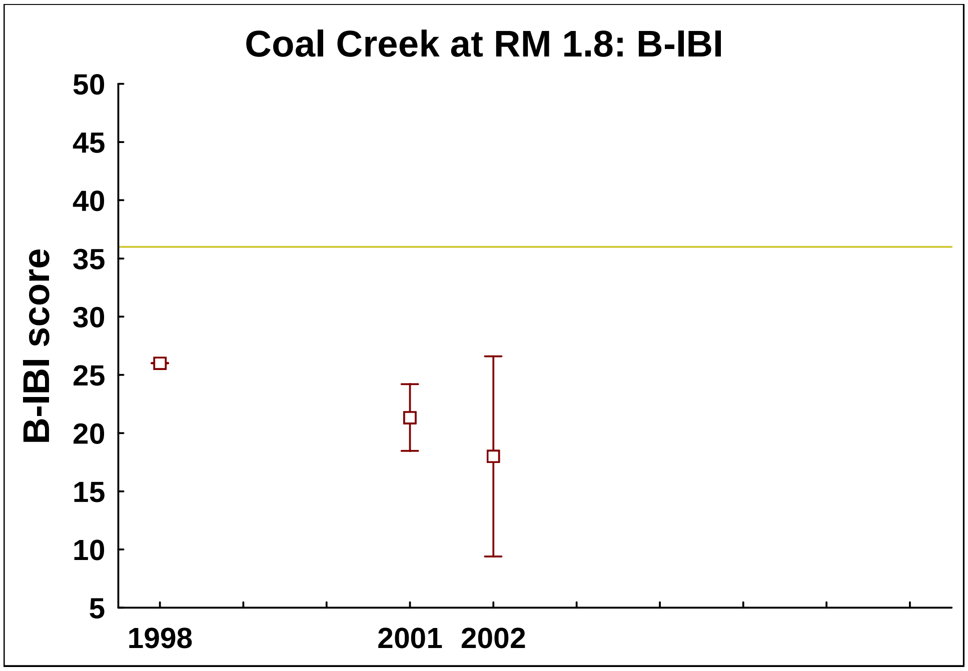
Coal Creek at RM 1.8

Three years of sampling data was available for this site; the most recent sampling year was 2002. Three sample replicates were collected at each sampling event.

1. Bioassessment scores

The total B-IBI score (expressed as a percent of maximum score) for sample replicates ranged from 32% to 46% of maximum over the period of study, indicating very poor to poor biological condition. Higher B-IBI scores in 1998 were significantly different (p = 0.010) from the other 2 years. Replicate scores are graphed in Figure 11. Almost all of the B-IBI metrics yielded low values at this site: only the tolerant taxa percent metric gave values that compared well to the expectations for regional values.

RIVPACS scores ranged from 0.56 to 0.76 (Figure 12), and there were no significant differences among the 3 sampled years (p = 0.390). Some replicates in each year attained scores that indicate unimpaired biological conditions.



Year	Group 1	Group 2
1998	*	
2001		*
2002		*

Figure 11. B-IBI scores (means and 95% confidence intervals) for Coal Creek at RM 1.8. Three replicate samples were collected in each year of sampling. The yellow line on the graph represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.010$) among years. The table shows the homogeneous groups of mean B-IBI scores resulting from post-hoc tests: B-IBI scores in 1998 were significantly lower than scores in all other years. There were no significant differences in B-IBI scores at this site in 2001 and 2002.

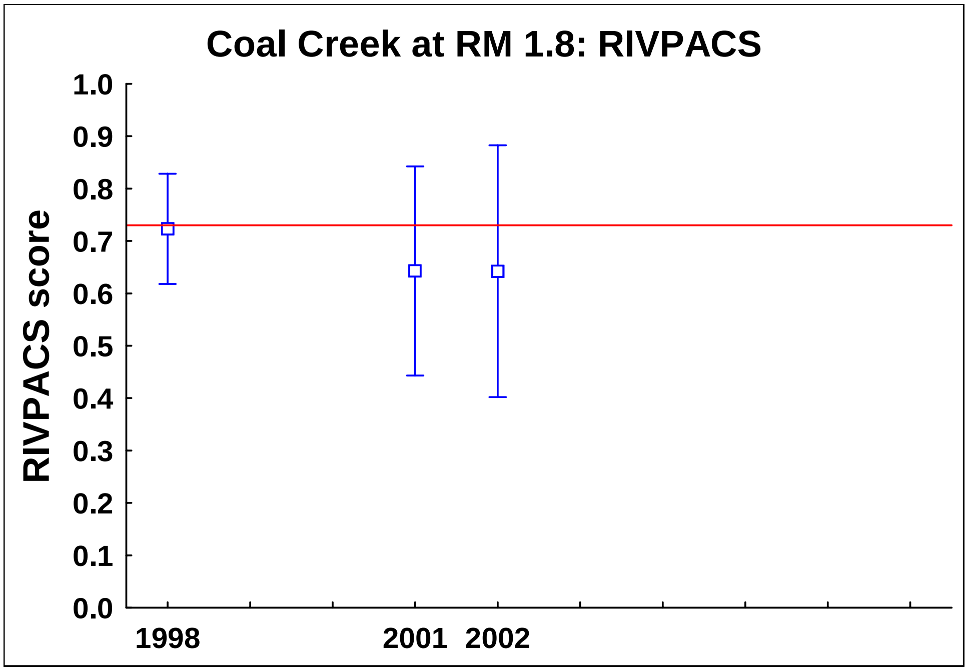


Figure 12. RIVPACS scores (means and 95% confidence intervals) for Coal Creek at RM 0.8. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates no significant differences (p = 0.390) among years.

2. Indicators of ecological condition

a. Water quality

Mayfly taxa richness (Figure 13a) was lower than expected at this site, and declined between 1998 and 2002. Similar to the other Coal Creek sites, the metric gave its poorest performance in 2001, when a single mayfly taxon was collected; this was the ubiquitous *Baetis tricaudatus*. HBI values were lower than the median value for City of Bellevue sites in this study, reflecting the dominance of moderately tolerant organisms at the RM 1.8 site. The MTI values are around the median for all sites. However, neither heptageniid mayflies nor the metal-sensitive *Paraleptophlebia* sp. was collected in any year, and the stoneflies *Sweltsa* sp. and *Skwala* sp. were rare after 1998. Metals contamination cannot be ruled out here.

b. Thermal condition

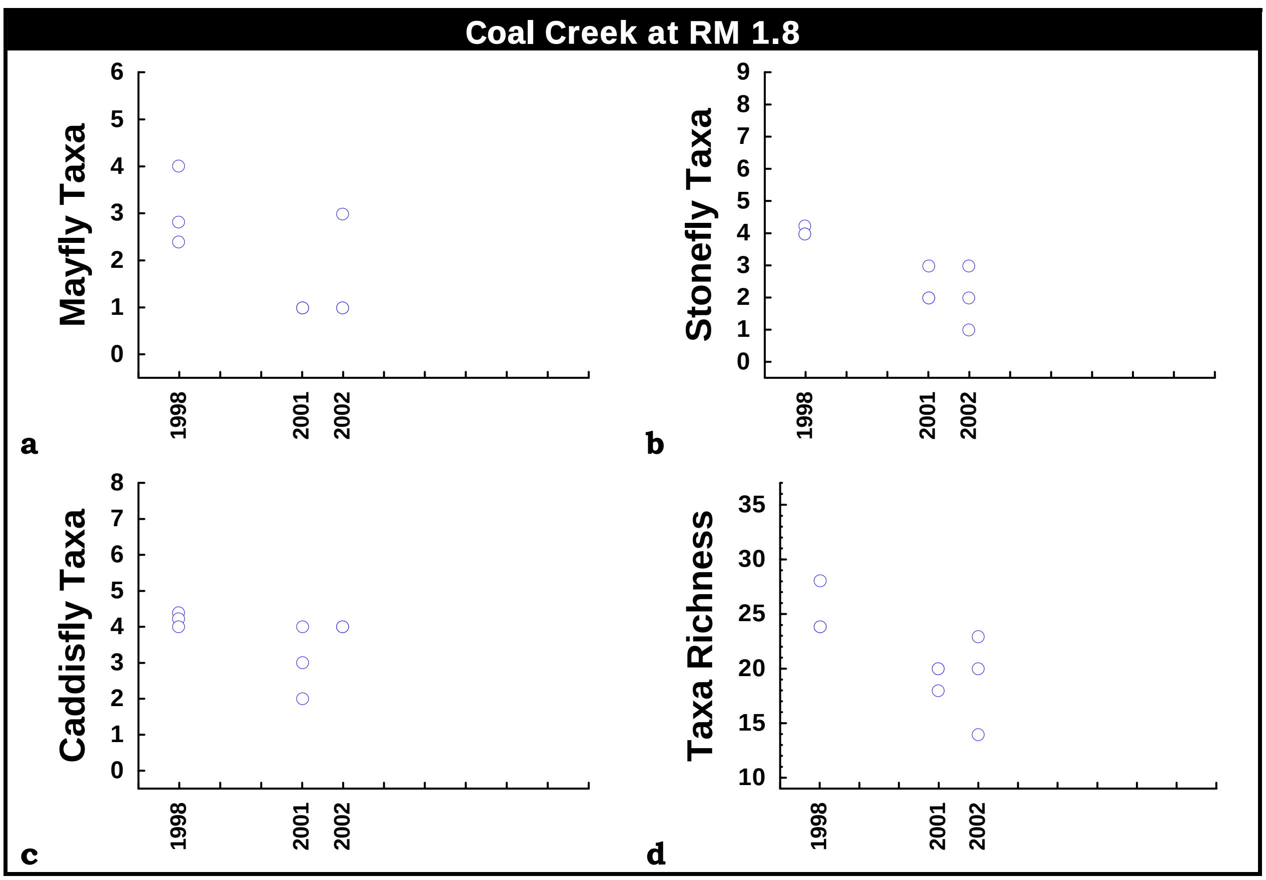
A single specimen of *Despaxia augusta* was collected here in 2002, otherwise, the site was devoid of cold stenotherm taxa. The calculated thermal preference of assemblages ranged from 13.9 to 14.3ºC over the study period.

c. Sediment deposition

The FSBI values indicated that the RM 1.8 site supported moderately sediment-tolerant assemblages. Clinger richness (Figure 13e) was stable between 1998 and 2002, but was somewhat lower than at the RM 2.3 site during those years. Caddisfly taxa richness (Figure 13c) in replicates was also constant over the time period, and was lower than expected. It seems likely that sediment deposition influenced the composition of assemblages at this site.

d. Habitat diversity and integrity

Taxa richness was high at this site in 1998, but declined over 2001 and 2002 (Figure 13d). Instream habitats may have been less diverse because of increased sediment deposition, or hydrologic variation may have influenced the fauna; it is noteworthy that all Coal Creek sites supported fewer taxa in 2001 and 2002. Long-lived taxa (Figure 13g) were diverse and abundant throughout the sampled period, suggesting that dewatering or scouring sediment pulses did not obliterate the fauna during these years. Gatherers dominated the functional composition of samples. Shredders persisted in all years, but they were never abundant, and predators were also not a significant functional component in any year.



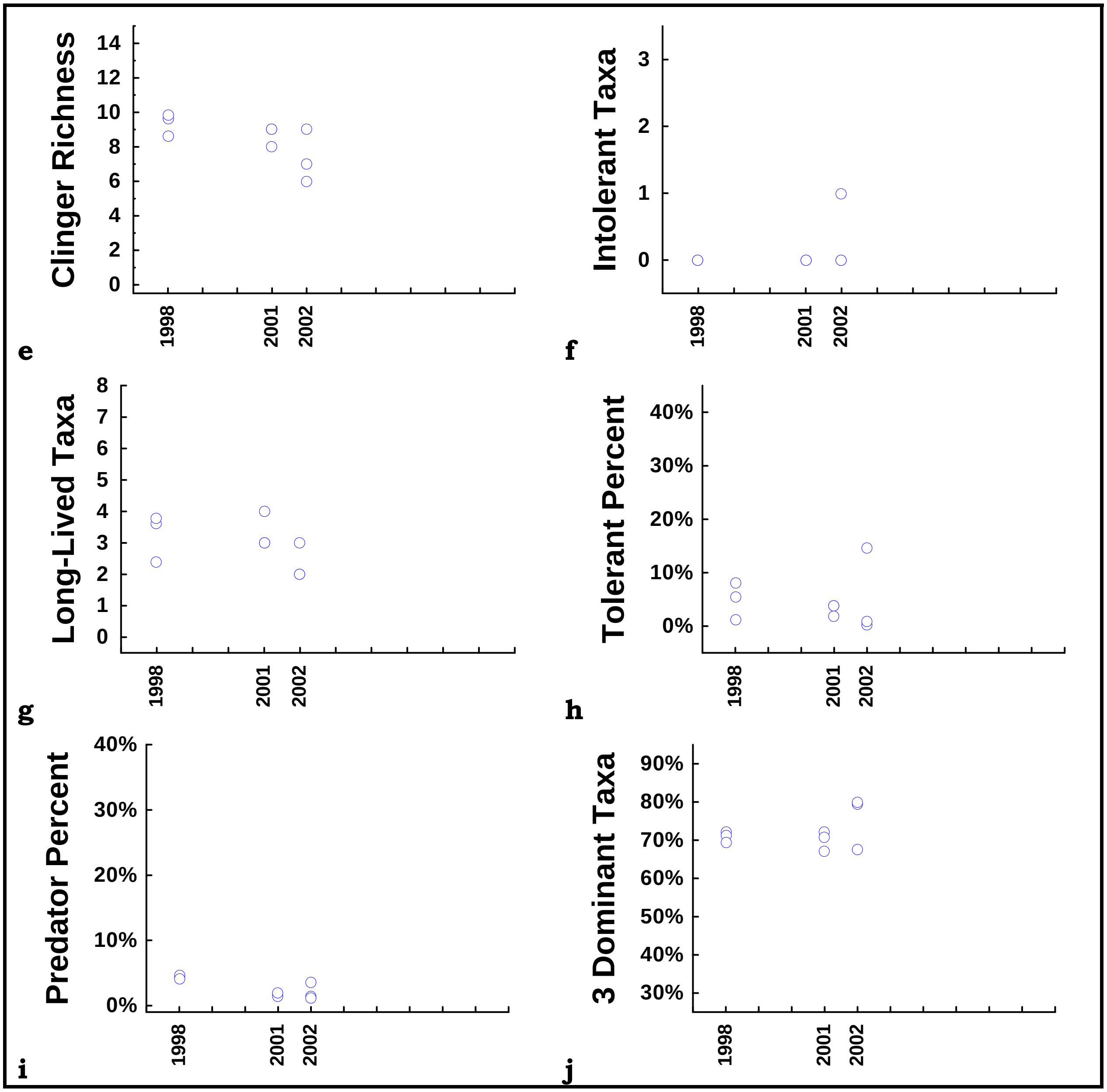
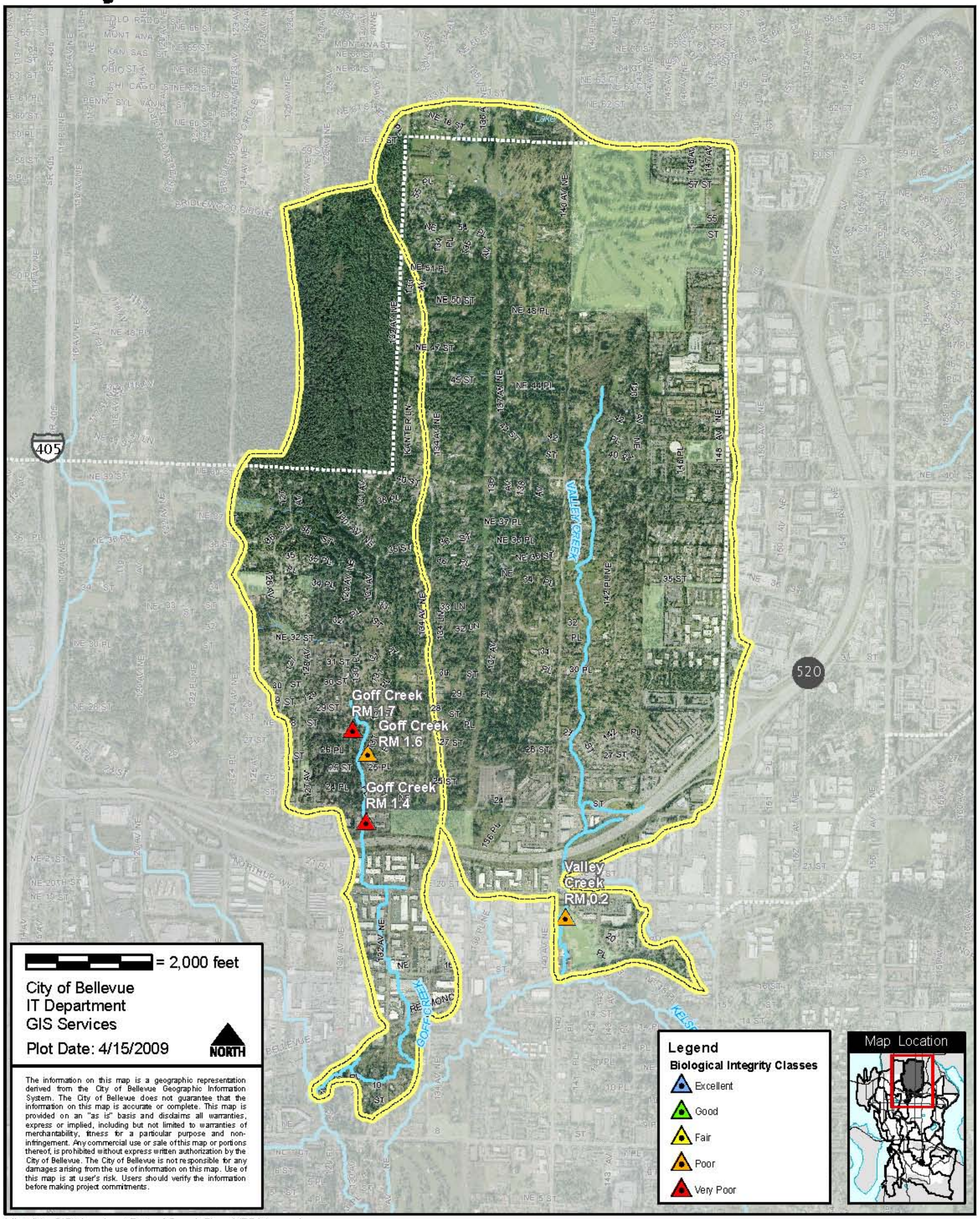


Figure 13a-j. Performance of B-IBI metrics at Coal Creek RM 1.8. Three replicate samples were collected in each year.

Macroinvertebrate Sampling Sites

Valley and Goff Creek Subbasins



V:\utpl\ArcGIS\MacroInvertBasins&SampleSites_MPSAtlas.mxd

Figure 14. Goff and Valley Creek basins, with 1998-2007 sampling sites. Biological integrity classes based on B-IBI scores (King County 2008a) are indicated by colored triangles.

Goff Creek

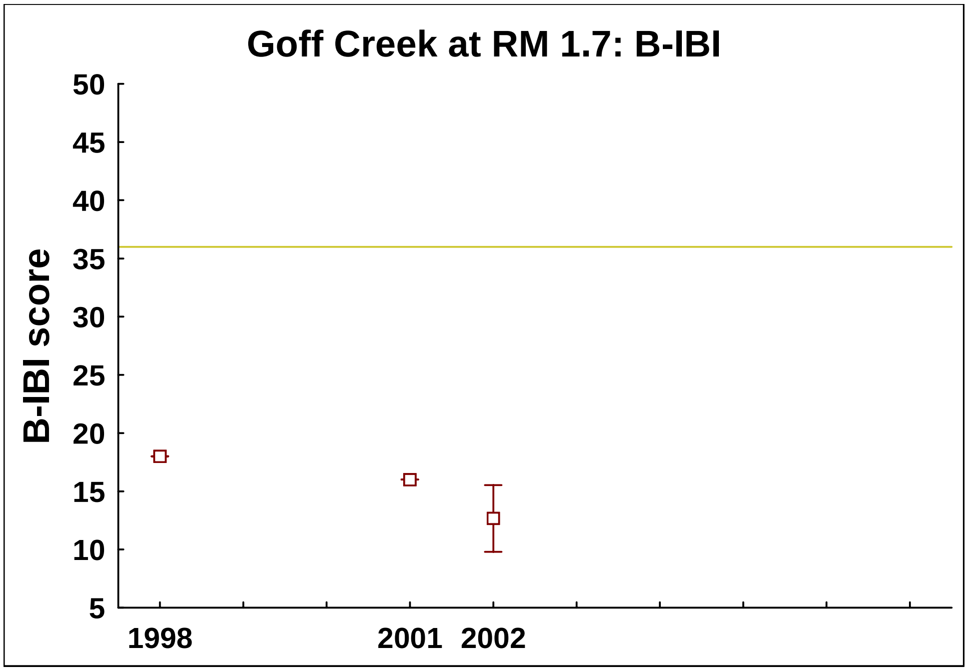
Goff Creek was sampled at 3 sites in 1998, 2001, and 2002. Three replicate samples were taken at the upper and bypass sites in 1998 and 2001, and at all sites in 2002. Two replicates were taken at the lower Goff Creek site in both 1998 and 2001. The map in Figure 14 indicates sampled sites on Goff Creek.

Goff Creek at RM 1.7

1. Bioassessment scores

B-IBI scores for replicate samples taken at Goff Creek at RM 1.7 ranged from 24% to 32% of maximum; all scores indicated very poor conditions (Figure 15). While the pollution tolerant percent metric suggested an intolerant assemblage in all years, all other B-IBI metrics gave results suggesting severe impairment of water quality and/or severe habitat disturbance. Analysis of variance demonstrated that B-IBI scores differed significantly among years ($p = 0.000$).

RIVPACS scores ranged from 0.25 to 0.44; all scores fell well below the impairment threshold set by WADOE (Figure 16), and analysis of variance indicated that scores were significantly different among years ($p = 0.019$). Scores in 1998 were higher than in 2001 or 2002.



Year	Group 1	Group 2	Group 3
1998	*		
2001		*	
2002			*

Figure 15. B-IBI scores (means and 95% confidence intervals) for Goff Creek at RM 1.7. Three replicate samples were collected in each year of sampling. The yellow line on the graph represents the threshold between “good” and “fair” conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates significant differences (p = 0.000) among years. The table shows the homogeneous groups of mean B-IBI scores resulting from post-hoc tests: B-IBI scores in 2002 were significantly lower than scores in all other years.

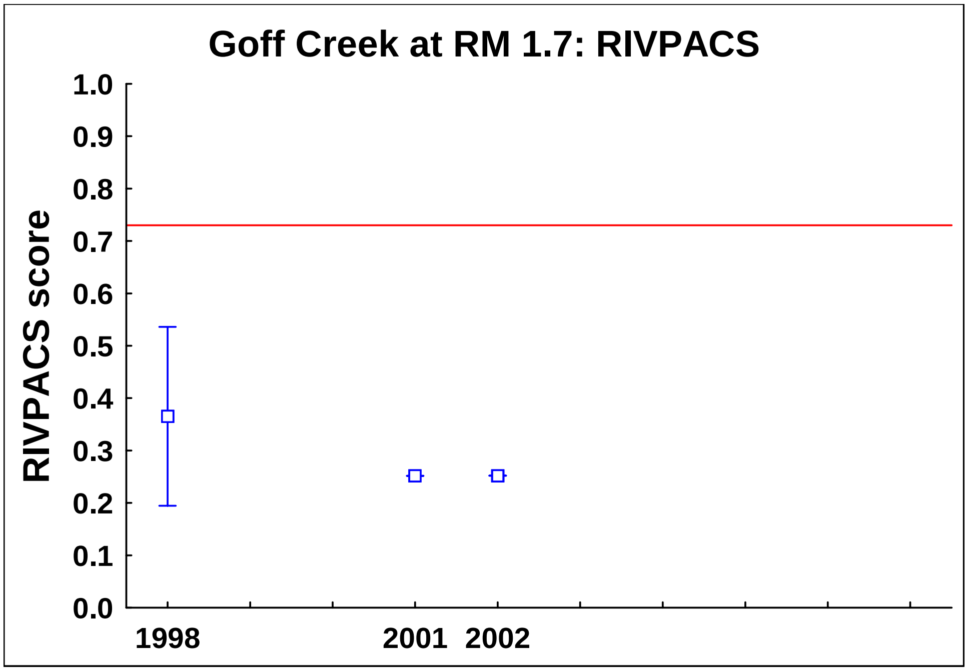


Figure 16. RIVPACS scores (means and 95% confidence intervals) for Goff Creek at RM 1.7. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates significant differences (p = 0.019) among years. Post-hoc t-test comparisons (Fisher's LSD), however, did not distinguish groupings.

2. Indicators of ecological condition

a. Water quality

The preponderance of non-insect taxa in replicates collected from Goff Creek at RM 1.7 strongly suggests that water quality was severely impaired here. Non-insect taxa accounted for about 45% of the organisms collected at the site in 1998 and 2001; in 2002, 72% of the animals in samples were non-insects. Especially prevalent among this group were oligochaetes. Populations of oligochaete worms in samples remained stable over the study period. Some oligochaetes are hemoglobin-bearers, but low taxonomic resolution of this group prevents a more accurate assessment of whether hypoxic substrates were present. Midges are also not identified to taxonomic levels that would allow enumeration of the hemoglobin-bearers among them. Despite the loss of information from midges and worms, other hemoglobin-bearing taxa, primarily planorbid snails, were especially abundant in 2002, accounting for 28% of the sampled animals.

Three mayfly taxa (Figure 17a) were counted in replicates collected in 1998, but in 2001 and 2002, the only mayfly taxon observed was the ubiquitous *Baetis tricaudatus*. No sensitive taxa were present in any year. The HBI value ranged from 6.39 in 1998 and 2001 to 7.09 in 2002, the latter value being among the highest at any site in this study. These findings support a hypothesis of severe impairment of water quality, perhaps due to nutrient enrichment.

Values for the MTI were higher than the median value for City of Bellevue sites in 1998 and 2001, but lower than the median in 2002. Heptageniid mayflies were absent from all collections, as were other metals-sensitive animals. Metals contamination cannot be ruled out at this site.

b. Thermal condition

Thermal preferences could not be estimated because of low taxa richness. Although a single cold stenotherm taxon (*Psychoglypha* sp.) was present in samples in 1998 and 2001, none were collected in 2002. Warm water temperatures in 2002 may have favored the increase in hemoglobin-bearing taxa in that year.

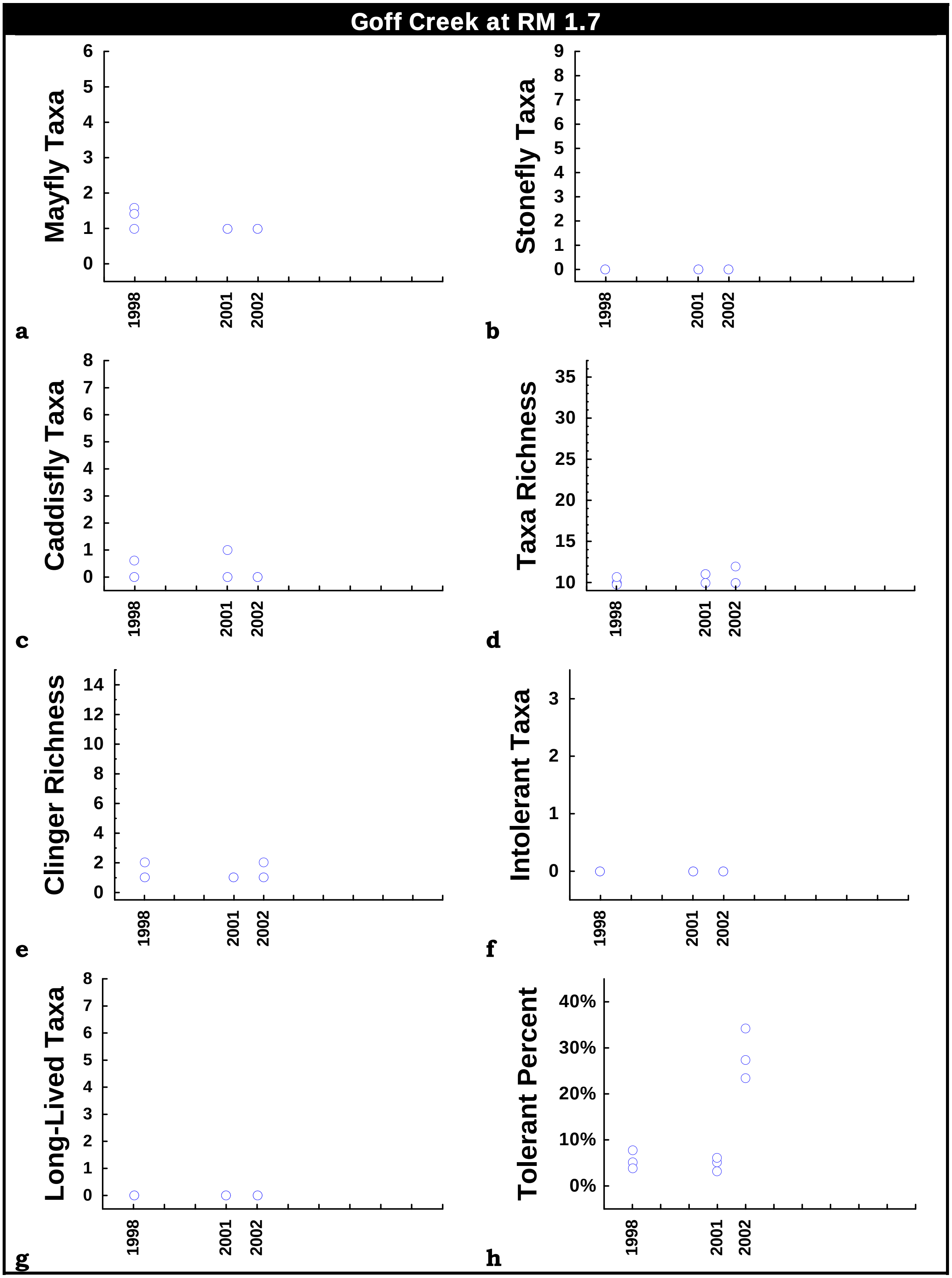
c. Sediment deposition

The large number of oligochaetes present in samples strongly suggests that fine sediment deposition was prevalent at this site on Goff Creek. In addition, there were low numbers of clinger taxa in all sampled years (Figure 17e) and caddisflies (Figure 17c) were rare in 1998 and 2001, and absent in 2002. These findings indicate that benthic substrates were probably dominated by fine sediments. The low taxa richness in these samples prevented the calculation of FSBI values.

d. Habitat diversity and integrity

Very low taxa richness (Figure 17d) over the 3 years of study suggest that instream habitats were impoverished or monotonous at the RM 1.7 site on Goff Creek. Metric and taxonomic indications of sediment deposition support this hypothesis. Only 12-15 taxa appeared in samples during the period. Not a single stonefly was collected. The absence of stoneflies at this site may be a consequence of poor water quality, but could be associated with unstable streambanks, loss of riparian function, or alterations to natural channel morphology. There were no semivoltine taxa in any sample; this suggests that the site may have been subjected to periodic dewatering, thermal extremes, or scour.

Although gatherers dominated in each year, the invertebrate fauna exhibited a functional shift over the time period. Scrapers became more abundant in 2002, and shredder taxa were not apparent after 1998. The scrapers collected in 2002 were snails, with the planorbids the most abundant group. The shift suggests that algal films may have become a more important energy source; increasing eutrophication may have supported algal growth.



Goff Creek at RM 1.7
Mayfly Taxa
Stonefly Taxa
Caddisfly Taxa
Taxa Richness
Clinger Richness
Intolerant Taxa
Long-Lived Taxa
Tolerant Percent
0%
10%
20%
30%
40%
1998
2001
2002
a
b
c
d
e
f
g
h

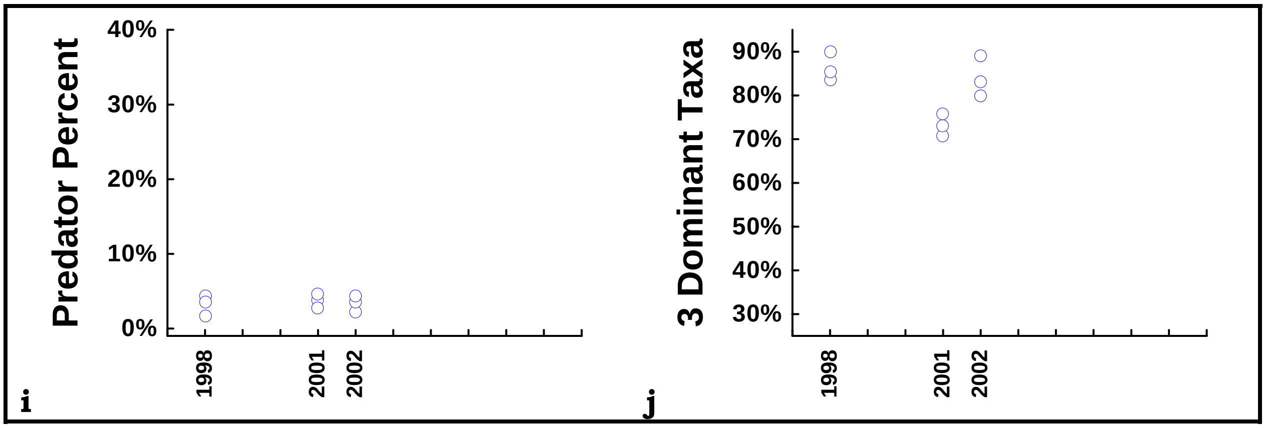


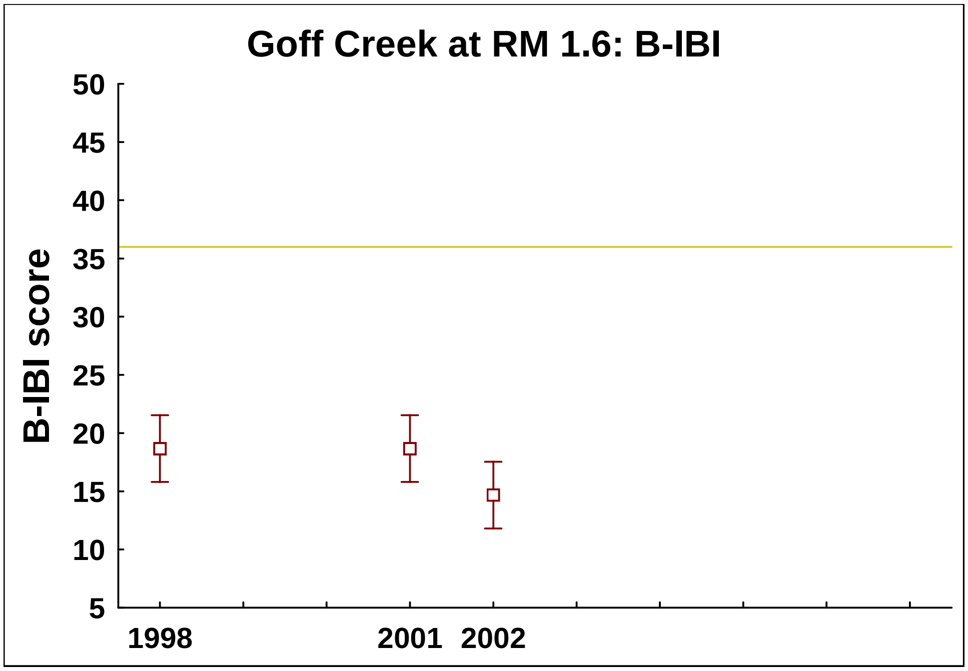
Figure 17a-j. Performance of B-IBI metrics at Goff Creek RM 1.7. Three replicate samples were collected in each year.

Goff Creek at RM 1.6

1. Bioassessment scores

B-IBI scores were significantly different (p = 0.008) among years at Goff Creek at RM 1.6), with scores for 2002 lower than the earlier years (Figure 18). Replicate scores ranged from 28% to 40% of maximum possible score, and indicated poor or very poor conditions throughout the study period. The overall scores were limited by low or very low scores for most individual metrics except the tolerant percent metric and the 3 dominant taxa percent metric, which yielded high or moderately high scores for all replicates.

RIVPACS scores exhibited no significant change over the study period (p = 0.594) (Figure 19). All scores fell well below the impairment threshold set by WADOE.



Year	Group 1	Group 2
1998	*	
2001	*	
2002		*

Figure 18. B-IBI scores (means and 95% confidence intervals) for Goff Creek at RM 1.6. Three replicate samples were collected in each year of sampling. The yellow line on the graph represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.008$) among years. The table shows the homogeneous groups of mean B-IBI scores resulting from post-hoc tests: B-IBI scores in 2002 were significantly lower than scores in the other years.

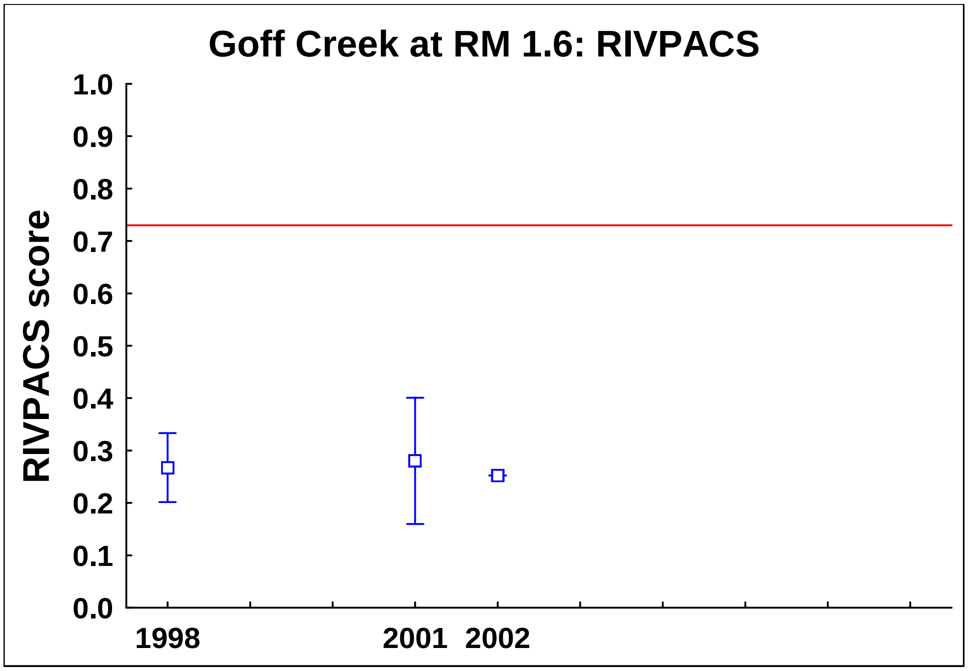


Figure 19. RIVPACS scores (means and 95% confidence intervals) for Goff Creek at RM 1.6. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates no significant differences ($p = 0.594$) among years.

2. Indicators of ecological condition

a. Water quality

Similar to the upstream site, the RM 1.6 site on Goff Creek supported a single mayfly taxon (*Baetis tricaudatus*) in 2001 and 2002 (Figure 20a). The loss of the sensitive heptageniid mayfly *Cinygma* sp., which was present in 1998, suggests that water quality may have worsened over the study period. The proportion of non-insect taxa steadily increased from 31% in 1998 to 65% in 2002. Non-insect taxa were dominated by oligochaetes until 2002, when planorbid snails dominated the invertebrate fauna. The prevalence of these hemoglobin-bearing animals suggests that eutrophication was increasing.

A few individuals in sensitive taxa (Figure 20f) were collected each year: 4 specimens of *Cinygma* sp. in 1998, a single specimen of the caddisfly *Ecclisomyia* sp. in 2001, and 2 specimens of the elmid beetle *Lara* sp. in 2002. These findings suggest that water quality impairment may have been mitigated somewhat by ground water inputs; seeps may have provided refuge for these taxa.

Values for the HBI increased from 6.73 to 7.54 between 1998 and 2002. By the latter year, the invertebrate assemblage supported at this site was one of the most tolerant assemblages in this study. The MTI values were lower in 2002 than in the earlier years, but metals-sensitive organisms were not collected after 1998. Metals contamination cannot be ruled out.

b. Thermal condition

Thermal preferences for invertebrate assemblages collected at this site could not be calculated because of low taxa richness. A few specimens of cold stenotherm taxa were collected in each year; these animals may have been confined to areas of ground water seepage.

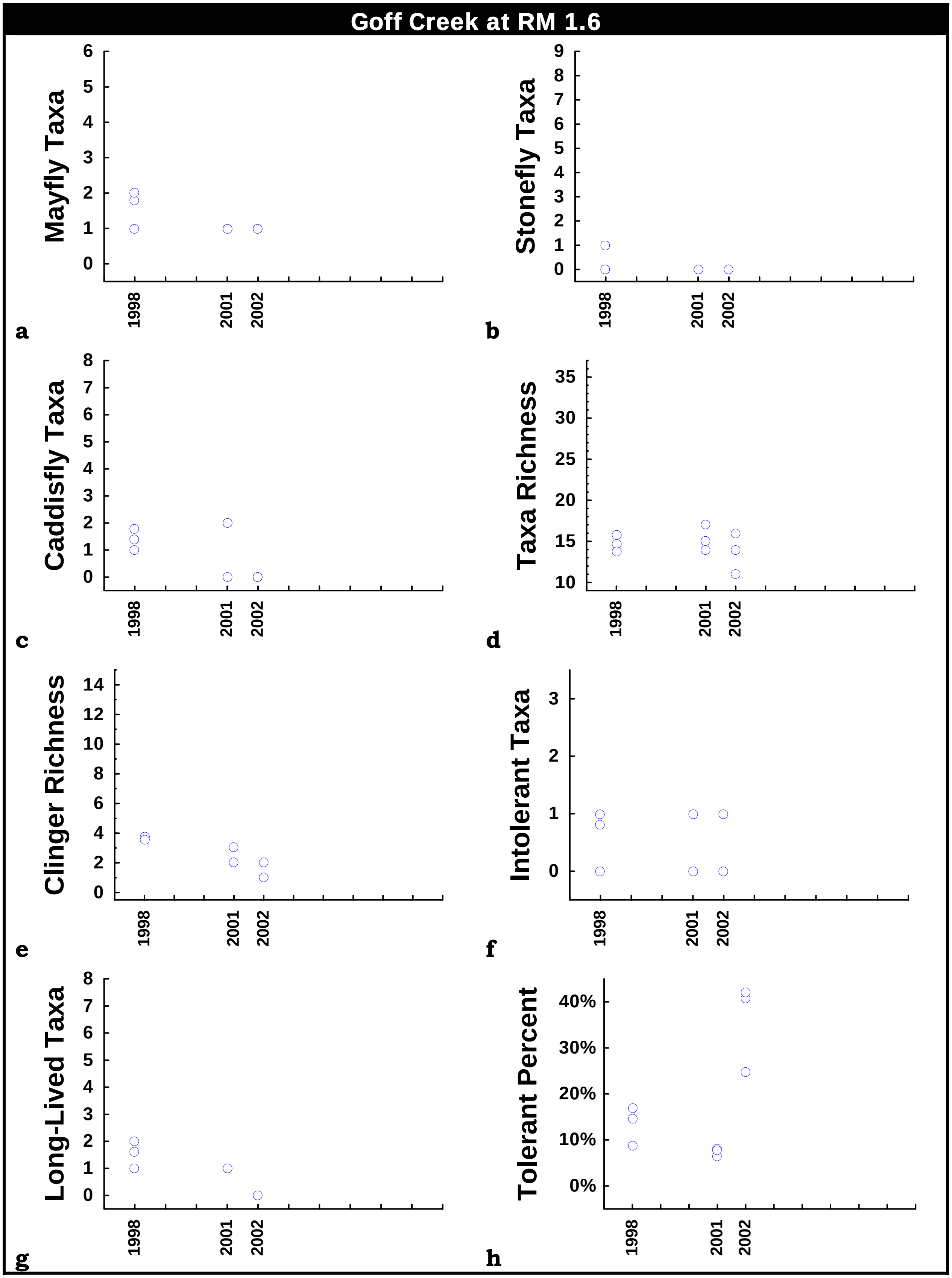
c. Sediment deposition

It seems likely that fine sediment deposition limited the fauna at the RM 1.6 site on Goff Creek. Clinger taxa (e.g. *Parapsyche almota* and *Lara* sp.) were much less diverse than expected, and richness in this group declined over the study period (Figure 20e). Caddisfly taxa richness was low in 1998 and 2001, and the group disappeared from samples in 2002 (Figure 20c). These findings suggest that sediment deposition may have increased between 1998 and 2002. The FSBI could not be calculated because of low taxa richness.

d. Habitat diversity and integrity

Taxa richness was low and stable over the period of study, diminishing from 25 taxa in 2001 to only 18 in 2002 (Figure 20d). This suggests that instream habitats were limited, and became more impoverished over the period. Indications of trends in sediment deposition support this hypothesis, as do the performance of metrics such as percent predators (Figure 20i), and the 3 dominant taxa percent (Figure 20j). Two specimens of an immature chloroperlid stonefly were collected in 1998, but this was the last time they were seen in samples from this site. Interstitial habitats may have been increasingly compromised by sediment. Long-lived taxa diminished over the period as well (Figure 20g); poor representation of these taxa may be related to catastrophes such as periodic dewatering, scour, or toxic pollutants.

Similar to the upstream site, scrapers became more abundant in 2001, and increased markedly in 2002. Shredder taxa were extremely rare after 1998. The scrapers were primarily planorbid snails, and increasing eutrophication is suggested. Predators were not a significant functional component in any year.


Goff Creek at RM 1.6
Mayfly Taxa
Stonefly Taxa
Caddisfly Taxa
Taxa Richness
Clinger Richness
Intolerant Taxa
Long-Lived Taxa
Tolerant Percent
1998
2001
2002
a
b
c
d
e
f
g
h

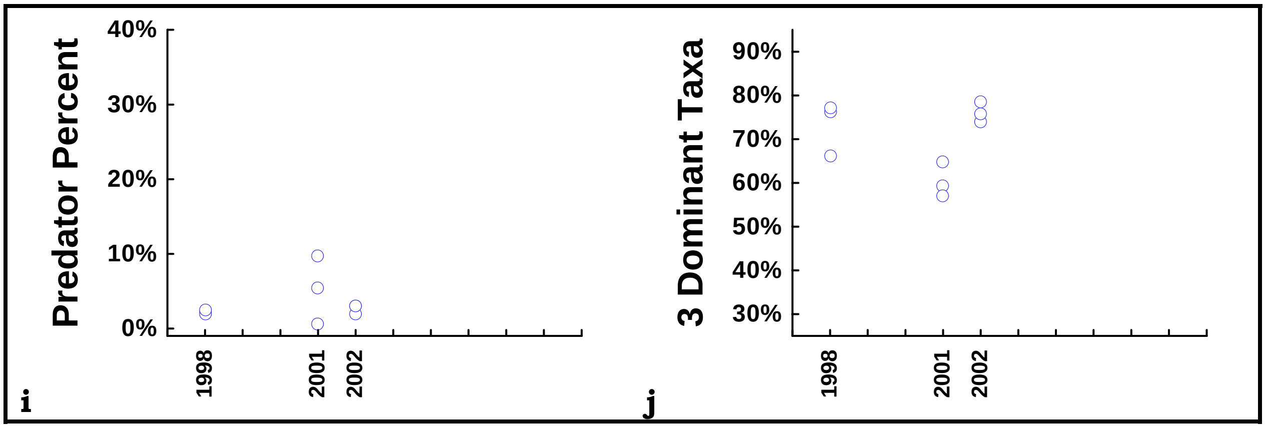


Figure 20a-j. Performance of B-IBI metrics at Goff Creek RM 1.6. Three replicate samples were collected in each year.

Goff Creek at RM 1.4

1. Bioassessment scores

B-IBI scores ranged from 28% to 36% of maximum at the RM 1.4 site on Goff Creek (Figure 21), and were variable between replicates in 1998 and 2001. However, means of the B-IBI scores did not vary much among years. Analysis of variance indicated no significant differences among mean scores over the years. The B-IBI indicated poor or very poor conditions. Overall scores were limited by poor values for all metrics except for the tolerant percent metric, which yielded high values for some replicates.

RIVPACS scores for Goff Creek at RM 1.4 did not differ significantly over the years of study (Figure 22). RIVPACS scores for the 2 replicates were widely divergent in 2001 and 2002. Other replicate scores ranged from 0.25 to 0.34. All scores were well below the WADOE impairment threshold.

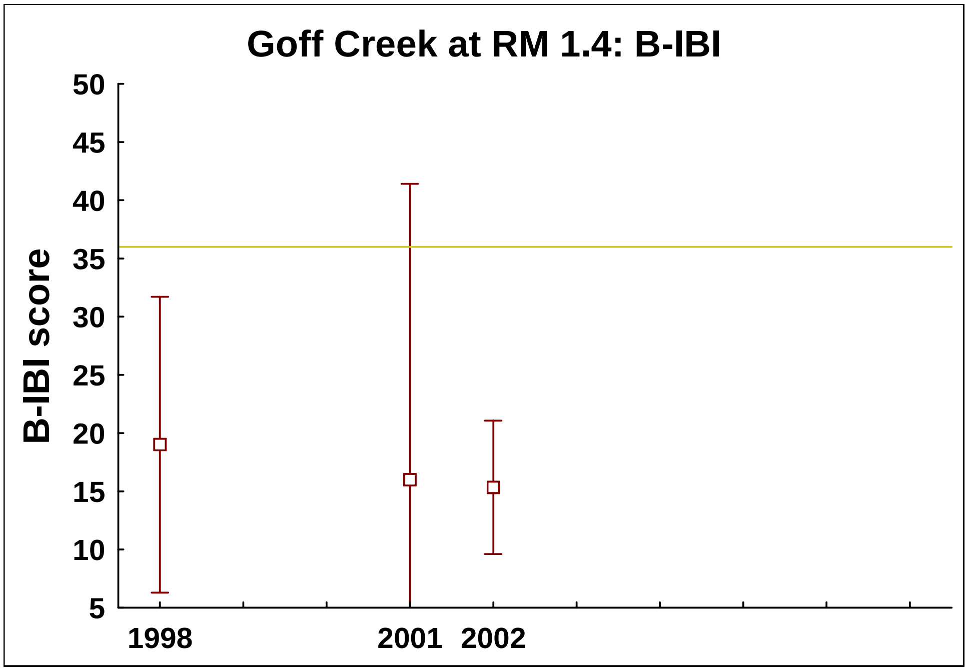


Figure 21. B-IBI scores (means and 95% confidence intervals) for Goff Creek at RM 1.4. Two replicate samples were collected in each year of sampling. The yellow line represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates no significant differences (p = 0.300) among years.

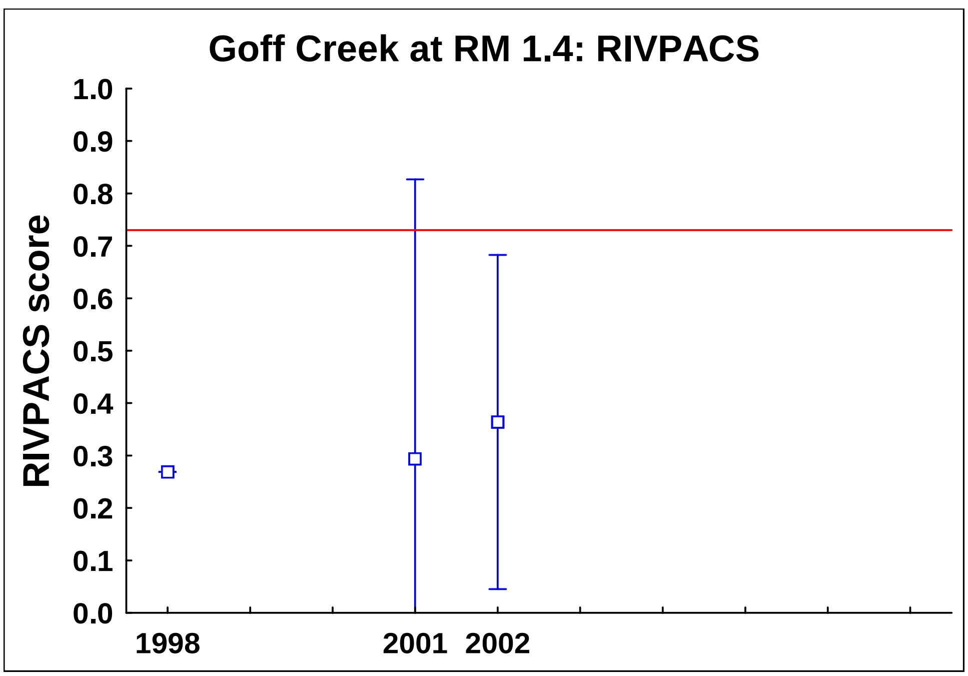


Figure 22. RIVPACS scores (means and 95% confidence intervals) for Goff Creek at RM 1.4. Two replicates were taken at this site in both 1998 and 2001; three replicates were taken here in 2002. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates no significant differences (p = 0.558) among years.

2. Indicators of ecological condition

a. Water quality

Similar to the other Goff Creek sites, the RM 1.4 site supported a fauna dominated by non-insects. Oligochaetes were the most abundant component of these assemblages; they accounted for 31% of the animals taken in replicates in 2002. Similar to the upstream sites, hemoglobin-bearing planorbid snails increased in abundance over the study period, suggesting that eutrophication and warm water temperatures may have resulted in low oxygen concentrations. Community tolerance, as measured by the HBI, was as high here as at the other 2 Goff Creek sites. Mayfly taxa richness was low in every year (Figure 23a), and no sensitive taxa were collected after 1998. All of these findings suggest that water quality was poor in the reach. MTI values were higher than the median value for City of Bellevue sites, indicating that the assemblages were moderately tolerant of metals, but small numbers of heptageniid mayflies persisted at the site throughout the study period.

b. Thermal condition

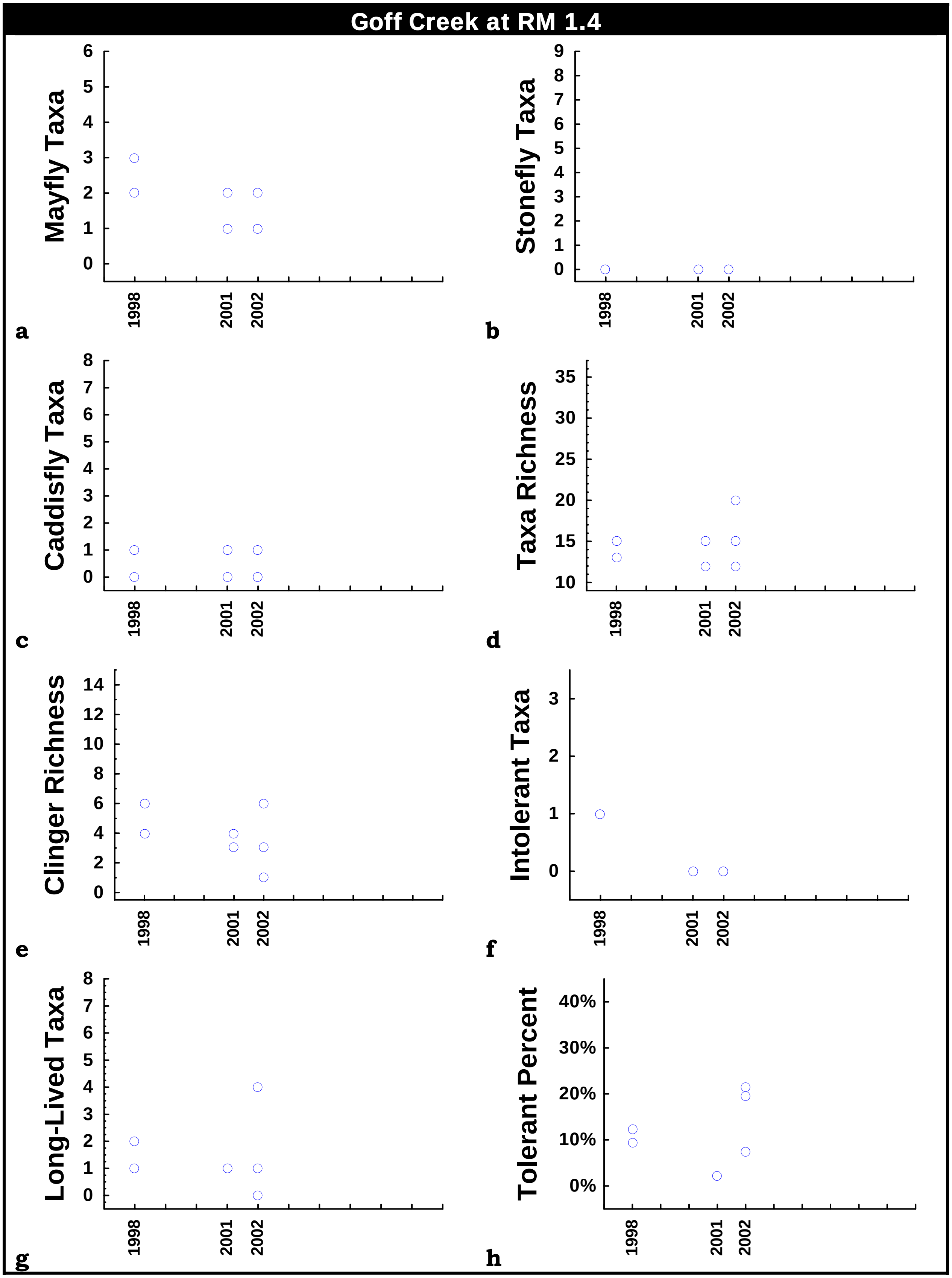
Cold stenotherm taxa were common in the 1998 replicates, but they were rare in 2001 and completely absent in replicates collected in 2002. Worsening water quality or warming water temperatures could account for the loss of these taxa. Low taxa richness prohibited reliable estimates of thermal preference.

c. Sediment deposition

Neither clingers (Figure 23e) nor caddisflies (Figure 23c) were well-represented in any year, and the increasing abundance of oligochaetes over the period of sampling strongly suggests that fine sediment deposition limited colonization of stony substrate habitats at this site. However, it is notable that clinger taxa were more diverse here than at the upstream sites on Goff Creek. It was not possible to calculate FSBI values for these assemblages due to low taxa richness.

d. Habitat diversity and integrity

Low taxa richness (Figure 23d) and the absence of stoneflies suggest that instream and reach-scale habitat features were disrupted in this reach of Goff Creek. Sediment deposition may have been the result of unstable streambanks. Unlike the other sites on Goff Creek, long-lived taxa were present here in 2002 (Figure 23g), suggesting that instream habitats were more stable than at the other sites. Shredders were rare; riparian inputs of large organic material may have been scarce, or hydrologic conditions may have been unfavorable for its retention. Although planorbid snails were more numerous in 2002, the magnitude of the increase was not as dramatic as at the other Goff Creek sites.


Goff Creek at RM 1.4
Mayfly Taxa
Stonefly Taxa
Caddisfly Taxa
Taxa Richness
Clinger Richness
Intolerant Taxa
Long-Lived Taxa
Tolerant Percent
1998
2001
2002
a
b
c
d
e
f
g
h

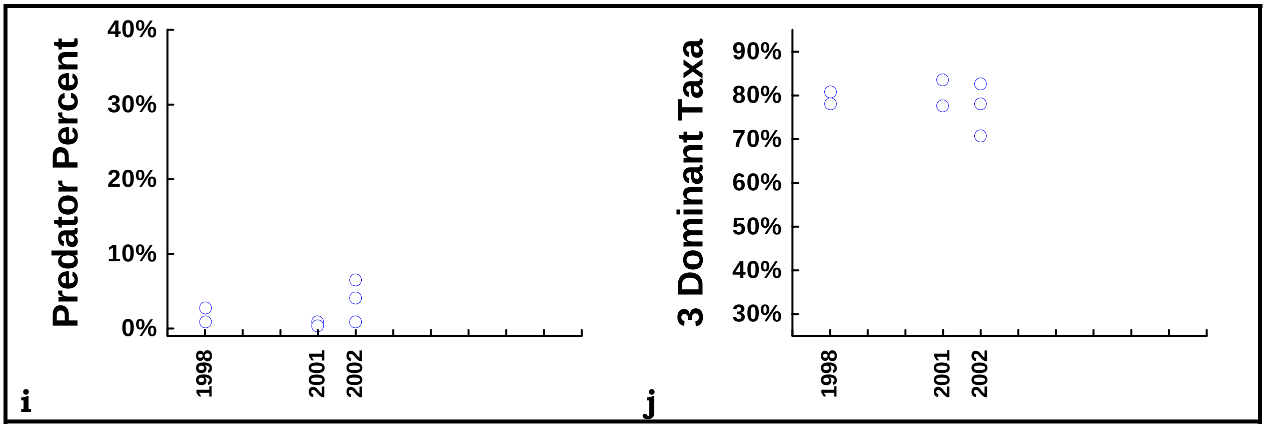


Figure 23a-j. Performance of B-IBI metrics at Goff Creek RM 1.4. Three replicate samples were collected in 2002, but only 2 replicates were collected in 1998 and 2001.

Valley Creek

A single site, at RM 0.2, was sampled on Valley Creek in 2005 and 2006. Two replicates were collected at each site. The map in Figure 14 indicates sampled sites on Valley Creek.

Valley Creek at RM 0.2

1. Bioassessment scores

B-IBI scores were identical in both of the years in which the Valley Creek site was sampled (Figure 24). Scores ranged from 32% to 36% of maximum, indicating poor biological conditions. Low overall scores can be attributed to low values for all B-IBI metrics except for the percent tolerant metric, which yielded high values for all replicates.

RIVPACS scores were well below the WADOE impairment threshold in 2005, and fell further in 2006 (Figure 25). Scores ranged from 0.32 to 0.40. A t-test for dependent samples indicated no significant difference ($p = 0.406$) between mean RIVPACS scores in 2005 and 2006.

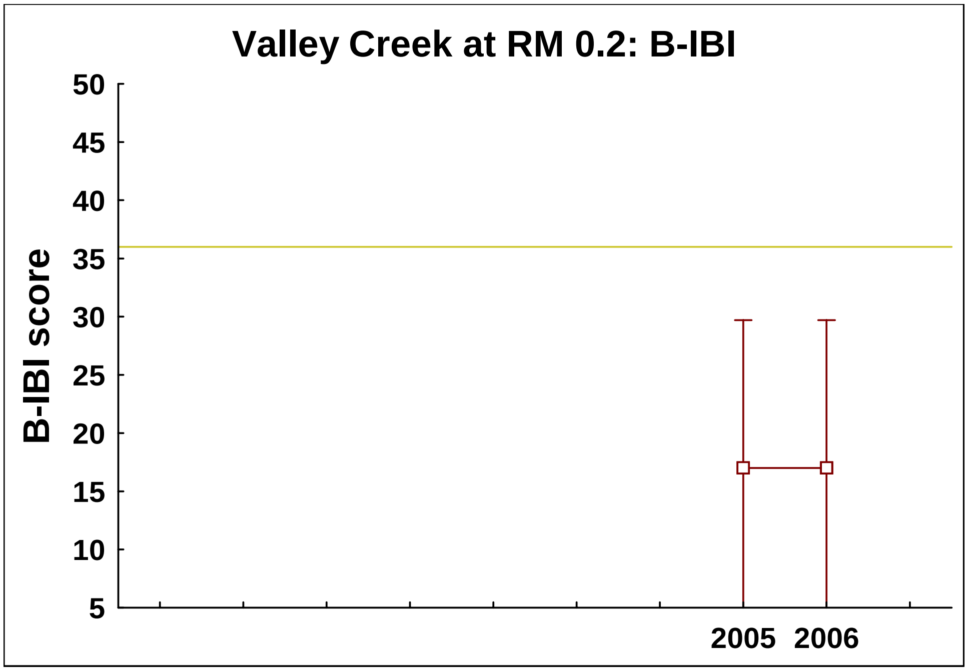


Figure 24. B-IBI scores (means and 95% confidence intervals) for Valley Creek at RM 0.2. Two replicate samples were collected in 2005 and in 2006. The yellow line represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Means and ranges of replicate scores were identical between the years.

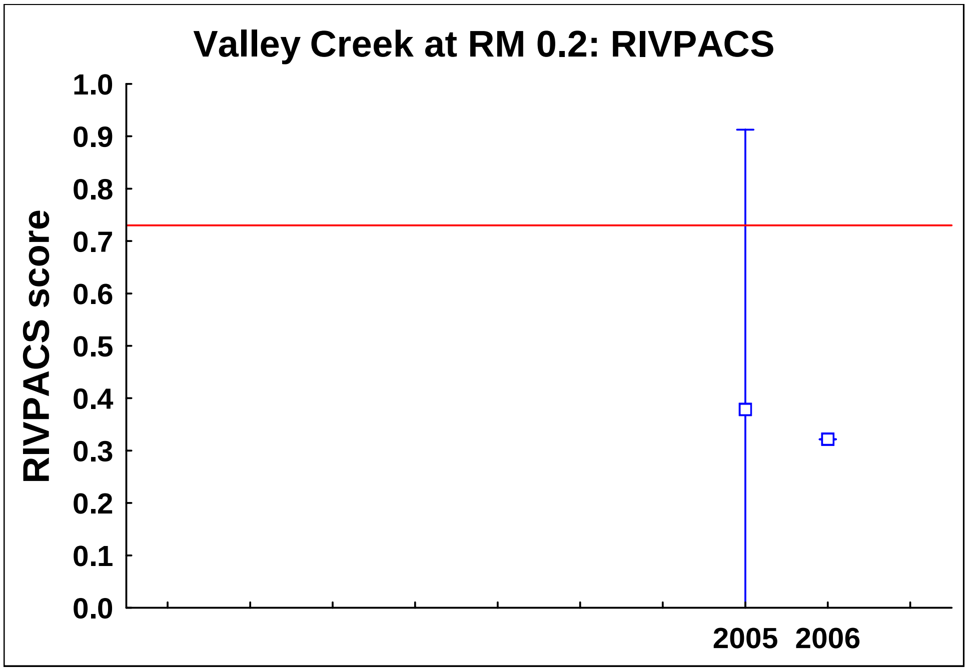


Figure 25. RIVPACS scores (means and 95% confidence intervals) for replicate samples collected in 2 years at Valley Creek at RM 0.2. Dotted lines are 95% confidence limits. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. A t-test for dependent samples indicated no significant differences between mean scores for 2005 and 2006.

2. Indicators of ecological condition

a. Water quality

A single mayfly taxon was collected in replicate samples taken at the Valley Creek site at RM 0.2 in both 2005 and 2006 (Figure 26a); this was the ubiquitous *Baetis tricaudatus*. In both years, the dominant taxon was the blackfly *Simulium* sp., which accounted for 32-37% of sampled animals. This finding suggests that fine organic particulates in suspension were a major energy source in this reach. Other dominant taxa included non-insects such as oligochaetes and amphipods (*Crangonyx* sp.); midges were also abundant. Altogether, these animals constitute a tolerant assemblage and suggest that water quality was degraded in the reach; nutrient enrichment may be indicated. High values for the HBI are consistent with an assemblage largely made up of tolerant organisms. There were no sensitive taxa in samples from either year.

b. Thermal condition

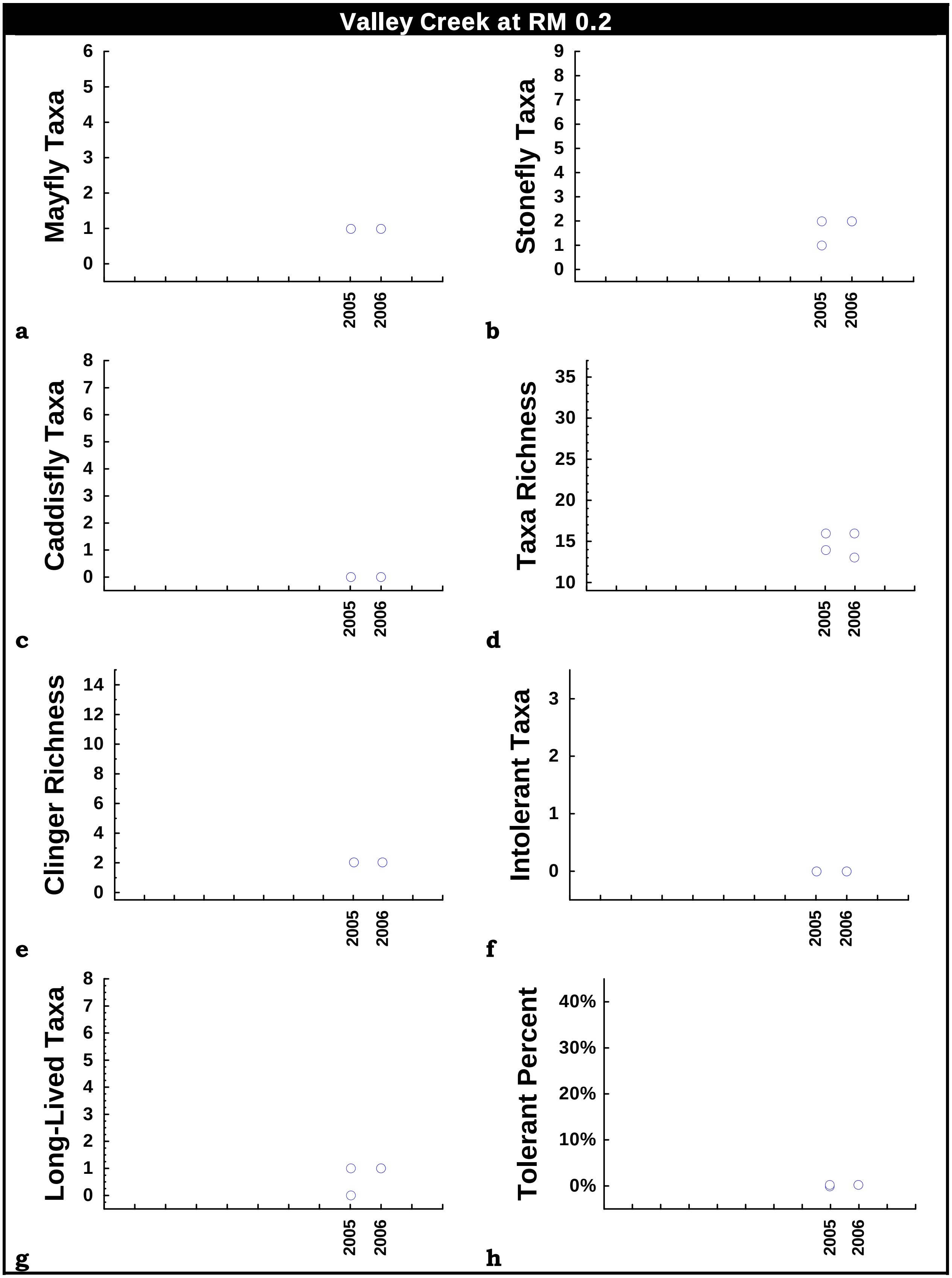
Because taxa richness was so low, thermal preferences could not be estimated. Cold stenotherm taxa were not present in any replicate, but it is unlikely that the fauna was stressed by thermal extremes, since 2 nemourid stonefly taxa (*Malenka* sp. and *Zapada cinctipes*) persisted here throughout the period of study.

c. Sediment deposition

Caddisflies were absent from the replicates, and clingers were poorly represented (Figure 26e); only 2 clinger taxa were collected. FSBI values could not be calculated because of low taxa richness. Fine sediment deposition may have been the greatest determinant of faunal composition at this site.

d. Habitat diversity and integrity

Very low taxa richness (Figure 26d) may have been related to impoverished instream habitats at this site. A single semivoltine taxon (*Optioservus* sp.) was collected, and the abundance of this animal was very low in both years. Periodic dewatering or scouring sediment pulses cannot be ruled out at this site. Other catastrophes, such as toxic pollutants or thermal extremes may also account for the lack of long-lived taxa. The functional composition of the assemblages was dominated by gatherers and filterers, but shredders accounted for 8% of animals in 2006. This suggests that large organic material in the form of leaf litter and woody debris from riparian sources was available.


Valley Creek at RM 0.2
Mayfly Taxa
a
Stonefly Taxa
b
Caddisfly Taxa
c
Taxa Richness
d
Clinger Richness
e
Intolerant Taxa
f
Long-Lived Taxa
g
Tolerant Percent
h
2005
2006

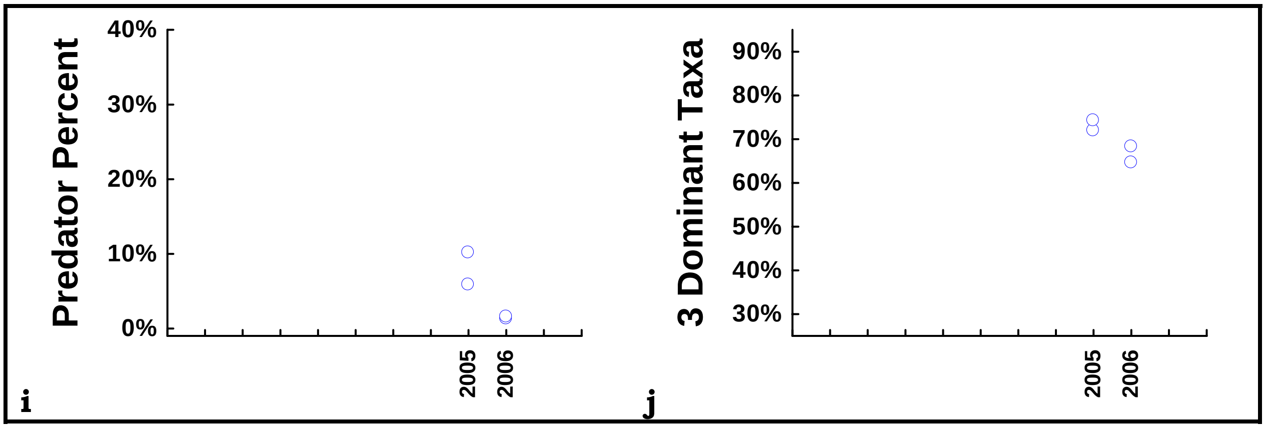


Figure 26a-j. Performance of the B-IBI metrics at Valley Creek RM 0.2. Two replicates were collected in 2005 and 2006.

Macroinvertebrate Sampling Sites

Kelsey Creek Subbasin

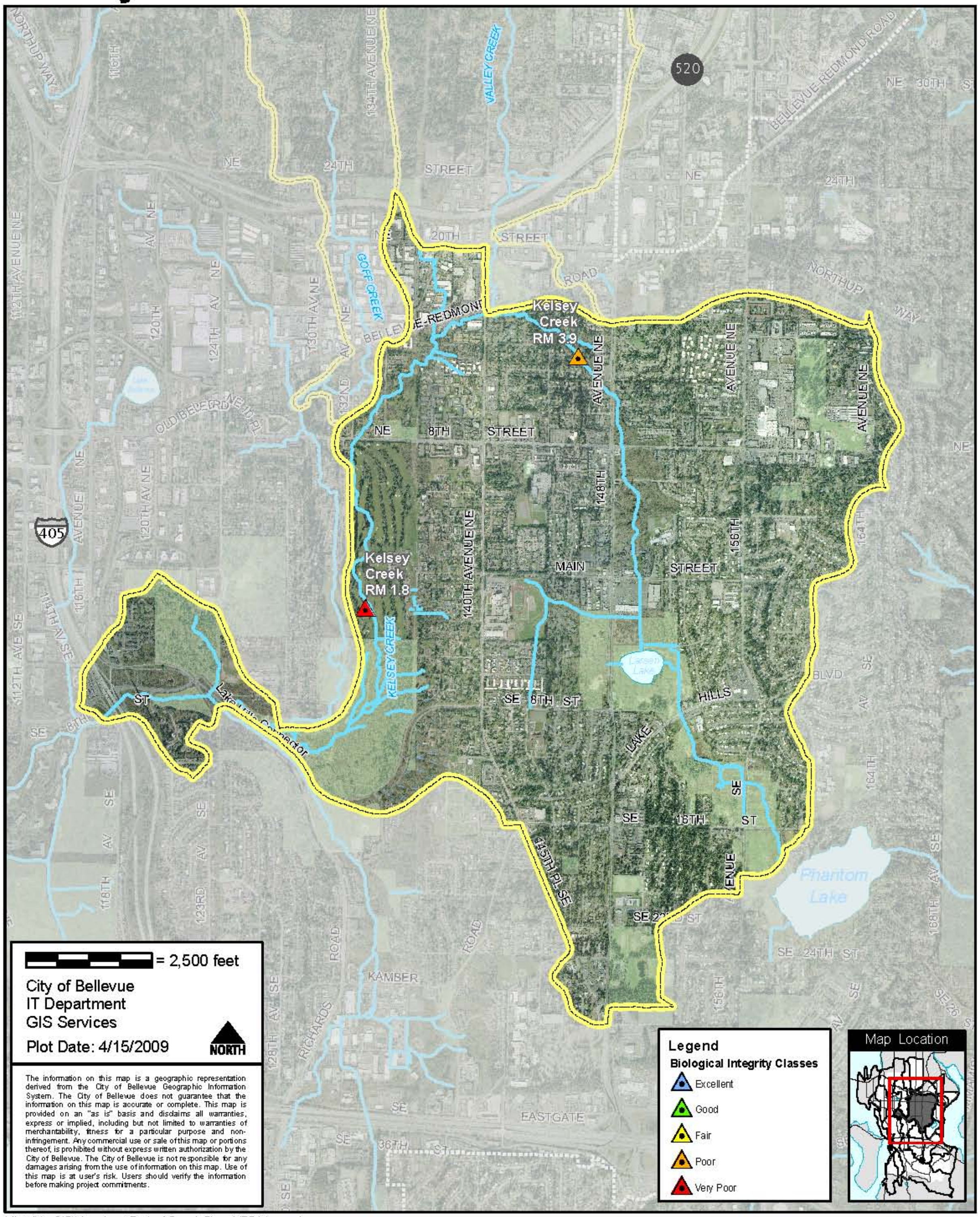


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Figure 27. Kelsey Creek basin, with 1998-2007 sampling sites. Biological integrity classes based on B-IBI scores (King County 2008a) are indicated by colored triangles.

Kelsey Creek

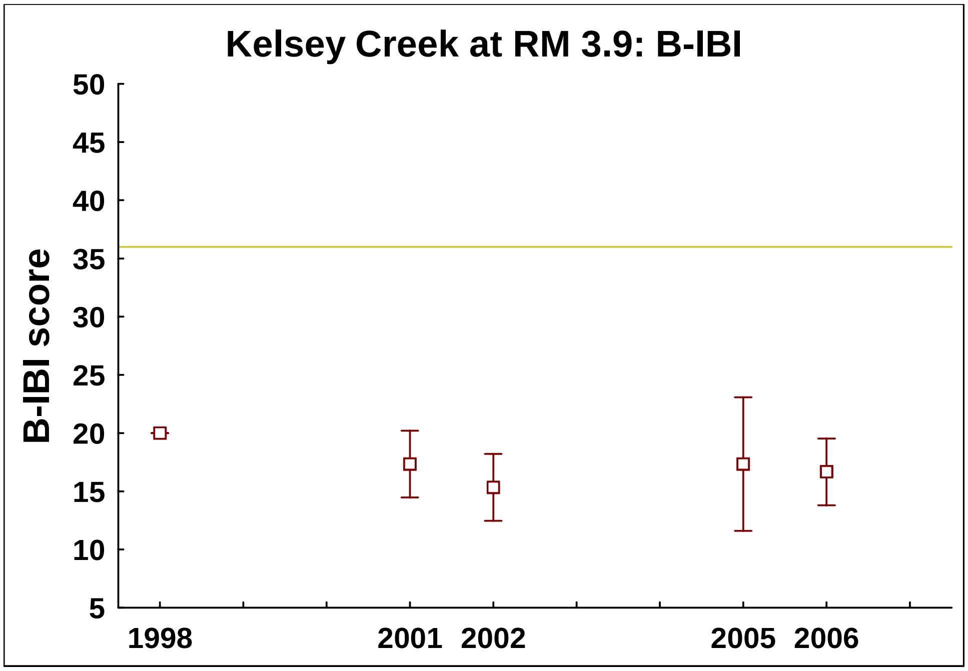
Kelsey Creek was sampled at 2 sites in 1998, 2001, 2002, 2005, and 2006. Three replicate samples were collected at both sites in each year. The map in Figure 27 indicates sampled sites on Kelsey Creek.

Kelsey Creek at RM 3.9

1. Bioassessment scores

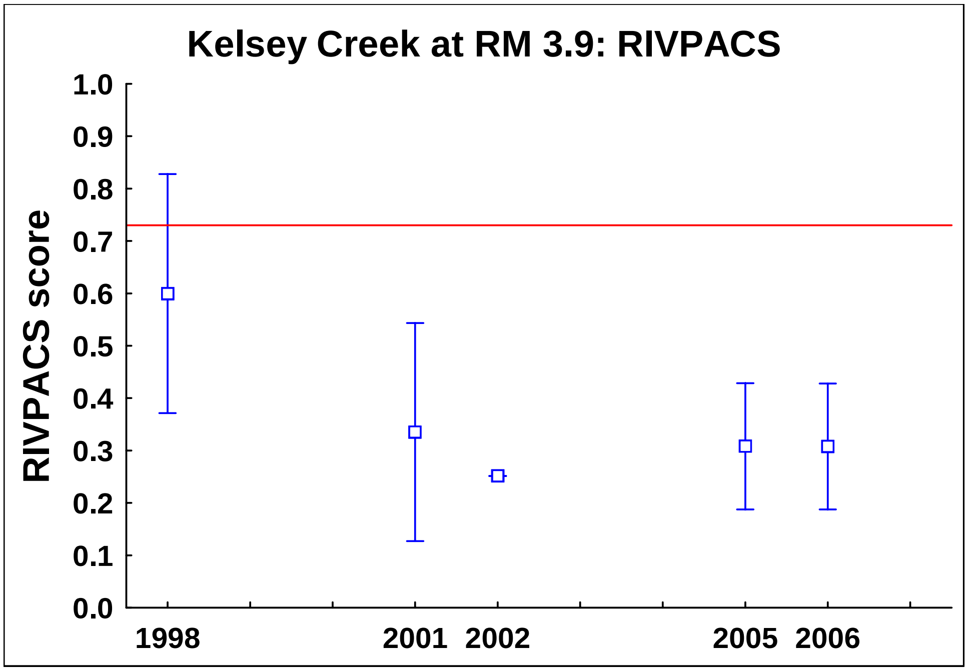
Analysis of variance indicated that the B-IBI scores in 1998 were significantly different ($p = 0.022$) from scores in other years at Kelsey Creek at RM 3.9 (Figure 28). Scores ranged from 28% to 40% of maximum, indicating poor or very poor biological conditions in all years. Low overall scores can be attributed to low scores for all individual metrics, except for the percent tolerant metric, which gave high scores for every replicate.

RIVPACS scores also demonstrated significant differences among years ($p = 0.000$) (Figure 29). Similar to the B-IBI results, 1998 proved to have the highest assessment scores compared to the other years of study. Scores in each year ranged from 0.25 to 0.69, and all fell below the impairment threshold set by WADOE.



Year	Group 1	Group 2
1998	*	
2001		*
2002		*
2005		*
2006		*
2007		*

Figure 28. B-IBI scores (means and 95% confidence intervals) for Kelsey Creek at RM 3.9. Three replicate samples were collected in each year of sampling. The yellow line on the graph represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates significant differences (p = 0.022) among years. The table shows the homogeneous groups of mean B-IBI scores resulting from post-hoc tests: B-IBI scores in 1998 were significantly higher than scores in the other years.



Year	Group 1	Group 2
1998	*	
2001		*
2002		*
2005		*
2006		*
2007		*

Figure 29. RIVPACS scores (means and 95% confidence intervals) for Kelsey Creek at RM 3.9. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.000$) among years. The table shows the homogeneous groups of mean RIVPACS scores resulting from post-hoc tests: RIVPACS scores in 1998 were significantly higher than scores in all other years.

2. Indicators of ecological condition

a. Water quality

Mayfly taxa richness (Figure 30a) was much lower than expected at the Kelsey Creek site at RM 3.9; the fauna consisted of a single taxon (*Baetis tricaudatus*) in 3 of the 5 years in which samples were taken. Most recently, in 2006, the sensitive heptageniid mayfly *Cinygma* sp. appeared in low numbers in the replicates, suggesting that the typically poor water quality conditions may be improving. Unfortunately, there is little evidence besides this that supports a hypothesis that water quality was better in 2006 than in previous years. The appearance of *Cinygma* sp. in the 2006 replicates may be attributable to drift from upstream sites, or may indicate areas where groundwater seeps influence water quality. HBI values remained high over the study period, indicating a tolerant assemblage in all years. Dominant taxa in every year included blackfly larvae (*Simulium* spp.), midges, and amphipods (*Crangonyx* sp.), suggesting large amounts of fine organic particulates in suspension and soft benthic substrates with a substantial organic component. Nutrient enrichment may account for the taxonomic structure of these assemblages.

b. Thermal condition

Two specimens of the mayfly *Cinygma* sp. were taken in replicate samples in 2006, but this was the only occurrence of a cold stenotherm taxon observed in the study period. The presence of the isopod *Caecidotea* sp. suggests that water temperatures were warm. Due to low taxa richness, reliable estimates of thermal preference for these assemblages could not be calculated.

c. Sediment deposition

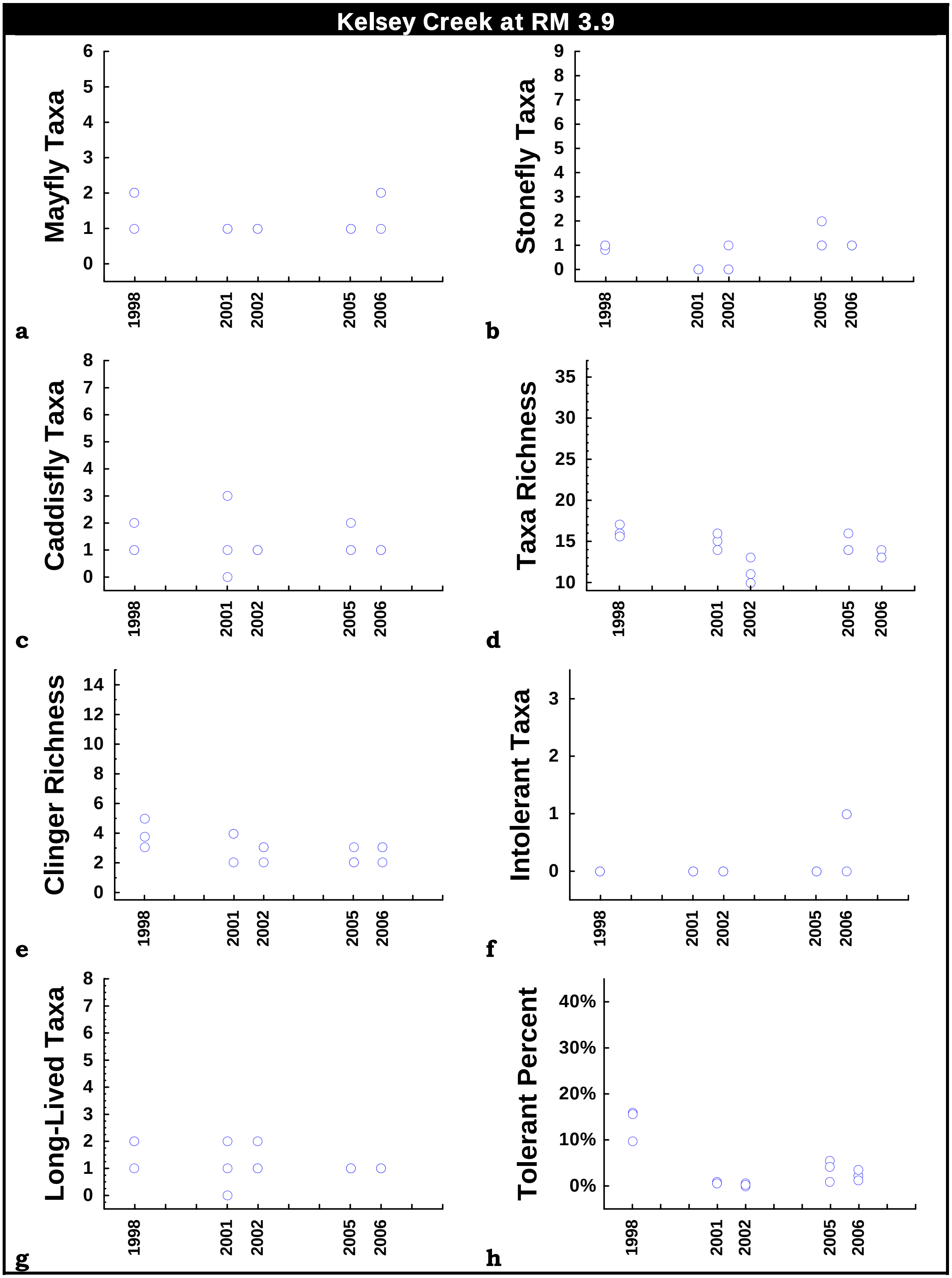
Although the abundance of oligochaetes in samples dropped over the study period, clinger taxa richness remained low (Figure 30e), as did caddisfly taxa richness (Figure 30c). Deposition of fine sediments apparently influenced the composition of the benthic fauna at RM 3.9. Low taxa richness prevented the calculation of FSBI values.

d. Habitat diversity and integrity

Instream habitat diversity was probably limited, since taxa richness was low at this site (Figure 30d). Faunal diversity was especially low in 2002, but remained relatively stable in all other years. A lack of large woody debris and monotonous instream substrates could contribute to the paucity of instream habitats. The relative abundance of predator taxa (Figure 30i) increased since 2001, possibly indicating increasing complexity of instream habitats. One or 2 stonefly taxa were collected in most years; these included the shredder *Malenka* sp. and the predator *Sweltsa* sp. Low stonefly richness may be related to channelization, unstable streambanks, or loss of riparian function.

A single long-lived taxon was collected in 2006; this was the caddisfly *Parapsyche almota*. Diversity in this group indicates stable instream conditions; dewatering, scour, or other catastrophic events that would prevent the completion of long life cycles are less likely to have occurred when long-lived taxa are abundant, diverse, and well-established. Since *P. almota* is not a typical pioneer taxon, and since it remained abundant at this site since 2002, it seems unlikely that large-scale disruption of instream habitats has recently occurred here.

The functional composition of sampled assemblages was simple, generally dominated by the gatherer and filterer feeding groups. Predators were more abundant in later years (Figure 30i), but shredders were scarce after 1998.


Kelsey Creek at RM 3.9
Mayfly Taxa
a
Stonefly Taxa
b
Caddisfly Taxa
c
Taxa Richness
d
Clinger Richness
e
Intolerant Taxa
f
Long-Lived Taxa
g
Tolerant Percent
h
1998
2001
2002
2005
2006

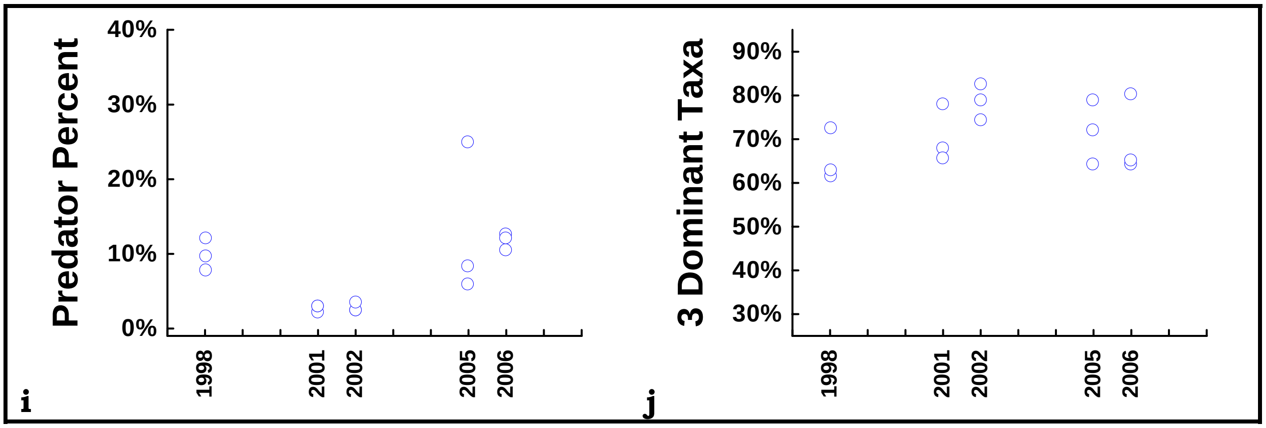


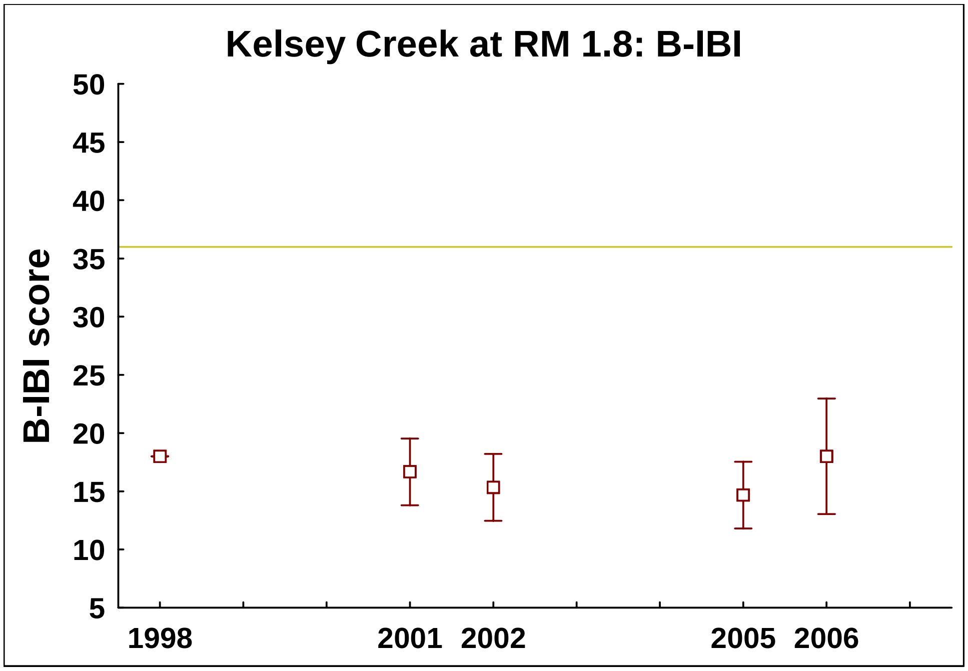
Figure 30a-j. Performance of B-IBI metrics at Kelsey Creek RM 3.9. Three replicate samples were collected in each year.

Kelsey Creek at RM 1.8

1. Bioassessment scores

B-IBI scores were significantly higher (p = 0.027) in 1998 and in 2006 than in other years at Kelsey Creek at RM 1.8 (Figure 31). Scores ranged from 28% to 40% of maximum, indicating poor or very poor biological conditions over the time period. There was very little variation among scores for replicates in any given year. Overall B-IBI scores were limited by low values for most metrics; only the percent tolerant metric gave consistently high values.

RIVPACS scores did not change substantially over the study period; analysis of variance indicates no significant differences (p = 0.256) in mean scores among years (Figure 32). Scores ranged from 0.25 to 0.42 and were always well below the impairment threshold set by WADOE.



Year	Group 1	Group 2
1998	*	
2001	*	*
2002		*
2005		*
2006	*	

Figure 31. B-IBI scores (means and 95% confidence intervals) for Kelsey Creek at RM 1.8. Three replicate samples were collected in each year of sampling. The yellow line on the graph represents the threshold between “good” and “fair” conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.027$) among years. The table shows the homogeneous groups of mean B-IBI scores resulting from post-hoc tests: B-IBI scores in 1998 and 2006 were significantly higher than scores in the other years.

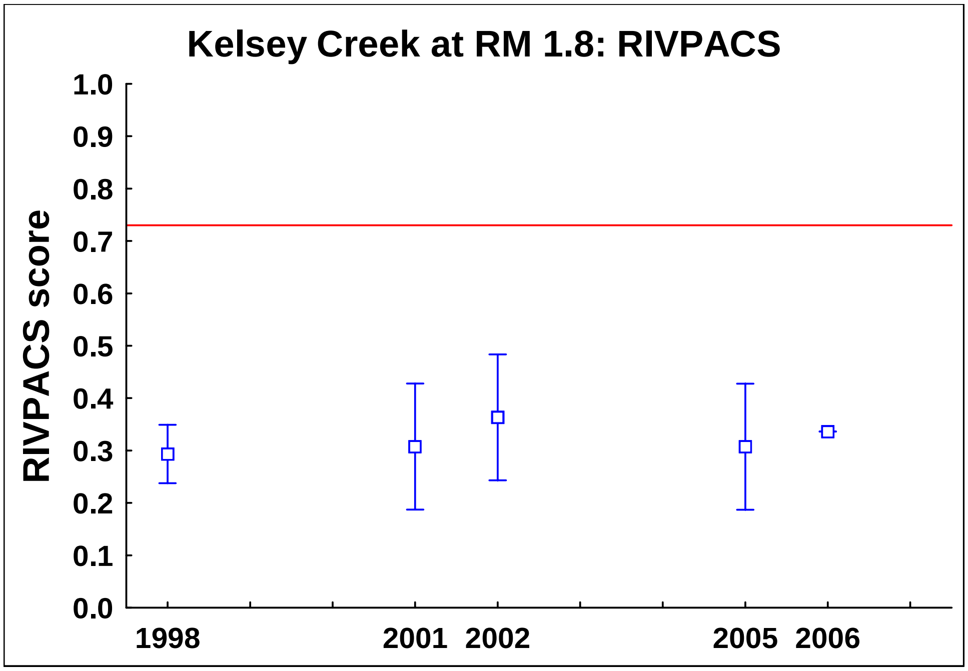


Figure 32. RIVPACS scores (means and 95% confidence intervals) for Kelsey Creek at RM 1.8. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates no significant differences (p = 0.256) among years.

2. Indicators of ecological condition

a. Water quality

Since 2001, the only mayfly taxon that was collected at Kelsey Creek at RM 1.8 was the ubiquitous *Baetis tricaudatus* (Figure 33a). However, HBI values for the assemblages collected here decreased in 2006, largely because of the large population of the stonefly *Malenka* sp. that appeared in that year. This taxon was present in very small numbers in 1998, but disappeared from samples in the intervening years. No sensitive taxa were collected in any year. Midges and amphipods (*Crangonyx* sp.) were dominant recently, with large numbers of blackfly larvae (*Simulium* sp.) persisting over the period of study. These findings suggest that water quality may have been compromised by fine organic particulates, indicating probable nutrient enrichment.

b. Thermal condition

Low taxa richness prevented the estimation of thermal preferences for the assemblages at RM 1.8. Cold stenotherm taxa were not collected in any year. The presence of the isopod *Caecidotea* sp., which was collected in 2005 and 2006, suggests that warm water temperatures characterized the site in those years.

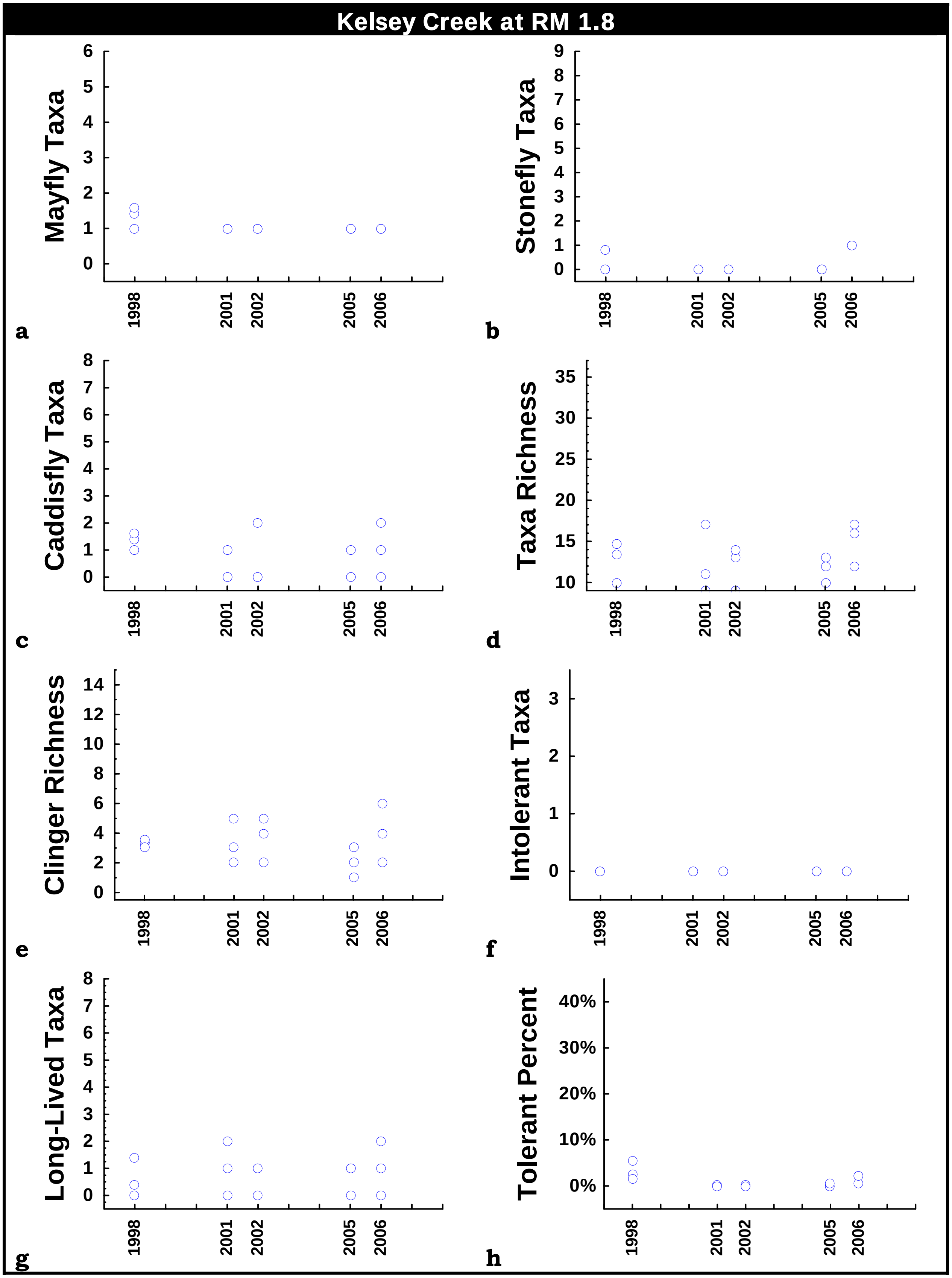
c. Sediment deposition

Except for 2001, the abundance of oligochaetes at RM 1.8 was never as high as at the RM 3.9 site. However, clinger richness (Figure 33e) was low here, as was caddisfly richness (Figure 33c). These findings suggest that deposition of fine sediments may have limited colonization of stony substrate habitats here. It was not possible to calculate values for the FSBI, since taxa richness was so low.

d. Habitat diversity and integrity

Since the faunal diversity (Figure 33d) was low at this site, it seems likely that instream habitat diversity was also low. The abundance of predators was also low in the reach, although these animals became more numerous in later years (Figure 33i). The presence of moderate numbers of copepods in samples collected in 2005 suggests that areas with low flow conditions were included in sampling efforts in that year.

The very low stonefly taxa richness (Figure 33b) suggests that reach-scale habitat features may have been disturbed. Low diversity among the stoneflies may be associated with unstable streambanks, alteration of natural channel morphology, or loss of riparian function. Long-lived taxa (Figure 33g) were neither diverse nor abundant at RM 1.8. Periodic dewatering, scouring sediment pulses, or toxic inputs cannot be ruled out. The functional composition of invertebrate assemblages was impoverished, consisting of a large number of gatherers and a few filter feeders and predators in most years. In 2006, functional complexity increased because of the addition of shredders, mainly the stonefly *Malenka* sp. The appearance of this taxon suggests that large organic material such as leaf litter and woody debris was available.


Kelsey Creek at RM 1.8
Mayfly Taxa
Stonefly Taxa
Caddisfly Taxa
Taxa Richness
Clinger Richness
Intolerant Taxa
Long-Lived Taxa
Tolerant Percent
1998
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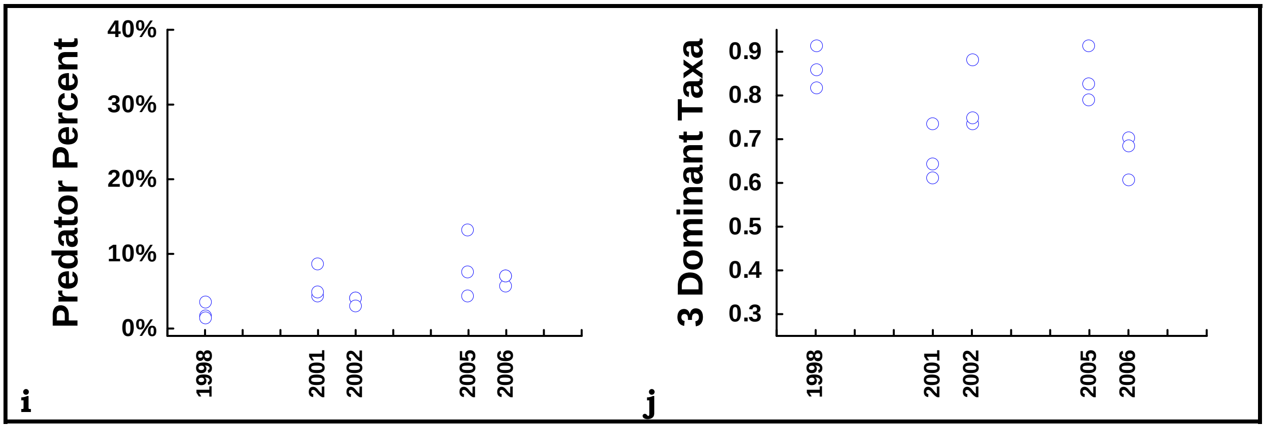

Figure 33a-j. Performance of B-IBI metrics at Kelsey Creek RM 1.8. Three replicate samples were collected in each year.

Macroinvertebrate Sampling Sites

Lewis Creek Subbasin

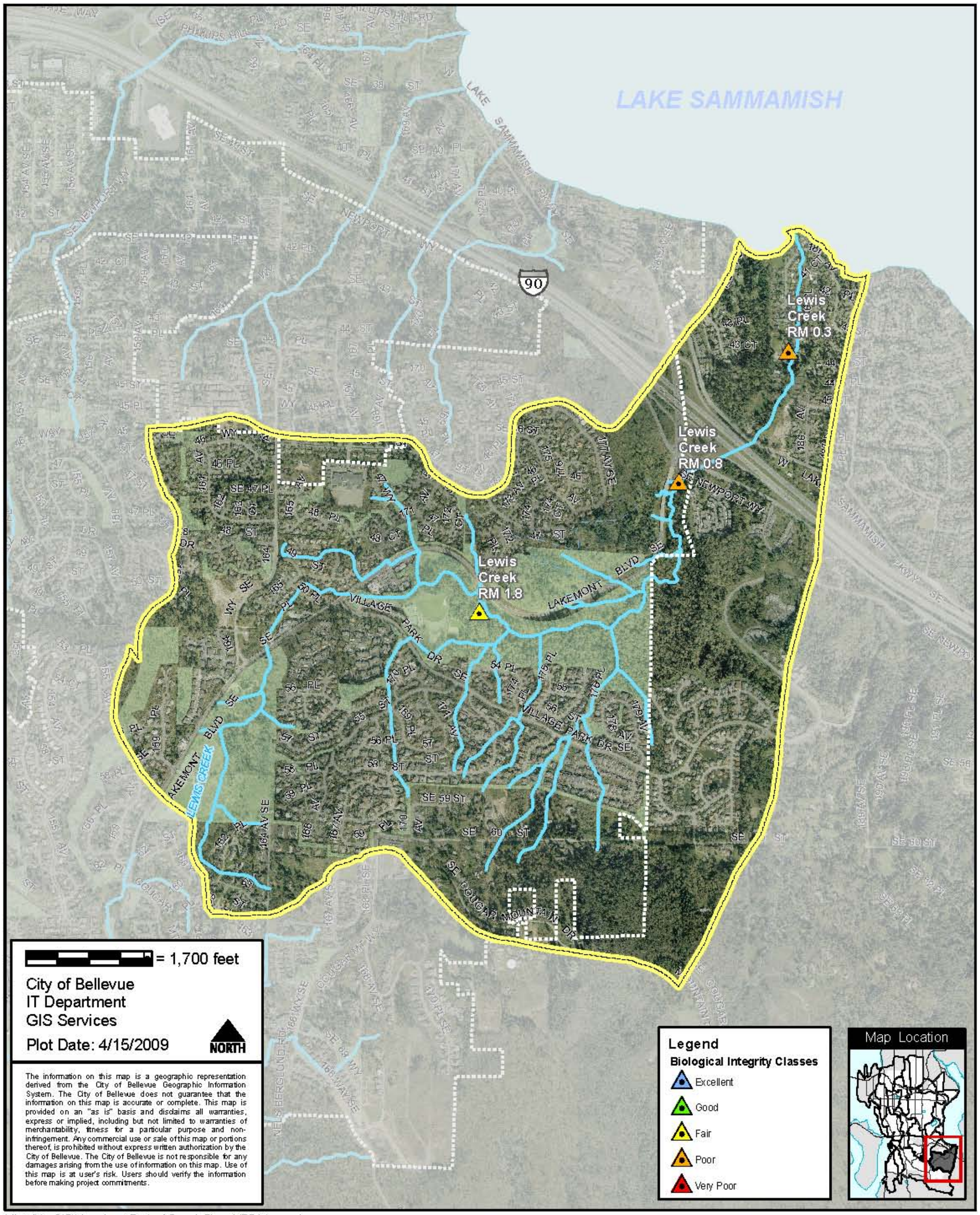

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Figure 34. Lewis Creek basin, with 1998-2007 sampling sites. Biological integrity classes based on B-IBI scores (King County 2008a) are indicated by colored triangles.

Lewis Creek

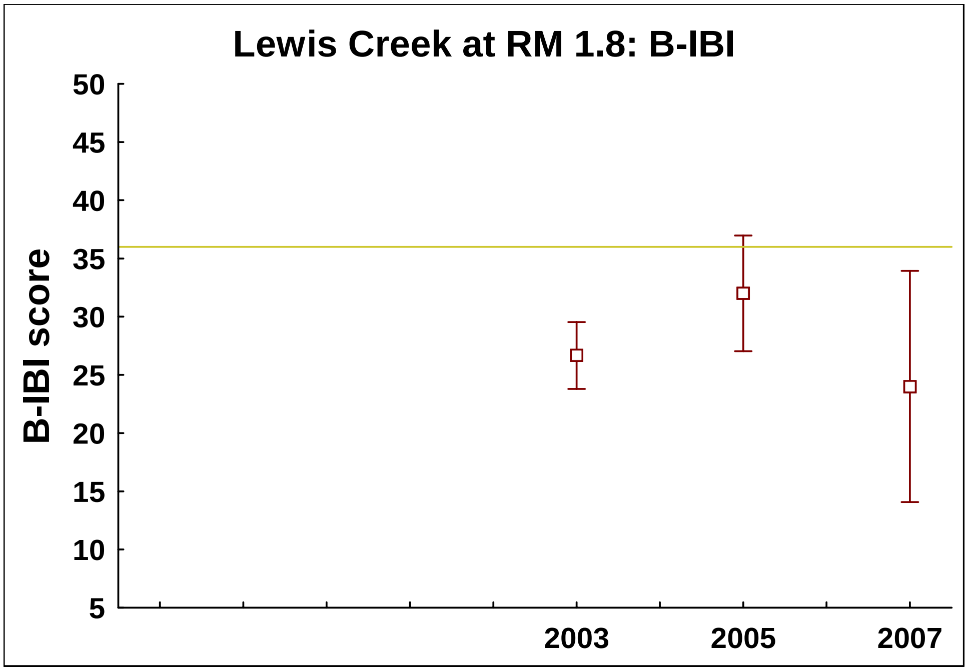
Lewis Creek was sampled in 3 locations over the study period. A site at RM 1.8 was sampled in 2003, 2005, and 2007. The site at RM 0.8 was sampled in 1998, 2001, 2002, 2003, 2005, 2006, and 2007. The site at RM 0.3 was sampled in 2005, 2006, and 2007. Three replicates were taken at each site in each sampling event. The map in Figure 34 indicates sampled sites on Lewis Creek.

Lewis Creek at RM 1.8

1. Bioassessment scores

Higher B-IBI scores in 2005 were followed by a decrease in scores in 2007, at the RM 1.8 site on Lewis Creek (Figure 35). Analysis of variance demonstrated that mean B-IBI scores varied significantly ($p = 0.027$) among the years of study. Mean B-IBI scores for 2005 were significantly higher than those of 2003 and 2007. Scores ranged from 40% to 68% of maximum, indicating poor to fair biological conditions at the site. Scores were limited by low values for mayfly taxa richness and sensitive taxa richness metric values in all years. Metrics returning higher scores included stonefly and caddisfly taxa richness, and total taxa richness.

There were no significant differences in RIVPACS scores among years ($p = 0.264$) (Figure 36). Some replicates scored at or above the WADOE impairment threshold in each year of sampling. RIVPACS scores ranged from 0.59 to 0.84.



Year	Group 1	Group 2
2003	*	
2005		*
2007	*	

Figure 35. B-IBI scores (means and 95% confidence intervals) for Lewis Creek at RM 1.8. Three replicate samples were collected in each year of sampling. The yellow line on the graph represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates significant differences ($p = 0.027$) among years. The table shows the homogeneous groups of mean B-IBI scores resulting from post-hoc tests: mean B-IBI score in 2005 was significantly higher than scores in the other years.

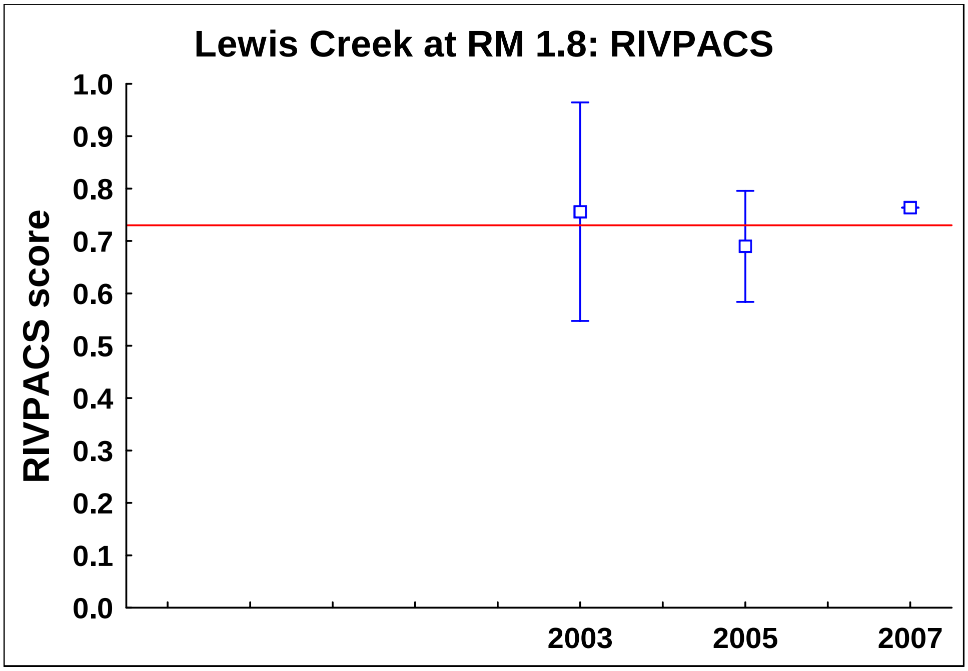


Figure 36. RIVPACS scores (means and 95% confidence intervals) for Lewis Creek at RM 1.8. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates no significant differences (p = 0.264) among years.

2. Indicators of ecological condition

a. Water quality

Mayfly taxa richness was lower than expected (Figure 37a) in every sampled year; the most abundant mayfly in all years was the ubiquitous *Baetis tricaudatus*. Although low mayfly taxa richness is suggestive of water quality degradation, this site supported sensitive taxa (Figure 37f) including chloroperlid stoneflies (e.g. *Paraperla* sp.). HBI values were among the lowest calculated for City of Bellevue sites in this study; invertebrate assemblages were relatively sensitive. It seems likely that water quality was fair to good in this reach.

b. Thermal condition

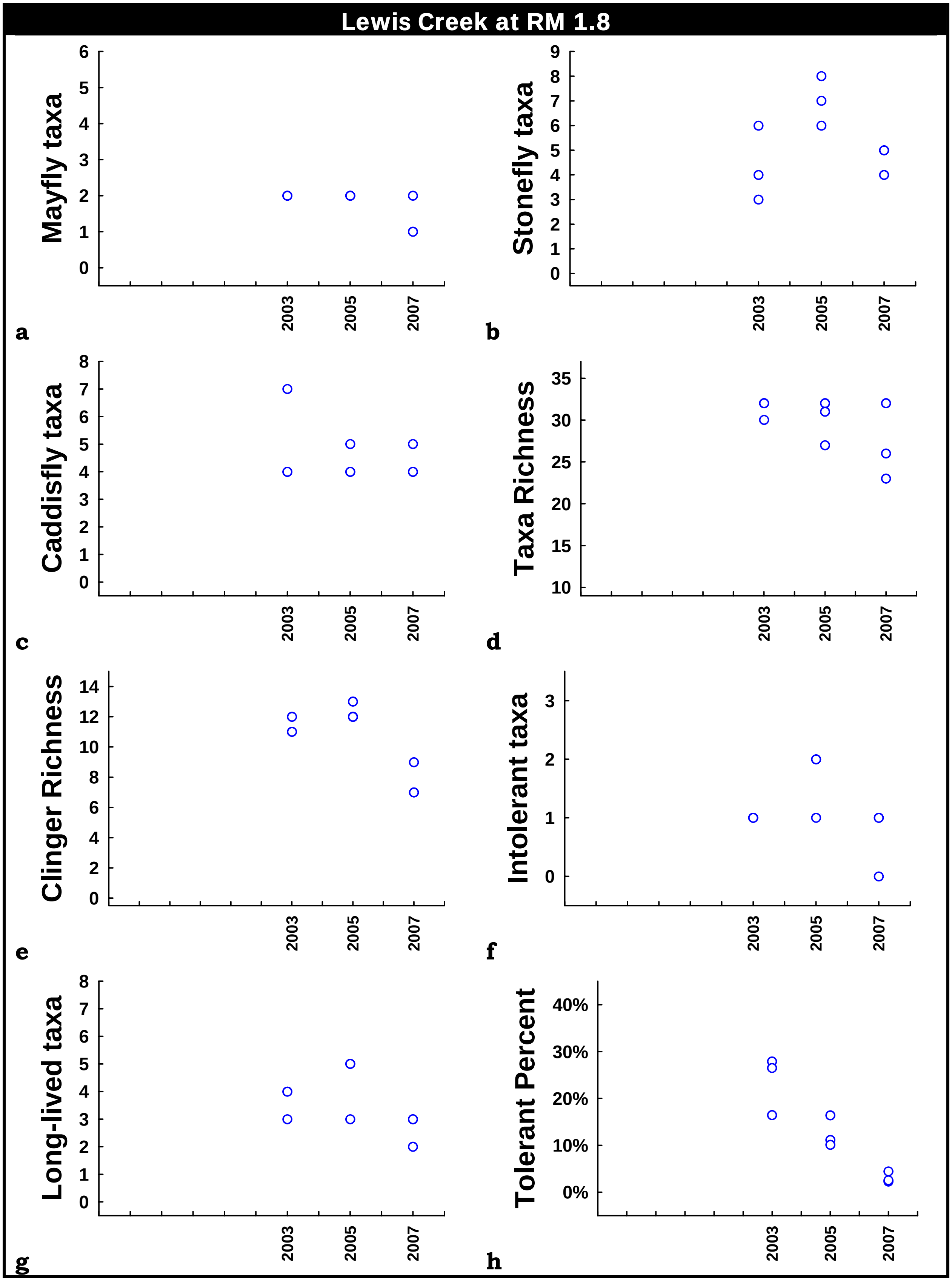
The calculated temperature preferences ranged from 12.7 to 13.5ºC; suggesting that the site at RM 1.8 may have been among the coldest sites studied. Thermal preference steadily increased over the time period, however, and while 3 cold stenotherm taxa were present in samples in 2003, only a single such taxon was present in 2007. Warming water temperatures between 2003 and 2007 cannot be ruled out.

c. Sediment deposition

Although clinger taxa richness (Figure 37e) was slightly lower than expected, Lewis Creek at RM 1.8 supported more such taxa than any other site in this study. Caddisfly taxa richness (Figure 37c) was high in every year, with each site supporting 5 to 7 caddisfly taxa. Colonization of stony substrate habitats was apparently not substantially limited by fine sediment deposition, especially in the earlier years of sampling. In 2007, the number of clinger taxa decreased, suggesting that sediment deposition may have been influential in that year. In 2005 and 2007, however, hyporheic stoneflies (*Paraperla frontalis* and *Kathroperla perdita*) were collected in samples, indicating that sediment deposition was probably not severe. FSBI values indicated moderately sediment-tolerant assemblages in every year.

d. Habitat diversity and integrity

The RM 1.8 site on Lewis Creek supported greater diversity of invertebrates than any other site in this study, and faunal richness remained high over the study period (Figure 37d). High taxa richness suggests that instream habitats were complex and undisturbed. Stonefly taxa richness (Figure 37b) was also high, which may indicate that reach-scale habitat features such as channel morphology, riparian function, and streambank vegetation were essentially intact. The abundance of predators (Figure 37i) decreased in 2007 compared to earlier years; this trend could be related to increased sediment deposition in that year. Long-lived taxa were present and abundant throughout the study period (Figure 37g), indicating that surface flow persisted year-round here, and that scouring sediment pulses or toxic pollutants were not influential. All expected functional components were present in every year.


Lewis Creek at RM 1.8
Mayfly taxa
Stonefly taxa
Caddisfly taxa
Taxa Richness
Clinger Richness
Intolerant taxa
Long-lived taxa
Tolerant Percent
2003
2005
2007
a
b
c
d
e
f
g
h

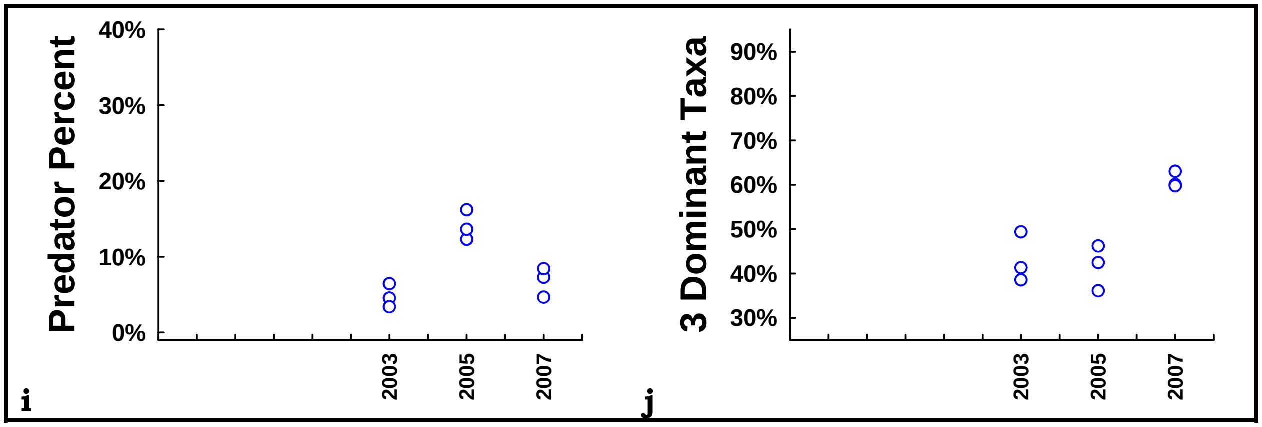


Figure 37. Performance of B-IBI metrics at Lewis Creek RM 1.8. Three replicate samples were collected in each year.

Lewis Creek at RM 0.8

1. Bioassessment scores

B-IBI scores ranged from 40% to 64% of maximum at the RM 0.8 site on Lewis Creek, indicating poor to fair biological conditions (Figure 38). Scores were limited by low values for the mayfly taxa richness and percent predator metrics. Metrics delivering high values included clinger taxa richness and caddisfly richness. The repeated measures analysis of variance test detected no significant differences (p = 0.236) among mean B-IBI scores over the years of study.

RIVPACS scores peaked in 2003 and 2005 at this site, but decreased in the following 2 years (Figure 39). Scores for replicates ranged from 0.59 to 0.92. All replicates collected in 2003, 2005 and 2006 yielded scores that fell above the WADOE impairment threshold. Some of the 1998, 2001, 2002 and 2007 replicates also gave scores that indicated unimpaired biological conditions as measured by the RIVPACS model. Repeated measures analysis of variance demonstrated significant differences (p = 0.009) in mean RIVPACS scores among years. Scores were significantly higher in 2003 and 2005 compared to the other years of study.

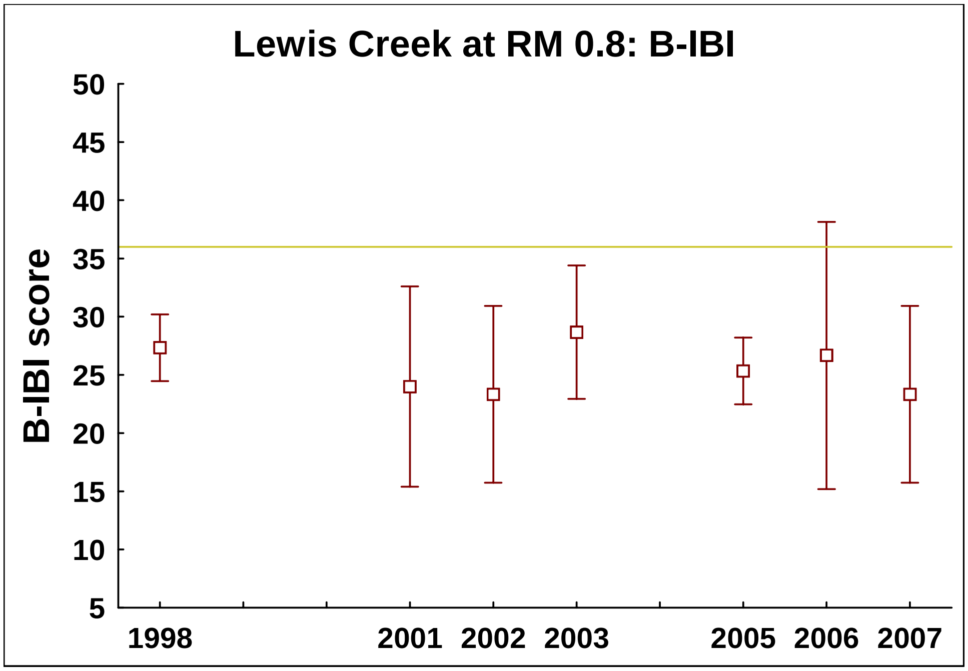
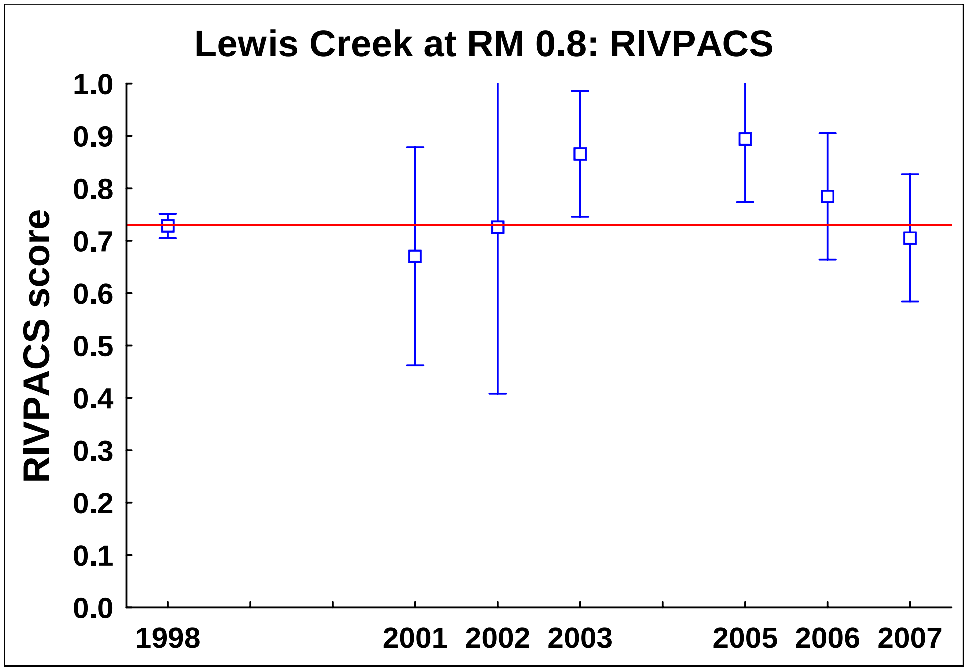


Figure 38. B-IBI scores (means and 95% confidence intervals) for Lewis Creek at RM 0.8. Three replicate samples were collected in each year of sampling. The yellow line represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates no significant differences ($p = 0.236$) among years.



Year	Group 1	Group 2
1998	*	
2001	*	
2002	*	
2003		*
2005		*
2006	*	*
2007	*	

Figure 39. RIVPACS scores (means and 95% confidence intervals) for Lewis Creek at RM 0.8. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates significant differences (p = 0.009) among years. The table shows the homogeneous groups of mean RIVPACS scores resulting from post-hoc tests: RIVPACS scores in 2003 and 2005 were significantly higher than scores in all other years.

2. Indicators of ecological condition

a. Water quality

Mayfly taxa richness was low at Lewis Creek at RM 0.8 throughout the study period (Figure 40a), and the ubiquitous taxon *Baetis tricaudatus* dominated the mayfly fauna in every year. However, sensitive taxa were supported at this site; as many as 4 such taxa were collected in replicates in 2003 and 2005. These included the stoneflies *Pteronarcys princeps* and *Despaxia augusta*; the sensitive montane taxon *Yoraperla brevis* was collected here in 1998. HBI values calculated for these assemblages were generally lower than the median value for all City of Bellevue sites. These findings suggest that water quality was good at this site.

b. Thermal condition

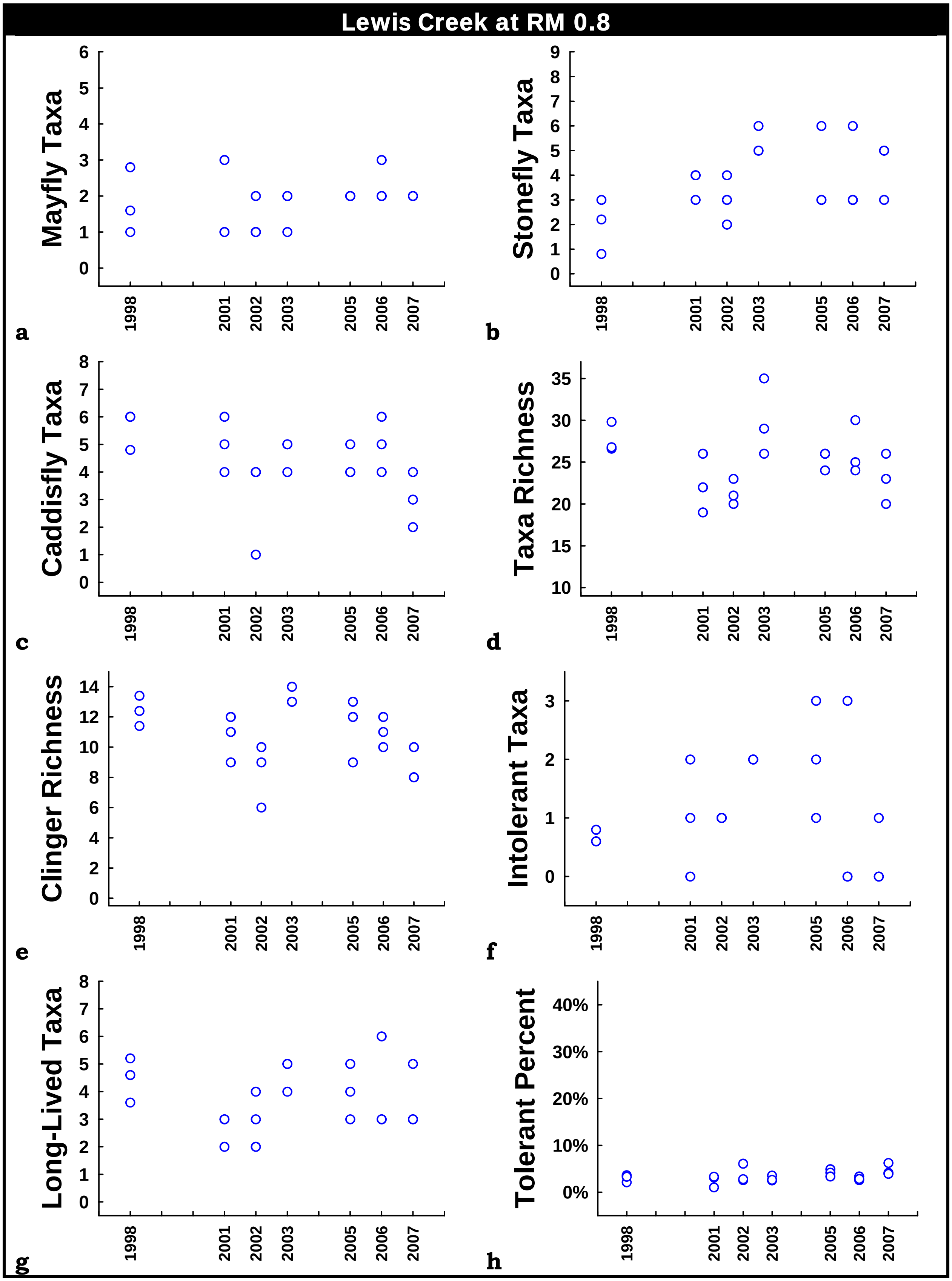
Cold water temperatures appear to have characterized the I-90 site; estimated thermal preferences for the assemblages collected here ranged from 12.41 to 13.90ºC. The turbellarian *Polycelis coronata* was identified in samples collected in 2006 and 2007. The presence of this flatworm suggests that cold groundwater seepage supplemented surface flow in the reach. Cold stenotherm taxa were collected in all years; these included the caddisfly *Cryptochia* sp. and stoneflies *Yoraperla brevis* and *Paraperla frontalis*.

c. Sediment deposition

Both clinger taxa richness (Figure 40e) and caddisfly taxa richness (Figure 40g) were high or very high in all years, suggesting that there was little or no impairment due to fine sediment deposition. Both groups were somewhat less diverse in 2002 and 2007 than in other years. The presence of the hyporheic stonefly *Paraperla frontalis* in 4 out of 6 years indicates that interstitial deposition of sediment was minimal in this reach. FSBI values calculated for these assemblages indicated moderate sediment tolerance, but these values were higher than the median values for City of Bellevue sites.

d. Habitat diversity and integrity

The RM 0.8 site on Lewis Creek supported more taxa (Figure 40d) than most City of Bellevue sites in this study, suggesting that instream habitats here were among the most diverse of any site. Stable streambanks, intact riparian function, and natural channel morphology may be indicated by the consistently high stonefly taxa richness over the period of study. Long-lived taxa (Figure 40g) were diverse and abundant, implying stable instream habitat conditions. The site did not support a diverse functional composition; gatherers dominated the feeding group distribution. Small numbers of predators, shredders, and scrapers were collected in every year, but their proportions were generally lower than expected.


Lewis Creek at RM 0.8
Mayfly Taxa
Stonefly Taxa
Caddisfly Taxa
Taxa Richness
Clinger Richness
Intolerant Taxa
Long-Lived Taxa
Tolerant Percent
1998
2001
2002
2003
2005
2006
2007
a
b
c
d
e
f
g
h

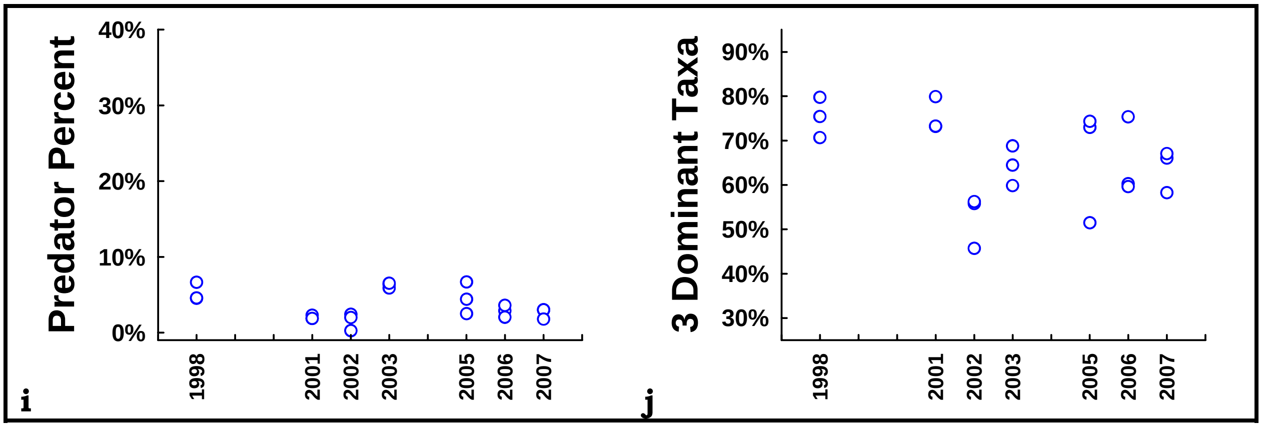


Figure 40a-j. Performance of B-IBI metrics at Lewis Creek RM 0.8. Three replicate samples were collected in each year.

Lewis Creek at RM 0.3

1. Bioassessment scores

B-IBI scores exhibited a slight negative trend between 2005 and 2007 (Figure 41) at the RM 0.3 site on Lewis Creek. Repeated measures analysis of variance detected no significant differences ($p = 0.406$) in mean B-IBI scores among years. Scores ranged from 44% to 60% of maximum, indicating poor to fair biological conditions, and were variable among replicates in both 2005 and 2006. Low B-IBI scores were generally the result of low values for mayfly taxa richness, caddisfly taxa richness, sensitive taxa richness, and percent predator metrics for all replicates in every year. In addition, the stonefly taxa richness metric yielded low values for most replicates over the period of study.

No significant differences ($p = 0.154$) in mean RIVPACS scores among years could be detected by the analysis of variance test (Figure 42). Scores ranged from 0.64 to 0.88. In each year, some replicate scores were higher than the WADOE threshold, indicating unimpaired conditions.

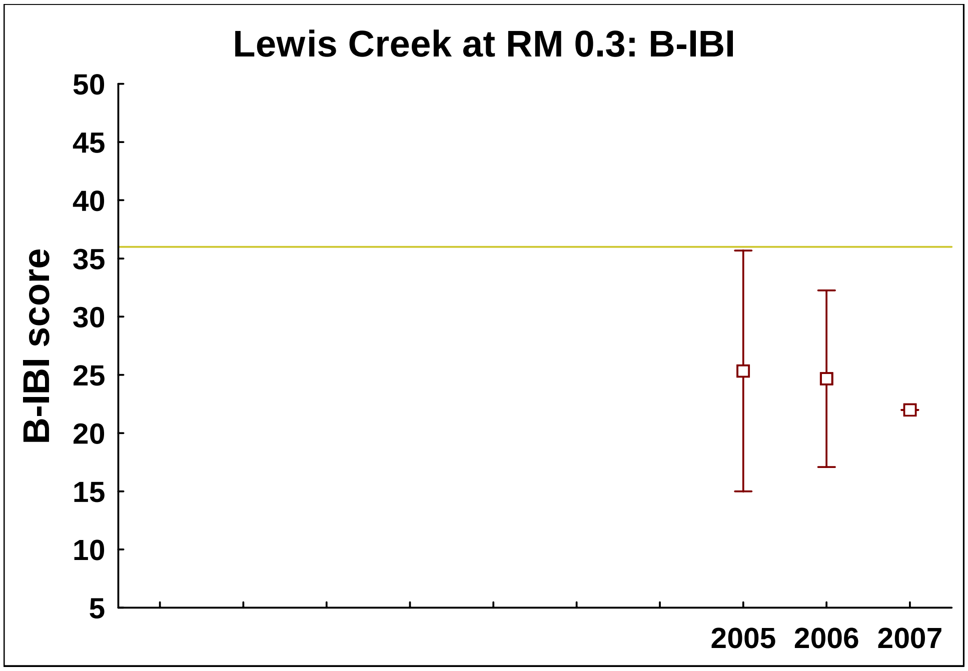


Figure 41. B-IBI scores (means and 95% confidence intervals) for Lewis Creek at RM 0.3. Three replicate samples were collected in each year of sampling. The yellow line represents the threshold between "good" and "fair" conditions (B-IBI score = 36). Repeated measures analysis of variance (random effects) demonstrates no significant differences (p = 0.406) among years.

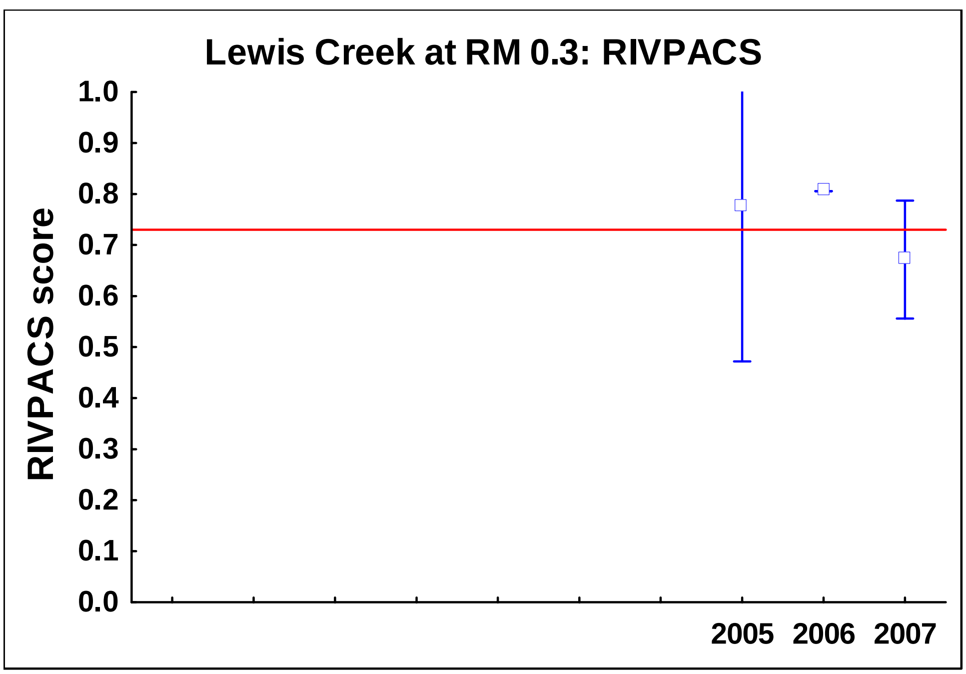


Figure 42. RIVPACS scores (means and 95% confidence intervals) for Lewis Creek at RM 0.3. Three replicate samples were collected in each year of sampling. The red line represents the WADOE impairment threshold (0.73) for RIVPACS scores. Repeated measures analysis of variance (random effects) demonstrates no significant differences (p = 0.154) among years.

2. Indicators of ecological condition

a. Water quality

The Lewis Creek site at RM 0.3 supported 3 mayfly taxa in every sampled year, and the composition of the mayfly fauna was stable during that time (Figure 43a). *Baetis tricaudatus* was the most abundant taxon in the group. In both 2006 and 2007, HBI values were above the median value for all City of Bellevue sites, indicating relatively tolerant assemblages. These findings suggest that water quality may have been impaired here; mild nutrient enrichment cannot be ruled out. Sensitive taxa managed to persist here (Figure 43f); in 2007, a few specimens of *Pteronarcys princeps* were collected.

b. Thermal condition

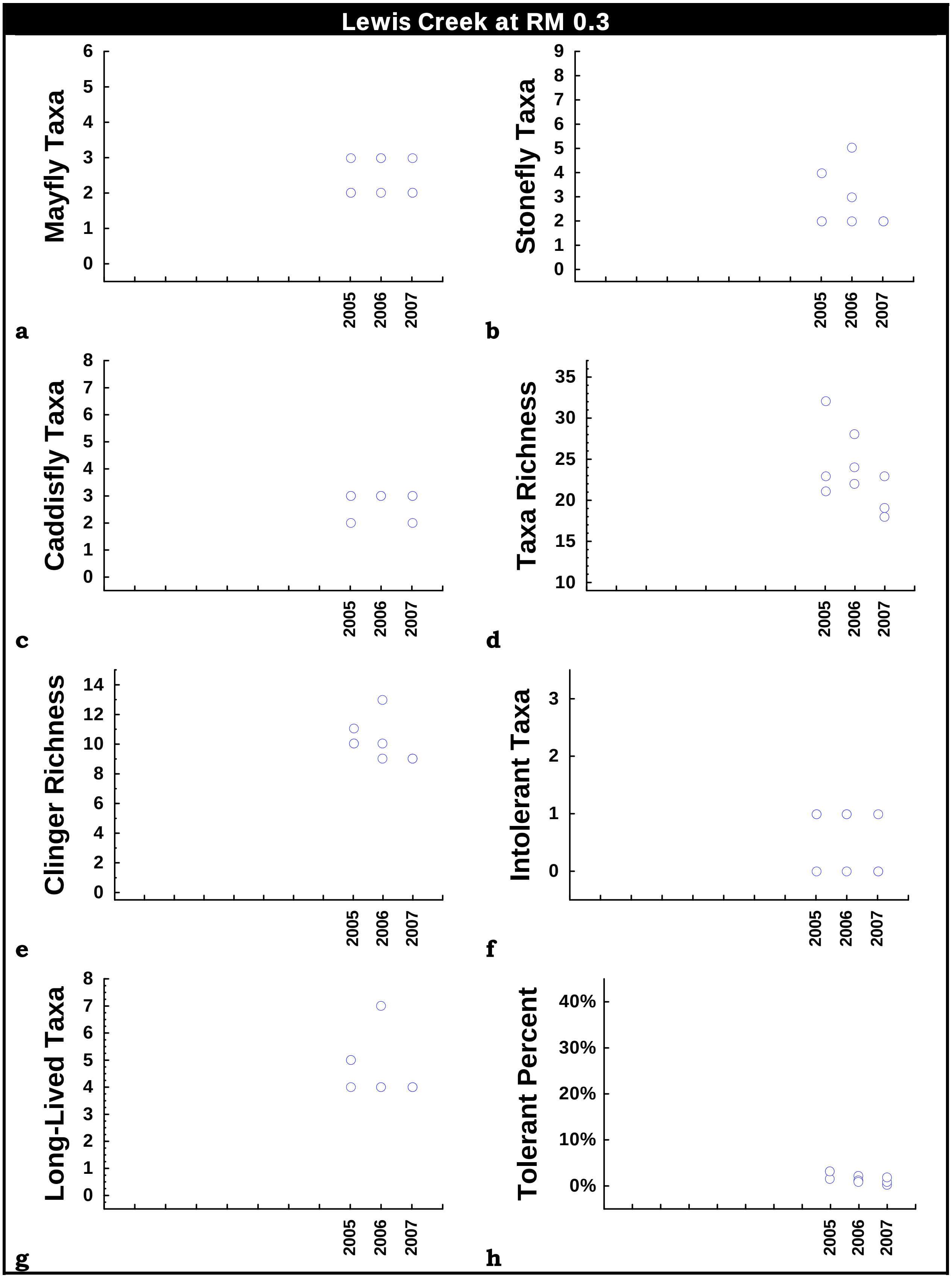
Cold stenotherm taxa were present at this site in 2005 and in 2007. Thermal preferences for assemblages ranged from 13.3 to 13.8ºC. Cold water temperatures are indicated, and the expected warming over the longitudinal profile of Lewis Creek was demonstrated by the increasing values for thermal preferences estimated at the 3 sampled sites.

c. Sediment deposition

Clinger taxa richness (Figure 43e) exceeded the median value for City of Bellevue sites, but the diversity of clingers decreased over the study period. During this time, caddisfly taxa richness fell as well (Figure 43c). FSBI values indicated that the assemblages were moderately sediment tolerant at this site. Mild sediment deposition may have influenced the composition of the benthic fauna at RM 0.3, especially in 2006 and 2007.

d. Habitat diversity and integrity

Although taxa richness (Figure 43d) was high in 2005, the number of taxa in replicates fell over the following years; lower than expected taxa richness in 2007 may have been associated with increasing monotony of instream habitats. Sediment deposition may account for these changes. A rich stonefly fauna (Figure 43b) over the period of study may be associated with stable streambanks, natural channel morphology, and intact riparian vegetation. Semivoltine taxa were diverse and abundant in all years (Figure 43g). The assemblages were functionally simple in every year, with gatherers dominating the mix and scrapers and shredders rare.



Lewis Creek at RM 0.3
Mayfly Taxa
Stonefly Taxa
Caddisfly Taxa
Taxa Richness
Clinger Richness
Intolerant Taxa
Long-Lived Taxa
Tolerant Percent
2005
2006
2007
a
b
c
d
e
f
g
h

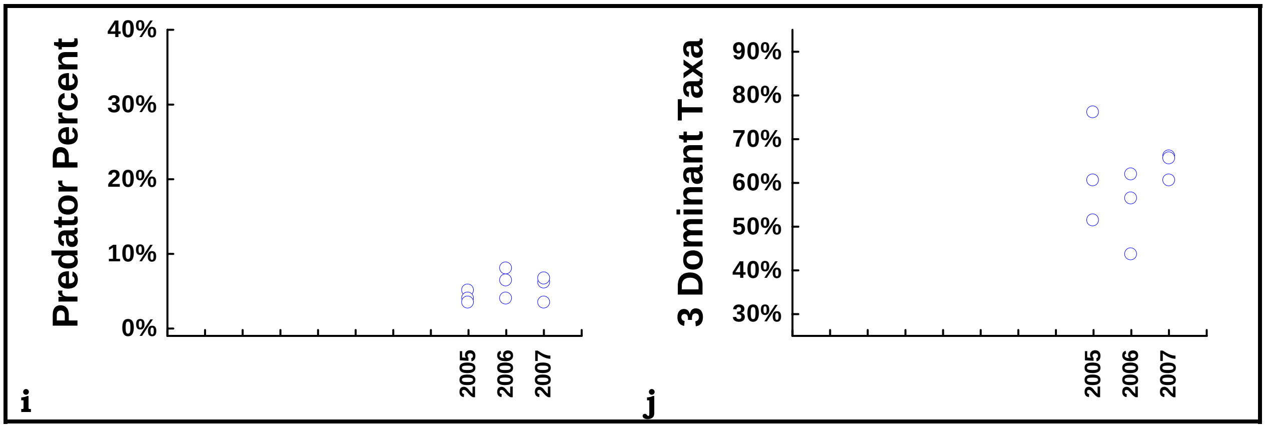


Figure 43. Performance of B-IBI metrics at Lewis Creek RM 0.3. Three replicate samples were collected in each year.

DISCUSSION

The highly urbanized watersheds in the City of Bellevue support aquatic invertebrate communities that often lack expected taxonomic and functional components. In particular, the assemblages collected in the Goff, Valley, and Kelsey Creek watersheds exhibited multiple sources of stress, most of which are probably related to alterations of the natural environment, and human-caused degradation to water quality.

The ordination study demonstrated groupings of sites based on the taxonomic composition of the aquatic assemblages; bioassessment scores generally distinguished the groups as well, with Coal Creek and Lewis Creek sites attaining higher scores for B-IBI and RIVPACS evaluations, and Goff, Valley, and Kelsey Creek sites invariably scoring lower. It would be convenient to chalk up these differences entirely to the intensity of human influence on the sites, but such a conclusion does not account for natural differences in these watersheds. Goff, Valley, and Kelsey Creeks are lower gradient systems, with headwaters no higher than about 500 feet. In contrast, Coal Creek and Lewis Creek originate at elevations above 1000 feet; at least in their upper reaches, gradients are steep in these watersheds. A well-documented pattern in western montane landscapes consists of sites with lower gradients supporting more tolerant assemblages, including animals better adapted to warmer water temperatures. They are dependent on feeding strategies based less on large organic material and more on small particles in suspension. These differences are associated with the naturally smaller substrate particle sizes, attenuated riparian inputs and shading, and slower current velocities.

The Valley Creek and Kelsey Creek watersheds are distinguished by having the largest percentages of impervious surface area, but the Goff Creek watershed has much less extensive urban development. Still, bioassessment scores are consistently low at Goff Creek sites, suggesting that low channel gradient may have had an additional effect on the biota. The steep ravine at the bypass site may be the result of historic channel downcutting, exacerbating the effects of sediment deposition, and flattening a channel that may have been steeper in the past.

Lewis Creek sites, on the other hand, may have features that mitigate the effects of more intense urban development; bioassessment scores for Lewis Creek sites were consistently higher than predicted by the extent of impervious surfaces in the watershed. The presence of a major detention and water quality treatment facility in the watershed may be influential; the presence and extent of this influence on biological assemblages should be studied. Higher channel gradient may result in better oxygenation, and may have a protective effect on the diversity of substrate components. Residential development may have more benign effects on water quality than industrial development. Additionally, wider zones of riparian vegetation may offer increased filtration and percolation, better shading and a different energy basis for invertebrate assemblages, suggesting that measures of riparian zone width and integrity may be a useful adjunct to future monitoring in Bellevue watersheds. Figures 44 and 45 show the relationship between impervious area and assessment scores (B-IBI and RIVPACS respectively) and demonstrate higher scores for Lewis Creek and lower scores for Goff Creek than predicted by the extent of urbanization.

The B-IBI and RIVPACS tools performed similarly for assemblages collected in the City of Bellevue. Correlation between the 2 methods was strong (Figure 3), and the ecological evidence discussed in the site-by-site narratives generally supported the results of the bioassessment tools; this suggests that either tool is useful for the monitoring of the City's streams. In some instances, RIVPACS scores were slightly lower than B-IBI scores at the more impaired sites (e.g. Goff upper, Kelsey at Glendale), but gave higher scores than B-IBI for less impaired sites (e.g. Coal at RM 4.0, Lewis at RM 0.8); the narrative analyses largely agrees with the more extreme scores. RIVPACS may have a slight advantage over B-IBI for expressing the intensity of impairment adherent to the magnitude of urbanization in some of the City's watersheds. It would seem prudent to continue to examine ecological information, such as taxonomic and functional composition, that can suggest probable stressors, in addition to considering simple scores.

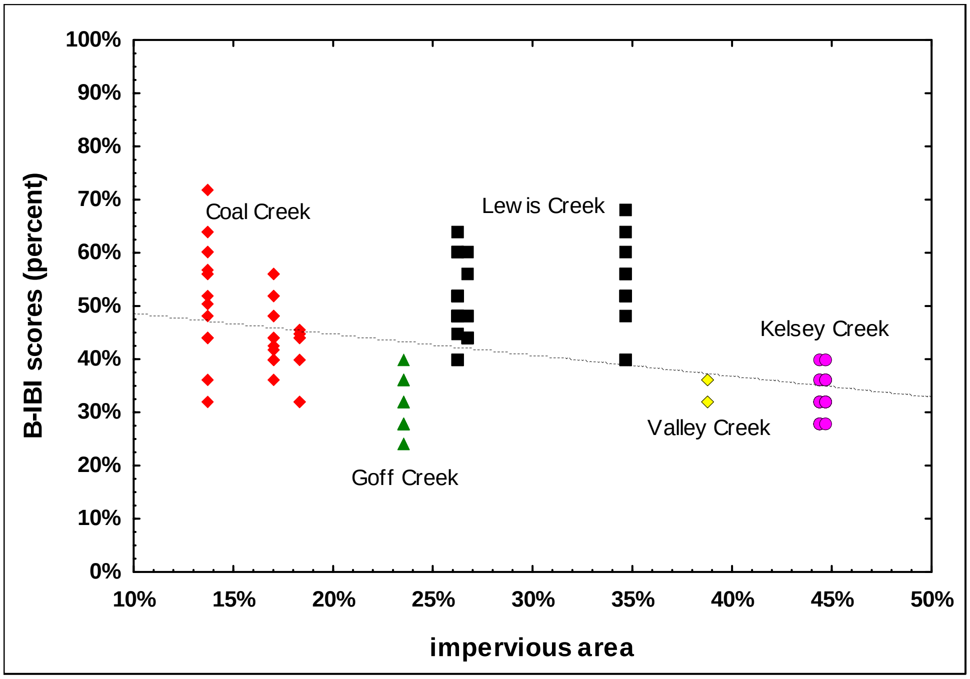


Figure 44. The relationship between the extent of impervious surfaces and B-IBI scores.

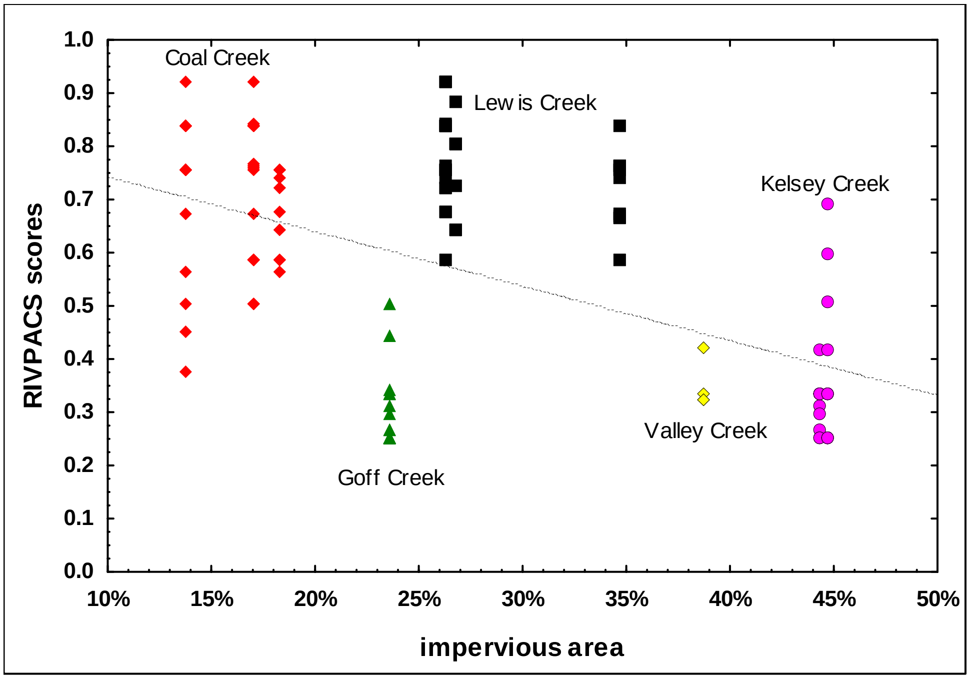


Figure 45. The relationship between the extent of impervious surfaces and RIVPACS scores.

The performance of most of the individual metrics that comprise the B-IBI were correlated with the intensity of urban development as measured by the percent of impervious area in watersheds; in addition, many other metric expressions of biological condition were also correlated with urbanization. These notable results are testament to the profound impact of urban development on the biological integrity of streams. The negative influence of impervious surfaces on aquatic invertebrate assemblages can be discerned by almost any evaluative parameter, including measures of diversity, tolerance, functional balance, habitus, or physiology. The abundance of animals in samples, which may be considered a measure of invertebrate density, was also associated with the magnitude of urbanization. Metrics with exceptionally strong associations with urbanization were mayfly taxa richness and the Metals Tolerance Index. Metrics that were not associated with the percent impervious area included intolerant taxa richness, percent predators, and hemoglobin-bearer richness.

Some metrics might demonstrate stronger association with stressors if taxonomic resolution were more rigorous for certain invertebrate groups. For example, hemoglobin-bearing taxa among the midges and oligochaetes cannot be distinguished unless these groups are identified to genus. The richness or abundance of hemoglobin-bearing invertebrates is useful in detecting low oxygen conditions in stream sediments; hypoxic sediments are associated with nutrient enrichment, warm water temperatures, or a combination of these stressors. It would not be surprising if the midge and oligochaete faunae at Goff and Kelsey Creek sites included considerable numbers of hemoglobin-bearing taxa.

When trends in scores could be identified, B-IBI and RIVPACS agreed on the direction of the trend; however, there were a few instances in which one tool demonstrated a trend

Table 6. Possible stressors, as suggested by the taxonomic and functional composition of invertebrate assemblages.

Drainage	Site	water quality degradation	metals	sediment deposition	thermal stress	habitat disruption
Coal	RM 4.0	•		•		?
	RM 2.3	•		•		?
	RM 1.8	•	?	•		•
Goff	RM 1.7	•	?	•	•	•
	RM 1.6	•	?	•	?	•
	RM 1.4	•		•	•	•
Kelsey	RM 3.9	•		•	•	•
	RM 1.8	•		•	•	•
Lewis	RM 1.8					
	RM 0.8					
	RM 0.3	•		•		•
Valley	RM 0.2	•		•		•

while the other did not. It is important to note that contemporary trends are not assessed at any Goff Creek site or at the RM 1.8 site on Coal Creek: data for these sites was not collected after 2002.

Table 6 summarizes the stressors suggested by the analysis of taxonomic and functional composition of invertebrate assemblages and described in the site-by-site narratives. Water quality degradation was apparent at most sites, evidenced by low mayfly taxa richness and measures of assemblage tolerance. Mayfly taxa were limited at all Bellevue sites: 5 or 6 unique taxa were the most that were supported at any site in the study. Water quality problems probably included nutrient enrichment at most sites; metals contamination was a possible additional stressor at several sites.

Fine sediment deposition was probably influential in all Bellevue streams, with the possible exception of 2 sites on Lewis Creek (Lewis at RM 1.8 and Lewis at RM 0.8). Clinger taxa and caddisfly taxa were poorly represented at all other sites. The diagnosis of sediment deposition may be confounded in situations where other factors limit the colonization of stony substrate habitats. These factors may include scouring flows that frequently and catastrophically redistribute sediments. Unstable instream habitats may also interrupt the long life cycles of semivoltine taxa.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that B-IBI and RIVPACS perform similarly in the assessment of sites in the City of Bellevue. However, the RIVPACS model tended to return higher scores than the B-IBI where biological conditions were better, as for Coal Creek and Lewis Creek sites. These higher scores generally conformed more closely to the evidence summarized in the site-by-site ecological analysis. The association of RIVPACS scores with the measure of urban development in watersheds was somewhat stronger than that of the B-IBI, However, because it is better-known among volunteer monitors and the public in general, and because it is relatively transparent and easy to describe, the B-IBI may be more conducive for presentation to general audiences.

Evidence that may indicate the presence of metals contamination could be discerned at some sites in 2 Bellevue watersheds: Coal Creek and Goff Creek. These pollutants should be further investigated by assaying the metals in sediments and in water, and if metals contamination is confirmed, possible sources should be identified. Sources may include runoff from streets and industrial areas, runoff from lawns treated with chemical agents, background levels in natural geologic formations, and others. If sources can be controlled or affected, measures to minimize metals in receiving streams should be undertaken.

Similarly, in watersheds where nutrient enrichment may stress the aquatic biota, nutrient concentrations in the water should be periodically measured in the laboratory. If excessive nutrients are found, potential sources such as lawn treatments should be assessed, and measures to reduce inputs should be undertaken. All sampled sites in the Coal Creek, Goff Creek, and Kelsey Creek watersheds exhibited water quality degradation that may have been related to nutrient enrichment, as did the single sampled site on Valley Creek, and the lowermost site on Lewis Creek.

Restoration of lost riparian function and protection of riparian areas which are currently functional would help to control thermal stress in the Goff Creek and Kelsey Creek watersheds, where warm water temperatures influence biological assemblages. Measures to reduce sedimentation, which is probably related to scouring flows, should be sought and implemented whenever possible, if instream and riparian habitats are to be restored or protected. Evidence of possible sediment influence could be detected at most sites in the City of Bellevue; only the upper and middle reaches of Lewis Creek supported assemblages that did not exhibit such evidence.

Continued monitoring of Bellevue streams is warranted, since taxonomic and metric information from macroinvertebrate sampling is useful for assessing habitat and water quality conditions. In order to maximize the information thus gathered, it is advisable to apply higher taxonomic resolution to the sampled macroinvertebrates. In particular, the midge fauna (Diptera: Chironomidae) is an important source of information related to dissolved oxygen conditions in the substrates of streams. Many of these animals carry hemoglobin in their circulating fluids and prefer low oxygen conditions. Identification of this group to generic levels would allow the calculation of the abundance and diversity of hemoglobin-bearing animals. The current protocols, which call for identification to family level, do not permit the separation of these important midges. Similarly, identification of oligochaete taxa to higher taxonomic resolution would permit the hemoglobin-bearing taxa in this group to be identified as well. Calculation of some B-IBI metrics would need to be adjusted to accommodate a revision of the protocols for taxonomic resolution, and the compatibility of data generated between 2001 and 2007 with data generated with updated protocols would need careful scrutiny. However, the additional taxonomic effort and the assessment of data compatibility would probably be rewarding, since several sites in the current study exhibit evidence of thermal stress and probable nutrient enrichment. Better information about the possible presence and extent of hypoxic sediments is an important condition worth monitoring.

The level of taxonomic resolution for all invertebrate groups as well as sample handling procedures should be clearly spelled out in protocols required of contracted laboratories that provide services in the processing and identification of aquatic invertebrates for bioassessment. These protocols should be carefully crafted with consideration of what information is desired, and they should be maintained from year to year if trends or comparisons are to be studied. Appendix B is a table listing a recommended standardization for taxonomic resolution that would maximize information for interpretation of invertebrate assemblages. To obtain consistency in the calculation of B-IBI, however, would require adjustment of data to conform to the lower resolution required by that tool.

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APPENDIX A. City of Bellevue sampling protocol

Field Protocols for Benthic Macroinvertebrate Sampling for Use With the Benthic Index of Biotic Integrity

City of Bellevue, Utilities Department

April, 2009

BACKGROUND

The City of Bellevue adapted these protocols from King County Water and Land Resources Division for use in Bellevue's streams beginning in 1998. Some of Bellevue's streams have fewer macroinvertebrates than found in most streams, so the protocols were modified: instead of collecting one sample from each of three riffles at a site, three samples are collected from each riffle and composited one sample jar, resulting in nine samples composited into three jars at each sample site. If a riffle is too small to accommodate three samples, multiple riffles are used.

OBJECTIVE

The City of Bellevue and the King County Water and Land Resources Division use the Benthic Index of Biotic Integrity (B-IBI; Fore et al. 1996) as a tool for quantitative, long-term bioassessment of streams as they respond to urbanization, watershed management, and restoration activities. For valid comparison of index scores, each set of data must be based upon samples collected and processed according to strictly defined protocols. Field protocols need to be documented for use with the B-IBI. The primary purpose of this document is to provide a written step-by-step field sampling protocol specifically for use with the B-IBI.

This discussion emphasizes field techniques. It is written with the intent that a person relatively unfamiliar with benthic sampling techniques may understand and use the directions. Before any field work is initiated, "study designers" should consider monitoring objectives, site selection, establishment of reference sites, QA/QC, personal safety, taxonomic standards, and data analysis. Discussion of these items can be found in the following documents:

- EPA: *Rapid Bioassessment Protocols for use in Streams and Rivers; Benthic Macroinvertebrates and Fish.* (Plafkin et al. 1989).

- EPA: *Region 10 In-Stream Biological Monitoring Handbook for Wadable Streams in the Pacific Northwest* (Hayslip 1993).

- USGS: *Methods for Collecting Benthic Macroinvertebrate Samples as Part of the National Water-Quality Assessment Program* (Cuffney et al. 1993).

- Washington Department of Ecology: *Instream Biological Assessment Monitoring Protocols: Benthic Macroinvertebrates* (Plotnikoff 1994).

- Oregon Department of Environmental Quality: *Oregon Nonpoint Source Monitoring Protocols Stream Bioassessment Field Manual: For Macroinvertebrates and Habitat Assessment* (Mulvey et al. 1992).

- Idaho Division of Environmental Quality: *Protocols for Assessment of Biotic Integrity (Macroinvertebrates) in Wadable Idaho Streams* (Clark et al. 1993).

- Alaska Department of Environmental Conservation: *Proposed Rapid Bioassessment Protocols for Alaska Streams and Rivers* (Alaska DEC 1996).

METHODS

This discussion will be presented in three parts. First is an equipment list. Second is a general discussion of recommended sampling considerations; rationale for these recommendations will be emphasized in the discussion of alternatives. The last part of this discussion details step-by-step instructions for collecting benthic macroinvertebrate samples.

Equipment

- Surber sampler, 1 square foot frame, with 500 micron mesh net
- Dish pans, white or light-colored
- Bucket
- One or two 500 micron sieves
- Weeding fork
- Data sheet, pencil
- 2 L Ethyl alcohol, 95%, denatured
- Three 500 mL sample jars with lids.
- Extra paper and tape for labels, permanent marker
- Spray bottle
- Plastic cups
- Spatula
- Thermometer and pH meter
- Forceps (entomological forceps work best) and spoon
- Watch with second hand
- Tarp

Sampling Considerations

- Samples are collected only once yearly during late summer, before fall and winter storms begin around August and September.
- A wait of at least three days before sampling is recommended following a storm or other disturbance in the stream.
- This protocol is recommended for wadable waters, generally first through fourth order streams.
- A minimum of three replicates are taken from each of three riffles. Replicates from a riffle are combined into one sample jar.
- After all organic material is separated and saved, all sample processing, including picking, is performed in the laboratory.

Sampling Instructions

1. Choose your site, and define the stream reach which comprises the site. The reach may be defined as part of a larger monitoring effort, such as a habitat assessment, salmon spawning survey area, etc., or may be defined solely for purposes of benthic collections. The reach should be representative of overall conditions in the area upstream, with a minimum length of 20 channel widths. The site should be located at least 50 meters upstream of any crossing.

2. Always work downstream to upstream. Avoid walking in the stream or causing any disturbance upstream of any location yet to be sampled. If previous activity has required walking in stream, wait at least three days before sampling.

3. Before entering the stream reach, determine sampling locations: After locating and sequentially numbering all riffles within the reach, use randomly-generated numbers to select three sampling locations. Riffles are defined as areas where water flows swiftly and turbulently, breaking over the substrate. In the absence of well-defined riffles, choose the fastest-flowing, most turbulent, non-depositional location possible. Prior visits to the reach, or a quick walk of the sampling reach (on the banks) is necessary for this step.

4. Sample at three randomly selected areas within each selected riffle, by walking and placing the net with eyes averted..

5. At each sampling location, approach from downstream, avert your eyes from the stream bottom (to avoid bias in setting the net) and set the net down firmly into the substrate with the opening perpendicular to the flow; use the weed fork or your hands to hold the front of the net frame down into the substrate. Also, make sure that the back part of the frame is securely "sealed" against the substrate to prevent organisms from washing under the frame. If any large cobble lying under the edge of the frame prevents a good "seal," pull it into the perimeter of the frame, even if part of the cobble lies outside the frame area. Perform this step quickly; be aggressive!

6. Once the net has been placed, work quickly. Organisms suspended in the water column may enter the net as they float downstream. This influence should be minimized as much as possible. In higher flow, one person may need to hold the net down while another takes the sample.

7. Scrub by hand using a brush all substrate particles large enough to pick up individually (large gravel and larger-sized particles), holding them inside the net so that all attached organisms wash into the net; discard the cobbles after scrubbing. As stone-cased caddisflies will be difficult to float or pick out of the non-organic material in the sample, you may wish to pick attached caddisflies off the particles and place them directly into the final sample container. Be consistent with whatever method you use to collect caddisflies.

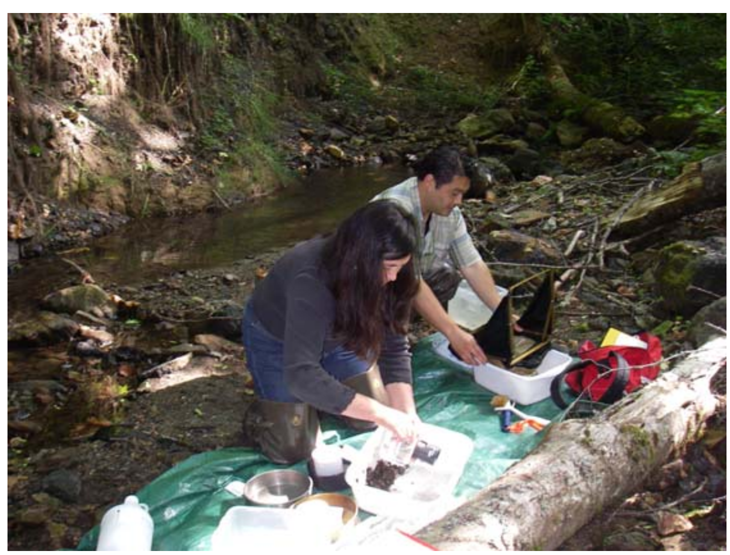
8. Using the weed fork, agitate the sediment within the perimeter of the frame to a depth of approximately 10 cm, or the length of the weeding fork, for 60 seconds. Make sure that the frame stays securely anchored in the substrate. Look for heavy organisms in the perimeter that may not have been carried by the current into the net (cased caddisflies, snails, mussels, etc.) and place them in the net as well.

9. If any large gravel or cobble particles have washed into the net during agitation of the sediment, you may reach in to pick them out before lifting the net. Ensure that the particles and your hands are well-rinsed by the stream water flowing into the net before you remove them.

10. Pick up the net, pulling it upstream as you lift it to rinse the organisms into the bottom of the net.

11. Holding the net vertically, use stream water and the sprayer to rinse organisms completely into the collector or the bottom of the net. When using stream water, splash the water through the net from the outside, or pour through a sieve to ensure that no additional organisms are inadvertently added to the sample. For removing small organisms which may cling to the net, one person may pour water through the net from the outside while another gently rubs the inside of the net with his or her hand.

12. Detach the collector and pour it into the dishpan; if your net does not have a detachable collector, pinch the net closed above the sampled material and then invert the net into the dishpan. Rinse the collector or the bottom of the net well to make sure all organisms are poured into pan. Have one person pick any organisms that remain stuck to



the net. You may wish to pick larger particles out of the dishpan, making sure no organisms are attached.

13. For mussels or crayfish, you may wish to note the organism in your field notes, or place a penciled note representing the organism into the sample jar, and replace the organism in the stream. Also, note and return any fish to the stream.

14. Add clean water (poured through a sieve) to the dishpan and agitate the pan to elutriate (float) the organisms. Pour the water and suspended organic material from the dishpan into a sieve, leaving the sand and gravel in the dishpan. Repeat this step at least five times, or until no visible organic particles are floated out of the inorganic material upon pouring. All organic material is included in the final sample, including macroinvertebrates, small particles, sticks or bark, leaves, and moss.

15. Pick the non-floating organisms out of the dishpan by hand and place them in the sample container. Organisms such as stone-cased caddisflies are often more visible among the sand particles with about an inch of water in the bottom of the dishpan. Sift through the inorganic particles several times for this step. Perform this step even if you have placed attached caddisflies directly in the sample container during sampling.

16. Gently use the spatula and clean (sieved) water to concentrate the sample material on one side of the sieve, and empty it into the sample jar. Add water and 95% alcohol to dilute to approximately 70-80% alcohol.

17. Ensure that the sample is placed in a correctly labeled jar with lid tightly secured.

18. Collect two more samples from randomly selected locations within the same riffle, or if the riffle is too small, from other riffles or suitable habitat as near as possible to the initial sample. Combine the three samples into one sample jar.

19. Label sample jars inside (pencil on paper tag) and outside (pen on masking tape) with site name (including stream name), date, replicate number, and sample identification number, if applicable.

20. On the data sheet, note the following information as it relates to the exact location where the sampling device is to be placed: time and date, personnel, stream name and site, replicate number, distance upstream or downstream from nearest cross-section or reference point, habitat type (riffle/run), estimated streamflow, velocity, depth, substrate type, weather, water temperature, water conditions (turbid, clear, etc.), estimated canopy cover, and other conditions (substrate armoring, adjacent large organic debris, leaf/litter accumulations, slime or moss, macrophytes, periphyton, roots or boulders embedded in sample area, etc.).

    To avoid disturbance of the reach, habitat measurements should be performed after all invertebrate sampling is complete. For suggested reach habitat information, consult the above references.

21. Rinse net, sieves, etc. well before proceeding to take next sample, at next randomly located riffle upstream.

APPENDIX B. Taxonomic resolution for City of Bellevue aquatic invertebrates

Group/Order	Family	Recommended Standard Taxonomic Resolution
Non-insects		Acarina = Acari
		Oligochaeta = genus
		Turbellaria = phylum, with exceptions:
		Polycelis coronata to species
		Nematoda = phylum
		Nematomorpha = phylum
		Gastropoda = genus, with exceptions:
		species for monotypic genera
		Hydrobiidae = family
		Bivalvia = family
		Branchiobdellida = Order
		Hirudinea = family
		species for monotypic genera
		Crustacea = genus, with exceptions:
		Ostracoda = class
		Copepoda = class
		Cladocera = class
Odonata		genus
Ephemeroptera		genus, with exceptions:
	all families	species for monotypic genera
	Baetidae	Acentrella = species
		Baetis = species
	Caenidae	genus
	Ephemerellidae	species
	Heptageniidae	genus, with exceptions:
		Epeorus = species
	Leptophlebiidae	genus
	Leptohyphidae	genus
Odonata		genus
Plecoptera		genus, with exceptions:
	all families	species for monotypic genera
	Capniidae	family
	Nemouridae	species or species group for Zapada
	Perlidae	species for Hesperoperla
	Pteronarcyidae	species for Pteronarcys
Hemiptera		genus, but ignore surface dwellers (i.e. Veliidae, Gerridae)
Coleoptera		genus, with exceptions:
		species for monotypic genera
Megaloptera		genus
Diptera		genus, with exceptions:
	Ceratopogonidae	subfamily
	Dolichopodidae	family
	Tabanidae	family
	Ephydridae	family
	Muscidae	family
	Sciomyzidae	family

Taxonomic resolution for City of Bellevue aquatic invertebrates (continued)

Group/Order	Family	Recommended Standard Taxonomic Resolution
	Chironomidae	genus including larvae and pupae, with exceptions:
		species for monotypic genera
		Cricotopus = sub-genus, except C. bicinctus, C. trifascia
		Potthastia = species group
		Arctopelopia, Conchapelopia, Hayesomyia, Helopelopia, Meropelopia, Rheopelopia, Telopelopia, and Thienemannimyia = Thienemannimyia Group
		Tvetenia = species or species group
Trichoptera		genus, with exceptions:
	all families	species for monotypic genera
	Rhyacophilidae	Rhyacophila = species or species group
	Hydropsychidae	Arctopsyche and Parapsyche to species
	Brachycentridae	Brachycentrus = species
	Limnephilidae	species for monotypic genera, Dicosmoecus = species
	Uenoidae	species for monotypic genera, Neophylax = species
Lepidoptera		genus