CHARACTERIZATION OF AQUATIC MACROINVERTEBRATE COMMUNITIES IN BATTLE CREEK IN 2001 AND 2002 TO SUPPORT WATERSHED ASSESSMENT AND FUTURE MONITORING

prepared for

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DISTRIBUTION

Copies of this report (file name = Terraqua and Kvam 2003.pdf) and raw data, including site-specific metric and index values and site-specific taxonometric counts, will be available on the internet by Fall 2003 at http://krisweb.com/ under the Battle Creek project.

INTRODUCTION

Aquatic macroinvertebrate diversity in Battle Creek was characterized in 2001 and 2002 to support an ongoing watershed assessment and to provide data that will be used to design future habitat monitoring programs. This document specifically reports the data and site-specific interpretations of the sampled aquatic macroinvertebrates. Additional interpretation, including descriptions of macroinvertebrate communities from a watershed-wide perspective, and relationships between physical habitat conditions and macroinvertebrate communities, will be presented in the final watershed assessment report (Terraqua Inc., in preparation).

Aquatic macroinvertebrate data are generally examined and interpreted to derive an assessment of physical, biological and chemical habitat conditions within streams. This is based on the understanding that macroinvertebrate communities respond in predictable ways to physical habitat disturbance, as has been documented in existing literature (Plafkin et al. 1989; Karr 1991; Resh and Jackson 1993). Hence, macroinvertebrate community structure data are often described in terms of "levels of impairment" which is almost interchangeably applied to interpret conditions of macroinvertebrate communities as well as their physical, biological and chemical habitat. For this reason, in the present study, we provide two levels of interpretation in the form of impairment scoring criteria based on metrics and multimetric indices.

The impairment scoring criteria and multimetric indices used in this study were developed in Oregon and Washington State (see Table 1 through Table 3) because scoring criteria and multimetric indices developed and tested in California do not yet exist (Harrington pers. comm.). Furthermore, the biotic similarity of salmonid dominated ecosystems throughout the West Coast region suggests that these Pacific Northwest-developed impairment scoring criteria and multimetric indices would apply to Battle Creek for that level of relative interpretation reported here. Finally, similar scoring criteria between the Oregon and Washington systems suggests that regional variation is not great, further supporting the decision to use these criteria in Battle Creek.

No attempt is made in this report to compare the macroinvertebrate communities in Battle Creek to other streams in northern California. Because macroinvertebrate community structure and diversity can vary based on ecoregion and stream size, the following descriptions of habitat conditions should be considered qualitative and specific to Battle Creek until criteria for northern California streams of a similar size and character are developed and tested. Once this work is complete, scheduled macroinvertebrate monitoring in the Battle Creek watershed can be designed to measure the physical and biological integrity of these and future samples relative to other California streams.

With some modifications, the physical and biological data gathered for this study can be used, in the future, to assess biological conditions in Battle Creek relative to other streams in California using a interpretive model currently being developed for the state (Hawkins 2001). However, further refinement of the model is needed before it will conform to procedures developed by the California Aquatic Bioassessment Workgroup (Harrington pers. comm.).

METHODS

Macroinvertebrate samples were collected according to River InVertebrate Prediction And Classification System (RIVPACS) protocol (Hawkins et al. 2001) from 44 stream sites within the Battle Creek watershed in the fall of 2001 and in the summer and fall of 2002. All but one sample site (i.e. site S101) were randomly selected using an unequal probability random tessellation stratified survey design for a continuous linear network population from fish bearing waters of the Battle Creek watershed, including sites in 1st through 5th order streams (Terraqua Inc., in preparation). Site S101 was chosen for a specific comparison not described in this study.

Samples were randomly subsampled using a Caton grid subsampling device. Individual organisms were picked from all subsampled grids using 10X microscopy to obtain a total of at least 500 individual organisms for taxonomic identification. Randomly selected grids were completely picked of all organisms. For 100 percent of samples, subsampling quality assurance procedures were applied: 10 percent of subsampled grids were examined for missed organisms (pass rate: all organisms were initially picked in 95 percent of subsamples; subsamples with missed organisms were brought up to 100 percent). Organisms were identified to the lowest possible level, except for midges (Diptera: Chironomidae), which were left at the family level per the study design. For 100 percent of samples, taxonomic determination quality assurance procedures were applied: a second taxonomist verified identifications (pass rate: two taxonomists agreed on 100 percent of organism identifications). Counts of organisms by site were entered into a spreadsheet and data entry quality assurance procedures were applied.

Following subsampling and macroinvertebrate identification, the data were analyzed as abundance by taxa by site. A number of biotic metrics and indices were generated that described the macroinvertebrate community at each site. The data set was described by season and year to account for seasonal and annual variations that may affect direct comparisons.

Attributes of the macroinvertebrate community that change in predictable ways in response to habitat disturbance are called "metrics." Seven metrics and two multimetric indices were characterized for each sample that was analyzed. These metrics, indices, and associated interpretation are described in the following subsections.

Metrics

A description of each metric follows, together with its expected response to disturbance. Table 1 and Table 2 show the range in metric values associated with particular scoring criteria.

- *Taxa Richness* – the total number of macroinvertebrate taxa present in each sample. This metric generally increases with improving water quality and/or habitat diversity.

- *EPT (Mayfly, Stonefly, and Caddisfly) Richness* – the number of distinct taxa within the insect orders Ephemeroptera (mayflies), Trichoptera (caddisflies), and Plecoptera (stoneflies). These orders are regarded to be relatively sensitive to pollution and like other groups of macroinvertebrates, are important items in fish diets. EPT richness values generally increase with improving water quality.

- *Sensitive Taxa Richness* – the number of taxa that are known to be very sensitive to stream disturbance. The presence of sensitive taxa indicates good water quality and natural, undisturbed habitat.

- *Cold Stenotherm Taxa Richness* – the number of taxa that prefer cold water. If cold stenothermic taxa are absent or rare, the community has likely experienced acutely high temperatures. Although no scoring criteria appear to be available for cold stenotherm taxa richness, as these taxa become more common, water quality improves. For purposes of this analysis, indicators of stream conditions using cold stenotherm taxa richness will be the same used for sensitive taxa richness.

- *Sediment Sensitive Taxa Richness* - these are taxa that are sensitive to inputs of fine sediment. Zero or a low number of sediment sensitive taxa suggests that sediment loading is influencing the macroinvertebrate community.

- *Percent Sediment Tolerant Taxa* – this is the relative abundance of taxa tolerant of fine sediment. A high percentage of sediment tolerant taxa suggest unusually high fine sediment loading.

- *Percent Dominant Taxon* – this is the percent contribution of the most numerically dominant taxon to the total number of invertebrates in a sample. A community dominated by a single taxon may indicate high levels of nutrient enrichment or organic pollution if macroinvertebrate density is high, or the presence of toxic contaminants if macroinvertebrate density is low.

Indices

Multimetric indices like the B-IBI and ODEQ Biotic Index are believed to be better at detecting habitat or macroinvertebrate community disturbances than single metrics (e.g. presence or absence of indicator species) because they use a number of biological attributes that integrate information from ecosystem, community, population, and individual levels (Barbour et al. 1999).

- *ODEQ Biotic Index*– The Oregon Department of Environmental Quality (ODEQ) recommends the use of either a multivariate or multimetric analytical procedure for the comparison of macroinvertebrate samples among sites as part of their Level 3 protocol (Hafele and Mulvey 1998). The ODEQ Biotic Index (ODEQ-

BI) incorporates 10 key biotic metrics , some of which are identified above (e.g., taxa richness, sensitive taxa richness, sediment sensitive taxa richness, percent sediment tolerant taxa, and percent dominant taxon) into an impairment score, which is used to describe overall stream condition or health. The impairment score is generated by summing individual metric scores for a total possible score of 50. The higher the total score, the lower the impairment. ODEQ-BI impairment scores were developed with data collected from first to third order streams in coastal Oregon (Hafele and Mulvey 1998).

- *Benthic Index of Biotic Integrity* – The Benthic Index of Biotic Integrity (B-IBI) is a multimetric index used to assess the biotic integrity of streams. The B-IBI is a modified version of the IBI that was first developed to study fish communities in midwestern streams (Karr 1991). The modification involves the use of 10 aquatic macroinvertebrate metrics rather than fish metrics to identify artificial or human disturbances.

  The metrics used in the calculation of the B-IBI include: 1) total taxa richness, 2) Ephemeroptera taxa richness, 3) Plecoptera taxa richness, 4) Trichoptera taxa richness, 5) intolerant taxa richness, 6) long-lived species taxa richness, 7) percentage of tolerant taxa, 8) percentage of predators, 9) clinger taxa richness, and 10) percentage of the three most numerically dominant taxa. Each metric in the B-IBI is given a score to reflect the level of disturbance that is detected by the metric (5 for minimal, 3 for moderate, and 1 for severe disturbance). Each metric score is summed to calculate the total B-IBI value. Higher B-IBI scores (total possible score of 50) indicate lower levels of physical, biological, and/or chemical disturbance that the site is presumed to have experienced.

Interpretation

Classification of stream conditions as "poor," "fair," or "good" are based on individual metric and multimetric index scores developed by ODEQ and the Washington State Department of Ecology (WDOE) and are not absolute. The ODEQ and WDOE criteria, for example, were developed for wadeable streams that drain forested watersheds in coastal Oregon and the Puget Sound Lowlands and thus may not be directly applicable to the Battle Creek samples. However, the climatological and physical similarities between Battle Creek and the regions where these interpretive indices were developed are strong enough that key animal communities (e.g. these other regions are comprised of salmonid dominated ecosystems as is Battle Creek) are likewise similar. This suggests that macroinvertebrate communities are also sufficiently similar among these regions that these interpretive criteria, especially the coarse scale low and high metric/index scores, are transferable between these two regions. Therefore, these comparisons, based on several macroinvertebrate metric scores, are interpreted using the ODEQ and WDOE criteria.

Interpretive scoring criteria are currently being developed for Northern California by California Aquatic Bioassessment Workgroup but are not yet complete and were unavailable for use in this study (Harrington, pers. comm.). Interpretive scoring criteria have been developed for California's Russian River (Harrington et al. 1999), but these were not used due to the authors' stated caution that more evaluation is needed to determine the usefulness of this Russian River system in other watersheds. Interpretive scoring criteria have been developed for Southern California but were not applicable to Battle Creek (Harrington, pers. comm.) presumably due to large biotic differences between these regions.

Table 1. Range of biotic metric values and associated scoring criteria for wadeable streams in coastal Oregon (Hafele and Mulvey 1998).

	Scoring Criteria		
Metric	5	3	1
	Good	Fair	Poor
Taxa Richness	>35	19-35	<19
EPT Richness	>21	11-21	<11
Sensitive Taxa Richness	>4	2-4	<2
Sediment Sensitive Taxa Richness	≥2	1	0
% Sediment Tolerant Taxa	<10	10-25	>25
% Dominant Taxa	<20	20-40	>40

Table 2. Range of biotic metric values and associated scoring criteria for wadeable streams in the Puget Sound Lowlands (Summers 2001).

	Scoring Criteria		
Metric	5	3	1
	Good	Fair	Poor
Taxa Richness	>40	20-40	<20
EPT Richness	>24	11-24	<11
Sensitive Taxa Richness	>3	3	<3

Table 3. Range of multimetric index values and associated scoring criteria for wadeable streams in coastal Oregon (Hafele and Mulvey 1998) and the Puget Sound Lowlands (Summers 2001).

	Interpretive Category			
Index	No Impairment	Slight Impairment	Moderate Impairment	Severe Impairment
ODEQ Biotic Index	>39	30-39	20-29	<20
B-IBI	>44	37-44	27-36	<27

RESULTS

FALL 2001

Taxa Richness - Total taxa richness values ranged from 24 to 47 (Figure 1). Sites S052, S004, and S017 had the lowest number of total taxa (range 24-32), suggesting the most degraded habitat conditions. Sites S001, S007, S010, and S002 had the highest number of total taxa (range 42-47), consistent with the lowest amount of disturbance.

EPT Richness - The number of EPT taxa ranged from 13 to 36 (Figure 2). Sites with the lowest EPT richness values were S052, S004, and S017 (13, 15, and 18, respectively), suggesting they were the most degraded. Low stonefly richness was typically the cause of low EPT richness. The highest EPT richness was recorded at sites S001, S010, and S002 (values of 36, 34, and 28, respectively), indicating the most healthy benthic habitat.

Sensitive Taxa Richness - The number of sensitive taxa ranged from 1 to 15 (Figure 3). Sites S004, S007, and S017 had the lowest number of sensitive taxa (1-2), indicating the most disturbed communities. Sites S001, S010, and S013 had the highest number of sensitive taxa (10-15), suggesting the most consistent water quality and habitat conditions.

Cold Stenotherm Taxa Richness - Cold stenothermic richness ranged from 1 to 14 (Figure 4). Sites S004 and S017 had only one cold stenothermic taxon, indicating water temperatures were highest at these two sites. The highest cold stenothermic richness was measured at sites S001, S010, and S013, which suggests stream conditions at these sites were least affected by unusual levels of thermal inputs.

Sediment Sensitive Taxa Richness - The number of sediment sensitive taxa ranged from 0 to 3 (Figure 5). Sites S004 and S017 had zero sediment sensitive taxa, suggesting acute levels of sediment loading. The number of sediment sensitive taxa peaked at 3 at sites S001 and S013, indicating substrates at these sites contained the lowest amounts of fine sediment. Sediment sensitive taxa at sites S001 and S013 included *Anagapetus*, *Arctopsyche grandis*, *Glossosoma*, *Parapsyche elsis*, and *Orohermes.*

Percent Sediment Tolerant Taxa - The relative abundance of sediment tolerant taxa ranged from 0 to 21 percent (Figure 6). The highest relative abundance of sediment tolerant taxa was recorded at stations S007, S004, and S011 (21, 18, and 12%, respectively), indicating these sites had experienced the highest sediment loading. Common sediment tolerant taxa at the three sites with the highest relative abundance of such taxa included *Tricorythodes minutus,* and the snails, *Vorticifex* and *Juga. Juga* was also the most dominant taxon at S007. However, snails feed on periphyton and their abundance can be directly related to seasonal peaks in periphyton productivity. Thus, the abundance of snails at sites S007 and S011 could be related to periphyton rather than sediment loading. The low relative abundance of sediment tolerant taxa at all other sites (less than 10 percent) suggests substrates at these sites contained the lowest amounts of fine sediment.

Percent Dominant Taxon - In the fall of 2001, the relative abundance of the dominant taxon at all Battle Creek monitoring sites ranged from 13 to 54 percent (Figure 7). Sites S011, S003, and S013 had the highest dominant taxon values (54, 47, and 43 %, respectively). Such imbalance indicates these sites were the most degraded. The dominant taxon at sites S011, S003, and S013 was *Simulium*, *Lepidostoma*, and chironomids, respectively. However, of these three taxa, only members of the chironomid family are known to be tolerant of degradation. Since they are filter feeders, *Simulium* production often increases in response to high loading of fine particulate organic matter. The lowest dominant taxon percentages (13 and 18%) were recorded at sites S002 and S004, suggesting these sites had the best water quality and habitat conditions.

ODEQ-BI -- Impairment Scores ranged from 28 to 46 (Figure 8). The greatest amount of impairment was recorded at sites S004, S052, and S017 (scores of 28, 32, and 34, respectively). The least impairment was measured at stations S002 and S001 (score of 46) and six other sites had scores that were 40 or higher.

B-IBI – In Fall 2001, B-IBI scores ranged from 28 to 48 (Figure 9). The most impairment was recorded at sites S052, S004, and S017 (scores of 28, 32, and 32, respectively). The low scores at these stations were influenced by a low relative abundance of predators and few mayfly and stonefly taxa. WDOE interprets scores of 27 to 36 in Puget Lowland streams as indicating moderate impairment of biological conditions (Summers 2001). The three highest scores were measured at S010, S001, and S002 (scores of 48, 46, and 44, respectively), suggesting the best biological integrity and most sites had B-IBI scores of at least 33. B-IBI scores of 45 or greater reflect natural biological conditions in Puget Lowland streams (Summers 2001).

SUMMER 2002

Taxa Richness - Total taxa richness ranged from 21 to 51 (Figure 10). Stations S015 and S020 had the lowest number of total taxa (21 and 23), reflecting the most impairment. Total taxa richness peaked at 50 and 51 at sites S033 and S038, indicating the most healthy conditions. The total number of taxa at most sites exceeded 40.

EPT Richness - EPT taxa richness ranged from 12 to 38 (Figure 11). Sites S020, S015, and S019 had the lowest EPT richness values (12, 13, and 17, respectively), suggesting the most impairment. The highest EPT taxa richness was recorded at sites S033, S026, and S033 (values of 38, 35, and 33, respectively), suggesting water quality and habitat conditions were best at these sites. The total number of EPT taxa at most sites was 24 or greater.

Sensitive Taxa Richness - The number of sensitive taxa ranged from 0 to 17 (Figure 12). Sites S019, S020, and S023 contained zero to only one taxon, indicating the most degraded conditions. The high number of sensitive taxa found at sites S026, S024, and S033 (16-17), suggests water quality and habitat conditions are best in these areas. Sensitive taxa richness at most sites was greater than 4.

Cold Stenotherm Taxa Richness - The number of cold stenothermic taxa ranged from 0 to 15 (Figure 13). Sites S019 and S020 had a cold stenothermic richness of zero, indicating water temperatures are highest at these sites and rise to a level that precludes particular macroinvertebrates. The highest number of cold stenothermic taxa was recorded at sites S026, S024, and S038, which reflects stream conditions that are not affected by unusually high water temperatures.

Sediment Sensitive Taxa Richness - The number of sediment sensitive taxa ranged from 1 to 4, suggesting no sites suffer from acute levels of sediment loading (Figure 14). Sites S055, S038, S033, S018, and S025 had at least 3 sediment sensitive taxa. Sediment sensitive taxa at these sites included *Orohermes*, *Glossosoma*, *A. grandis*, *P. elsis*, *Wormaldia*, and *Dolophilodes*.

Percent Sediment Tolerant Taxa - The relative abundance of sediment tolerant taxa ranged from 0 to 8 percent (Figure 15). Although sites S037, S038, and S006 may have experienced the highest sediment loading, the sediment tolerant taxa percentages at all sites suggest no impairment from sediment.

Percent Dominant Taxon - In the summer of 2002, the relative abundance of the dominant taxon at all Battle Creek monitoring sites ranged from 12 to 42 percent (Figure 16). Site S019 exhibited the most degraded conditions and was also the only site with a dominant taxon value that was greater than 40 percent. The dominant taxon at S019 was chironomids. Sites S037, S023, and S038 had the lowest relative abundance of dominant taxon (12, 18, and 19%, respectively), suggesting these were the least disturbed sites.

ODEQ-BI - Impairment Scores ranged from 32 to 48 (Figure 17). Scores indicate sites S019, S020, and S015 have experienced the most impairment. All other stations had a total score of at least 40, which for coastal Oregon streams reflects slight to no impairment. The highest score indicates the least disturbance occurred at sites S038 and S037.

B-IBI – In Summer 2002, B-IBI scores ranged from 24 to 46 (Figure 18). The lowest score of 24 indicates that sites S015 and S020 have experienced the most degradation. The low scores at these sites were influenced by a low relative abundance of predators and few mayfly and stonefly taxa. The best biological integrity was measured at site S033. Five other sites had a score of 44, which reflects natural biological conditions in Puget Lowland streams.

FALL 2002

Taxa Richness - The number of total taxa ranged from 19 to 55. Sites S016, S062, and S101 had the lowest community diversity (taxa richness range 19-28), reflecting the most disturbed habitat (Figure 19). The healthiest conditions were at sites S063, S057, and S009 where taxa richness ranged from 40 to 54.

EPT Richness - EPT taxa richness ranged from 10 to 34 (Figure 20). The lowest EPT richness associated with S016, S044, and S062 (10, 13, and 13, respectively) indicated these sites were the most impaired. Low stonefly richness was typically the cause of low number of EPT taxa. Sites S063, S057, S029, and S009 had the best water quality and habitat as suggested by the number of EPT taxa at these sites (25-34).

Sensitive Taxa Richness - The number of sensitive taxa ranged from 0 to 13 (Figure 21). Sites S032, S043, and S044 had the lowest sensitive taxa richness (0-1), indicating the poorest water quality and habitat conditions. Sites S063 and S056 had the highest number of sensitive taxa (13 and 9), suggesting the least disturbance, and three other sites had at least five.

Cold Stenotherm Taxa Richness - Cold stenothermic richness ranged from 0 to 12 (Figure 22). Sites S043 and S032 did not contain any cold stenothermic taxa, suggesting this site experiences water temperatures that are too warm for particular benthic fauna. The highest number of cold stenothermic taxa were found at sites S063, S056, S016, and S029, indicating these sites have a temperature profile that is preferred by coldwater species.

Sediment Sensitive Taxa Richness - The number of sediment sensitive taxa ranged from 0 to 4 (Figure 23). Sites S016 and S043 had zero sediment sensitive taxa, which may suggest acute levels of sediment loading. Sites S063 and S047 had at least 3 sediment sensitive taxa, a value that reflects healthy stream conditions in coastal Oregon. Sediment sensitive taxa at these sites included *Orohermes*, *Anagapetus*, *Glossosoma*, *A. grandis*, *Wormaldia*, and *Dolophilodes*.

Percent Sediment Tolerant Taxa - The relative abundance of sediment tolerant taxa ranged from 0 to 33 percent (Figure 24). Percentages indicated the highest relative sediment loading occurred at sites S044, S061, and S057 (33, 19, and 13%, respectively). Common sediment tolerant taxa included *Tricorythodes minutus,* and *Juga*. *T. minutus* and *Juga* were also the most dominant taxon at sites S044 and S061, respectively. All other sites had sediment tolerant taxa percentages that were less than 10 percent.

Percent Dominant Taxon - In the fall of 2002, dominant taxon percentages at all Battle Creek monitoring sites ranged from 13 to 77 percent (Figure 25). The two highest percentages at sites S016 and S047 (77 and 42%) suggest these were the most disturbed. The dominant taxon at sites S016 and S047 was chironomids and *Simulium*. Sites S063, S029, and S061 had the lowest relative abundance of the dominant taxon, (13-18%).

ODEQ-BI - ODEQ Impairment Scores ranged from 28 to 48 (Figure 26). Low scores of 28, 30, and 32 recorded at sites S044, S043, and S016, respectively, were representative of the most degraded conditions. The least impairment was measured at sites S063, S056, and S057 (scores of 48, 46, and 44, respectively). A total of six sites had impairment scores that suggested good community diversity with little to no disturbance.

B-IBI – In Fall 2002, B-IBI scores ranged from 28 to 46 (Figure 27). The lowest biotic integrity or most impairment was recorded at sites S016, S044, and S062 (scores of 28, 28, and 30, respectively). Half of the sites had scores of 38 or higher. The peak biotic integrity measured at S063 and S057 (scores of 46 and 44) is similar to scores depicting natural conditions in Puget Lowland streams.

DISCUSSION

Fall 2001

Both the B-IBI and the ODEQ indices indicated that sites S004, S017, and S052 were the most impaired in the fall of 2001 (Figures 8 and 9). Although other stressors are likely, the fact that zero sediment sensitive taxa were recorded at site S004 suggests sediment loading may be affecting this benthic community. High water temperatures may also be influencing community diversity at S004 and S017. Site S017 also contained zero sediment sensitive taxa, but the relative abundance of sediment tolerant taxa at this site was very low, suggesting different impairments may be depressing total community richness. Despite dominant taxon percentages that suggested the most impaired conditions, sites S011, S003, and S013 had B-IBI and ODEQ scores that implied only slight impairment. It is possible that whatever is favoring production of the dominant taxa at these sites is not detrimental to the balance of the community.

Both B-IBI and ODEQ scores in fall 2001 suggested sites S001, S002, and S017 experienced the best water quality and habitat conditions.

Based on the ODEQ-BI, 64 percent of the sites monitored in fall 2001 indicated no impairment or good conditions when viewed in a watershed context (Table 4). High percent dominant taxon values, moderate taxa richness, and a low diversity and high abundance of sediment sensitive taxa depressed ODEQ-BI scores relative to the summer of 2002. However, conditions in fall 2001 appeared to be better than fall 2002. The high relative abundance in sediment tolerant taxa observed in the fall is likely the result of increased snail abundance, which tends to naturally peak in the fall. Overall taxa richness also tends to be lower in the fall compared to summer. Regardless, ODEQ-BI and B-IBI scores indicated no sites were severely impaired or in poor condition in fall 2001.

Summer 2002

Both the B-IBI and the ODEQ metrics indicated that sites S015, S019, and S020 were the most impaired in the summer of 2002 (Figures 17 and 18). Due to a low relative abundance of sediment tolerant taxa and the presence of sediment sensitive taxa, it is likely that some stress other than sediment loading is affecting these benthic communities. However, the presence of zero cold stenotherm taxa at sites S019 and S020 suggests that high water temperatures or thermal inputs may influence the macroinvertebrate community at these two sites. The high relative abundance of chironomids at S019 suggests this site may also be experiencing an unusually high loading of fine organic matter.

Both B-IBI and ODEQ scores suggested sites S033, S037, and S038 were the least impaired or experienced the best water quality and habitat conditions in the summer of 2002.

The ODEQ-BI suggested 82 percent of the sites monitored in summer 2002 were not impaired or were in good condition when viewed in a watershed context (Table 4). Taxa richness in the summer of 2002 was higher than either fall 2001 or 2002. Conversely, the relative abundance of sediment tolerant taxa was lowest in the summer because snails were more abundant in the fall. This greater taxa diversity and low abundance of sediment sensitive taxa generated higher ODEQ-BI scores relative to both sets of fall data. No sites were severely impaired or in poor condition in summer 2002 according to ODEQ-BI.

Fall 2002

Both the B-IBI and the ODEQ metrics indicated that sites S016 and S044 were the most impaired in the fall of 2002 (Figures 26 and 27). Given the high number of sediment sensitive taxa and low relative abundance of sediment tolerant taxa, high sediment loading is probably not a major impairment at site S016. Conversely, due to a low number of sediment sensitive taxa and a high relative abundance of sediment tolerant organisms, S044 is likely affected by high sediment loading. Furthermore, the most dominant taxon at site S044 (*T. minutus*) is sediment tolerant. The high relative abundance of chironomids at S016 indicates this site may be experiencing an unusually high loading of fine organic matter or inorganic flocculent (which was observed during habitat analyses; Terraqua Inc., in preparation).

Both B-IBI and ODEQ scores suggested sites S056, S057, and S063 exhibited the best water quality and habitat conditions in fall 2002.

Based on the ODEQ-BI, 38 percent of the sites monitored in fall 2002 indicated no impairment or good conditions when viewed in a watershed context (Table 4). High percent dominant taxon values, low taxa richness, and a low diversity and high abundance of sediment sensitive taxa depressed ODEQ-BI scores relative to the summer and fall 2001 data. Similar to fall 2001, high snail abundance in fall 2002 contributed to the high sediment tolerant taxa percentages. Nonetheless, both ODEQ-BI and B-IBI scores indicated no sites were severely impaired or in poor condition in fall 2002.

Table 4. Condition summary of sites based on macroinvertebrate metrics and indices for fall 2001, summer 2002, and fall 2002.

Season	Metric/Index	Percent of Sites in Good Condition	Percent of Sites in Fair Condition	Percent of Sites in Poor Condition
Fall 2001	Taxa Richness	54	46	0
11 sites	EPT Richness	54	46	0
	Sensitive Taxa Richness	46	45	9
	Cold Stenothermic Taxa Richness	45	37	18
	Sediment Sensitive Taxa Richness	18	64	18
	% Sediment Tolerant Taxa	73	27	0
	% Dominant Taxon	18	55	27
	ODEQ-BI	64	36	0
	B-IBI	18	82	0
Summer 2002	Taxa Richness	88	12	0
17 sites	EPT Richness	71	29	0
	Sensitive Taxa Richness	59	23	18
	Cold Stenothermic Taxa Richness	59	18	23
	Sediment Sensitive Taxa Richness	29	71	0
	% Sediment Tolerant Taxa	100	0	0
	% Dominant Taxon	18	76	6
	ODEQ-BI	82	18	0
	B-IBI	6	82	12
Fall 2002	Taxa Richness	50	50	0
16 sites	EPT Richness	38	62	0
	Sensitive Taxa Richness	31	50	19
	Cold Stenothermic Taxa Richness	25	44	19
	Sediment Sensitive Taxa Richness	13	74	13
	% Sediment Tolerant Taxa	81	13	6
	% Dominant Taxon	25	62	13
	ODEQ-BI	38	62	0
	B-IBI	6	94	0

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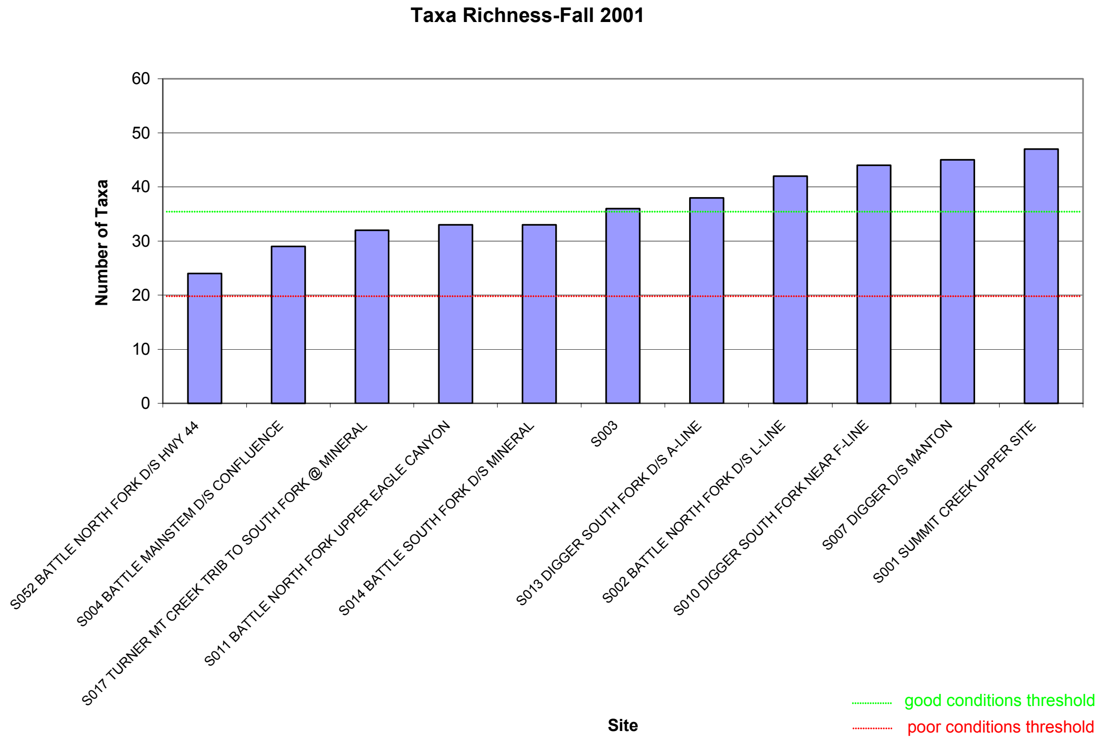

Figure 1. Comparison of taxa richness at 11 sites within Battle Creek watershed in Fall 2001.

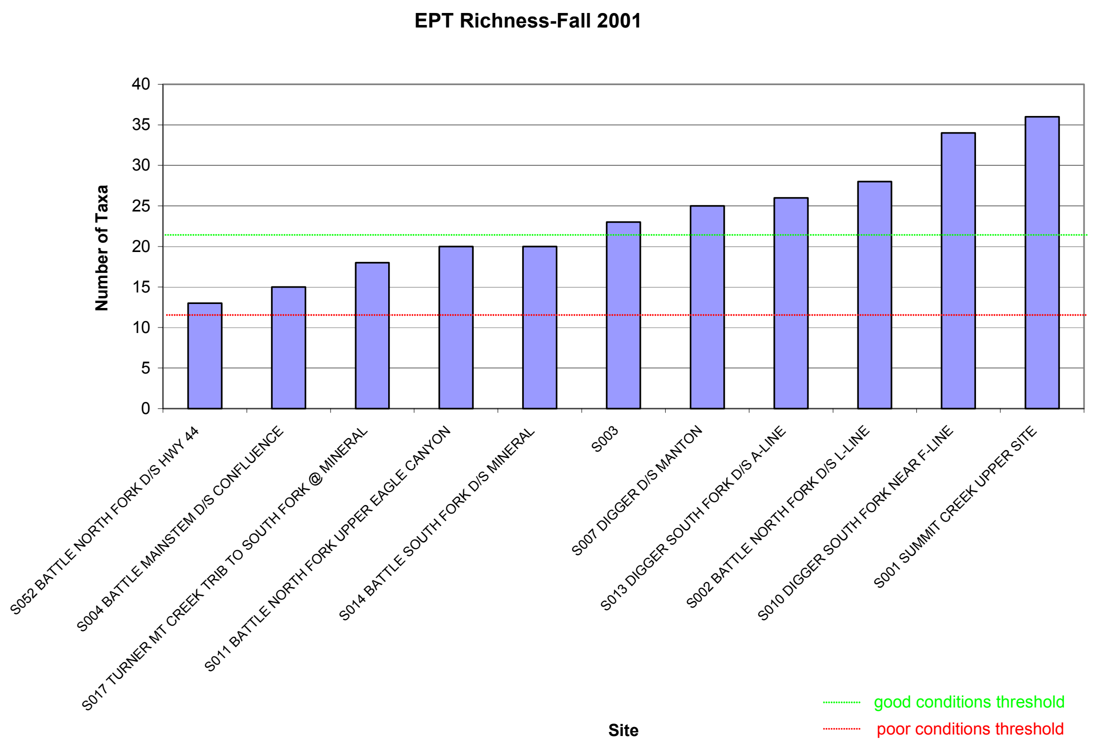

Figure 2. Comparison of EPT richness at 11 sites within Battle Creek watershed in Fall 2001.

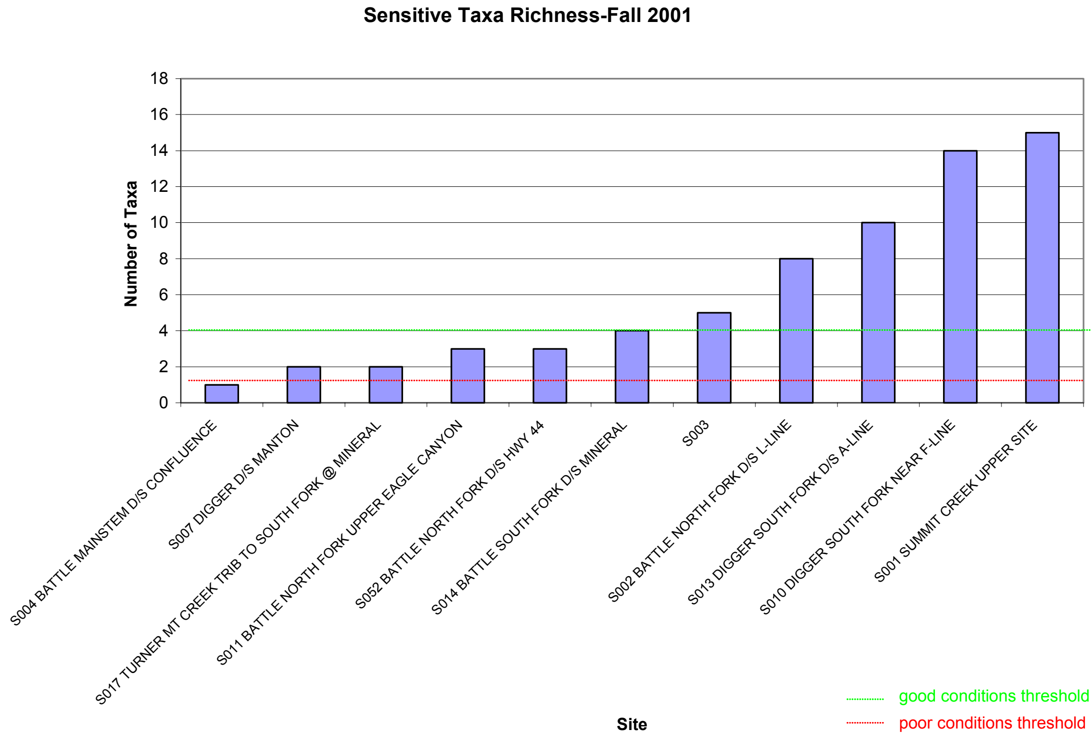

Figure 3. Comparison of sensitive taxa richness at 11 sites within Battle Creek watershed in Fall 2001.

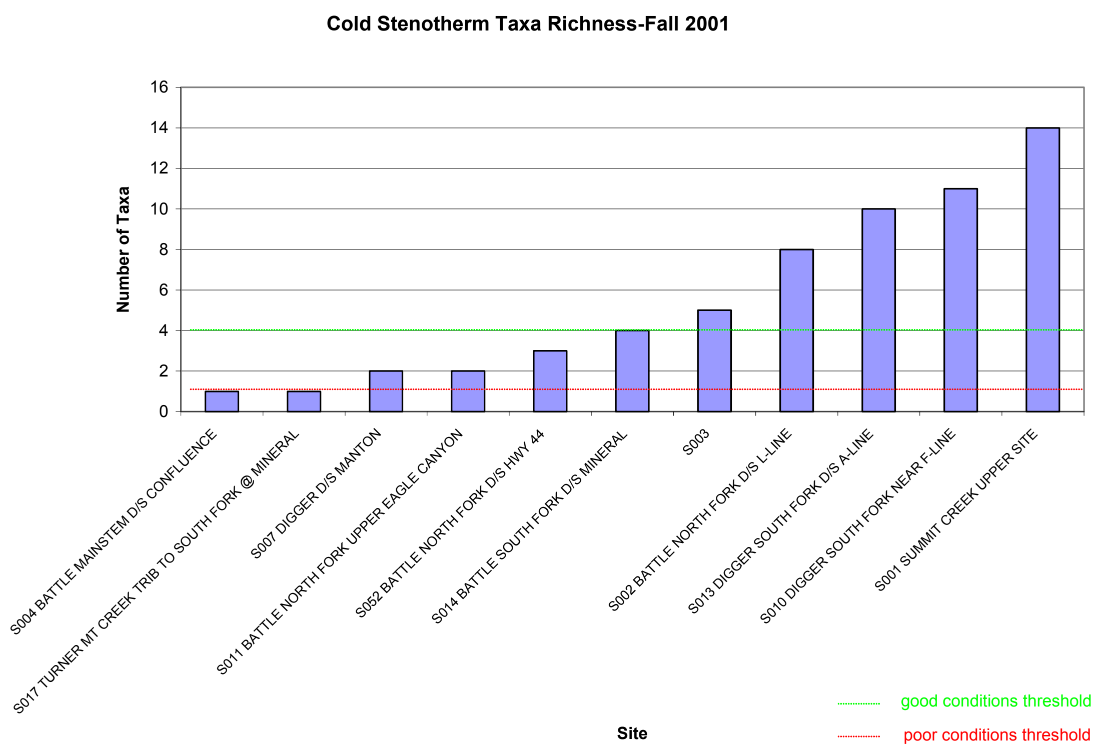

Figure 4. Comparison of cold stenotherm taxa richness at 11 sites within Battle Creek watershed in Fall 2001.

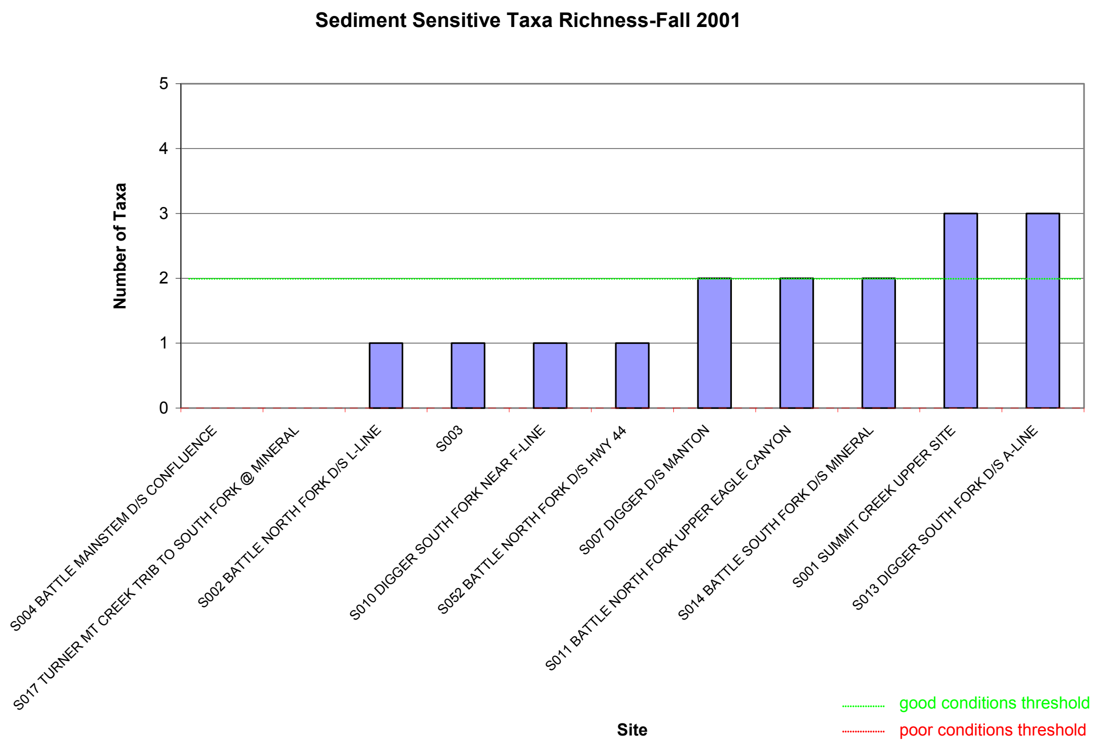

Figure 5. Comparison of sediment sensitive taxa richness at 11 sites within Battle Creek watershed in Fall 2001.

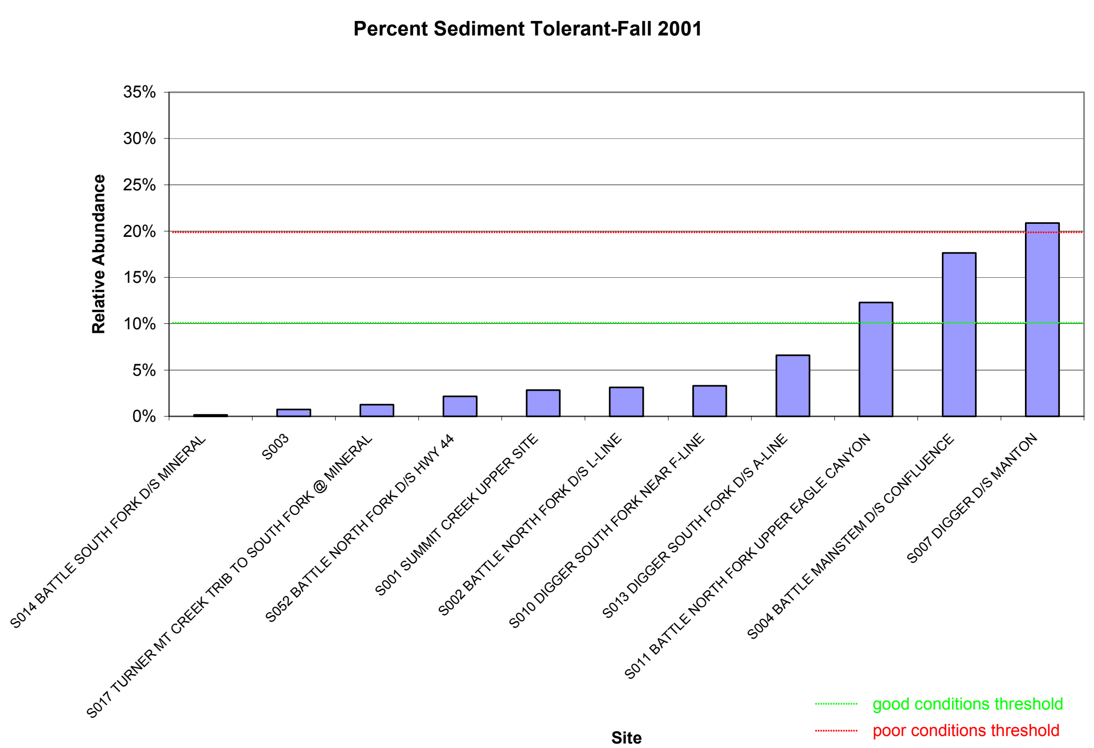

Figure 6. Comparison of percent sediment tolerant taxa at 11 sites within Battle Creek watershed in Fall 2001.

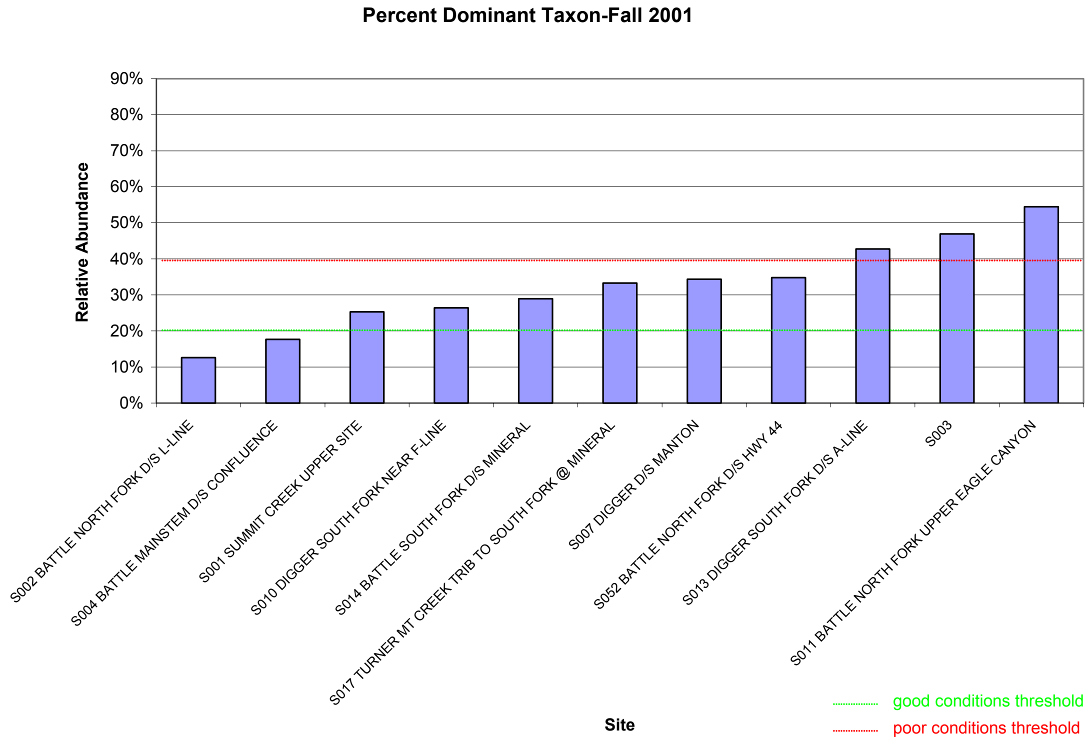

Figure 7. Comparison of percent dominant taxon at 11 sites within Battle Creek watershed in Fall 2001.

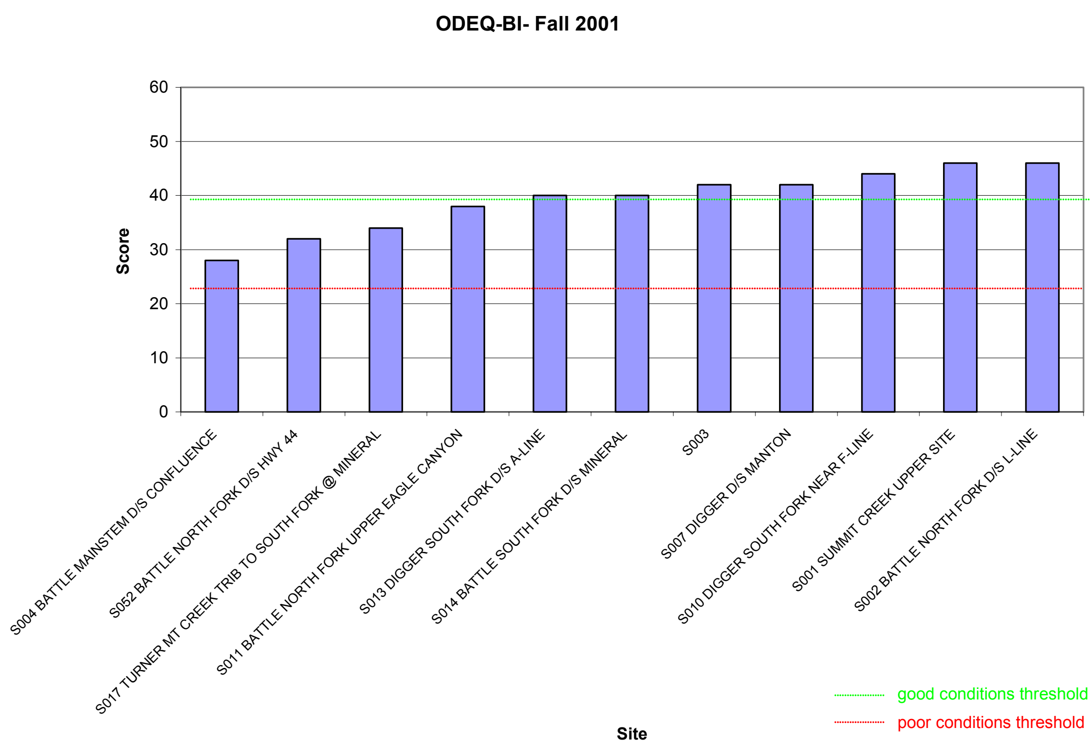

Figure 8. Comparison of ODEQ-BI at 11 sites within Battle Creek watershed in Fall 2001.

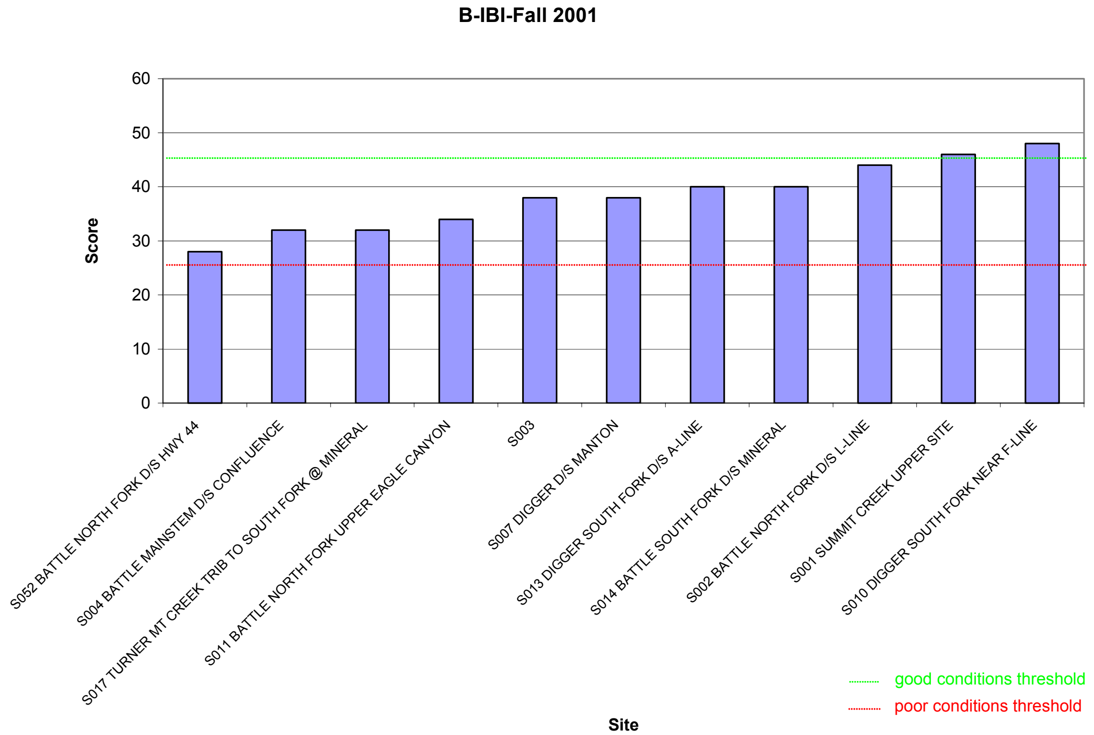

Figure 9. Comparison of B-IBI at 11 sites within Battle Creek watershed in Fall 2001.

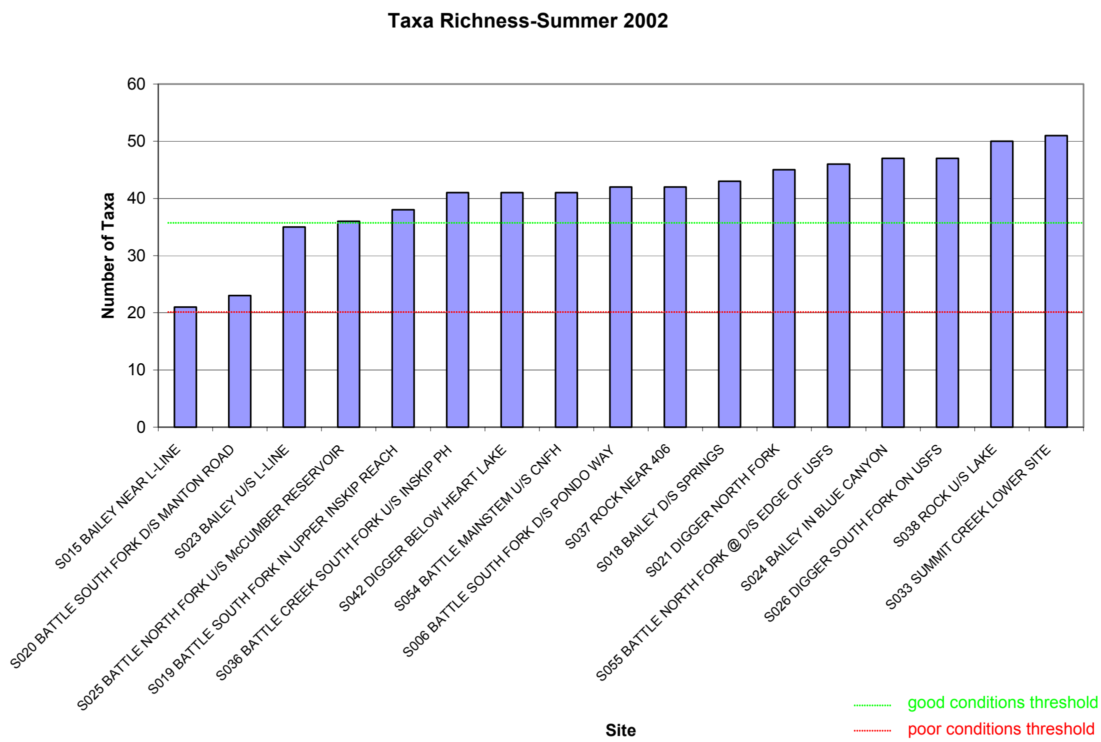

Figure 10. Comparison of taxa richness at 17 sites within Battle Creek watershed in Summer 2002.

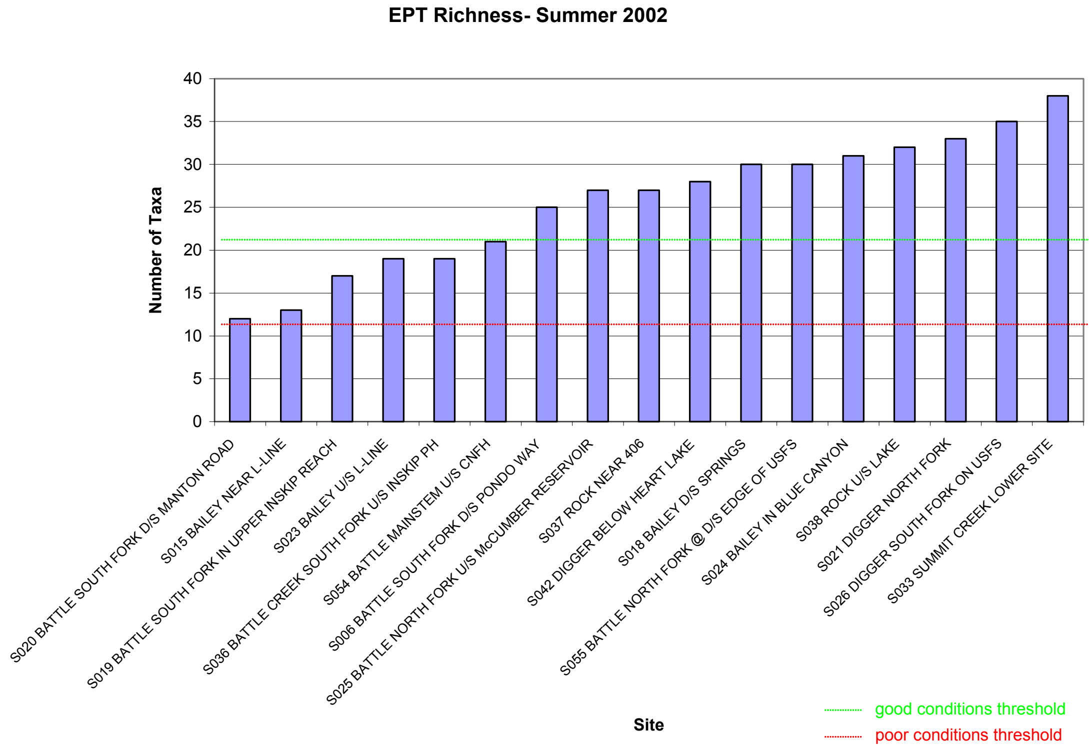

Figure 11. Comparison of EPT richness at 17 sites within Battle Creek watershed in Summer 2002.

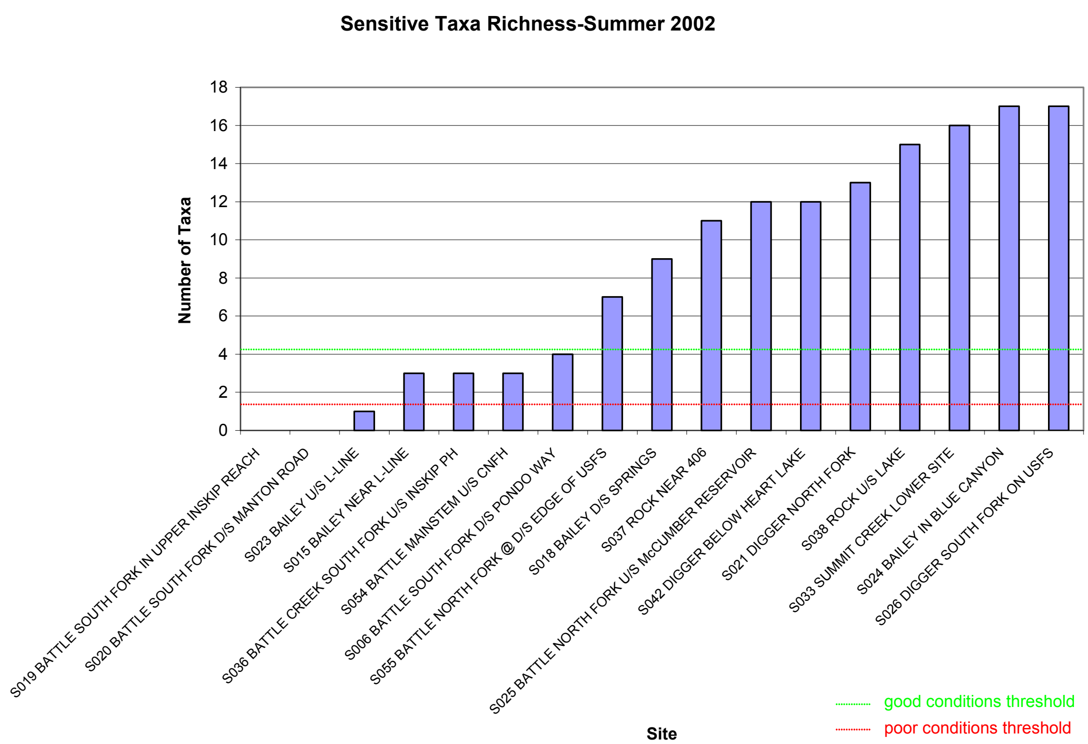

Figure 12. Comparison of sensitive taxa richness at 17 sites within Battle Creek watershed in Summer 2002.

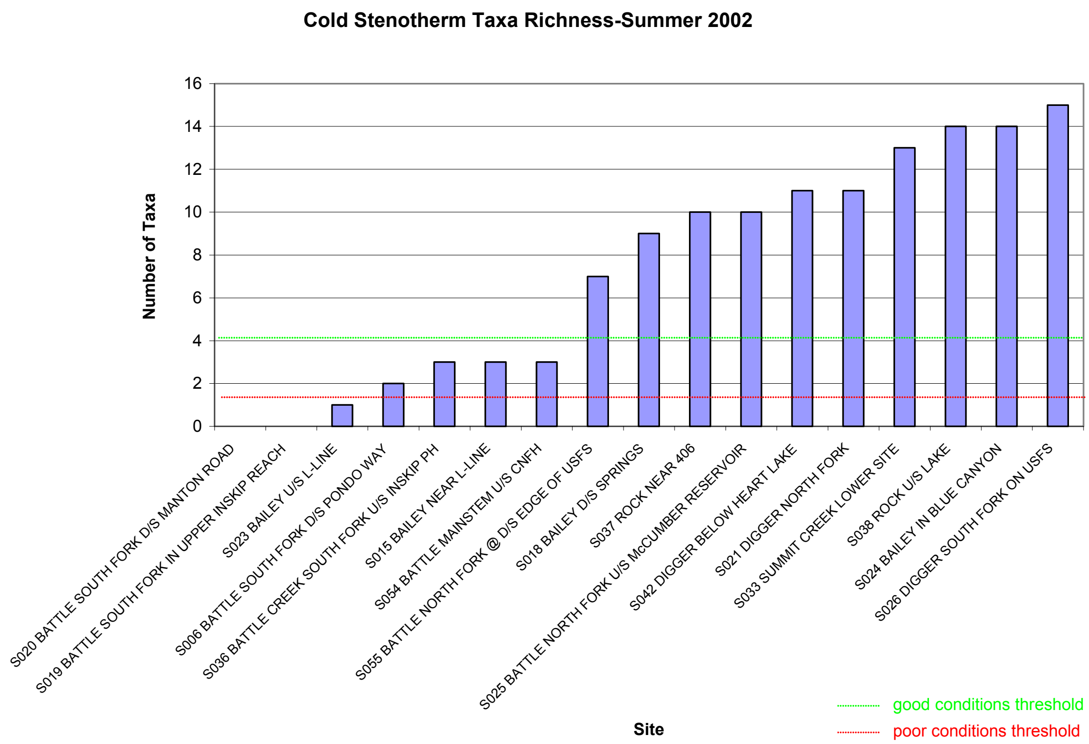

Figure 13. Comparison of cold stenotherm taxa richness at 17 sites within Battle Creek watershed in Summer 2002.

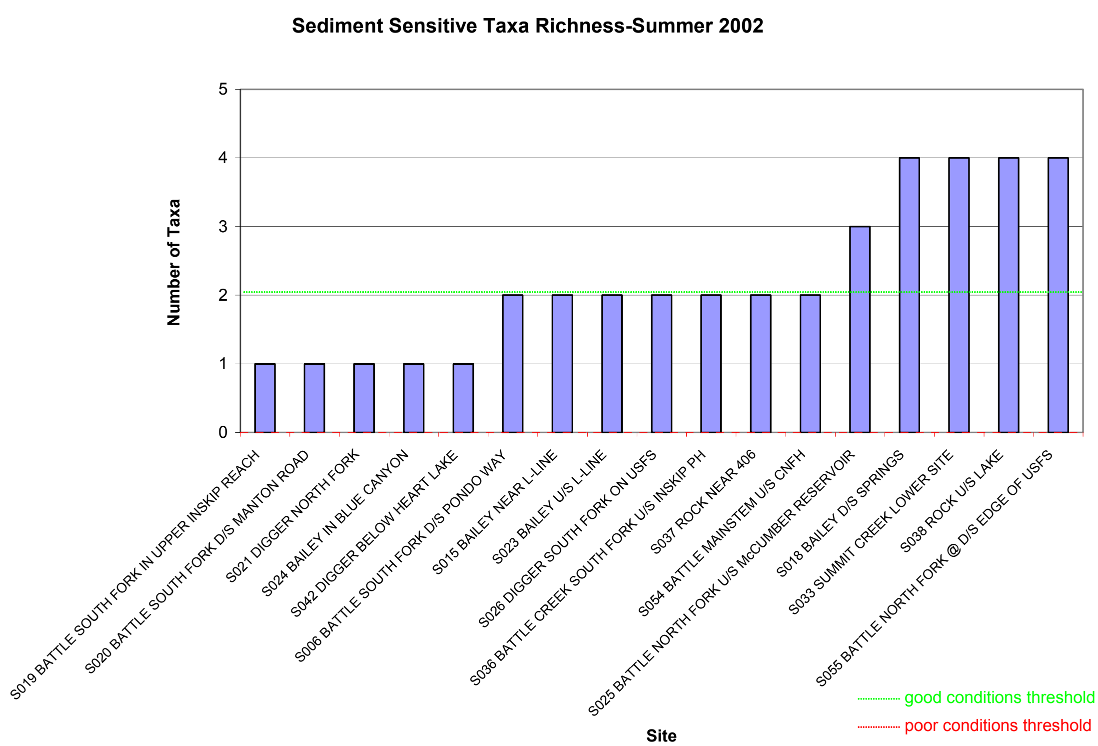

Figure 14. Comparison of sediment sensitive taxa richness at 17 sites within Battle Creek watershed in Summer 2002.

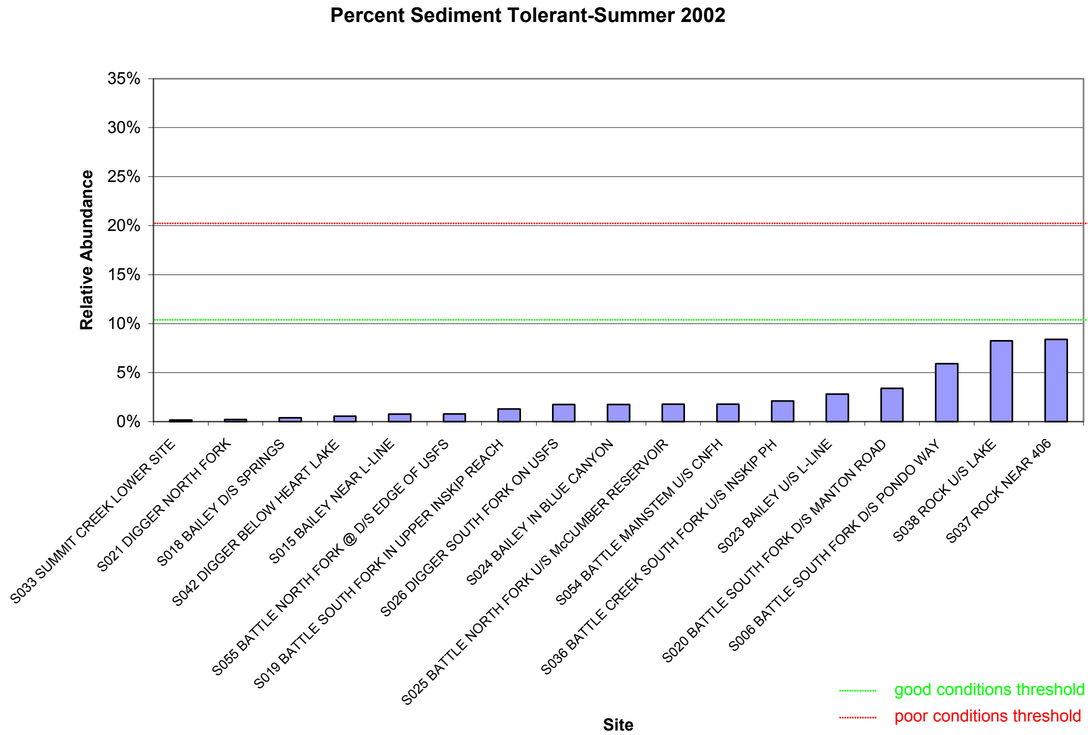

Figure 15. Comparison of percent sediment tolerant taxa at 17 sites within Battle Creek watershed in Summer 2002.

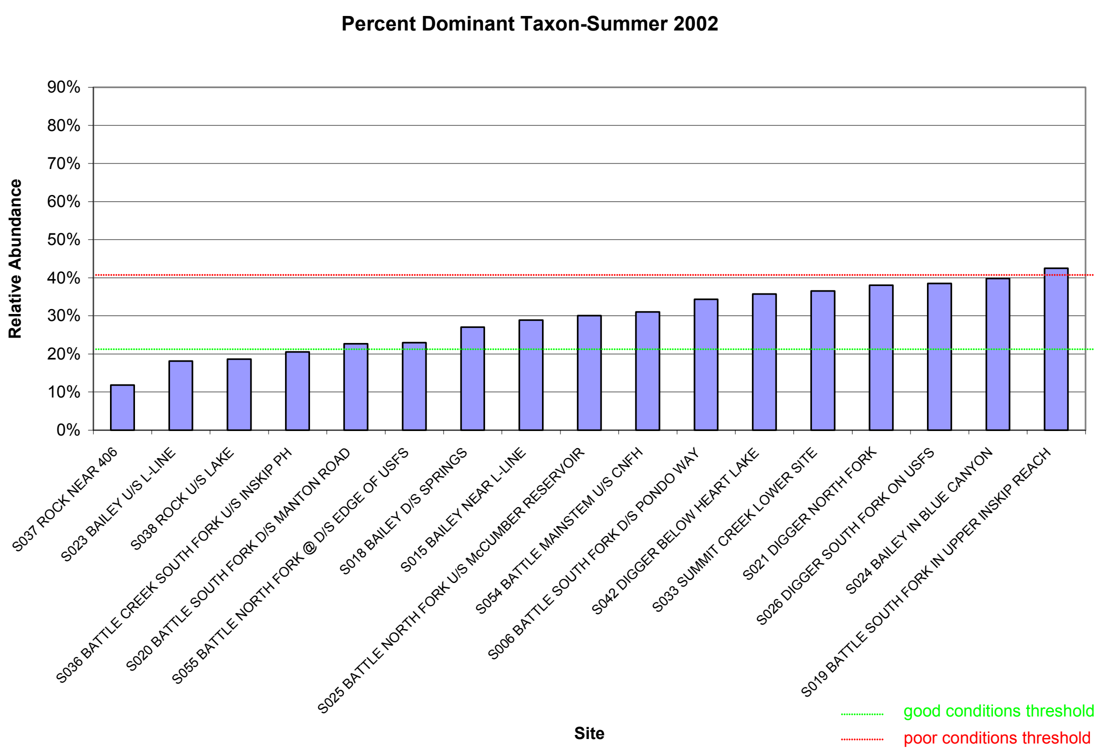

Figure 16. Comparison of percent dominant taxon at 17 sites within Battle Creek watershed in Summer 2002.

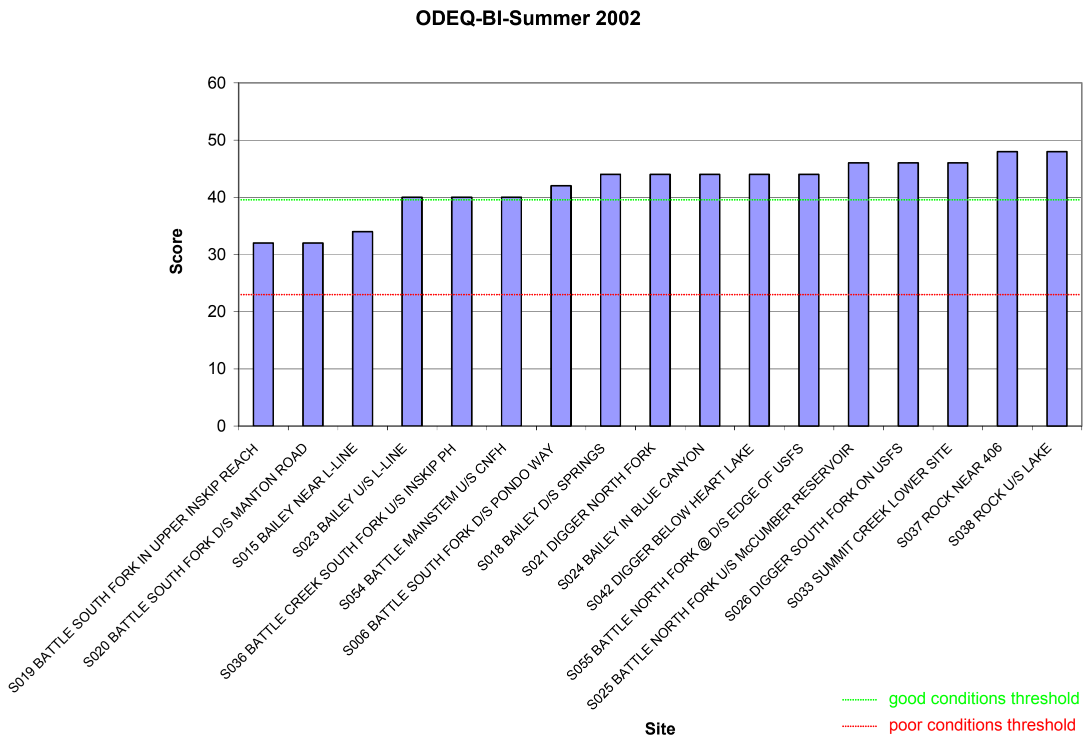

Figure 17. Comparison of ODEQ-BI at 17 sites within Battle Creek watershed in Summer 2002.

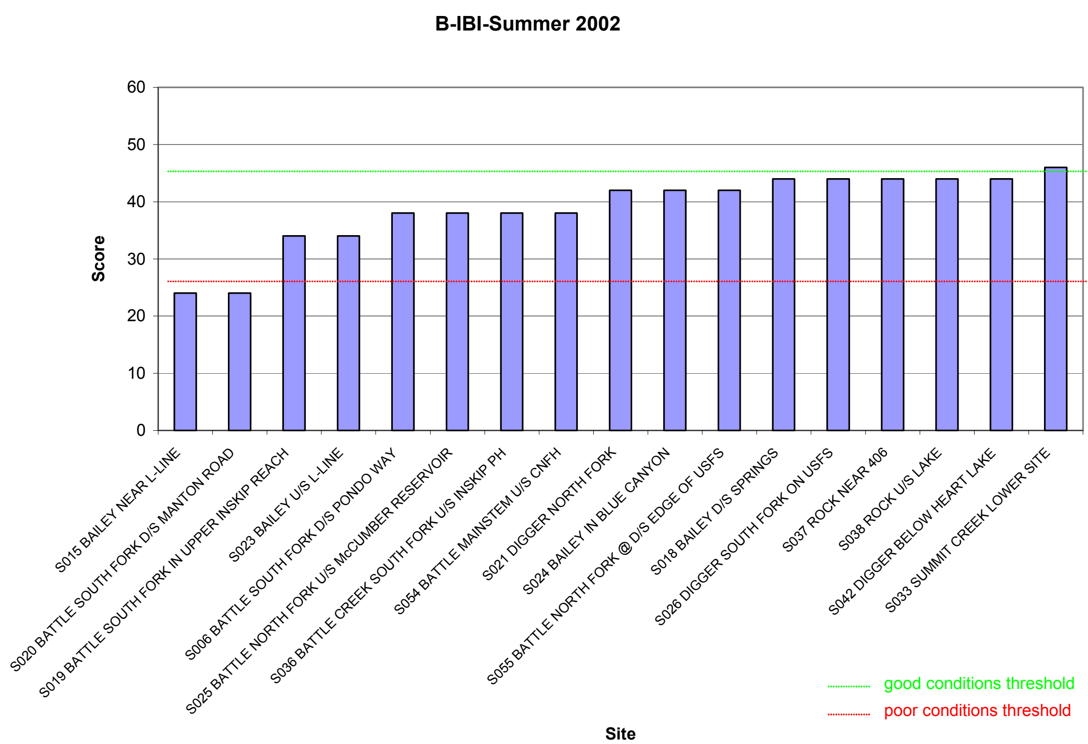

Figure 18. Comparison of B-IBI at 17 sites within Battle Creek watershed in Summer 2002.

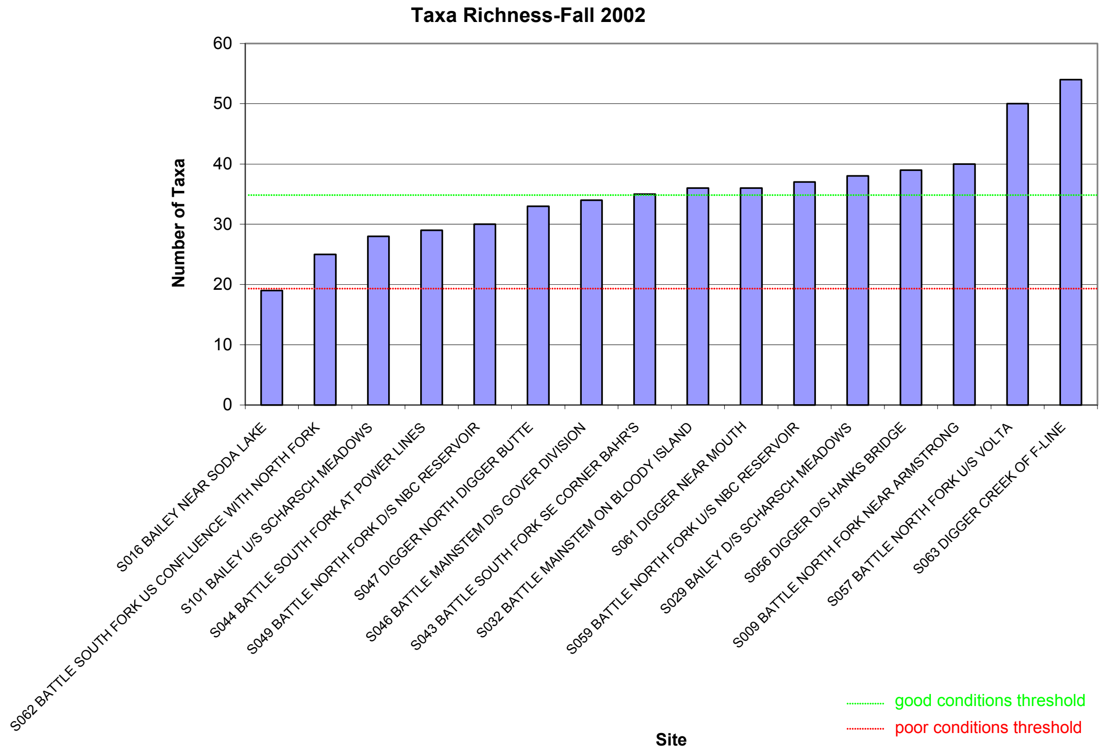

Figure 19. Comparison of taxa richness at 16 sites within Battle Creek watershed in Fall 2002.

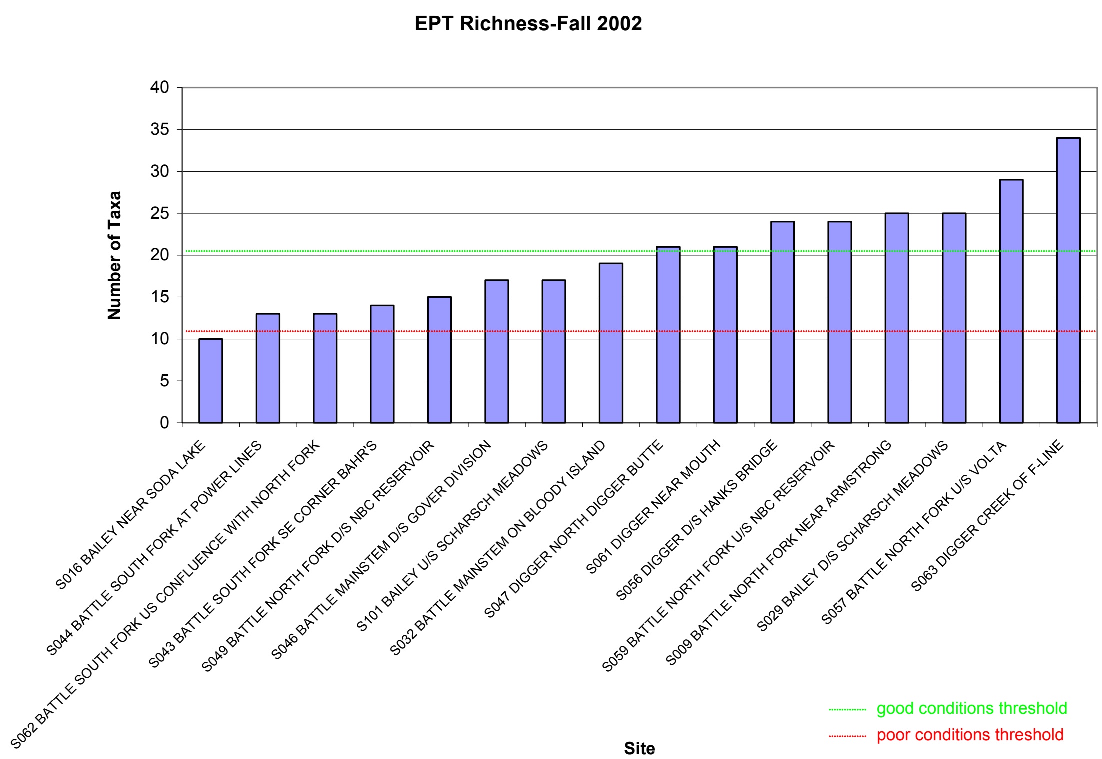

Figure 20. Comparison of EPT richness at 16 sites within Battle Creek watershed in Fall 2002.

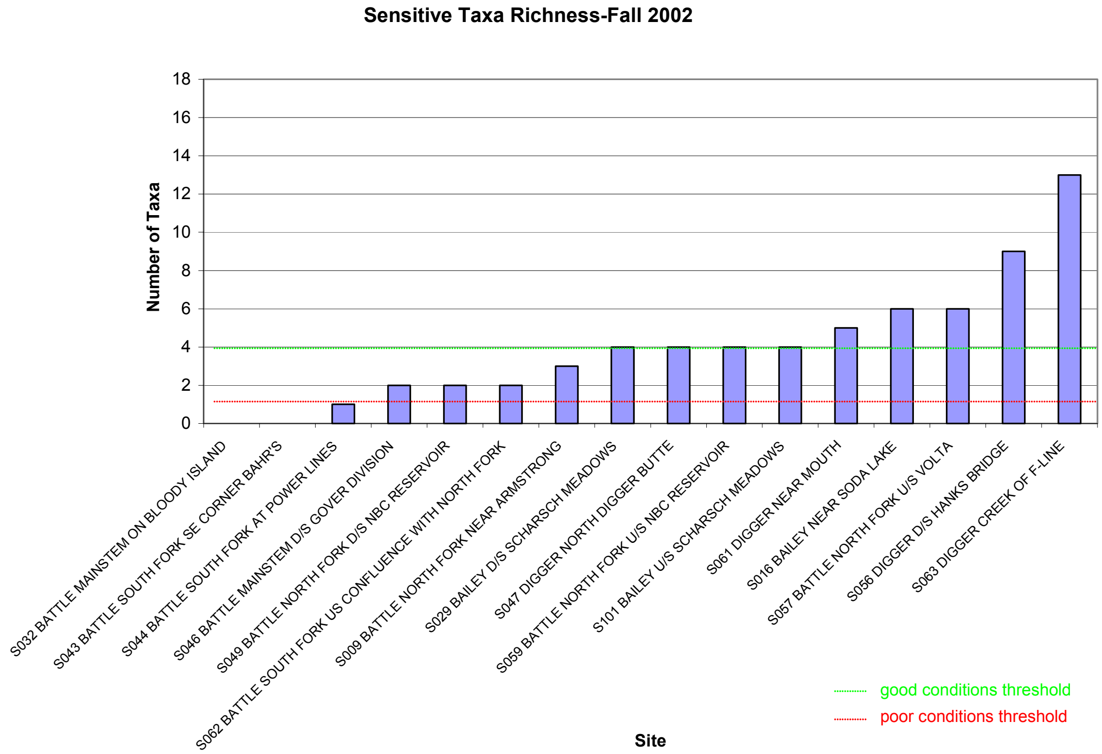

Figure 21. Comparison of sensitive taxa richness at 16 sites within Battle Creek watershed in Fall 2002.

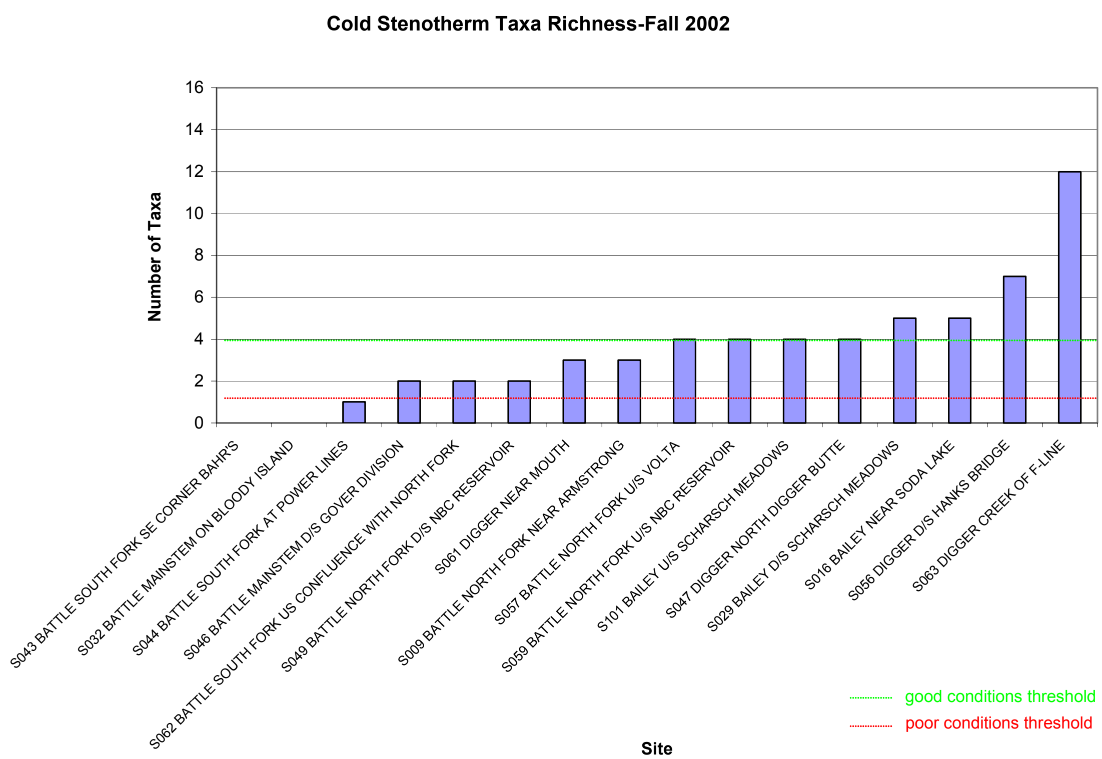

Figure 22. Comparison of cold stenotherm taxa richness at 16 sites within Battle Creek watershed in Fall 2002.

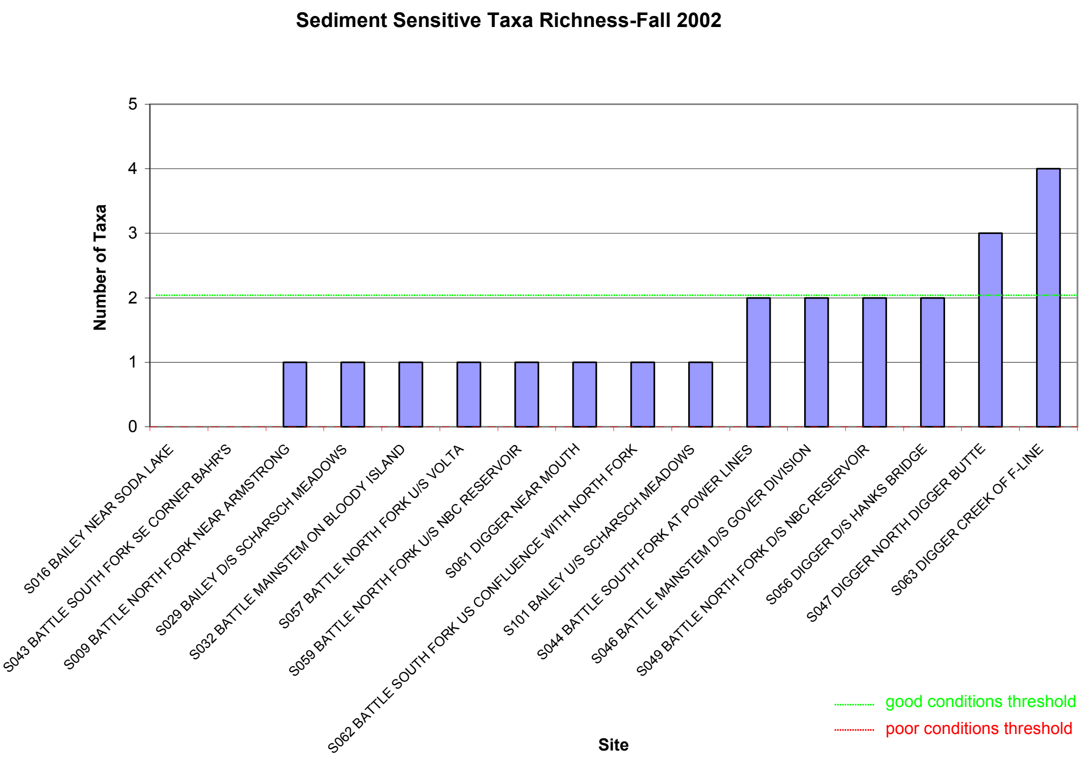

Figure 23. Comparison of sediment sensitive taxa richness at 16 sites within Battle Creek watershed in Fall 2002.

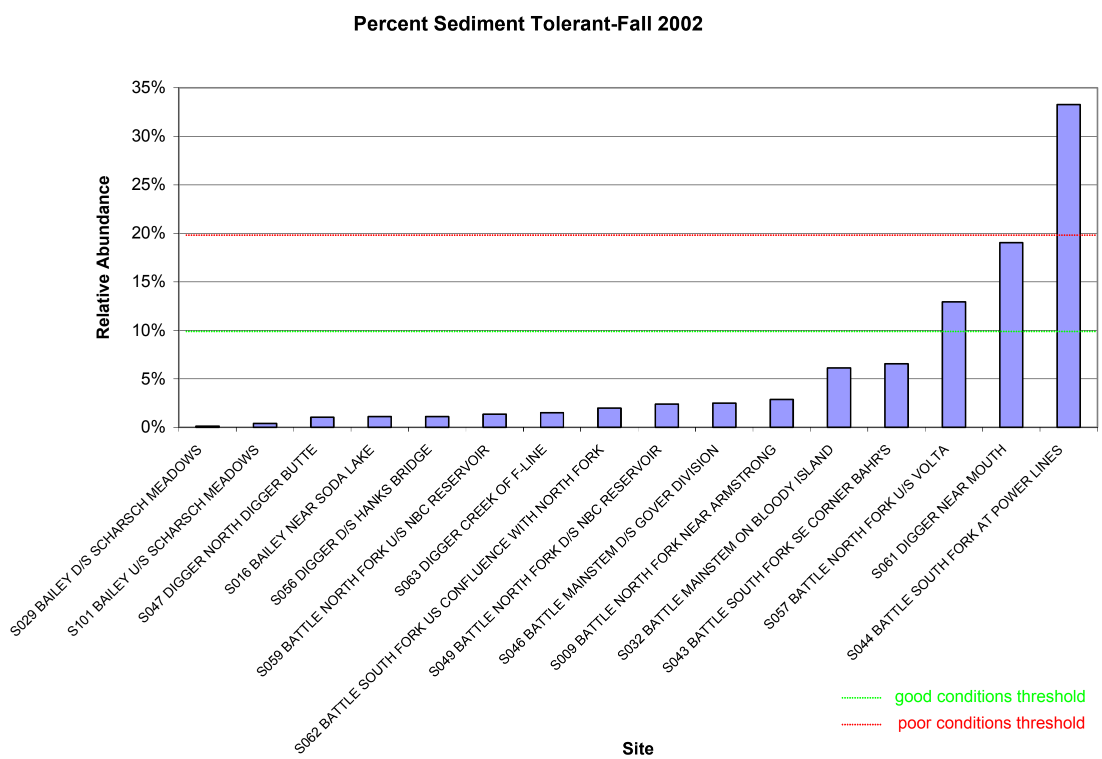

Figure 24. Comparison of percent sediment tolerant taxa at 16 sites within Battle Creek watershed in Fall 2002.

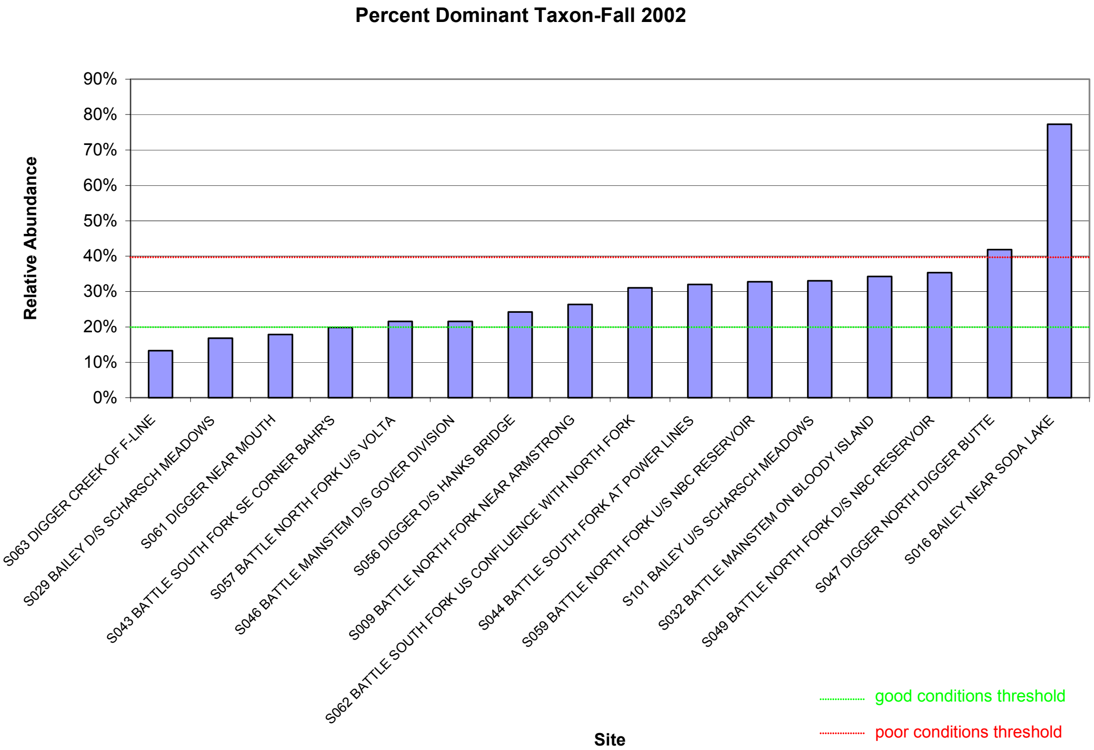

Figure 25. Comparison of percent dominant taxon at 16 sites within Battle Creek watershed in Fall 2002.

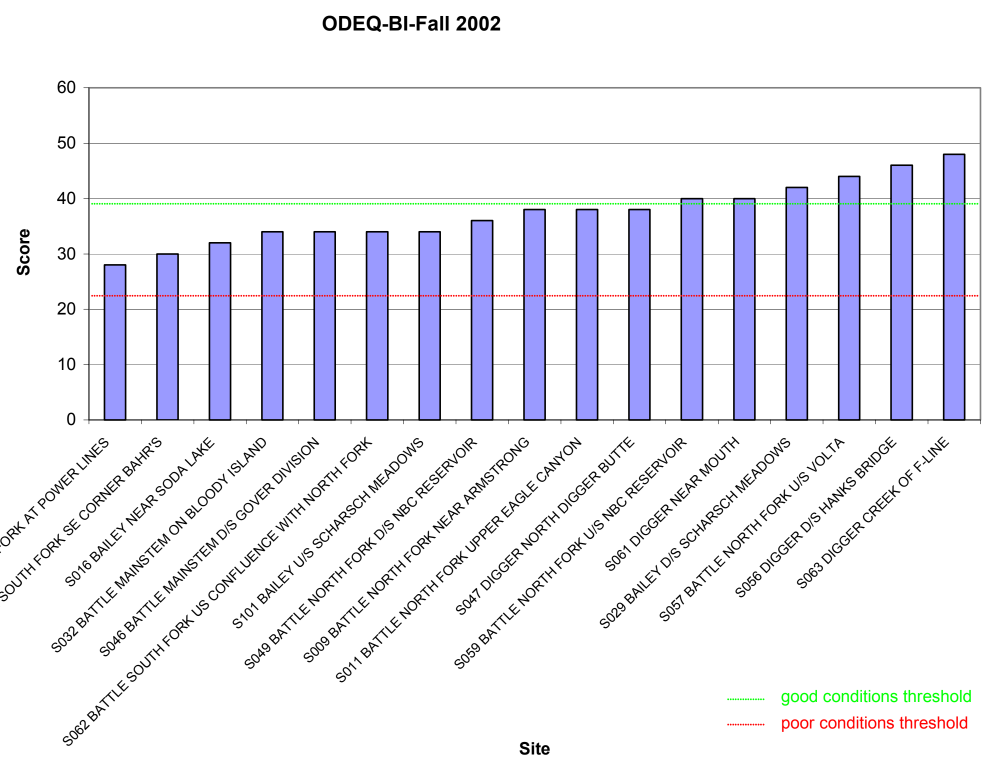

Figure 26. Comparison of ODEQ-BI at 16 sites within Battle Creek watershed in Fall 2002.

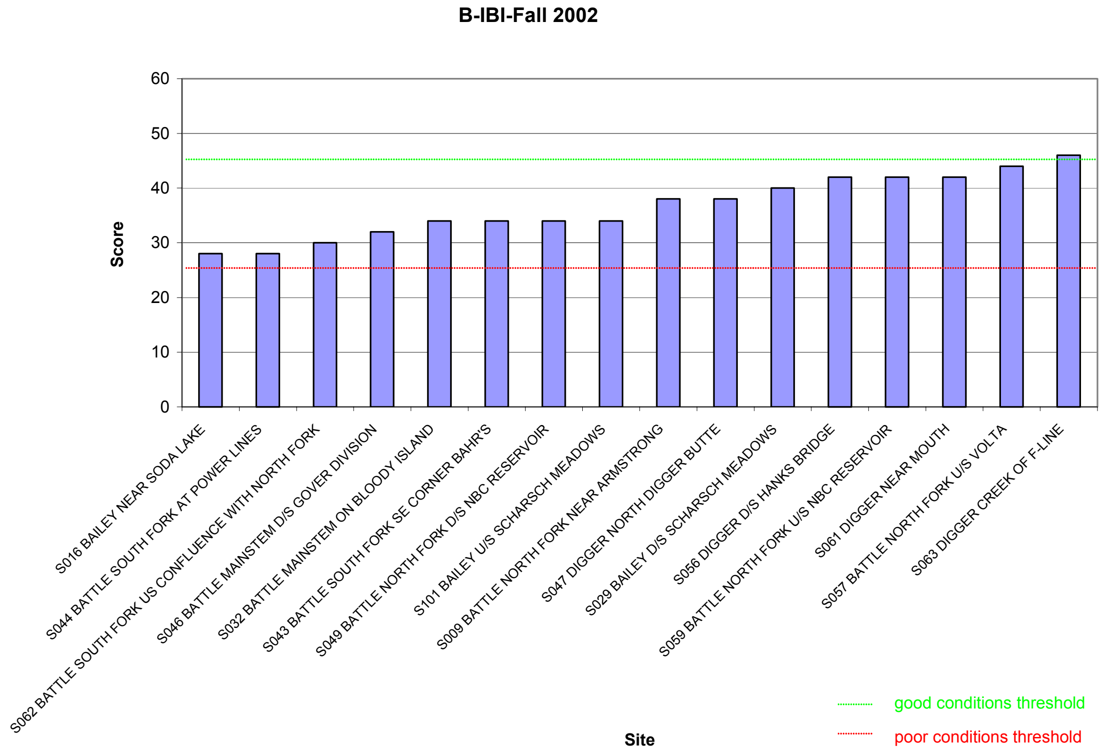

Figure 27. Comparison of B-IBI at 16 sites within Battle Creek watershed in Fall 2002.